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PRODUCTIVITY IMPULSES FROM REGIONAL INTEGRATION: LESSONS FROM ROAD OPENINGS*

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Abstract. In recent years, assessment of wider economic impacts has become an integrated part of transportation appraisal in many developed countries. The practices have also spread to sparsely populated countries, for which the empirical evidences for such impacts remain thin. In this paper, we conduct a multi-level examination on productivity impulses of regional integration caused by road constructions in Coastal Southern Norway. We measure market access in the national road network by power and exponential distance decay, using local estimates for the distance decay parameters from Holmen (2022a) in our baseline specifications. Our endogeneity test and earlier studies suggest that productivity analyses of impulses from Norwegian road constructions do not suffer from reverse causality. Still, we operate with buffer zones of twenty traveling kilometers around each receiver of impulses from market access, where traveling times are held constant. Total factor productivity is pre-estimated, before the impacts of increased market access are assessed at firm and industry level. We find some indications of more commuting and regional industry restructuring subsequent to road openings. The most striking evidences are nevertheless that the openings neither appear to have enhanced productivity growth at firm level nor induced welfare-enhancing reallocation of factor inputs within or between local industries.

Keywords: urban economics; rural economics; infrastructure, productivity; wider economic impacts; market access; road constructions; transportation appraisal

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JEL Classifications: D24, F15, R11, R12

Additional disciplines: economics, transportation planning

1. Introduction

There is a growing consensus in the economic geography literature that there may be causal linkages from economic density to productivity (see for instance Graham et al. 2010 and Behrens et al. 2014). Theoretical rationales for such linkages include direct transportation costs savings, production agglomeration and competition

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effects.[†] Yet, causal identification of impulses on productivity has proved challenging (e.g. Graham et al. 2010, Straub 2011 and Melo, Graham and Brage-Ardao 2013). This has become an important focus in recent research on agglomeration and productivity.

For mobility, traveling speed constitutes a direct substitute for physical proximity in most contexts. In the recent literature, proximity is often interpreted in broader terms than the pure physical sense, also involving traveling time reductions (e.g. Rice, Venables and Patacchini 2006 and Graham et al. 2010). While new major road constructions often have limited impact on traveling distances, they may reduce traveling time substantially.

By this broader interpretation of proximity, studies of road constructions may shed light on the relationship between productivity and economic density. For an economic actor, decreased traveling time and transportation costs to surrounding areas imply more potential profitable economic transactions with other firms and individuals, as well as better access to public goods and fiercer competition. Moreover, new major road constructions in populated areas may increase local value creation by growing the market access for local economic actors and strengthen the local competition. Yet, infrastructure projects for transportation may be motivated by or related to productivity concerns, so the causality in the decision-making should be addressed in such studies.

Until recently, many of the studies in this literature have been macro-oriented. Furthermore, the empirical strategies aimed to determine causal linkages from economic density to productivity has not always been convincing (confer Melo, Graham and Noland 2013 for a review).

In recent years, the research field of wider impacts from infrastructure projects has become more micro-oriented and more focused upon causal impacts from increased market access induced by transportation infrastructure explicitly. Holl (2016) finds support for productivity effects from proximity to highways in the Spanish manufacturing sector. She exploits 1760 postal routes and the old Roman roads as sources to exogenous variation, also controlling for human geographic, geologic and historic circumstances. Another study that applies historical routes for instrumentation is carried out by Duranton, Morrow and Turner (2014). They find that American cities with more highways specialize in sectors producing heavy goods. Some other studies also instrument road expansions on historical routes (e.g. Baum-Snow 2007 and 2010, Michaels 2008, Duranton and Turner 2011 and 2012, Garcia-López, Holl and Viladecans-Marsal 2015 and Baum-Snow et al. 2017) or physical geography (e.g. Banerjee, Duflo and Qian 2012, Faber 2014, Jebwad and Moradi 2016 and Alder 2019).

Utilizing a market access index based on traveling time and employment figures, Gibbons et al. (2019) find that new road infrastructure in the United Kingdom provides positive impulses on local employment, number of firms and productivity in small-scale geographical areas. To address possible reverse causality challenges related to road constructions, the authors hold traveling times constant over time within buffer zones. Gibbons et al. conclude that new transport infrastructure attracts transport-intensive firms to the local area from other areas. Studying US highways outside metropolitan areas, Chandra and Thompson (2000) find evidence that positive impulses for service industries in regions with new highways partly come at the expense of rural regions nearby. Their identification strategy is to consider areas that 'just happen to be along the new route' between two major

[†] Direct transportation costs savings involve cost reductions related to actual transportation processes (e.g. Shirley and Winston 2004 and Venables 2007). Production agglomeration involves synergies in production for firms and individuals being near each other. Important production agglomeration arguments include sharing of product markets, factor markets and common goods; more efficient matching of factor inputs and learning in terms of knowledge exchange (confer Duranton and Puga 2004 and Rosenthal and Strange 2004 for overviews, both building on Marshall 1890). Competition effects include firm selection, disciplinary competition effects and impacts on market power exploitation (e.g. Fujita 1988, Melitz and Ottaviano 2008 and Behrens Duranton and Robert-Nicoud 2014). We refer to Holmen and Hansen (2020) for a general review of impacts of transportation measures.

cities, an identification strategy later adapted by several other studies (e.g. Holl 2004, Melo, Graham and Noland 2010, Ghani, Goswami and Kerr 2016 and Ahlfeldt and Feddersen 2018).

The new empirical evidence has contributed to justification of supplementary quantitative analysis for wider economic impacts in ex ante transportation appraisal, carried out before project implementation. Moreover, conduction of such analyses has over the last decade become standard in transportation appraisal in many Western countries, including several ones that are more sparsely populated (e.g. Wangsness, Rødseth and Hansen 2017 and Holmen, Biesinger and Hindriks 2020). These studies often indicate wider economic impacts of tens or hundreds for road construction projects located in rural countries (e.g. Tveter and Mørkrid 2018), but the empirical foundation of such effects in rural areas remains thin.

Admittedly, some studies apparently find support for productivity impulses from road constructions in more rural areas. Notably, Börjesson et al. (2019) and Tveter (2021) find indications of higher wages subsequent to expansions in the road network, assessing Mid-Sweden including Stockholm and most of Norway's municipalities respectively. Yet, neither of these studies control for industry-year fixed effects, and both simply assume that there is no reverse causality associated with the investments. The later assumption was made based on previous findings suggesting that net benefit of road construction projects do not affect the selection of Norwegian and Swedish road construction projects, as long as the net benefits were positive in Sweden and even regardless of the sign of the net benefit in Norway (Eliasson et al. 2015). In case of Tveter (2021), the study takes place over the financial crisis from 2006 to 2009, where oil and gas supply industry had very strong development near some of the road projects implemented (e.g. the areas surrounding the Eiksund Connection and European Route 18 in Agder). Overall, the empirical evidence for wider economic impacts in rural areas are at least questionable.

In this paper, we study impulses from regional integration on productivity in a rural business sector, exploiting changes in traveling time caused by major road constructions. Utilizing the richness of Norwegian firm and panel data of the road network between Norwegian and zip codes and municipalities in the neighboring countries from 2004 to 2014, we conduct detailed investigations on the heterogeneity related to impulses from road constructions. Earlier studies suggest that productivity studies of Norwegian road constructions do not suffer from reverse causality, a finding that is confirmed by our endogeneity tests. Still, we operate with buffer zones of twenty kilometers traveling kilometers (measured in the initial year) around each receiver of impulses from market access to adjust for potential endogeneity, as suggested by Donaldson and Hornbeck (2016) and Gibbons et al. (2019). Here, the traveling times are held constant, both to adjust for potential exceptions from exogeneity and to limit the influence of noise in our data.

As our study region, we focus on Coastal Southern Norway, which has three advantages for identification. First, the timing of the concrete road constructions and the implementation of Norwegian road constructions more generally are relatively detached from concerns about productivity potential (confer subsection 2.1 and appendix A for elaboration on this matter). Second, the geographic structure is rather transparent with relatively homogenous industry composition for a given urbanization level with most regional economic activities located along the 250 kilometers of coastline. The fact that the region is relatively small and concentrated enables us to explore composition effects of road openings somewhat systematically. Third, the region has experienced a relatively large number of road openings, causing substantial traveling time reductions over just a decade. Since the turn of the millennium, no other Norwegian road openings inducing more than five minutes' traveling time reductions have concerned more inhabitants within half an hour's reach on both sides of the road segments in question than the segment at European Route 18 between Kristiansand and Grimstad. Two other construction projects in the region induced some of the highest traveling time reductions in Norway after the turn of the millennium (i.e. European Route 39 between Flekkefjord and Lyngdal and County Route 465 in Vest-Agder between Farsund and Kvinesdal).

We address both productivity impulses at firm level and composition effects related to factor allocation, which both contribute to higher productivity at a regional level. Hereby, we investigate how increased market access impacts productivity differently depending on industry, firm size and entrepreneurial status. We pre-estimate total factor productivity by Wooldridge and Levinsohn-Petrin's production estimation procedures at firm and industry level, which are state-of-the art procedures for causal productivity studies in large panel dataset. To control for firm-specific and industry-specific price developments, we introduce a new control for terms of trade in our firm regressions. As for robustness, we also explore how our results are affected by the use of alternative neoclassical and control function approaches to production estimation, as well as use of alternative control groups beyond our study region. To be able to distinguish between local displacement effects and partial national effects (before potential general equilibrium mechanisms come into play), we choose to operate both a core study region, consisting of Coastal Southern Norway, and an extended study region, also involving municipalities in neighboring regions not located next to major road openings (confer subsection 2.1 for details).

Agglomeration synergies for an economic actor tend to increase with the number of possible economic interactions with other firms and individuals in surrounding areas. Similarly, improved market access to product and factor markets will tend to increase competition locally. To capture the key features of regional integration, we apply two alternative market access measures – one with power distance decay and one with exponential distance decay. For both functions, we apply the distance decay parameter values estimated by non-linear estimation techniques for municipalities in the Southern parts of Norway in Holmen (2022a), controlling for annual growth trend, capital intensity and industry composition.

Our study relates to the empirical literature on composition effects of market enlargement. Combes et al. (2012) study regional densification and productivity in France with a nested model for selection and agglomeration synergies. They find that firm selection is insufficient to explain regional productivity differences. Combes et al. also find that regional productivity is determined not only by productivity at the enterprise level, but also by the development of employment in companies and regions. Several other authors also find that highways attract economic activities, thereby increasing the local density of economic activities (confer Redding and Turner 2015 and Combes and Gobillon 2015 for general reviews).

2. Empirical Strategy

In this section, we present our empirical strategy for addressing the productivity impact of regional integration caused by new road constructions. First, we address our identification of regional integration through road constructions. We account for the geography in the study region and argue that the timing of local road constructions is largely detached from productivity concerns. Second, we present a framework suited for estimating market access measures that capture the agglomeration decay over space, controlling for differences in capital intensity, industry composition and economic growth trend. We also adjust the market access measure to design hypothetical market measures suited for placebo tests. Third, we account for the estimation techniques applied to estimate total factor productivity. In particular, we focus on techniques that address the simultaneity biases related to endogenous factor inputs and controls suited for catching industry-specific developments. To control for firm-specific productivity developments, we introduce a new firm-specific control for terms of trade. Fourth, we present our framework for studying causal productivity impulses of increased market access on TFP and factor usage. Factor usage is also included at this point, considering that composition effects contribute to aggregate TFP developments.

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2.1 Identification of Regional Integration through Road Investments

Although economic impacts of transportation measures in secondary markets – so-called wider economic impacts – often come out with substantial magnitudes in empirical research, they are commonly omitted from cost-benefit analyses. For that reason, several researchers have addressed the importance of and potential issues with obtaining reliable estimates for wider economic impacts in recent years (e.g. Venables 2007, Vickerman 2007, Banister and Thurstain-Goodwin 2011, Graham and Gibbons 2019 and Holmen, Biesinger and Hindriks 2020). In the context of the related empirical investigations, there has been a debate in the literature to what extent implemented road construction projects' effect on productivity can be considered as exogenous and thereby suited for causal identification (e.g. Baum-Snow 2010, Funderburg et al. 2010, Crescenzi and Rodríguez-Pose 2012, Leduc and Wilson 2012, Redding and Turner 2015, Holl 2016 and Gibbons et al. 2019). If road decision processes leading up to road investments paid little attention to productivity potential and associated conditions, road openings may be a valid source of exogenous variation in economic density without further instrumentation. At least the endogeneity challenge would be less severe.

Throughout our study period, economic appraisal including cost-benefit analysis was mandatory for major Norwegian road investments (i.e. above NOK 1 billion in current prices), which are carried out by the public sector. As accounted for in subappendix A.1, studies on Norwegian road investment decisions indicate that these are relatively detached from concerns about net benefits in general and productivity potential in particular. Instead, 0the project selection is largely influenced by regional horse-trading and solid state finances, as well as maintenance and safety concerns. Considering that Norwegian road construction projects are commonly motivated by other factors than productivity potential, they appear as a good case for studies of regional integration caused by road openings, although instrumentation may still be needed. Rather than studying the country as a whole with all its regional heterogeneity, we choose to turn our attention to a transparent region with relatively homogenous industry composition. Most road openings after the turn of the millennium either occurred in close proximity to the capital area of Oslo parallel to the implementation of other infrastructure projects or in form of new mainland connections and fjord crossings in more sparsely populated areas along the Western and Northern Coast.[‡] In contrast to this, Coastal Southern Norway constitutes a relatively homogenous, transparently structured and populated Norwegian region with major road constructions at different points in time. Coastal Southern Norway also distinguishes itself from other Norwegian regions by being subject to relatively many road openings after the turn of the millennium. As briefly reviewed in the introduction in section 1, there are some notable studies on productivity impulses from increased market access caused by expansion of the road network.

To study the productivity impact of regional integration, we focus on Southern Norway in the period from 2004 to 2014. Our study region is rather streamlined with main traffic arteries along a coastline of 250 kilometers and limited population in non-coastal parts of the region. The regional capital, Kristiansand, is located in the middle of the region's coastline with comparable population bases on each side. The municipalities east of Kristiansand are located in Aust-Agder county, while Kristiansand and the municipalities west of Kristiansand are part of Vest-Agder county.[§] The terrain is relatively similar along the coast of Southern Norway. The geographic structure means that it becomes easier to isolate the impact of decreased traveling times. Another advantage with our study case is that the industry composition for a given urbanization level is relatively homogeneous across

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[‡] In the 2000s, major road openings along the Western coast of Norway included National Route 519 Finnfast, County Route 553 in Rogaland by the T-Connection, National Route 13 Hardanger Bridge, National Route 635 Eiksund Connection and National Route Atlantic Tunnel, while European Route 10 Lofast constituted the largest road opening in Northern Norway by far. In the capital area of Oslo, new road openings occurred incrementally along European Route 18 south of the city on both sides of the Oslofjord, while European Route 6 and the Oslo Airport at Gardermoen were gradually expanded north of the capital.

[§] January 1. 2020, Aust-Agder county and Vest-Agder county were merged to form Agder county.

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municipalities in the region. Thus, potential shocks in the business sector should be rather evenly distributed over the region, limiting industry-related measurement errors that are not captured by firm- and industry-specific controls. A clear geographic structure also makes it easier to keep track of regional composition effects related to the spatial allocation of labor.

The municipalities along the coastline and the remaining suburban municipalities bordering on Kristiansand accounted for 89.9 percent of the inhabitants in Southern Norway in 2004, and 90.3 percent of the population in 2014. In our study, we focus on these municipalities and neglect the more peripheral non-coastal municipalities, since they are somewhat different by nature. We also include the inland municipalities which surround Kristiansand. With a population of 264 200 inhabitants in 2004 and 297 100 inhabitants in 2014, the region is relatively small compared to most regions previously studied in the agglomeration literature (confer section 4 for descriptive statistics). In Fig. 1 below, we have provided a map over the study region with indications of population level in the start of our study period, as well as the location of major road openings and road construction packages during our study period.

The clear structure of our study region also enables us to track the decision processes related to all main arteries between the municipalities in our study, in addition to Kristiansand. Four road packages cover all main roads between municipalities in our study. The renewal of European Route 18 in Southern Norway covers the municipalities located east of Kristiansand, while the renewal of European Route 39 covers the municipalities located west of Kristiansand. Furthermore, the Lister Package covers the study region's western municipalities, some of which are located along European Route 39, while the Kristiansand Package covers Kristiansand and its suburbs. The Setesdal Region, located in the Northern non-coastal part of Aust-Agder, was not covered by any of these packages, but instead granted an own package (i.e. the Setesdal Package).

The location of European Route 18 and 39 in Southern Norway does to a large extent follow the Norwegian main road from Oslo to Stavanger from the 1800s (Irgens 1978). Much of today's route segments were built in the postwar era, when parts of them were placed inland instead of going through the coastal towns. A comprehensive overview of the changes in the road network during our study period, as well as some historical context, is provided in subappendix A.2.

Three major road construction projects were realized in Southern Norway in the years between 2004 and 2014 – one in connection with European Route 18 (east in our study region) and two in connection to the Lister package (west in our study region). 30th of August 2006, a renewal of European Route 39 between Flekkefjord and Lyngdal in connection with the Lister package reduced the traveling time at the route segment by 17 minutes, from 46 to 29 minutes. 26th of August 2009, the traveling time between Kristiansand and Grimstad on European Route 18 was reduced by 12 minutes, from 34 to 22 minutes. Since the turn of the millennium, no other major road constructions in Norway (inducing traveling time reductions of at least five minutes) have concerned more people (within 30 minutes from the reduction sites) on both sides of the renewed route segment. Also connected to the Lister Package, County Route 465 in Vest-Agder between Farsund and Kvinesdal was renewed in the period from 2009 to 2012, reducing the traveling time between the municipalities by 18 minutes, from 52 minutes to 34 minutes. Of these, 5 minutes' traveling time reduction was induced 24th of November 2009, while the reduction of the 13 remaining minutes was realized 19th of October 2012.

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Fig. 1. Overview over the core study region of Costal Southern Norway with highlighting of municipal populations in 2004 and new major road constructions (light green arrows) and road packages (indicated by ovals of dashed lines) from 2004 to 2014

Beyond these three projects, the road network in our study region was affected by the renewal of European Route 18 between Risør and Gjerstad 20th of August 2004 (reducing traveling time by 6 minutes), gradual increases in speed limits on County Route 751 in Vest-Agder between Kvinesdal and Hægebostad from 2008 to 2013 (reducing traveling time by 5 minutes) and the renewal of County Route 43 in Vest-Agder between Farsund and Lyngdal (reducing traveling time by 2 minutes). There were no major road constructions within the immediate vicinity outside our study region, so other road constructions in the neighboring regions are unlikely to have had substantial direct impacts on the economic outcomes along the coastline of Southern Norway (but they may of course have induced general equilibrium mechanisms).

Reviewing the decision documents for the major road projects in Southern Norway during our study period, we do not find conclusive evidence that rules out that productivity potential could been decisive for their realization. In the public decision documents, the road constructions are primarily motivated by traffic mobility and need for maintenance and improved road standards without mentioning productivity potential. The timing of the different projects also appears to be rather random beyond maintenance considerations. Yet, direct transportation costs savings and housing and labor market region integration are also presented as arguments in the decision documents, particularly in the most recent ones. Although the argumentation in the project documents may not have influenced project selection in practice, it is reasonable to question whether the road investments can be considered exogenous to economic outcomes. Thus, we conduct endogeneity tests to address this matter and adjust our empirical identification strategy accordingly, a matter that we will address in subsections 2.2 and 5.1.

Instead of applying a general equilibrium framework, we conduct a flexible and detailed econometric investigation on productivity impulses of increased market access caused by road investments. The downside is that we neither capture potential national displacement nor ripple effects. In order to shed light on the distinction

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between local displacement effects and partial national effect, we operate with an extended study region in addition to our core study region of Southern Norway. Our extended control region includes the two counties of Southern Norway (i.e. Aust-Agder and Vest-Agder), their bordering counties (i.e. Rogaland and Telemark) and their bordering counties again (i.e. Buskerud, Hordaland and Vestfold). Together, our extended study region covers the most southern parts of Norway. Compared to the rest of Norway, these regions are relatively comparable to Southern Norway in terms of somewhat similar industry structure and degree of urbanization.

In Fig. 2, we have illustrated our extended study region, where our core study region of Coastal Southern Norway is colored in blue and the rest of the extended study region is colored in green. We have utilized dark colors for municipalities with road openings inducing traveling time reductions of at least five minutes within 30 minutes' reach during our study period and light colors for other municipalities.

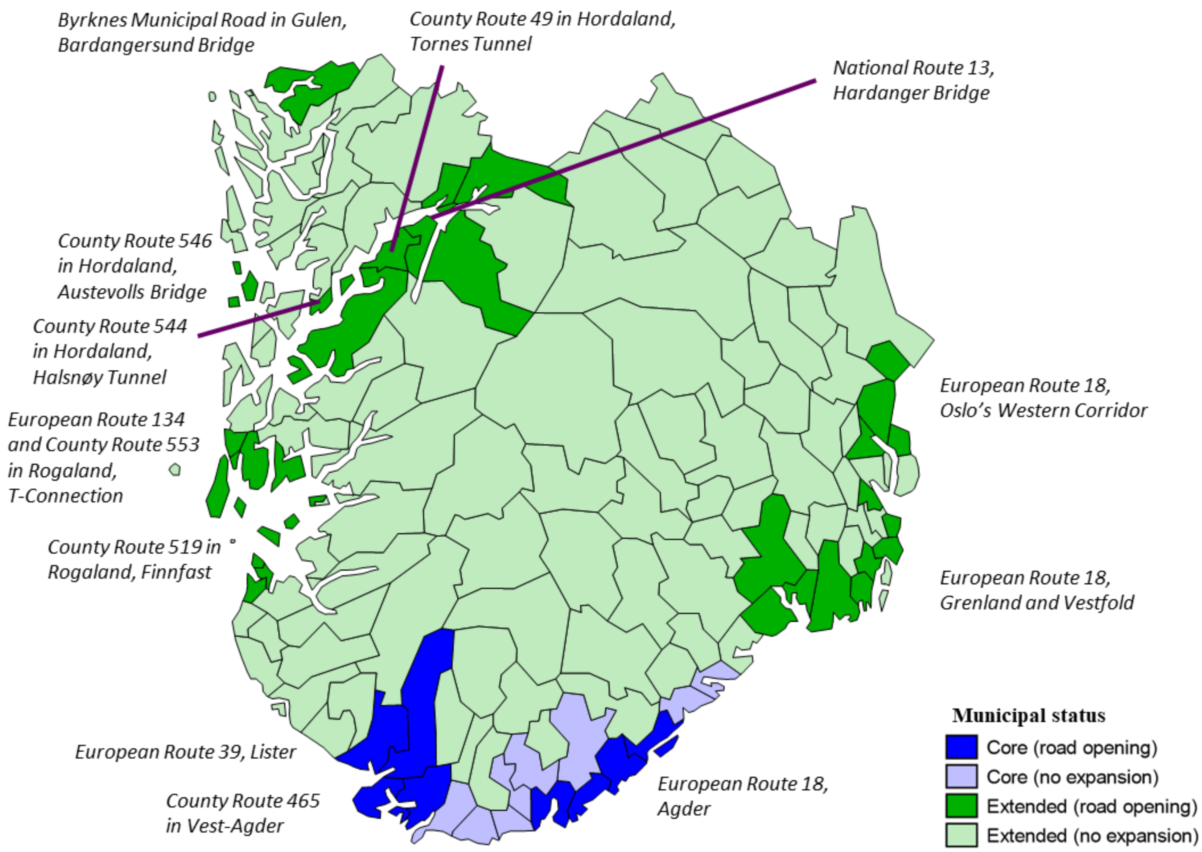

Fig. 2. Overview over our core study region of Coastal Southern Norway (colored in blue) and our extended study region also including municipalities in neighboring counties (colored in green). Municipalities with road openings inducing five minutes traveling time reductions from 2004 to 2014 within 30 minutes' reach are shaded in dark colors and the other municipalities are colored in light colors.

Since our focus is on productivity impulses in Southern Norway, we omit the municipalities next to road openings in the extended study region. Municipalities are only excluded when the concerned road renewals constitute their fastest traveling path to surrounding destinations. Overall, our extended study region (including Coastal Southern Norway) consists of 142 municipalities, of which 29 are taken out as a consequence of our exclusion criterion. Compared to the road openings in Southern Norway, the concerned constructions either involve traveling time reductions of just above five minutes within 30 minutes realized incrementally over time (i.e. European Route 18

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in Eastern Norway), realization in the end of our study period (i.e. the T-Connection) or relatively rural areas on one side of the construction route segment (i.e. Finnfast) or a combination of these characteristics (i.e. the other highlighted connections outside Southern Norway).

2.2 Market Access Measures

In order to study how productivity depends on spatial configuration, we need to apply a market access measure that captures proximity to and the magnitude of places with economic activity nearby into account. Market access functions should also capture how impulses from economic activities diminish over space, a phenemonon known as 'agglomeration decay' or 'distance decay'.

In our main estimation, we will make use of market access functions with power distance decay and exponential distance decay, exploiting the parameter estimated estimated by Holmen (2022a). He estimates the market access functions with power distance decay and exponential distance decay for the Southern parts of Norway by nonlinear estimation techniques at municipal level, controlling for capital intensity, annual growth trend and industry composition. Holmen's findings suggest a relative sharp distance decay in rural areas compared the urban, which are more commonly addressed in the literature.

Formally, let $\mathcal{D}_{r,t}$ denote a matrix consisting of traveling times between region r and all regions s at time t, while $d_{r,s,t}$ is the minimum traveling time between municipality r and municipality s at time t. Furthermore, let $\mathcal{N}_t$ be a vector of the labor stock in all municipalities at time t, while $N_{s,t}$ is number of employees with workplace in municipality s. Note that $N_{s,t}$ could be considered as a proxy for potential market connections at given locations, while $d_{r,s,t}$ could be considered as a proxy for frictions in connectivity. We denote the distance decay parameter by $\hat{\delta}^{pow}$ in case of power distance decay and $\hat{\delta}^{exp}$ in case of exponential distance decay.
We calculate estimate logarithm of market access, $g_{r,t}$, for each municipality at each time, which are applied in our further empirical investigations:

$$(1)\ g_{r,t}^{pow}\left(\mathcal{N}_t,\mathcal{D}_{r,t}\right)=\ln\left(\sum_{s=1}^{S}\frac{N_{s,t}}{d_{r,s,t}{}^{\delta^{pow}}}\right),\quad g_{r,t}^{exp}\left(\mathcal{N}_t,\mathcal{D}_{r,t}\right)=\ln\left(\sum_{s=1}^{S}\frac{N_{s,t}}{\exp\left(d_{r,s,t}\delta^{exp}\right)}\right)$$

where δ^{pow} and δ^{exp} is set equal to the values equal to 2.3 and 0.07 respectively, in accordance with the findings of Holmen (2022a). Further investigations with lower decay parameter values are briefly pursued in appendix A.
In our study, we focus on productivity impulses from increased market access caused by changes in the road network. Urbanization patterns related to employment and settlement will also constitute important sources for increased market access, but these may be subject to even more severe endogeneity challenges. Thus, local developments in employment and economic performance are interlinked. In our investigations, we therefore utilize market access measures, where employment is held constant at the initial level in 2004 (i.e. $\mathcal{N}_{t_0}$):

$$(2)\ g_{r,t}^{pow}\left(\mathcal{N}_{t_0},\mathcal{D}_{r,t}\right)=\ln\left(\sum_{s=1}^{S}\frac{N_{s,t_0}}{d_{r,s,t}{}^{\delta^{pow}}}\right),\quad g_{r,t}^{exp}\left(\mathcal{N}_t,\mathcal{D}_{r,t}\right)=\ln\left(\sum_{s=1}^{S}\frac{N_{s,t_0}}{\exp\left(d_{r,s,t}\delta^{exp}\right)}\right)$$

In line with the advice of Holmen (2022a), we measure potential market connections by the average of employment by residence and employment by workplace, as these measures' relevance differs from market to market. Furthermore, we will keep employment constant to the initial level to avert endogeneity issues.

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Consistent with the empirical strategy of Gibbons et al. (2019), and Donaldson and Hornebeck (2016), we fix the traveling times within buffer zones surrounding each location, in our case fixed to twenty traveling kilometers (measured in the initial year).[**] While Gibbons et al. use buffer zones as a way of obtaining causal identification, an additional justification for us has been to limit noise associated with small changes in traveling time in our data. In this regard, it is worth noting that our market access measures pass the reverse causality test with regard to productivity (as explained further in subsection 5.1).[††]

In addition to designing instruments, we want to construct suitable market access measures for placebo tests. In our study case, the road opening that affected by far the most people took place in 2009, but road openings also induced substantial traveling time reductions in 2006 and 2012 (confer subsection 2.1 with elaboration in subappendix A.2). In our placebo investigation, we let the period from 2004 to 2006 be the pretreatment placebo period with traveling times and employment figures for 2004, and the period from 2007 and 2008 the posttreatment placebo period with traveling times and employment figures of 2014. We omit the municipalities next to the construction in 2006 (i.e. Flekkefjord and Lyngdal) from this exercise. When designing the placebo measure for the road construction, we hold the population constant at 2004 levels for all year and use 2004 traveling time spans for the pretreatment period and 2014 traveling time spans for the posttreatment period (i.e. $g^{f}_{r,t}\left(\mathcal{D}_{r,t};\mathcal{N}^{pl}_{t}\right)$).

While the estimation of the decay parameters in Holmen (2022a) is carried out at municipal level, we apply the parameter estimates at zip code levels. This raises a concern about small traveling times below the ones typically observed between municipalities and averagely within municipalities. Especially the exponential distance decay function is very sensitive to small values. In coastal municipalities along Southern Norway, the average internal traveling time in the municipalities ranges from nine to 13 minutes except for one outlier on each side. Robustness checks carried out by Holmen suggest that setting the minimum traveling time equal to ten minutes has little impact on the distance decay parameters. The geographical detail level of which zip codes are defined varies substantially between municipalities.

In addition, our traveling time involves some random noise, while the market access functions by construction appear to be oversensistive to changes in traveling time, when the traveling time is low. To limit the noise associated with changes in low traveling time, we set the minimum traveling time to ten minutes in our further

[**] To deal with endogenous scheme location, Gibbons et al. (2019) operate with buffer zones of 10 to 30 kilometers from the project sites in their study of economic impulses from expansion of the road network the modern United Kingdom. By the same token, Donaldson and Hornbeck (2016) operate with buffers from 10 to 100 miles from railways and waterways in their study of expansion of the rail network in the United States in the 1800s.

[††] We have also explored an alternative identification strategy with two sets of instrument candidates, inserting alternative measures for distance friction and potential market connection into the market access functions in equations **Error! Reference source not found.**. In the design of the first set of instruments, we replaced traveling times with air distances as distance measure, also adjusting for average traveling time reductions in the road network. In the design of the second set of instruments, we replaced employment with severe victims in accident (i.e. fatalities or severely injured) per road surface during the past five years on a preexisting road as measure for potential market connections, once again adjusting for average traveling time reductions in the road network. The adjustment of aggregate changes in traveling time was carried out at county level in addition to national level, since several studies over time suggest that the distribution of road funding between Norwegian counties has been stable over time (e.g. Strand 1983 and 1993, Nyborg and Spangen 1996 and Strand et al. 2015 – confer subappendix A.1). For this purpose, we employed data on victims with severe injuries, fatalities and road surface from Statistics Norway, as well as air distances calculated based on coordinates and the Earth's curvature. Yet, we abandoned the instrumentation strategy, as our market access measure with constant employment and buffer zones passed the endogeneity test (confer subsection **Error! Reference source not found.**), and because the instrument candidates turned out to have limited internal validity within the study region under investigation. Yet, this identification strategy could still be useful in other contexts. Similarly, potential market connections (e.g. employment) might be instrumented in studies of market access growth related to urbanization trends and industry developments.

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empirical investigations.[‡‡] Robustness checks carried out by Holmen suggest that this assumption would not change the estimates for the distance decay parameters much. Note that our specifications with buffer zones and fixed traveling time beyond some limit in principle still allows for differences in market access beyond ten minutes, but they will be captured by the regressions fixed effects.

2.3 Total Factor Productivity Estimation

We will now account for how we estimate total factor productivity[§§] over industries at firm level and municipality level in our main analyses, as well as at municipal level in the preparation of the market access measure. Other components of technical productivity, such as scale efficiency and allocative efficiency, are briefly assessed in appendix B. In our empirical analyses, we first estimate total factor productivity as the regression residual of the production function specification. Then, we assess the impact of increased market access on total factor productivity (TFP) in line with the next subsection. Note that is standard to apply a two-stage procedure in non-frontier productivity studies on panel data (e.g. Graham et al. 2010 and Holl 2016). The approach implies that TFP implicitly will be a function of market access:

$$(3)\ a_{i,t} = a_{i,t}\left(g_{i,t}^{f}\right)$$

where $a_{i,t}$ is total factor productivity (in natural logarithmic form) in firm or regional industry i at time t with corresponding gravity measure $g_{i,t}^{f}$ with distance decay assumption f.

While the first estimation step is all about obtaining the most reliable TFP estimates, the second estimation step addresses the endogeneity issues related to changes in market access, as explained in the next subsection. As long as firm does not move, changes in market access will be outside the firms' control, so the associated variables are not considered as control variables in firms' profit optimization in our main specifications.[***] If the few cases where firms choose to move to another municipality, it will be accounted for as an entry and exit in our study.

In our productivity investigations, we control for the development in terms of trade for each observation unit (i.e. firms or industries). Comparison of development in price margins over industries and municipalities reveals

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[‡‡] An alternative would be to add a constant, which could be interpreted as a fixed traveling time regardless of actual transportation process. This alternative assumption did however provide less robust results in the empirical estimation of the market access function, as rendered in **Error! Reference source not found.** in case of no such assumptions, so we abandoned it. Note that our specifications with buffer zones and fixed traveling time beyond some limit in principle still allows for differences in market access beyond ten minutes, but they will be captured by the regressions fixed effects.

[§§] Theoretically, TFP accounts for effects in total output growth relative to the growth in factor inputs for a given production technology. In measurement, growth in TFP corresponds to the portion of output not explained by the amount of input factors, expressed by the Solow residual in the production function and the error term. This implies that total factor productivity estimates will not only capture technological progress and possibly factor efficiency in the strict sense, but also omitted variables (e.g. infrastructure and institutional factors). In addition, the TFP estimates will be affected by simultaneous biases related to the factor input, measurement errors and specification errors. Improvements' scale and allocative efficiency will not be captured by TFP measures.

[***] Admittedly, our applied approach involves an efficiency loss, since we estimate TFP and the impact of increased market access on TFP growth in two separate steps. An alternative procedure would be to estimate TFP with market access as a control variable in a single step. This would be to assume that firms adapt their factor utilization directly to changes in market access. A one-step approach would neither allow us to correct for observation unit fixed effects, industry-year developments nor clustering of standard errors on observation units, which corresponds to the approach suggested in the following subsection. As the control variables for terms of trade include regional factor prices for buildings and land area, the specification might also suffer from simultaneity, if these prices are affected by the increase in market access. We therefore stick with a two-step procedure as our main specification, but report the main results for a one-step procedure in appendix A. Note that a two-step procedure recently has been undertaken by several notable contributions, including the ones by Gibbons et al. (2019) and Holl (2016).

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substantial differences in the terms of trade development within our study region. Firms maximize profits in current prices and not in fixed prices, so this should be accounted for in our TFP estimation. Profit maximization suggests that a beneficial price development may make the firm willing to accept a lower marginal productivity.[†††] We assess the net value added-based terms of trade for an observation as the ratio between output-based price deflators for net value added and input-based price deflators for components of net value added. While the output deflators capture the product price development after intermediates are paid, the input deflators capture the price development for the internal factor inputs. Since we have access to disaggregate deflators for different key economic components over industries, we have the option to calculate both output-based and input-based deflators by utilizing price contribution from different components. By this methodology, the net value added-based terms of trade $T^s_{i,t}$ for study unit i at time t can be calculated by **Error! Reference source not found.** below:

$$T^s_{i,t} = \frac{V^{FP,output}_{i,t}}{V^{FP,input}_{i,t}} = \frac{X^{FP,output}_{i,t} - M^{FP,input}_{i,t} - D^{FP,input}_{i,t}}{W^{FP,input}_{i,t} + R^{FP,input}_{i,t}} = \frac{\frac{X^{CP}_{i,t}}{X^{def,output}_{i,t}} - \sum_{j=1}^{J=2} \frac{M^{CP}_{j,i,t}}{M^{def}_{j,i,t}} - \sum_{c=1}^{C=10} \frac{D^{CP}_{c,i,t}}{K^{def,input}_{c,i,t}}}{\frac{W^{CP}_{i,t}}{W^{def,input}_{i,t}} + R^{CP}_{i,t} \frac{\sum_{c=1}^{C=10} K^{CP}_{c,i,t} / K^{def,input}_{c,i,t}}{\sum_{c=1}^{C=10} K^{CP}_{c,i,t}}} \quad (4)$$

where $V_{i,t}$, $X_{i,t}$, $W_{i,t}$, $R_{i,t}$, $M_{i,t}$, $D_{i,t}$ and $K_{i,t}$ are net value added, gross production, labor costs, net operational profits, intermediates, capital depreciations and fixed capital services for observation unit i at time t respectively. We utilize that all mentioned variables could be measured in current prices, fixed output prices and fixed input prices with corresponding output deflators and input deflators. At last, we have two forms of intermediates j with $M_{i,t} = \sum_{j=1}^{J=2} M_{j,i,t}$ and ten types of fixed capital c with $K_{i,t} = \sum_{c=1}^{C=10} K_{c,i,t}$ and $D_{i,t} = \sum_{c=1}^{C=10} D_{c,i,t}$ (confer subsection 3.1 for elaboration on subgroups). Note that the somewhat messy fraction involving fixed capital services and net operational profits implies that the net operational revenues are deflated with a capital deflator weighted over capital forms in line with each capital stock's annual user contribution.

Terms of trade in period t as expressed in equation **Error! Reference source not found.** are not suited as a control in the production estimation directly, since the input factors might be adjusted in period t, inducing a simultaneous bias in case of inclusion of the variable. We solve this challenge by instead applying the volumes from period $t-1$ as proxies for the volumes in current period, while valuing the volumes in the prices at period t:

$$T^s_{i,t} = \frac{\frac{X^{CP}_{i,t-1}}{X^{def,output}_{i,t}} - \sum_{j=1}^{J=2} \frac{M^{CP}_{j,i,t-1}}{M^{def}_{j,i,t}} - \sum_{c=1}^{C=10} \frac{D^{CP}_{c,i,t-1}}{K^{def,input}_{c,i,t}}}{\frac{W^{CP}_{i,t-1}}{W^{def,input}_{i,t}} + R^{CP}_{i,t-1} \frac{\sum_{c=1}^{C=10} K^{CP}_{c,i,t-1} / K^{def,input}_{c,i,t}}{\sum_{c=1}^{C=10} K^{CP}_{c,i,t-1}}} \quad (5)$$

[†††] The impact of terms of trade on total factor productivity has not been devoted much attention in the economic productivity literature, particularly not at micro level. The topic is studied by inter alia Diewert and Morrison (1985), Fox and Kohli (1998) and Kehoe and Ruhl (2008).

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Lagged volume variables are not always available at firm level, as firms are entering and exiting their markets over time. In this case, we use lagged industry- and municipality-specific volumes (i.e. A64 second revision, confer subsection 3.1) instead. In cases where an industry is absent from a municipality, we apply lagged volumes at national level instead.

We estimate TFP by applying non-frontier techniques to production estimation. Our main analyses are carried out with the estimation procedures developed by Wooldridge (2009). In the robustness analyses in appendix B, we utilize a wide range of control function and neoclassical estimation procedures. The purpose is both to address the results' robustness and to illuminate how different key features in the production estimation affect the results. We apply net value added as our production measure, which captures the ability to transform technological change into income and final demand.[‡‡‡]

Control function techniques are semi-parametric non-frontier production estimation procedures that apply control functions to handle simultaneous biases originating from estimating output at the same time as factor inputs, particularly fixed capital stock. Following Olley and Pakes (1996), some new non-frontier and semi-parametric approaches to total factor productivity have emerged to deal with the endogeneity challenge with help of control functions. These methods may also address selection biases related to exits. In their paper, Olley and Pakes suggest investments as a proxy to handle the simultaneous bias related to fixed capital. Considering that investments often are zero, Levinsohn and Petrin (2003) suggest intermediates as an alternative proxy to investments. They apply a somewhat more general data generating process than Olley and Pakes do (controlling for heteroskedasticity and autocorrelation in of the error terms).

Various modifications in these approaches have been suggested to address potential dependence challenges.[§§§] Two important contributions in this regard are Wooldridge (2009) and Ackerberg, Caves and Frazer (2015). Further developing Levinsohn and Petrin's estimation procedure with intermediates as proxy, Wooldridge (2009) proposes to jointly estimate the elasticities for employment and capital in a single step. He computes standard errors with general method of moments rather than bootstrapping, such that efficiency increases, and computation of standard errors becomes easier. Rather than inverting unconditional input demand functions as Olley and Pakes and Levinsohn and Petrin (2003) and Wooldridge (2009) do, Ackerberg, Caves and Frazer (2015) condition the inverted input demand function on choice of labor input. This does in turn allow for a more general data generating process, where Blundell and Bond's (2000) dynamic panel estimator is exploited. The authors' own

[‡‡‡] There are some advantages to using value added as production measure instead of gross production. First, we avoid the issue with double counting of intermediates over firms at aggregate level, which makes the results vulnerable to consolidation. Second, we do not need to address that providers of intermediate inputs do not have to be local. Third, we avoid more complex estimation procedures. On the other hand, value added-based TFP measures ignore the magnitude of intermediate inputs. Thereby, it assumes no surplus extraction between providers of intermediates and providers of internal factor inputs. What is more, zero or negative value added may be a problem when value added is chosen as production measure. Given zero pure profit and Cobb-Douglas technology, the relationship between gross production-based TFP estimates and gross value added-based TFP estimates could be derived by applying the ratio between gross production and value added, known as the Dolmar factor (Dolmar 1961). We refer to Balk (2009) for a review of the relationship between gross production-based and value added-based TFP estimation. We choose to measure value added in net terms rather than gross terms for two reasons. First, depreciation is a cost and therefore does not belong in the output measure. Second, we have capital depreciation figures with sufficient quality to do so.

[§§§] Potential collinearity issues (as pointed out by Bond and Söderbom 2005) are particularly important. This challenge is more severe when gross production is applied as production measure rather than value added (which we use). Gandhi, Navarro and Rivers (2020) show that control function methods are not identified non-parametrically in the case of flexible inputs. They suggest utilizing non-parametric information contained in the first order conditions for the flexible inputs to resolve this issue. We refer to Van Beveren (2012) for a practical review and comparison of new non-frontier and semi-parametric approaches to TFP estimation.

Monto Carlo experiments reveal that more robustness in Ackerberg, Caves and Frazer's approach does come at an efficiency cost.

Wooldridge's (2009) estimation procedure is chosen in our baseline empirical investigations due to relatively efficient optimization algorithms, the advantages by using intermediates as proxy instead of investments, efficient implicit selection correction and decent small sample properties. A one stage procedure also makes computation of standard errors easier, although it requires non-linear estimation for a larger set of parameters than the other approach. Wooldridge's procedure is somewhat more complex one-step estimation by general method of moments, so we are aware of possible estimation challenges related to estimation on small samples. The other control function estimation procedures applied estimate the production function in two steps and thereby involve efficiency losses in the estimation. The possible collinearity challenge in Levinsohn and Petrin's procedure associated with intermediates as proxy for productivity shocks may cause a challenge in case of this approach, although it is less severe when value added is applied as production measure instead of gross production. Ackerberg, Caves and Frazer's estimation approach has relatively poor small sample properties, while Olley and Pakes' (1996) approach is somewhat more basic than the other mentioned control function approaches and relies on positive investments as a proxy to investment shocks. Due to the mentioned weaknesses, these estimation approaches are only applied in our robustness checks.

To implement the control function estimation procedures, we apply the Stata program '*prodest*', developed by Rovigatti and Mollisi (2018). We utilize positive gross investments as proxy[****] in Olley and Pakes' procedure and intermediates as proxy in the other procedures. Prodest also allows us to apply implicit selection correction related to exits, which we apply at firm level.

Production estimation may also suffer from other biases than simultaneous biases (e.g. endogenous factor inputs) and selection biases (e.g. in the case of entry and exits). These include measurement biases (e.g. imprecise price deflators or errors in the financial reporting) and specification biases (e.g. omitted variables or limitations of the Cobb-Douglas technology assumption). To address the robustness of our results with regard to these possible biases and illuminate the results of more basic approaches to production estimation, neoclassical estimation techniques come in handy. As simple benchmarks in our productivity estimation in appendix B, we estimate total factor productivity with Cobb-Douglas technology with ordinary least squares, both controlling for terms of trade development and not. Furthermore, we estimate total factor productivity in a panel data linear least square effects fixed effect framework to decrease the measurement errors by controlling for year and observation units fixed effects, as well as autocorrelation and heteroscedasticity.

In addition, we assess the specification bias by detaching ourselves from the Cobb-Douglas technology assumption about an elasticity of substitution equal to one. Instead, we assume a Constant Elasticity of Substitution (CES) technology, following the estimation procedures suggested by Kmenta (1967). First, we apply the nonlinear least squares estimation method, seeing that the CES production function cannot be monotonically transformed into a linear function. In this case, we assume constant return to scale and skip fixed effect dummies to obtain convergence. Second, we a panel data linear least square with year and observation unit fixed effects to estimate Kmenta's Taylor approximation of the CES-function, controlling for heteroskedasticity and autocorrelation. Note that this Taylor approximation collapses to a variant of the translog representation suggested by Berndt and Christensen (1973).

[****] When looking into negative investments in our data, it appears that large negative investments in line with large positive investments predict a reactive actor and improved productivity. Thus, the relationship between gross investments and predicted productivity appears to be nonlinear around zero. We therefore ignore negative investments rather than creating a gross investment index in our implementation of Olley and Pakes' and Ackerberg, Caves and Frazer's estimation procedures, being aware that the methods only allow for one proxy.

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2.4 Measuring Impact of Increased Market Access

Our object is to explore the impact of increased market access on total factor productivity and input factor usage. We aim to find out how impulses on firm level productivity and factor allocation contribute to higher social wealth. In order to do so, we make use of a panel data least square framework with year fixed effects, observation unit fixed effects (i.e. firm, industry or municipality), and standard errors clustered on observation units.

Our starting point for impact measurement is a panel data least square regression framework with fixed effects that assess the impact of increased market access on a given economic key variable. We let $x_{i,t} = \{a_{i,t}, l_{i,t}\}$ be log of total factor productivity ($a_{i,t}$) or labor input ($l_{i,t}$) for observation group r at year t.[††††] Our regression equation is then given by:

$$(6)\ x_{i,t} = \beta_0 + DJT_{J(i),t} + DU_i + \beta_1 \hat{g}^{f}_{r(i),t}(\mathcal{N}_{t_0}, \mathcal{D}_{r,t}) + \varepsilon_{i,t}$$

where $DJT_{J(i),t}$ is an industry-year dummy for observation unit i's industry J (i.e. A64 Rev. 2 industry, confer subsection 3.1) at time t and DU_i is a dummy for observation unit i. Note that $DJT_{J(i),t}$ collapses to year dummies in regressions are municipal industries and municipalities. $\varepsilon_{i,t}$ is the error term corrected for spherical correlation patterns, and β_0 and β_1 are regression coefficients. β_1 can be interpreted as an agglomeration elasticity. The key to assessing the possible impact of the road opening lies of course in whether β_1 is significant different from zero or not.

$g^{f}_{r(i),t}(\mathcal{N}_{t_0}, \mathcal{D}_{r(i),t})$ represents the market access function for firm i in region r at time t, given distance decay assumption f. As accounted for in subsection 2.2, we hold employment matrix ($\mathcal{N}_{t_0}$) constant in the market access function to adjust for urbanization trends. Furthermore, we let the distance matrix ($\mathcal{D}_{r(i),t}$) vary freely over time beyond buffer zones of twenty traveling kilometers (measured in the initial year) from each location (as endogeneity tests and background literature suggest that causal effects can be captured without instrumentation, confer subsection 5.1 and appendix A respectively). By this specification of approach, we only capture changes in market access related to decreased traveling times and not changes related to other labor market developments.

In case of production estimation, selection biases related to firm exits are implicitly taken into account in the control function approaches. When investigating average impact on firm size in a supplementary analysis, we instead utilize Heckman's correction procedure (confer Heckman 1979) to correct for this bias, still applying firm fixed effect, industry-year interaction dummies and clustering of standard errors on firms. This is further accounted for in subappendix B.3.

Utilizing the placebo measures for market access established in subsection 2.2, we will now construct a framework for placebo testing to enable revelation of potential underlying trends. Again, we utilize a panel data least square framework with industry-year interaction dummies (simplifying to year dummies on aggregated observation level), observation unit group fixed effects and clustering standard errors on observation units.

[††††] In appendix B, we extend the vector of outcome variables $x_{i,t} = \{a_{i,t}, l_{i,t}, k_{i,t}, F_{i,t}\}$ to include fixed capital services ($k_{i,t}$) and firm size in terms of the number of persons engaged (i.e. employees and self-employed) per firm ($F_{i,t}$) for observation group r at year t.

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We use 2004 to 2008 as our placebo test period, since only one substantial road construction opening took place in this period. This opening was between Lyngdal and Flekkefjord municipalities, which therefore are taken out of the sample in the placebo tests. In our placebo test framework, we pretend that the road constructions took place in the beginning of 2007, thereby applying 2004 to 2006 as our placebo pretreatment period and 2007 to 2008 as our placebo posttreatment period. In the placebo measure for market access, we hold the labor stocks constant at 2004 levels and apply 2004 traveling time spans for the placebo pretreatment period and 2014 traveling time spans for the placebo posttreatment period (i.e. $g^{f}_{r(i),t}(\mathcal{N}_{t_0}, \mathcal{D}^{pl}_{i,t})$).

$$(7)\ x_{i,t} = \beta_0^{pl} + DJT^{pl}_{J(i),t} + DU^{pl}_i + \beta_1^{pl} g^{f}_{r(i),t}(\mathcal{N}_{t_0}, \mathcal{D}^{pl}_{i,t}) + \varepsilon^{pl}_{i,t}$$

where $DJT^{pl}_{J(i),t}$ is an industry-year dummy for observation unit i's industry J at time t and DU_i is a dummy for observation unit i. Furthermore, $\varepsilon^{pl}_{i,t}$ is the error term corrected for heteroskedasticity and autocorrelation, while β_0^{pl}, β_1^{pl} and β_2^{pl} are regression coefficients. Note that a β_1^{pl} significantly different from zero or of the same magnitude as β_1 indicates there might be an underlying trend. A significant placebo test could of course also be an expression of a temporary random deviation from a more ordinary development path. It could even involve lagged impulses of market access, or responses to the announcement of a road opening rather than the road opening itself (probably more relevant for factor utilization than productivity). Yet, it does in any case indicate that corresponding potential significant impulse estimates may be questionable. Comparison of estimates for β_1 and β_1^{pl} can also be useful when considering potential impacts of the road constructions.

3. Data Sources

To be able to study regional integration impacts from major road constructions, we have combined and processed various sources for firm data and traveling data. These data are accounted for in the following.

3.1 Firm Data

In our analyses, we apply accounting data from the Norwegian Register of Business Enterprises at the Brønnøysund Register Centre (Norwegian Register of Business Enterprises in short) from 2004 to 2014, where data for 2003 is used in addition to estimate terms-of-trade control. The Norwegian Register of Business Enterprises covers about 95 percent of the business sector employment in Norway including public firms (Holmen 2022b). For some firm branches in some years, the zip codes are missing or did not exist in our study period. In this case, we exploit our own mapping of historical zip codes, time series of reported zip codes, correspondence between postal box codes and physical zip codes and other reported geographical information to determine geographical location by zip code, when possible. When monetary values are stated in foreign currency, we convert the monetary values to NOK, using the Norwegian Central Bank's statistics for historical exchange rates. As justified in subsection 2.1, we limit our study to 16 municipalities along the coastline of Southern Norway.

Applying European enterprise register data involves a branch challenge, since the geographic distribution of economic activities beyond employment in firms with branches at multiple geographic locations is not

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identified.[‡‡‡‡] Consequently, we limit ourselves to single-branch firms in analyses concerning other economic key variables than employment, since we do not have geographic identification for activities within multi-branch firms.[§§§§] To avoid possible biases related to single-branch firms becoming multi-branch firms over the study period and vice versa, we classify all firms that are multi-branch firms at least once during our study period as multi-branch firms. For each year, we also ommit firms without employment or fixed capital holdings, as such firms are rather peculiar, and both factor inputs are essential in neoclassical production functions.

In some of our analyses on employment composition effects, we have approximated the distribution of labor costs over branches in multi-firm by the help of employment shares and industry belonging, as previously done in Holmen (2022b). In cases where firms are registered with more employees than its branches, the surplus of employees are allocated to their headquarters. Formally, labor costs $w_{b,t}$ in branch b at time t is approximated as:

$$(8)\ w_{b,t} = \frac{\frac{\tilde{w}_{i(b),t}}{\tilde{n}_{i(b),t}} n_{b,t}}{\sum_{\hat{b}=1}^{B_{f(b)}} \frac{\tilde{w}_{i(\hat{b}),t}}{\tilde{n}_{i(\hat{b}),t}} n_{\hat{b},t}} w_{f(b),t}$$

where $\tilde{w}_{i(b),t}$ and $\tilde{n}_{i(b),t}$ are the labor costs and employment for single-branch firms in the industry $i(b)$ of branch b at time t respectively, while $w_{f(b),t}$ and $B_{f(b)}$ are labor costs and the number of branches in firm f of branch b respectively. Put differently, $w_{f(b),t}$ is the labor costs to be distributed, while the fraction corresponds to branch b's share of the variable at firm level. Single-industry ratios are obtained from the enterprise register, when available, and from the national accounts otherwise.

In our study, we utilize the industry classification standard applied in European national accounts, A64 second revision. We have grouped the industries defined by the A64 second revision industry classification into ten industries, as accounted for in the Table 1. We do not consider resource industries, oil and gas extractors, construction, finance and insurance and real estate and non-market-oriented industries. These industries are excluded because of measurement and identification issues, as they are either relatively volatile, not profit-driven, strongly driven by international prices and local natural resources, strongly regulated, requiring alternative measurement of value added, directly affected by road construction processes or poorly captured by the enterprise register. Higher market access might induce productivity impulses in these industries as well, but since they are likely to create noise in our analyses, we exclude them.

In addition, we omit the oil and gas suppliers, since these firms generally have had a stronger development than mainland suppliers across NACE codes, strongly dependent on the development in the oil and gas markets (e.g. Grünfeld et al. 2013). This industry sector is also characterized by quality competition, resulting in relatively heterogeneous performance, which is unlikely to be related to expansion of the road network. Since the NACE system largely constitutes an activity-based rather than a market-oriented industry classification, these firms

[‡‡‡‡] Firms with reporting duty to the Norwegian Register of Business Enterprises are only obliged to report industry belonging, number of employees, head quarter status and geographic location are reported at branch level.

[§§§§] Studying the Canadian manufacturing sector, Rigby and Brown (2015) investigates how agglomeration gains differ between single-branch and multi-branch firms. Their empirical results suggest that single-branch firms obtain stronger productivity gains from the matching of workers and knowledge spillovers, whereas multi-branch obtain stronger productivity gains from the presence of upstream input suppliers. In general, they find that single-branch firms obtain more agglomeration gains than multi-branch firms do. To the contrary, Rosenthal and Strange (2003) find little evidence that aggregate agglomeration impulses differ for subsidiaries and independent units. Studying six manufacturing industries in the United States, they only find significant differences in agglomeration benefits for the fabricated manufacturing industry.

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cannot be identified by the traditional NACE system. Instead, we have applied the oil and gas firm population developed by International Research Institute of Stavanger and Menon Economics with regional collaborators[*****] (Blomgren et al. 2015). It contains firms that mainly deliver goods to the petroleum extractors' value chain. The firm population is also utilized in some supplementary investigations in subappendix B.5.

Table 1. Industry classification

Industry sector	NACE codes
Consumer good manufacturing	NACE 8 to 15, 18 and 31 to 32
Material manufacturing	NACE 16 to 17 and 19 to 25
Technological manufacturing	NACE 26 to 30 and 33
Wholesale and vehicle trade	NACE 45 to 46
Retail trade	NACE 47
Transportation	NACE 49 to 52 except 49.5, 50.101 and 50.201
Tourism	NACE 55 to 56 and 70
Information services	NACE 58 to 63
Knowledge consultancy	NACE 69 to 75
Business support services	NACE 77 to 78 and 80 to 82

We apply processed fixed figures (i.e. figures for fixed capital services, gross investments, depreciation in fixed prices and industry- and asset-specific capital deflators), obtained from Holmen (2022b).[†††††] We will operate with ten different forms of fixed capital; `land area', 'buildings', 'construction', 'machinery', 'equipment', 'small means of transportation', 'large means of transportation and mobile production units', 'research and development', 'patents' and 'cultivated biological resources'. Furthermore, we operate with two forms of intermediates – 'commodity purchases' and 'service purchases', which include electricity purchases, but exclude financial costs. Commodity and service deflators are also obtained from Holmen (2020), which are based on the Norwegian national accounts' gross production and intermediate deflators and industry input-output matrixes. Note that regional price developments are accounted for in the capital deflators for buildings and land area and the service purchase deflators (which is affected at a rate proportional to share of services purchases related to real

[*****] Regional collaborators include Bodø Science Park, Center for Economic Research at Norwegian University of Science and Technology, Eastern Norway Research Institute and Impello Management.

[†††††] Holmen (2022b) estimates fixed capital figures by the perpetual inventory methods with industry-specific capital deflators and depreciation rates, utilizing firm data from the Norwegian Register of Business Enterprises and macro data derived from inter alia the Norwegian National Accounts. In case of real estate, the deflators are also regional. For asset forms without capital depreciation, the author uses book value adjustment instead. We utilize fixed capital services as our capital measure, which adjusts the capital utilization for capital composition by weighting each type of asset in accordance to their stock volume and annual required return (confer Jorgenson and Griliches 1967 and Christensen and Jorgenson 1969 for details on the concept). We refer to Holmen (2022b) for details on the practical implementation of the fixed capital services concept.

estate).[‡‡‡‡‡] In addition, we apply industry-specific deflators for gross production deflators and use industry-specific development in labor costs per person employed to deduce labor costs input deflators.

3.2 Spatial Data

In our research, we utilize annual traveling time data between all Norwegian zip codes (represented by post offices) from 2004 and 2014. The data are constructed by the Institute of Transport Economics and Menon Economics based on Geographic Information Systems data from the Norwegian Mapping Authority's '*Elvegdata*', which contains periodical shapefiles of the Norwegian route network. The calculations are carried out with the Dijkstra's (1959) algorithm, using the application '*Network Analyst'* in ArcGis. Traveling times are based on speed limits, implying that road quality that does not alter speed limits or distance (e.g. measures that reduce congestion or variations in waiting time at ferry crossings) is left unaccounted for. The same goes for more generalized transportation costs (e.g. road tolls and logistical optimization). Moreover, traveling time reductions related to waiting and more generalized transportation costs often partly depend on local economic outcomes and would in that case be endogenous. Ferry transitions are assigned five minutes boarding time and a speed of 15 kilometers per hour.

The basic data from these calculations involve snap shots of the road network at different points in time. We have recalculated them into annual averages, where we have taken into account what time of the year major road construction projects were implemented. In this regard, all road connections with a traveling time reduction above five minutes within thirty minutes in the dataset were quality assured and corrected in case of inaccuracies. In the quality assurance of the Norwegian traveling data, the Norwegian Public Road Administration's project database was utilized. A few temporary breaches in the road network (e.g. due to winter closed roads or ferry crossings) were identified and corrected. Data from Gule Sider and Google Maps have been used to connect geographical destinations to the road network in a few incidences of missing data. To account for traveling data to neighboring countries, the Institute of Transport Economics has collected traveling times to all municipalities in Denmark, Sweden, Northern Finland (i.e. Kajanaland, Lapland and Pohjois-Pohjanmaa counties) and Murmansk Oblast from all border crossing from Norway, using Open Street Map. Note that this includes all foreign municipalities within six hours' reach from Norway including travel by ferry.

The division for population statistics at Statistics Norway has calculated the built-up areas of each zip code based on maps over buildings and population in Norway. Based on these areas, we have approximated internal traveling distances, assuming that the average traveling time equals half of the radius of a circle with similar area. In line with assumptions made by the division for population statistics at Statistics Norway, we assume a speed limit of 60 kilometers per hour within zip codes. We do not allow internal traveling times within zip codes to change over time, but we set them equal to their approximated value in the initial year (i.e. 2004). We refer to the acknowledgement section towards the end of this paper for an overview of the people, who have contributed to the construction of the traveling dataset.

Employment at residence and workplace and population figures are obtained at zip code level and municipal level from Statistics Norway. The geographical location information of between 1.5 to 3 percent of employment figures at municipal level is not identified at zip code level. We have distributed municipal employment figures without known zip code location proportionately to the annual employment shares within the municipalities. Employment and population figures for municipalities in the other neighboring countries are collected from Statistics Denmark,

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[‡‡‡‡‡] In the fixed capital and deflator data applied, it is distinguished between regional price differences related to real estate capital and real estate purchases, based on processed price data from Statistics Norway and Eiendomsverdi (confer Holmen 2020 for details). The other price deflators are national, implying that we will not be able to adjust for local price variations for other economic components beyond what follows from differences in industry composition and differences in the relative strengths of the ground components.

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Statistics Finland and Statistics Sweden. For Murmansk Oblast, we approximate employment and population data by combining municipal data from City Population with regional data from Russian Federal State Statistics Service and national data from the World Bank and the International Labour Organization. Here, we have stipulated the local development based on the aggergate development and figures, and otherwise assumptions about geometric growth in years between the reported observations.

Data utilized to shed light on descriptive statistics, including statistics on income and population, are collected from Statistics Norway. We apply dwelling prices harmonized over quality at municipality level, which are processed by Holmen (2022b), based on price statistics from Eiendomsverdi and Statistics Norway. In this data, the municipal composition of dwelling types is assumed to be the same as at national level.

4. Descriptive Statistics

Before carrying out our empirical investigations, it is worth taking a closer look at the development patterns in our study region. In the following, we will present the main regional economic development of Coastal Southern Norway compared to the rest of Norway and look at status and development for market access in the region.

4.1 Economic Development in the Study Region

In Fig. 3 below, we depict some important development patterns for our study region of Coastal Southern Norway, benchmarked against the other municipalities in our extended study region. A peculiar characteristic of our study region is that it has built up a large supply industry for the petroleum sector over our study period. Accordingly, we have excluded petroleum suppliers from our sample, as accounted for in subsection 3.1. We see relatively weak developments in employment by working place and in the unemployment rate in Coastal Southern Norway late in the study period. Similarly, the housing price development was relatively weak in Coastal Southern Norway in the last years of our study period. Throughout our study period, Coastal Southern Norway had a stronger population growth for people at working age than the rest of our extended study region, while the development in average personal income follows about the same development path.

Our data selection contains 6,134 firms in the core study region and 26,602 firms in the extended study region (including our core study region) over 11 years. In 2004, these firms employed 18,154 persons in the core study region and 81,472 persons in the extended study region, compared to 21,291 and 97,372 in 2004 respectively. As accounted for in section 3.1, we have neglected certain industries (i.e. industries with developments dominated by natural resources, heavy capital investments and non-market-oriented industries) and multi-branch firms to achieve a cleaner identification. Per 2004, 58.2 and 65.0 percent of the employees registered in the Norwegian Enterprise Register worked in the selected industries in the core study region and the extended study region respectively, whereof 49.6 and 49.8 percent worked in single-branch firms. Per 2014, the share of enterprise employment working in the selected industries had fallen to 51.8 percent in the core study region and to 59.1 percent in the extended study region. Yet, the single-branch firms' share of employment in the selected industries remained nearly the same, at 48.7 percent in the core study region and 48.3 percent in the extended region in 2014.

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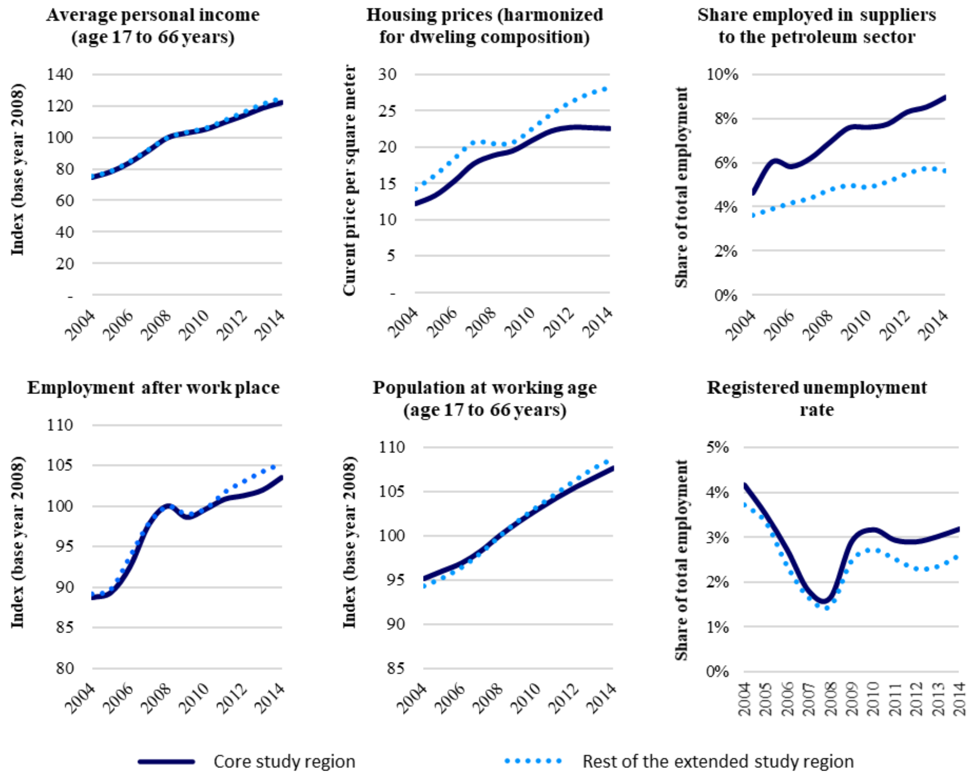

Fig. 3. Development for the whole study region compared to other municipalities with intermediate urbanization level with 2008 as base year. Money terms are stated in current prices.

In Fig. 4, we provide more comparative statistics on Coastal Southern Norway and the rest of our extended study region. We see that overall development in productivity and net value added is not very strong, which must be seen in relation to changes in the industry composition and omission of industry developments from our study (e.g. the rise of the oil and gas supply sector). Overall, the in-sample developments in the core study region and the rest of the extended region follow each other rather closely across variables over our study period.

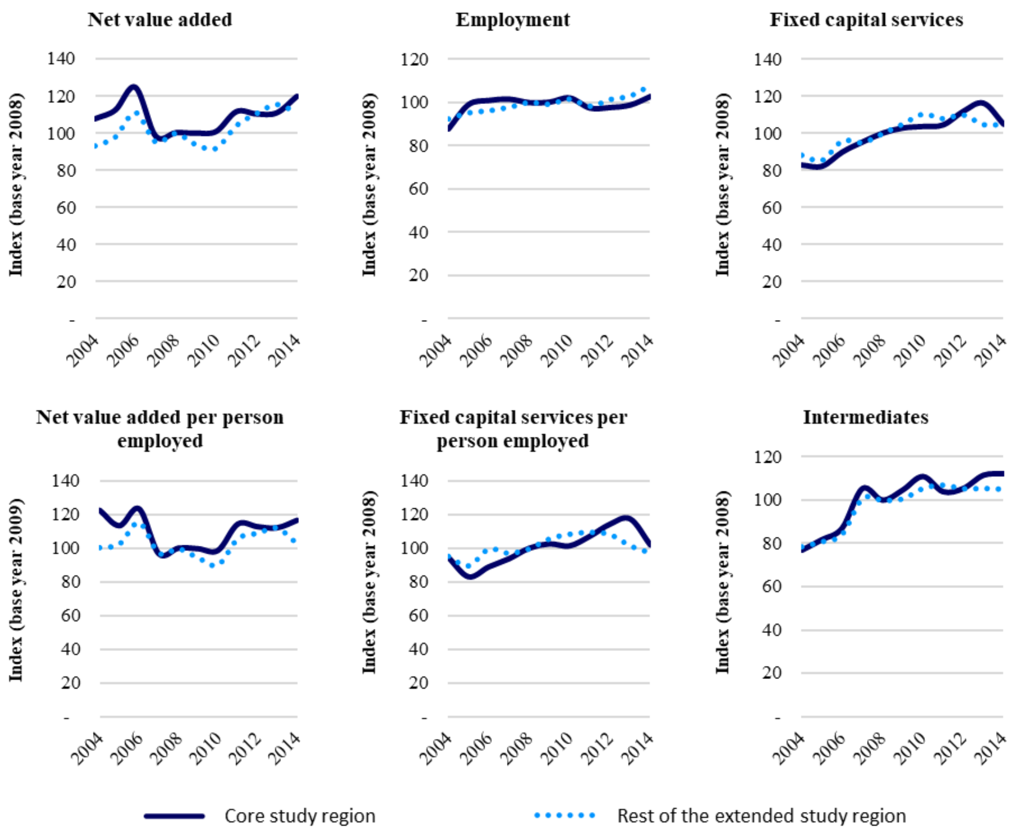

Fig. 4. Development for our data sample in the study region compared to other municipalities with intermediate urbanization level estimated by 2008 as base year. Money terms are stated in fixed prices at average price level from 1999 to 2014.

4.2 Status and Development in Market Access

In the following, we will account for status development in market access measures with power and exponential distance decay, measured by the framework established in subsection 2.2. In line with Holmen (2002a), we have set the power distance decay parameter to $\delta^{pow} = 2.3$ and the exponential distance decay parameter to $\delta^{exp} = 0.07$. In both cases, we hold employment (the applied source of potential market connections) constant to the initial year and operate with constant traveling time within buffer zones of twenty traveling kilometers from each location. We will focus on our core study region, as we have excluded municipalities close to road openings from our extended study region and the remaining municipalities only are subject to low or relatively moderate changes in market access.

In Fig. 5, we depict the measured market access in 2004 by the two measures compared to Kristiansand – the regional largest city (marked by dark blue in the maps). As expected, the alternative measures show resembling market access patterns. We see that the differences in market access between Kristiansand and the second most central municipalities in the region are a bit larger in case of power distance decay measure than in case of exponential distance decay measure. In case of exponential distance decay, measured market access is closely related to proximity to Kristiansand, while the pattern is somewhat weaker in case of power distance decay.

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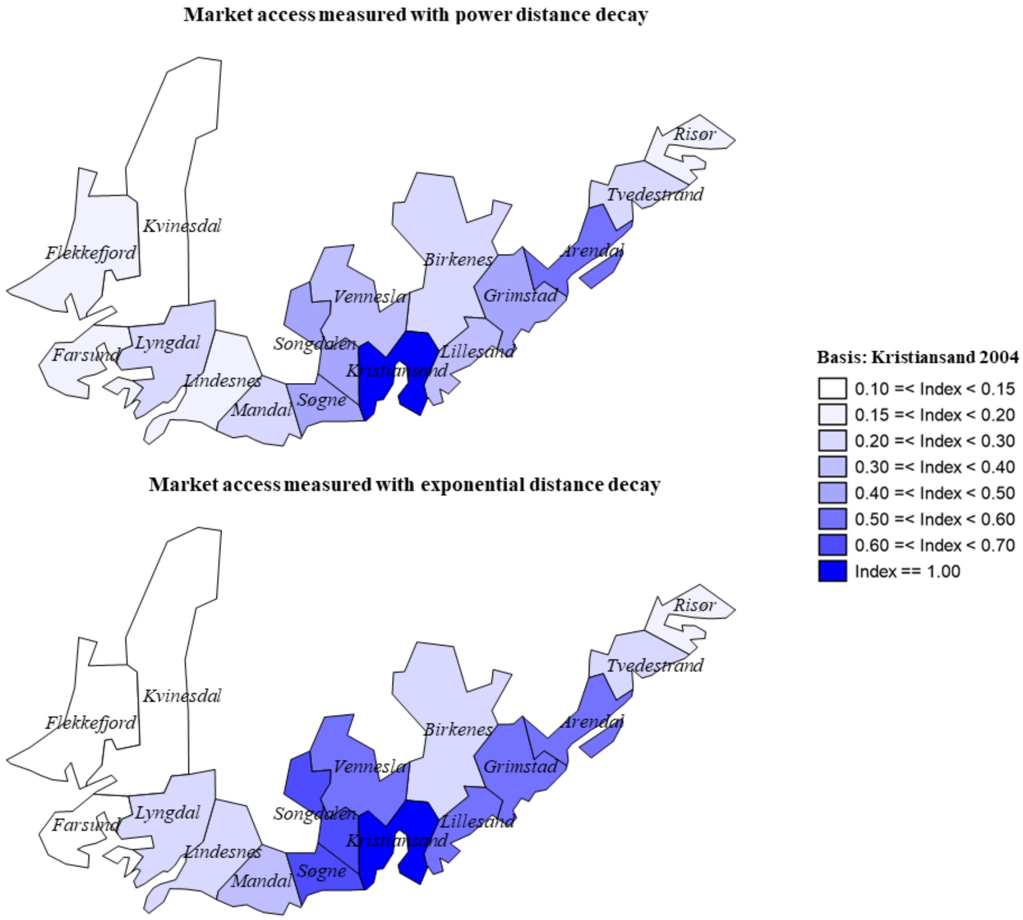

Fig. 5. a) Market access in our study region in 2004 measured with a) power distance decay function with $\delta^{pow} = 2.3$ (top) and b) exponential distance decay function with $\delta^{exp} = 0.07$ (bottom). Measured relative to the market access in Kristiansand in 2004

In Fig. 6, we have illustrated the municipal increases in market access during our study period from 2004 and 2014. The highest increase in market access by both measures occurred in connection with the renewal of European Route 18 east of Kristiansand in August 2009, through Lillesand to Grimstad. The highest relative increase in market access by both market access measures occurred in Lillesand (marked in dark blue), which became more integrated with both of its neighboring municipalities. Northeast of our study region, Risør and Tvedestrand were also affected by another road opening at European Route 18 north towards Gjerstad municipality and Telemark county, which was implemented already in August 2004. Note that market access is measured on an annual basis.

The increase in market access in the Lister Region (capturing the four municipalities west in our study region) were subject to two investments, which triggered modest increases in market access. Although the investments induced substantial traveling timesavings, the traveling times between the municipalities remained relatively high. The first of these projects was realized at European Route 39 along the regional west-east axis of the Lister Region in August 2006, whereas the second was implemented incrementally from November 2009 and October 2012 along the regional north-south axis of the Lister Region at County Route 465 in Vest-Agder. The regional increase in market access in the Lister region was more prominent, when exponential distance decay was applied, than when power distance decay was applied, given our pre-estimated distance decay parameters. This is partly

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due to lower initial market access levels in case of exponential distance decay. The highest increase in market access in this subregion occurred in Flekkefjord (the municipality located farthest west in our study region).

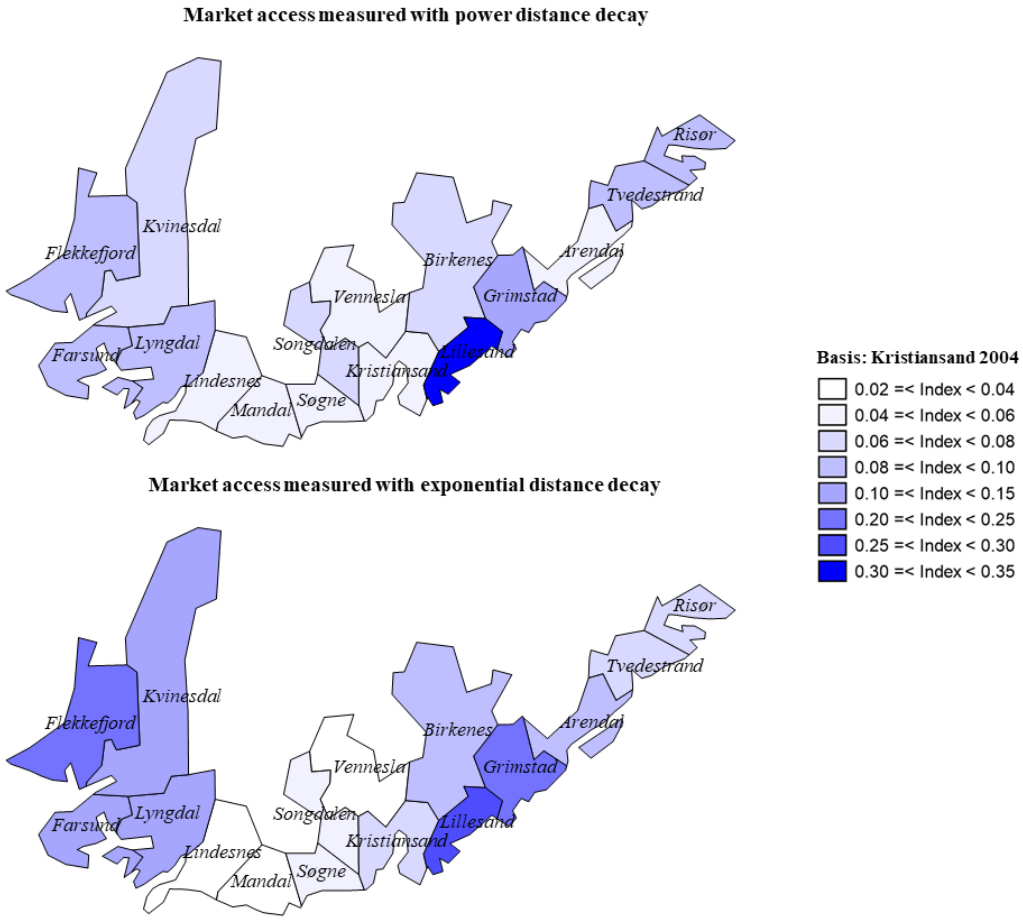

Fig. 6. a) Increase in market access in our study region from 2004 to 2014 measured with a) power distance decay function with $\delta^{pow} = 2.3$ (top) and b) exponential distance decay function with $\delta^{exp} = 0.07$ (bottom). Measured relative to the market access in Kristiansand in 2004

5. Empirical Investigations

In this section, we study the productivity impact of regional integration caused by road constructions empirically. We start by verifying the endogeneity of Norwegian road investments. Then we consider productivity impulses at firm level, before we turn to composition effects. Composition effects from regional integration affect the aggregate productivity developments through changes in factor allocation and heterogeneous impacts over firms. They may occur within or between industries and regions. Various robustness checks are provided in appendix B.

We distinguish between three types of composition effects. First, we consider intra-industry composition effects, which reflect that regional integration may have different impacts at firm level and at industry level. This may be due to heterogeneous impact over firm sizes or restructuring within the industry under investigation. Second, we assess composition effects between industries at a given location. These reflect local reallocation of factor inputs,

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possibly towards industries with higher factor return. Third, we address regional composition effects. These reflect how the regional factor allocation between municipalities is affected.

5.1 Endogeneity of Norwegian Road Investments

As briefly discussed in subsection 2.1 and elaborated on in subappendix A.1, earlier studies suggest that concerns about wider economic impacts and net benefits more generally play a rather limited role in the practical decision processes that lead up to new road construction projects. To ascertain that road construction does not suffer from reverse causality with respect to productivity in our study sample, we have performed a simple endogeneity test, by considering last period's labor productivity impact on current period's road-related increases in market access. We consider three regional delimitations with municipal level over ten years – the coastal municipalities in Southern Norway (i.e. our core study region), the Southern counties of Norway (i.e. the extended region applied in our estimation of the distance decay parameters) and the whole country. For each municipality, we considered the weighted traveling time to all 3,196 geographical zip codes in Norway as well as 465 municipalities in the neighboring countries (confer subsection 3.2 for details).

As depicted in Table 2, the test indicates that Norwegian road construction can be considered exogenous to productivity, regardless of the choices of regional delimitation and distance decay pattern. For our study region, the p-values range from 45 to 55 percent, so no further testing is needed. We report the results on municipal level, as economic activity is rather uneven between zip codes, but it can be noted that the results also hold on regressions at zip code level.

Table 2. Impact of lagged net value added per person engaged on market access from 2004 to 2014, estimated on municipal level. (* for $p < 0.1$, ** for $p < 0.05$ and *** for $p < 0.01$)

Market access (*logarithm*)	**Core study region**		**Extended study region**		**Whole country**	
Industry structure control	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**
Capital intensity control	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**
Specification with power distance decay						
Lagged net value added per person engaged	0.018 (0.023)	0.015 (0.020)	0.000 (0.003)	0.000 (0.003)	-0.002 (0.001)	-0.002 (0.001)
Specification with exponential distance decay						
Lagged net value added per person engaged	0.014 (0.023)	0.014 (0.022)	-0.001 (0.005)	-0.001 (0.005)	-0.003 (0.002)	-0.003 (0.002)
No. of observations	160	160	1,420	1,420	4,277	4,277

5.2 Genuine Productivity Effects at Firm Level

Our baseline results for productivity impulses at firm level are shown in

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Table 3. The results provide little evidence of firm level TFP impulses from expansion in the road network. Within Coastal Southern Norway, there are weak indications that the local tourism industry has had relatively high productivity growth in areas close to major road openings, but this result disappears when we apply our broader study region. By a similar token, there are some indications of productivity improvements in information service firms close to road openings, but this result is clearly induced by an underlying productivity trend, when we consider the broader study region.

In the manufacturing sector in Coastal Southern Norway, consumer material manufacturing firms close to road openings seem to have escaped a negative underlying trend, while the opposite is the case for technological manufacturing firms. Yet, neither of these results hold when the extended study region is applied. In case of technological manufacturing, the development may have been influenced by the rise of the regional oil and gas supply manufacturing industry (which we have omitted from our study, confer subsection 3.1) in the study region over the study period. For the other industries investigated, our main regressions at firm level produce no significant results. Overall, the point results are influenced considerably by what market access function is applied, but the overall patterns are the same.

Supplementary investigations to these analyses are reported in subappendix B.1. Breakdown of firms lasting over our study region into subsamples based on firm size gave few indications of productivity impulses from increased market access. Our supplementary analyses suggest that small firms in Coastal Southern Norway within tourism, material manufacturing and wholesale and vehicle trade have had a stronger productivity growth than other firms in the region. Yet, these results do no longer hold when we consider a broader control region.

With regard to robustness, alternative estimation procedures on firms lasting over our study period and less aggressive distance decay patterns produce somewhat different results, occasionally involving slightly stronger indications of productivity impulses for consumer manufacturing firms and weaker indications for tourism firms within Coastal Southern Norway. In particular, our baseline results involving positive productivity impulses for tourism firms at firm level do not appear very robust, while positive productivity impulses on firms within consumer manufacturing appear to be subject to an underlying trend in case of application of the extended study region. Both firms within tourism and consumer manufacturing seemingly receive positive productivity impulses from increased market access when less aggressive distance decay patterns are assumed, but only when our regressions are limited to our core study region. Exclusion of our regression control for terms of trade from our baseline regression and implicit estimation of the market access impulses in the production estimation also involve some weak indications of productivity impulses, but the differences from the baseline regressions are likely to be related to lack of control for industry-specific developments.

Moreover, the patterns remain the same with few indications of productivity impulses when a broader study region is applied. In the subappendix B.1, we also consider impulses from higher market access through road openings on other components of technical productivity than TFP at firm level, including scale efficiency and allocative efficiency. These analyses clearly suggested that no such impulses were in play.

Overall, our firm level investigation does not provide any convincing and unequivocal evidence of firm productivity impulses from regional integration caused by major road openings. In some industries, there are weak indications that regional firms close to road openings have experienced stronger productivity growth than other regional firms prior to openings. Yet, these results are no longer significant when a broader study region is applied.

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Table 3. Impacts and placebo impacts of increased market access caused by traveling time reduction on TFP over industries at firm level, estimated by linear panel data regressions using industry-specific year dummies, firm fixed effects and clustered standard errors on firms. Market access is measured with power distance decay ($\delta^{pow} = 2.3$) and exponential distance decay ($\delta^{exp} = 0.07$). TFP is pre-estimated by Wooldridge's estimation procedure with terms of trade as control variable and correction for firm exits. (* for p < 0.1, ** for p < 0.05 and *** for p < 0.01)

Impact on TFP	**Impact**				**Placebo**			
Study region	**Core**		**Extended**		**Core**		**Extended**	
Industry \ distance decay	**Power**	**Exp.**	**Power**	**Exp.**	**Power**	**Exp.**	**Power**	**Exp.**
	0.614	0.867	-0.047	0.108	-6.433***	-3.318**	0.041	0.096
Consumer manufacturing	(0.460)	(0.599)	(0.260)	(0.331)	(0.951)	(1.370)	(0.324)	(0.440)
	n = 1,139	n = 1,139	n = 4,770	n = 4,770	n = 510	n = 510	n = 2,306	n = 2,306
	1.289	0.752	0.002	-0.121	0.190	0.235	-0.096	-0.195
Material manufacturing	(0.947)	(0.700)	(0.131)	(0.131)	(0.313)	(0.387)	(0.247)	(0.332)
	n = 1,348	n = 1,348	n = 6,291	n = 6,291	n = 651	n = 651	n = 3,089	n = 3,089
	0.439	0.662	1.092	0.857	1.471***	3.089***	0.279	0.121
Technological manufacturing	(0.407)	(0.533)	(1.047)	(1.047)	(0.494)	(1.013)	(0.435)	(1.048)
	n = 841	n = 841	n = 3,787	n = 3,787	n = 387	n = 387	n = 1,794	n = 1,794
	0.985	1.500	0.067	0.079	0.285	0.336	0.092	0.113
Wholesale and vehicle trade	(0.625)	(1.110)	(0.121)	(0.123)	(0.234)	(0.365)	(0.075)	(0.110)
	n = 3,793	n = 3,793	n = 17,113	n = 17,113	n = 1,709	n = 1,709	n = 8,072	n = 8,072
	0.078	-0.355	0.112	0.061	-0.109	0.828	-0.667	-1.317
Retail trade	(0.327)	(0.829)	(0.152)	(0.216)	(1.054)	(1.926)	(0.914)	(1.764)
	n = 5,014	n = 5,014	n = 20,832	n = 20,832	n = 2,306	n = 2,306	n = 10,251	n = 10,251
	0.116	0.038	0.035	0.060	4.187	2.942	-0.014	0.055
Transportation	(0.682)	(0.869)	(0.096)	(0.101)	(2.753)	(1.863)	(0.230)	(0.234)
	n = 1,572	n = 1,572	n = 8,770	n = 8,770	n = 670	n = 670	n = 3,796	n = 3,796
	10.85*	19.05***	1.174	0.191	-1.090***	-1.457**	0.794	1.044**
Tourism	(5.738)	(7.171)	(4.222)	(3.534)	(0.372)	(0.643)	(0.657)	(0.420)
	n = 1,968	n = 1,968	n = 8,530	n = 8,530	n = 821	n = 821	n = 3,806	n = 3,806
	0.313*	0.563*	0.111*	0.124*	-0.172	-0.250	0.095	0.148*
Information services	(0.188)	(0.288)	(0.068)	(0.072)	(0.261)	(0.313)	(0.138)	(0.088)
	n = 1,434	n = 1,434	n = 6,191	n = 6,191	n = 623	n = 623	n = 2,688	n = 2,688
	0.232	0.138	0.143	0.074	0.234	0.132	0.084	0.092
Knowledge consultancy	(0.234)	(0.247)	(0.092)	(0.101)	(0.661)	(0.700)	(0.110)	(0.093)
	n = 5,068	n = 5,068	n = 20,271	n = 20,271	n = 2,039	n = 2,039	n = 8,494	n = 8,494
	-0.132	0.043	0.510	0.301	0.671	1.499*	0.208	0.326
Business support	(0.366)	(0.416)	(0.495)	(0.270)	(0.626)	(0.791)	(0.221)	(0.216)
	n = 1,203	n = 1,203	n = 5,747	n = 5,747	n = 477	n = 477	n = 2,226	n = 2,226

5.3 Productivity Effects at Industry Level

Firm level productivity impulses generally do not coincide with the industry productivity at municipal level. First, productivity impulses may be uneven distributed over firm size, where unweighted firm level regressions like ours will put relatively much weight on small firms. To the contrary, our municipal level regressions will weight each municipality equally, regardless of their industry size provided that they are active. Second, factor inputs many be reallocated to more productive firms, inducing industry productivity gains even without firm productivity impulses.

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As we do not find any clear indications of productivity impulses at firm level, intra-industry composition effects between firms appear to be plausible explanations for potential industry productivity impulses of increased market access caused by new road constructions. Furthermore, industrial observation units at municipal level imply that industries in municipalities with low activity are weighted equally to major municipal industry clusters. This weighing will also affect the results, if factor inputs of an industry are reallocated between relatively urban and relative rural areas subsequent to a major road opening.

In our baseline regressions at industry level, we utilize municipal industries as observation units. Intra-industry composition effects over regions are investigated further in relation to regional composition effects in subsection 5.5. Our baseline results for industry productivity are depicted in

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Table 4.

The three manufacturing industries and wholesale and vehicle trade all show signs of productivity impulses from the road openings, but in all four cases the placebo tests reveal underlying development trends. The remaining service industries show few signs of productivity impulses, although in some of them, both positive and negative significant underlying development trends seem to have changed (i.e. retail trade, transportation industry and information services).

Supporting examinations on potential productivity effects at industry level are to be found in subappendix B.3. Results from alternative specifications to our baseline regressions reported in

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Table 4 produces similar results without any notable different conclusions (i.e. involving estimation on disaggregated industry aggregates, alternative approaches to TFP estimation and less aggressive distance decay).

In our investigation of potential intra-industry composition effects contributing to higher productivity at industry level, we have also decomposed each industry into masses of lasting firms and entering and exiting firms. These investigations give some indications of a restructuring of the retail industry next to road constructions, but not for other industries.

In line with similar investigations at firm level, we neither find signs of increased scale efficiency nor allocative efficiency. For retail trade and to a somewhat lesser extent business support, we find signs of retail industry restructuring towards larger multi-branch firms in areas close expansions in the road network, subsequent to the corresponding road openings.

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Table 4. Impacts and placebo impacts of increased market access caused by traveling time reduction on TFP over industries at municipal level, estimated by linear panel data regressions using year dummies, municipality fixed effects and clustered standard errors on municipalities. Market access is measured with power distance decay ($\delta^{pow} = 2.3$) and exponential distance decay ($\delta^{exp} = 0.07$). TFP is pre-estimated by Wooldridge's estimation procedure with terms of trade as control variable and correction for industry closures. (* for p < 0.1, ** for p < 0.05 and *** for p < 0.01)

Impact on TFP	Impact				Placebo			
Distance decay	Core		Extended		Core		Extended	
Industry \ Study region	Power	Exp.	Power	Exp.	Power	Exp.	Power	Exp.
Consumer manufacturing	4.551***	6.354**	-0.509	-0.130	14.410	12.660	21.24***	12.82***
	(1.392)	(2.271)	(2.888)	(2.027)	(13.840)	(12.300)	(6.076)	(4.777)
	n = 174	n = 174	n = 1,028	n = 1,028	n = 70	n = 70	n = 471	n = 471
Material manufacturing	5.082**	4.401	5.141**	2.960	-6.669	-7.256	9.527**	5.607
	(2.180)	(2.869)	(2.050)	(1.965)	(7.763)	(7.439)	(4.696)	(3.521)
	n = 176	n = 176	n = 1,126	n = 1,126	n = 70	n = 70	n = 515	n = 515
Technological manufacturing	10.32*	7.071	11.30***	8.904***	14.77**	11.03**	-1.682	-1.792
	(5.280)	(4.295)	(3.669)	(3.272)	(6.257)	(5.004)	(4.556)	(2.667)
	n = 162	n = 162	n = 911	n = 911	n = 62	n = 62	n = 406	n = 406
Wholesale and vehicle trade	2.192***	1.581**	3.419**	2.990**	3.406**	3.312**	10.59***	7.480**
	(0.483)	(0.665)	(1.432)	(1.176)	(1.250)	(1.289)	(3.568)	(3.121)
	n = 176	n = 176	n = 1,137	n = 1,137	n = 70	n = 70	n = 506	n = 506
Retail trade	-0.553	-0.390	0.749	0.033	3.954*	3.483**	-0.395	0.008
	(0.371)	(0.499)	(1.216)	(1.070)	(1.903)	(1.566)	(2.665)	(1.844)
	n = 176	n = 176	n = 1,188	n = 1,188	n = 70	n = 70	n = 526	n = 526
Transportation	-0.689	-1.068	-1.186	-0.844	1.411	1.796	5.002***	2.420**
	(1.189)	(1.022)	(1.490)	(1.090)	(3.440)	(2.409)	(1.558)	(1.079)
	n = 173	n = 173	n = 1,117	n = 1,117	n = 70	n = 70	n = 498	n = 498
Tourism	0.925	1.645	-0.326	0.006	1.541	0.230	4.732	1.103
	(2.214)	(2.042)	(1.621)	(1.392)	(2.830)	(1.854)	(4.722)	(2.789)
	n = 164	n = 164	n = 1,061	n = 1,061	n = 62	n = 62	n = 457	n = 457
Information services	-1.041	-0.524	-1.484	-1.328	-29.79**	-25.40**	8.700	6.898
	(1.235)	(0.804)	(1.558)	(1.306)	(11.660)	(9.175)	(5.507)	(4.161)
	n = 163	n = 163	n = 907	n = 907	n = 59	n = 59	n = 400	n = 400
Knowledge consultancy	0.480	0.772	-0.033	-0.280	-0.689	-1.452	-2.337	-1.755
	(0.390)	(0.484)	(1.040)	(1.206)	(1.155)	(1.630)	(2.909)	(2.222)
	n = 176	n = 176	n = 1,158	n = 1,158	n = 70	n = 70	n = 519	n = 519
Business support	-0.592	-0.039	0.009	-0.061	7.654	7.167	5.890	3.589
	(1.857)	(1.924)	(2.165)	(1.835)	(9.492)	(7.490)	(3.556)	(2.160)
	n = 161	n = 161	n = 874	n = 874	n = 62	n = 62	n = 363	n = 363

5.4 Inter-Industry Factor Composition Effects

At a given location, aggregate productivity impulses from regional integration may occur due to inter-industry composition effects, even when industry level productivity impulses are absent. Such composition effects between industries necessarily involve reallocation of factor inputs to more efficient factor utilization. We will focus mainly on reallocation of labor, as the aggregate labor's share of net value added is nearly 90 percent, and as fixed capital either tends to be mobile (e.g. machinery and equipment, means of transportation and immaterial capital) or immobile (e.g. buildings and construction) subsequent to investments.

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In principle, there is a distinction between industries that provide constructions and services for the local community and industries producing commodities and services which are primarily targeted towards export outside the region. Industries dominated by export will be more flexible with regard to adjustment in activity level than industries dominated by the provision of goods consumed locally. In practice, the distinction is not clean cut, as some industries may produce goods for both local and external consumption, where the degree of exporting activities depends on competitiveness and composition of their deliveries. Firms in some industries may also deliver customized deliveries to dominate firms in their local industry, which in turn are tied up in global value chains. Overall, a strengthening of the regional trade balance is in principle not tied to particular industries in the long run, making the activity levels of the associated industries considerably more flexible than the ones associated with local service industries. For all industries, however, improvements in the work distribution between industries within or across municipalities could contribute to higher productivity at macro level.

In our investigation of composition effects between industries, we will carry out regression analyses at municipal level for each industry, but also consider the aggregate developments in our core study region and the rest of our extended study region. As mentioned in the previous subsection, usage of municipalities as unweighted observation units implies that municipal industry observations – with limited, but positive, activities – are weighted equally as municipal industries representing larger industry clusters.

In Table 5, we shed light on the overall movement of labor across sectors over the study period. As we have employment figures for branches in multi-branch firms in addition to single-branch firms, we include these in our baseline investigation. On the left hand side of the table, we have shown the labor costs in each industry in the core study region and in the rest of the extended study region. Differences in labor costs do of course partially reflect differences in human capital, but still give an indication of the industries' labor compensation capability. In the middle of the table, we depict the employment distribution over industries in the initial study year of 2004. On the right hand side of the table, we show the growth in employment shares measured in percentage points from 2004 and 2008, and further from 2008 to 2014. As the largest changes in market access take place in 2009, the period of 2004 to 2008 could roughly be considered as the pretreatment period, while 2009 to 2014 can be roughly considered as the treatment period for this exercise.

Overall, Table 5 shows no clear indications that employment distribution has moved towards industries with relatively high labor cost levels (i.e. labor cost level above average). The manufacturing sector held a relatively strong position in Coastal Southern Norway over our study period, which is actually even stronger than the table suggests, as we have omitted oil and gas suppliers from our study sample. Prior to 2009, the employment shares of high-remuneration industries were mostly growing more (measured in percentage points) in the extended study region than along the coastline of Southern Norway, with technological manufacturing as a notable exception.

Among the service industries with relatively low remuneration (i.e. labor cost level below average), the employment shares of Coastal Southern Norway grew relatively much in the tourism industry and the retail industry and relatively little in the business support industry.

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Table 5. Annual growth in employment shares in single- and multi-branch firms across industries measured by percentage points with additional depiction of average relative labor costs and initial employment shares. The shares are limited to our industry selection. Labor costs are deflated with basis in average cost levels from 1999 to 2014. Comparison between Coastal Southern Norway (core study region) and municipalities in neighboring counties. Industries with higher labor costs or growth in employment share than the benchmark region are indicated by green color.

Impact on employment	Relative labor cost level		Share of employment in single- and multi-branch firms					
Period	Average 2004-2014		Status 2004		Annual growth 2004-2008		Annual growth 2008-2014	
Industry / study region	Core	Extended except core	Core	Extended except core	Core	Extended except core	Core	Extended except core
Consumer manufacturing	0.9685	0.9715	0.0688	0.0704	-0.0046	-0.0020	-0.0011	-0.0011
Material manufacturing	1.2066	1.2484	0.1563	0.1163	-0.0046	-0.0035	-0.0030	-0.0027
Technological manufacturing	1.4534	1.4425	0.1208	0.1164	0.0052	0.0005	0.0034	0.0010
Wholesale and vehicle trade	1.0852	1.1026	0.1259	0.1252	-0.0019	-0.0014	-0.0001	0.0001
Retail trade	0.6090	0.5643	0.1968	0.1877	0.0008	0.0003	0.0023	0.0001
Transportation	0.9975	0.9514	0.0866	0.1063	-0.0021	-0.0021	-0.0014	-0.0008
Tourism	0.5516	0.6150	0.0695	0.0757	0.0014	0.0003	0.0016	0.0011
Information services	1.3768	1.3846	0.0483	0.0527	-0.0016	-0.0006	-0.0003	0.0001
Knowledge consultancy	1.3224	1.3622	0.0617	0.0741	0.0018	0.0018	0.0012	0.0020
Business support	0.7365	0.7961	0.0654	0.0754	0.0057	0.0067	-0.0024	0.0003

In the period from 2008 to 2014, the Coastal Southern Norway's relatively development patterns in employment share of remained largely the same in the period from 2004 to 2008. Among industries with relatively high wage levels, Coastal Southern Norway's relative growth in employment shares measured by percentage points rose compared to the previous growth period in some industries (e.g. material manufacturing, wholesale and vehicle trade and information services) and fell in others (e.g. technological manufacturing and knowledge consultancy). By the same token, the relative developments in employment composition for Coastal Southern Norway show no clear patterns of restructuring away from low-remuneration industries (e.g. the growth in employment shares measured by percentage points becomes relatively weaker for tourism and business support, but stronger for retail trade).

Although regional developments show no clear signs of factor improvements between industries caused by road openings, restructuring between industries over municipalities within Southern Norway could potentially have contributed to higher regional value creation. In

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Table 6, we consider how municipal employment shares (given our industry selection) have been affected by increased market access through new road constructions, including both single- and multi-branch firms.

Our results suggest that the tourism industry has experienced relatively high employment growth in municipalities close to road openings, at least within Coastal Southern Norway. A similar development after adjustment for a negative underlying trend is seen in the retail industry, where the results once again are stronger within our core study region. On the other hand, the municipal knowledge consultancy industries located close to new road construction appear to have had a negative development subsequently to the corresponding openings.

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Table 6. Impacts and placebo impacts of increased market access caused by traveling time reduction on municipal employment shares in single- and multi-branch firms over industries, estimated by linear panel data regressions using municipality fixed effects and clustered standard errors on municipalities. Market access is measured with power distance decay ($\delta^{pow} = 2.3$) and exponential distance decay ($\delta^{exp} = 0.07$). Core region: Coastal Southern Norway. Extended region: Coastal Southern Norway and municipalities in neighboring counties not located next to road openings. (* for p < 0.1, ** for p < 0.05 and *** for p < 0.01)

Impact on employment	Impact				Placebo			
Study region	Core		Extended		Core		Extended	
Industry \ distance decay	Power	Exp.	Power	Exp.	Power	Exp.	Power	Exp.
Consumer manufacturing	0.008	-0.060	0.045	0.017	-0.072	-0.018	-0.192	-0.135
	(0.042)	(0.072)	(0.066)	(0.057)	(0.100)	(0.094)	(0.132)	(0.095)
	n = 174	n = 174	n = 1,079	n = 1,079	n = 80	n = 80	n = 500	n = 500
Material manufacturing	-0.132	0.057	-0.394***	-0.288**	1.263**	0.964	0.229	0.189
	(0.187)	(0.230)	(0.126)	(0.113)	(0.582)	(0.570)	(0.194)	(0.161)
	n = 176	n = 176	n = 1,151	n = 1,151	n = 80	n = 80	n = 535	n = 535
Technological manufacturing	0.024	0.090	-0.051	0.005	-0.070	-0.083	0.197	0.108
	(0.146)	(0.198)	(0.148)	(0.137)	(0.271)	(0.251)	(0.161)	(0.116)
	n = 172	n = 172	n = 1,026	n = 1,026	n = 76	n = 76	n = 467	n = 467
Wholesale and vehicle trade	-0.049	-0.051	0.091	0.075	-0.177	-0.101	-0.078	-0.098*
	(0.064)	(0.083)	(0.144)	(0.102)	(0.184)	(0.185)	(0.065)	(0.052)
	n = 176	n = 176	n = 1,159	n = 1,159	n = 80	n = 80	n = 528	n = 528
Retail trade	0.170**	0.034	-0.018	-0.090	-0.966**	-0.812**	-0.363***	-0.280**
	(0.080)	(0.134)	(0.158)	(0.121)	(0.332)	(0.297)	(0.120)	(0.114)
	n = 176	n = 176	n = 1,236	n = 1,236	n = 80	n = 80	n = 559	n = 559
Transportation	-0.085*	-0.081	0.045	-0.008	-0.134	-0.112	0.354*	0.490*
	(0.043)	(0.073)	(0.133)	(0.094)	(0.367)	(0.299)	(0.199)	(0.257)
	n = 176	n = 176	n = 1,138	n = 1,138	n = 80	n = 80	n = 514	n = 514
Tourism	0.084***	0.076**	0.139	0.155*	0.047	0.033	0.014	0.002
	(0.026)	(0.032)	(0.097)	(0.078)	(0.159)	(0.144)	(0.098)	(0.114)
	n = 164	n = 164	n = 1,112	n = 1,112	n = 72	n = 72	n = 497	n = 497
Information services	-0.057	-0.069	0.015	-0.010	0.011	0.003	-0.075	-0.111
	(0.052)	(0.048)	(0.049)	(0.049)	(0.050)	(0.042)	(0.088)	(0.087)
	n = 168	n = 168	n = 956	n = 956	n = 74	n = 74	n = 434	n = 434
Knowledge consultancy	-0.088***	-0.093**	0.025	0.031	0.046	0.050	0.072	0.068
	(0.021)	(0.032)	(0.054)	(0.038)	(0.106)	(0.096)	(0.078)	(0.067)
	n = 176	n = 176	n = 1,195	n = 1,195	n = 80	n = 80	n = 546	n = 546
Business support	0.128	0.115	0.052	0.062	0.165	0.166	-0.088	-0.037
	(0.078)	(0.106)	(0.084)	(0.076)	(0.108)	(0.111)	(0.106)	(0.113)
	n = 166	n = 166	n = 953	n = 953	n = 73	n = 73	n = 412	n = 412

In subappendix B.4, we report supporting analyses to the investigations on industry composition effects carried out in this subsection. The most striking finding of these investigations is the lack of agreement of the results for only single branch firms and all firm branches, including branches of firms that were multi-branch firms at least once over our study period. This mismatch supports the hypothesis that the road constructions in Coastal Southern Norway have not induced substantial composition effects between industries at either municipal or regional level. Another difference is that the employment development for business support services becomes relatively negative, when employment stocks replaces employment shares as outcome variable in the baseline regressions. Considering changes in fixed capital, our supportive analyses suggest that increased market access through expansion of the road network had no clear impact on the fixed capital intensity.

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5.5 Regional Factor Composition Effects

Regional integration through new road construction may contribute to higher factor return on regional level, even in the absence of positive productivity impulses and factor composition effects at local level. Such effects could occur through improvements in factor composition effects between different locations, where factor inputs are reallocated from regions with relative higher factor return after the implementation of a transportation measure.
In Fig. 7, we have considered how the regional commuting into and out from Kristiansand city has developed over our study period. To make the figure easier to read, we have colored the municipalities in Aust-Agder county – which to a varying degree were affected by the opening of European Route 18 between Kristiansand and Grimstad August 2009 – in blue. By the same token, we have colored the municipalities in Vest-Agder county – on the other side of Kristiansand – in green.

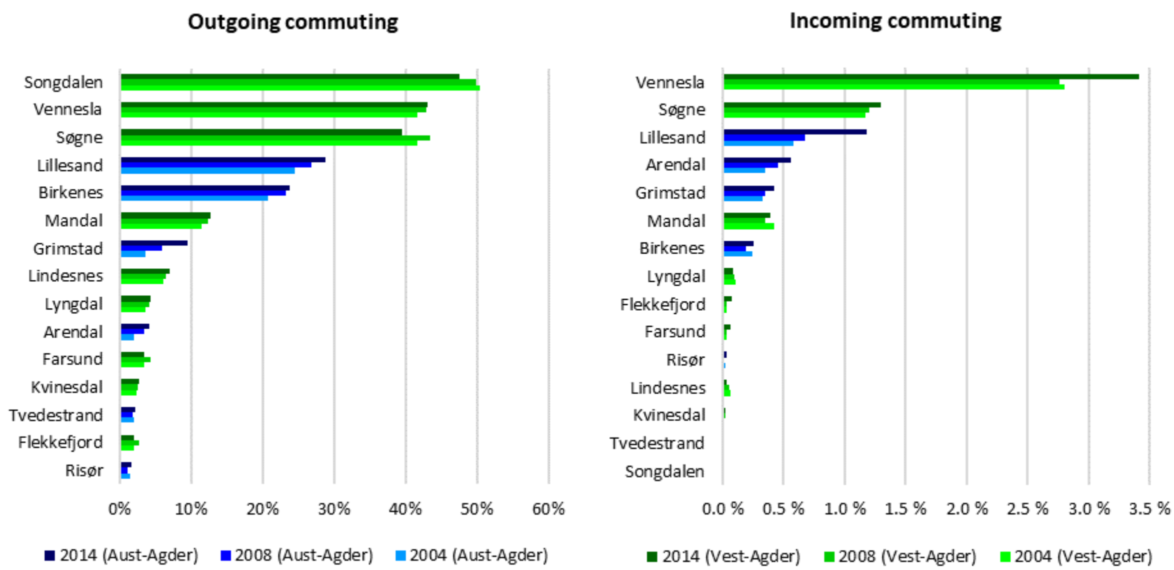

Fig. 7. a) Outgoing commuting rates (l.h.s.) and b) incoming commuting rates (r.h.s) into and out from Kristiansand in 2004, 2008 and 2014 with depiction of county (Aust-Agder in blue and Vest-Agder in green)

We see that all municipalities located in Aust-Agder experienced increased commuting towards Kristiansand from 2008 to 2014. The largest increases are seen in Lillesand, Grimstad and Arendal, which are the three municipalities affected the most by the renewal of European Route 18 in addition to Kristiansand. On the other hand, the commuting rates to Kristiansand from other municipalities in Vest-Agder remained the same or even declined in this period, such as in Songdalen and Søgne. We also note that Flekkefjord – which experienced traveling time reductions from August 2006 through the renewal of European Route 39 – increased its commuting to Kristiansand from 2004 to 2008, although the levels were low, and the rates decreased again from 2008 to 2014.

If we look at incoming commuting to the other municipalities of Coastal Southern Norway from Kristiansand, we still see clear increases in the commuting rates concerning Aust-Agder. Yet, the municipalities on the other side of Kristiansand, particularly Vennesla and Søgne, also experienced increased commuting from the city. Thus, we are reluctant to make categorical conclusions on the role of the opening of European Route 18. The increase of commuting between Kristiansand and Lillesand – the municipality measured to be subject to the highest increase in market access – could be seen in conjunction with the Norwegian Communications Authority's move from

Oslo to Lillesand May 2007. With the new directorate followed 140 workplaces, which corresponded to 4.2 percent of the workplaces in Lillesand at the time.

In subappendix B.5, we carry out supplementary investigations on regional composition effects. Here, we examine the changes in commuting patterns within Southern Aust-Agder in relation to the regional road opening at European Route18 and within the Lister Region in relation to the regional road openings at European Route 39 and County Route 465 in Vest-Agder. In this analysis, we also find that commuting into the more urban municipalities has increased, subsequent to the openings. When conducting a regression analysis on outgoing commuting after the increase in market access caused by expansions in the road network, the results become insignificant, although they are significantly different from the placebo trend. This weakens the hypothesis that increased market access improves regional social wealth considerably through stimulating commuting somewhat, even though alternative investigations and various explanations could be put forward in the opposite direction. Investigating the potential gains of commuting, it appears as if both the highest levels and increases in outgoing commuting shares, and possible gains for commuting, occur from the municipalities in Coastal Aust-Agder to Kristiansand in relation to the opening at European Route 18. Yet, we approximate these gains to be relatively modest in the big picture, amounting to less than NOK 10 million in fixed prices at average price level from 1999 to 2014.

Looking more closely at the regional work distributions within each industry, we do not find any clear indications of a welfare-improving reallocation of labor between Kristiansand and its eastern suburbs (defined as Lillesand, Grimstad and Arendal) subsequent to the road opening at European Route 18. Some weak tendencies are still seen in the data, inter alia including a weakening of the retail industry in Kristiansand's eastern suburbs.

At last, we conduct regression analyses on how various measures for employment and fixed capital holdings are affected by increased market access through road constructions at macro level, controlling for local oil and gas supply activities. In these regression analyses, we do not find any sign of increased factor input utilization in municipalities next to new road constructions, subsequent to their opening.

6. Discussion and Conclusions

Urban areas are on average more productive than peripheral areas. In the economic geography literature, there is a growing consensus that firms in principle may benefit from high mobility to surrounding areas. While traveling distances seldom change much, new major road construction projects may reduce traveling time substantially. This suggests that studies of road constructions might shed light on the relationship between productivity and economic density.

Some recent papers provide microeconomic evidence on productivity impulses from increased market access through expansion in the road network (e.g. Duranton, Morrow and Turner 2014, Hall 2016 and Gibbons et al. 2019). Yet, productivity impulses in rural areas in developed countries and composition effects are seldom addressed. Despite of limited of empirical evidence, supplementary quantitative analyses on wider economic impacts constitute an integrated part of the transportation appraisal practices in many sparsely populated countries (e.g. Wangsness, Rødseth and Hansen 2017 and Holmen, Biesinger and Hindriks 2022).

As a sparsely populated country with solid state finances, Norway has invested relatively much in road infrastructure over the last decades. Coastal Southern Norway constitutes a transparent and streamlined region subject to several major road constructions over a brief period of time. Thus, it emerges as a good case study suited to providing new insights to the literature on productivity impulses from market access and transportation networks with focus on productivity, composition effects and rural areas. Since the turn of the millennium, no

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road openings have reduced traveling time between each other for more a larger number of Norwegians with each other (through a traveling time reduction of at least five minutes within 30 minutes' reach) than European Route 18 at in Coastal Southern Norway. If regional integration caused by road constructions were to boost total factor productivity at firm level in sparsely populated areas of developed countries, Coastal Southern Norway therefore appears as a reasonable place to look for such effects.

In this paper, we have studied productivity impulses from increased regional integration through road constructions in the business sector of Coastal Southern Norway from 2004 to 2014. We assess both productivity impulses at firm level and composition effects within and between industries and locations, which possibly contribute to higher factor return for the region as a whole. Admittedly, road constructions may be motivated by or related to productivity, so the causality in the decision-making must be addressed in such studies. Both our own causality checks and previous studies in the literature (reviewed in more detail in appendix A) suggest that the implementation of Norwegian road constructions is exogenous with respect to productivity, we proceed to our analyses on productivity impulses from increased market access without instrumentation of the latter variable. Still, we operate with buffer zones of twenty traveling kilometers (measured in the initial year) around each receiver of impulses from market access, where the traveling times are held constant, both to handle potential local endogeneity and data noise.

We measure market access under assumptions of power distance decay and exponential distance decay, exploiting the estimates for the Southern parts of Norway from Holmen (2022a) in our baseline regressions. As we are only interested in increases in market access caused by expansions in the road network and not the ones that are intertwined with urbanization developments, we hold our measure for potential market connections (i.e. mean of employment by residence and workplace) constant in our operational implementation of the market access measure.

As our baseline framework for industry-specific empirical examinations, we apply a panel data linear least square specification with industry-year dummies and observation units (i.e. firms or municipal industries) as basis for fixed effects and clustering of standard errors. We pre-estimate total factor productivity by Wooldridge's estimation procedure, controlling for developments in terms of trade. To be able to distinguish between local displacement effects and more direct contributions to higher social wealth (before potential displacement effects and ripple effects through general equilibrium mechanism), we conduct our analyses both on our core study region alone (i.e. Coastal Southern Norway) and a broader study region, also consisting of comparable municipalities in neighboring counties (except the ones next to new road openings). As actual impulses from expansions in the road network may easily be confused with underlying development trends, we also introduce a framework for placebo testing, where we pretend that road openings were realized at an earlier point in time. To alter robustness and obtain a deeper insight into the study phenomena, various further investigations and robustness tests were carried out in addition, as reported in appendix B.

Overall, our empirical investigations neither provide robust support to productivity impulses from road constructions at firm or industry level. Furthermore, welfare-enhancing composition effects between industries do not appear to be prevailing. Our results provide some support to the hypothesis that industry restructuring has occurred in areas next to new road constructions, inter alia within the retail trade industry. However, these tendencies do not provide traceable productivity impulses that could be traced to higher aggregation level in a robust manner and may be interlinked with underlying development patterns. In principle, fiercer competition for some industries (e.g. retail trade and transportation) or more efficient regional industry organization could have led to higher consumer surplus for households rather than increased producer surplus. Yet, our study does not provide supporting evidence for such hypotheses.

Lastly, we consider regional composition effects. There are clear indications that regional integration through new road constructions contributes to higher commuting to the rural integrated area to the urban areas. This is particularly the case for the commuting from Coastal Aust-Agder to the regional city of Kristiansand along European Route 18, which represents the route that induced the highest increase in market access in our study. Nevertheless, we approximate the gain from commuting due to the road opening to be relatively low. Furthermore, we are also unable to relate these developments to a particular reallocation of industry activities. We do not find signs of increased factor usage subsequent to road openings.

Moreover, the economic appraisal associated with the three major road openings assessed in our study involves a negative net benefit of NOK 269.4 million.[§§§§§] We estimate the regional increases in market access caused by expansion in the road network to be 7.6 percent in case of power distance decay and 9.6 percent in case of exponential distance decay. Given our rough estimates for the regional GDP in our study region,[******] compensation for the negative net costs of the project would have required an agglomeration elasticity in the range from 0.003 to 0.004. Even though these estimates are relatively low compared to other agglomeration elasticities found in the literature, our empirical analyses suggest that the agglomeration elasticity is unlikely to be anywhere close to this level of magnitude. Overall, our study does not support the hypothesis that expansions in the road network produce substantial productivity impulses in rural areas of developed countries. This suggest that possible inclusion of wider economic impacts in transportation appraisal should be done with caution, particularly in less inhabited areas. Moreover, our study provides little support to the current transportation appraisal practices on wider economic impacts, applied in some sparsely populated countries.

For further research, we encourage more studies on wider economic impacts in rural areas and how such impacts vary over the degree of urbanization. Impulses form increased market access induced by other infrastructure or urbanization should also be explored further. Measurement of market access should also be investigated further, possibly involving choices of functional form and contents, as well as heterogeneities concerning industries and geographic configuration. Furthermore, our empirical results suggest that road openings may have affected the regional organization of some industries, which constitutes a topic that may be explored further, either taking an even more micro-oriented econometric approach or exploring general equilibrium mechanisms. At last, our results on regional factor composition effects suggest that commuting may contribute some to higher regional value creation. This topic should be investigated properly with data on individuals, for instance by matching new commuters with similar individuals in other regions that do not start to commute.

[§§§§§] The net benefits for the road investments are estimated to be NOK minus 692.9 million for the investment at European Route 18 between Kristiansand and Grimstad, NOK 255.8 million for the investment at European Route 39 between Flekkefjord and Lyngdal and NOK 167.7 million for the investment at County Route 465 in Vest-Agder between Farsund and Kvinesdal (Norwegian Ministry of Transport and Communications 2002 and 2004, and Transportation and Communications Committee at the Storting 2002 and 2005). All this figures are recalculated to fixed prices at average price levels from 1999 to 2014 with analysis year in the middle of this period (i.e. between 2006 and 2007) based on the concurrent appraisal methodology with a discount rate of 0.06, a deflation rate of 0.02 and an appraisal period of 25 years (Norwegian Ministry of Finance 2005 and Norwegian Public Road Administration 2006).

[******] In this calculation, we approximated the regional GDP by two alternative approaches, which led to estimates of roughly the same magnitude. In the first approach, we took basis in Statistics Norway's regional accounts and approximate our study region's share of GDP in Aust-Agder and Vest-Agder's counties by help of employment statistics from Statistics Norway. Second, we took basis in our enterprise data and added value added estimates for firms without reporting duty and public sector firms based on employment and industry statistics from Statistics Norway. In both cases, we also utilized the national accounts deflators.

References

Ackerberg, D. A., Caves, K., & Frazer, G. 2015. Identification properties of recent production function estimators. *Econometrica*, 83(6), 2411-2451. https://doi.org/10.3982/ECTA13408

Ahlfeldt, G. M., & Feddersen, A. 2018. From periphery to core: measuring agglomeration effects using high-speed rail. *Journal of Economic Geography*, 18(2), 355-390. https://doi.org/10.1093/jeg/lbx005

Alder, S. 2019. Chinese Roads in India: The Effect of Transport Infrastructure on Economic Development. Working Paper, University of North Carolina, Chapel Hill. http://dx.doi.org/10.2139/ssrn.2856050

Balk, B. M. 2009. On the relation between gross output–and value added–based productivity measures: The importance of the Domar factor. *Macroeconomic Dynamics*, 13(S2), 241-267. https://doi.org/10.1017/S1365100509090130

Banerjee, A., Duflo, E., & Qian, N. 2020. On the road: Access to transportation infrastructure and economic growth in China. *Journal of Development Economics*, 102442. https://doi.org/10.1016/j.jdeveco.2020.102442

Banister, D., & Berechman, Y. 2001. Transport investment and the promotion of economic growth. *Journal of Transport Geography*, 9(3), 209-218. https://doi.org/10.1016/S0966-6923(01)00013-8

Baum-Snow, N. 2007. Did highways cause suburbanization?. *The Quarterly Journal of Economics*, 122(2), 775-805. https://doi.org/10.1162/qjec.122.2.775

Baum-Snow, N. 2010. Changes in transportation infrastructure and commuting patterns in US metropolitan areas, 1960–2000. The *American Economic Review*, 100(2), 378. https://doi.org/10.1257/aer.100.2.378

Baum-Snow, N., Brandt, L., Henderson, J. V., Turner, M. A., & Zhang, Q. 2017. Roads, railroads, and decentralization of Chinese cities. *Review of Economics and Statistics*, 99(3), 435-448. DOI: https://doi.org/10.1162/REST_a_00660

Behrens, K., Duranton, G., & Robert-Nicoud, F. 2014. Productive Cities: Sorting, Selection and Agglomeration. *Journal of Political Economy*, 122(3), 507-553. https://doi.org/10.1086/675534

Berndt, E. R., & Christensen, L. R. 1973. The translog function and the substitution of equipment, structures, and labor in US manufacturing 1929-68. *Journal of Econometrics*, 1(1), 81-113. https://doi.org/10.1016/0304-4076(73)90007-9

Börjesson, M., Isacsson, G., Andersson, M., & Anderstig, C. 2019. Agglomeration, productivity and the role of transport system improvements. *Economics of Transportation*, 18, 27-39. https://doi.org/10.1016/j.ecotra.2018.12.002

Blomgren, A., Quale, C., Austnes-Underhaug, R., Harstad, A. M., Fjose, S., Wifstad, K., Mellbye, C., Amble, I. B., Nyvold, C. E., Steffensen, T., Viggen, J. R., Inglebæk, F., Arnesen, T., & Hagen, S. E. 2015. A survey of employees in Norwegian petroleum-related businesses, with a particular focus on supplier firms' employees related to exports (in *Norwegian*), ordered by The Norwegian Oil and Gas Association, report IRIS 2015/031. URL: https://norceresearch.brage.unit.no/norceresearch-xmlui/handle/11250/2631778

Blundell, R. & Bond, S. 2000. GMM estimation with persistent panel data: an application to production functions. *Econometric Reviews*, 19(3), 321-340. https://doi.org/10.1080/07474930008800475

Bond, S., & Söderbom, M. 2005. Adjustment costs and the identification of Cobb Douglas production functions. Economics department working paper, Oxford, W04. DOI: https://doi.org/10.1920/wp.ifs.2005.0504

Chandra, A. & Thompson, E. 2000. Does public infrastructure affect economic activity?: Evidence from the rural interstate highway system. *Regional Science and Urban Economics*, 30(4), 457-490. https://doi.org/10.1016/S0166-0462(00)00040-5

Christensen, L. R. and Jorgenson, D. W. 1969. The measurement of US real capital input, 1929–1967. *Review of Income and Wealth*, 15(4), 293-320. https://doi.org/10.1111/j.1475-4991.1969.tb00814.x

Combes, P. P., Duranton, G., Gobillon, L., Puga, D., & Roux, S. (2012). The productivity advantages of large cities: Distinguishing agglomeration from firm selection. *Econometrica*, 80(6), 2543-2594. https://doi.org/10.3982/ECTA8442

Combes, P. P. & Gobillon, L. 2015. The empirics of agglomeration economies, Chapter 5 in Handbook of Urban and Regional Economics, edited by G. Duranton, V. Henderson and W. Strange, vol 5. Elsevier. https://doi.org/10.1016/B978-0-444-59517-1.00005-2

Crescenzi, R., & Rodríguez-Pose, A. 2012. Infrastructure and regional growth in the European Union. *Papers in Regional Science*, 91(3), 487-513. https://doi.org/10.1111/j.1435-5957.2012.00439.x

Davidian, M., & Giltinan, D. M. 2003. Nonlinear models for repeated measurement data: An overview and update. *Journal of Agricultural, Biological, and Environmental Statistics*, 8(4), 387. https://doi.org/10.1198/1085711032697

Davis, M. A., Fisher, J. D., & Whited, T. M. 2014. Macroeconomic implications of agglomeration. *Econometrica*, 82(2), 731-764. https://doi.org/10.3982/ECTA9029

Diewert, W. E., & Morrison, C. J. 1985. Adjusting output and productivity indexes for changes in the terms of trade. NBER WORKING PAPER SERIES. Working Paper No. 1561https://doi.org/10.3386/w1564

Dijkstra, E. W. 1959. A note on two problems in connexion with graphs. *Numerische Mathematik*, 1(1), 269-271. https://ir.cwi.nl/pub/9256/9256D.pdf

Dolmar, E. D. 1961. On the Measurement of Technological Change. *The Economic Journal,* LXXI, 709-729. https://doi.org/10.2307/2228246

Donaldson, D., & Hornbeck, R. 2016. Railroads and American economic growth: A ‘market access’ approach. *The Quarterly Journal of Economics*, 131(2), 799-858. https://doi.org/10.1093/qje/qjw002

Duranton, G., & Puga, D. 2004. Micro-foundations of urban agglomeration economies. Handbook of regional and urban economics, 4, 2063-2117. https://doi.org/10.1016/S1574-0080(04)80005-1

Duranton, G., Morrow, P. M., & Turner, M. A. 2014. Roads and Trade: Evidence from the US. *The Review of Economic Studies*, 81(2), 681-724. https://doi.org/10.1093/restud/rdt039

El-Geneidy, A. M., & Levinson, D. M. 2006. Access to destinations: Development of accessibility measures. https://conservancy.umn.edu/handle/11299/638

Eliasson, J., Börjesson, M., Odeck, J., & Welde, M. 2015. Does benefit–cost efficiency influence transport investment decisions? *Journal of Transport Economics and Policy (JTEP)*, 49(3), 377-396. URL: https://www.ingentaconnect.com/content/lse/jtep/2015/00000049/00000003/art00002

Faber, B. 2014. Trade integration, market size, and industrialization: evidence from China's National Trunk Highway System. *Review of Economic Studies*, 81(3), 1046-1070. https://doi.org/10.1093/restud/rdu010

Fox, K. J., & Kohli, U. 1998. GDP growth, terms-of-trade effects, and total factor productivity. *Journal of International Trade & Economic Development*, 7(1), 87-110. https://doi.org/10.1080/09638199800000006

Fujita, M. 1988. A monopolistic competition model of spatial agglomeration: Differentiated product approach. *Regional Science and Urban Economics*, 18(1), 87-124. https://doi.org/10.1016/0166-0462(88)90007-5

Fujita M., Krugman P., & Venables, A. J. 1999. The spatial economy: Cities, regions and international trade, MIT Press, Cambridge MA. Available for purchase: https://www.amazon.com/Spatial-Economy-Cities-Regions-International/dp/0262561476

Funderburg, R. G., Nixon, H., Boarnet, M. G., & Ferguson, G. (2010). New highways and land use change: Results from a quasi-experimental research design. Transportation research part A: policy and practice, 44(2), 76-98. https://doi.org/10.1016/j.tra.2009.11.003

Gandhi, A., Navarro, S., & Rivers, D. A. (2020). On the identification of gross output production functions. *Journal of Political Economy*, 128(8), 2973-3016. https://doi.org/10.1086/707736

Garcia-López, M. À., Holl, A., & Viladecans-Marsal, E. 2015. Suburbanization and highways in Spain when the Romans and the Bourbons still shape its cities. *Journal of Urban Economics*, 85, 52-67. https://doi.org/10.1016/j.jue.2014.11.002

Ghani, E., Goswami, A. G., & Kerr, W. R. 2016. Highway to success: The impact of the Golden Quadrilateral project for the location and performance of Indian manufacturing. *The Economic Journal*, 126(591), 317-357. https://doi.org/10.1111/ecoj.12207

Gibbons, S., Lyytikäinen, T., Overman, H. G., & Sanchis-Guarner, R. 2019. New road infrastructure: The effects on firms. *Journal of Urban Economics*, 110, 35-50. https://doi.org/10.1016/j.jue.2019.01.002

Graham, D. J., & Gibbons, S. 2019. Quantifying Wider Economic Impacts of Agglomeration for Transport Appraisal: Existing Evidence and Future Directions. *Economics of Transportation*, 19, 100121. https://doi.org/10.1016/j.ecotra.2019.100121

Graham, D. J., Melo, P. S., Jiwattanakulpaisarn, P., & Noland, R. B. 2010. Testing for causality between productivity and agglomeration economies. *Journal of Regional Science*, 50(5), 935-951. https://doi.org/10.1111/j.1467-9787.2010.00676.x

Griliches, Z., & Jorgenson, D. W. 1966. Sources of measured productivity change: Capital input. *The American Economic Review*, 56(1/2), 50-61. https://www.jstor.org/stable/1821267

Grünfeld, L. A., Holmen, R. B., Gulbrandsen, M. U., & Wifstad, K. 2013. Competitiveness and wage growth: Some updated indicators and perspectives (in *Norwegian*), topical comment. *Samfunnsøkonomen*, 2014/9. URL: https://docplayer.me/462808-Samfunnsokonomen-nr-1-2014-128-argang-holden-grunfeld-mfl-bjerkholt-hauge-hawkins.html

Hansen, W. G. 1959. How accessibility shapes land use. *Journal of the American Institute of Planners*, 25(2), 73-76. https://doi.org/10.1080/01944365908978307

Harris, C. D. 1954. The Market as a Factor in the Localization of Industry in the United States. *Annals of the association of American Geographers*, 44(4), 315-348. https://doi.org/10.1080/00045605409352140

Heckman, J. 1979. Sample Selection Bias as a Specification Error. *Econometric*a, 47(1). https://doi.org/10.2307/1912352

Holl, A. 2004. Manufacturing location and impacts of road transport infrastructure: Empirical evidence from Spain. *Regional Science and Urban Economics*, 34(3), 341-363. https://doi.org/10.1016/S0166-0462(03)00059-0

Holl, A. 2016. Highways and productivity in manufacturing firms. *Journal of Urban Economics*, 93, 131-151. https://doi.org/10.1016/j.jue.2016.04.002

Holmen, R. B. 2020. Heterogeneity in Fixed Capital Estimation: Implications for Productivity Estimation. Chapter 4 in Productivity and Mobility in Holmen, R. B. (2020). A dissertation submitted to BI Norwegian Business School for the degree of PhD. PhD specialization: Economics. Series of Dissertations 7/2020. Contact information for access: rbh@toi.no

Holmen, R. B. 2022a. Agglomeration Decay in Rural Areas. *Insights into Regional Development*, 4(3), 139-155. https://doi.org/10.9770/IRD.2022.4.3(9)

Holmen, R. B. 2022b. Fixed Capital Estimation: Utilization of Macro Data to Account for Capital Heterogeneity at Firm Level. Beta *Scandinavian Journal of Business Research*. Forthcoming. URL: https://www.idunn.no/journal/beta

Holmen, R.B., Biesinger, B., Hindriks, I., (2022). Impacts from transportation measures in national appraisal guidelines: Coverage and practices. *Archives of Transport*, 63(3), 67-111. https://doi.org/10.5604/01.3001.0015.9928

Holmen, R. B., & Hansen, W. 2020. The Scientific Foundation for Impacts Estimation in Transportation Appraisal: A Literature Review. Chapter 2 in Productivity and Mobility in Holmen, R. B. (2020). A dissertation submitted to BI Norwegian Business School for the degree of PhD. PhD specialization: Economics. Series of Dissertations 7/2020. Contact information for access: rbh@toi.no

Irgens, J. B. 1978. Around the main route of Western Norway (in *Norwegian*). Published by Historielaget for Dypvåg, Holt og Tvedestrand. Contact information for access: janoaslaksen@gmail.com

Jedwab, R., & Moradi, A. 2016. The permanent effects of transportation revolutions in poor countries: evidence from Africa. *Review of Economics and Statistics*, 98(2), 268-284. https://doi.org/10.1162/REST_a_00540

Jorgenson, D. W., & Griliches, Z. 1967. The explanation of productivity change. *The Review of Economic Studies*, 34(3), 249-283. https://doi.org/10.2307/2296675

Kehoe, T. J., & Ruhl, K. J. 2008. Are shocks to the terms of trade shocks to productivity? *Review of Economic Dynamics*, 11(4), 804-819. https://doi.org/10.1016/j.red.2008.04.001

Kmenta, J. 1967. On estimation of the CES production function. *International Economic Review*, 8(2), 180-189. https://doi.org/10.2307/2525600

Leduc, S., & Wilson, D. 2012. Roads to prosperity or bridges to nowhere? Theory and evidence on the impact of public infrastructure investment (No. w18042). National Bureau of Economic Research. https://doi.org/10.1086/669173

Levinsohn, J., & Petrin, A. 2003. Estimating production functions using inputs to control for unobservables. *The Review of Economic Studies*, 70(2), 317-341. https://doi.org/10.1111/1467-937X.00246

Marshall, A. 1890. Principles of economics, revised 1920. London: Mac-Millan. Available for purchase: https://www.amazon.com/Principles-Economics-Great-Alfred-Marshall/dp/1573921408

McCann, P. 2005. Transport costs and new economic geography. *Journal of Economic Geography*, 5(3), 305-318. https://doi.org/10.1093/jnlecg/lbh050

Melitz, M. J., & Ottaviano, G. I. 2008. Market size, trade, and productivity. *The Review of Economic Studies*, 75(1), 295-316. https://doi.org/10.1111/j.1467-937X.2008.00505.x

Melo, P. C., Graham, D. J., & Brage-Ardao, R. 2013. The productivity of transport infrastructure investment: A meta-analysis of empirical evidence. *Regional Science and Urban Economics*, 43(5), 695-706. https://doi.org/10.1016/j.regsciurbeco.2013.05.002

Melo, P. C., Graham, D. J., & Noland, R. B. 2009. A meta-analysis of estimates of urban agglomeration economies. *Regional Science and Urban Economics*, 39(3), 332-342. https://doi.org/10.1016/j.regsciurbeco.2008.12.002

Melo, P. C., Graham, D. J., & Noland, R. B. 2010. Impact of Transport Infrastructure on Firm Formation: Evidence from Portuguese Municipalities. *Transportation Research Record*, 2163(1), 133-143. https://doi.org/10.3141/2163-15

Michaels, G. 2008. The effect of trade on the demand for skill: Evidence from the interstate highway system. *The Review of Economics and Statistics*, 90(4), 683-701. https://doi.org/10.1162/rest.90.4.683

Norwegian Ministry of Finance 2015. Productivity – Underpinning growth and welfare. The Productivity Commission's First Report (in *Norwegian*), review from a Royal Decree 7 February 2014, submitted to the Ministry of Finance on 10 February 2015, Norwegian Official Report 2015:1. URL https://www.regjeringen.no/no/dokumenter/nou-2015-1/id2395258/

Norwegian Ministry of Transport and Communications 2002. About Some Matters on the Ministry of Transport and Communications' remit (*in Norwegian*), recommendation from the Ministry of Transportation and Communications of 6 June 2002, government approved the same day, proposition to the Storting no. 60 (2001-2002). URL: https://www.regjeringen.no/no/dokumenter/stprp-nr-60-2001-2002-/id206253/

Norwegian Ministry of Transport and Communications 2004. On the implementation of E18 Grimstad – Kristiansand as PPP pilot project with partial toll financing (in *Norwegian*), recommendation from the Ministry of Transportation and Communications of 17 December 2004, government approved the same day, proposition to the Storting no. 33 (2004-2005). URL: https://www.regjeringen.no/no/dokumenter/stprp-nr-33-2004-2005-/id210243/

Norwegian Public Road Administration 2006. Manual 140, impact assessments (*in Norwegian*), guidance. URL: https://vegvesen.brage.unit.no/vegvesen-xmlui/bitstream/handle/11250/195982/HB-140-2006.pdf?sequence=1&isAllowed=y

Nyborg, K., & Spangen, I. 1996. Political decisions about investment in roads, Interviews with members of the Transportation and Communications Committee at the Storting (in *Norwegian*), TØI note 1026/1996. URL: https://www.toi.no/getfile.php?mmfileid=11400
Olley, G. S., & Pakes, A. 1996. The dynamics of productivity in the telecommunications equipment industry. Econometrica 64 (6):1263–1297. DOI: https://doi.org/10.3386/w3977

Redding, S. J., & Turner, M. A. 2015. Transportation costs and the spatial organization of economic activity. *Handbook of Regional and Urban Economics*, 5, 1339-1398). Elsevier. https://doi.org/10.1016/B978-0-444-59531-7.00020-X

Rice, P., Venables, A. J., & Patacchini, E. 2006. Spatial determinants of productivity: analysis for the regions of Great Britain. *Regional Science and Urban Economics*, 36(6), 727-752. https://doi.org/10.1016/j.regsciurbeco.2006.03.006

Rigby, D. L., & Brown, W. M. (2015). Who benefits from agglomeration? *Regional Studies*, 49(1), 28-43. https://doi.org/10.1080/00343404.2012.753141

Rosenthal, S. S., & Strange, W. C. 2003. Geography, industrial organization, and agglomeration. *Review of Economics and Statistics*, 85(2), 377-393. https://doi.org/10.1162/003465303765299882

Rosenthal, S. S., & Strange, W. C. 2004. Evidence on the nature and sources of agglomeration economies. *Handbook of Regional and Urban Economics*, 4, 2119-2171. https://doi.org/10.1016/S1574-0080(04)80006-3

Rovigatti, G., & Mollisi, V. 2018. PRODEST: Stata module for production function estimation based on the control function approach. Statistical Software Components. URL: https://ideas.repec.org/c/boc/bocode/s458239.html

Sevtsuk, A., & Mekonnen, M. 2012. Urban network analysis. Revue internationale de géomatique–n, p. 287-305. URL: https://www.sutd.edu.sg/cmsresource/idc/papers/2012_Urban_Network_Analysis_A%20New%20Toolbox_for_ArcGIS.pdf

Shirley, C., & Winston, C. 2004. Firm inventory behavior and the returns from highway infrastructure investments. *Journal of Urban Economics*, 55(2), 398-415. https://doi.org/10.1016/j.jue.2003.11.001

Skogstrøm, J. F., Grünfeld, L. A., Aalen, P., Holmen, R. B., & Mariussen, Å. 2015. Interaction between city and surrounding areas as a source of economic growth (in N*orwegian*), Menon Publication 3/2015. URL: https://www.menon.no/wp-content/uploads/05by-og-omland-endelig-14-april.pdf

Skogstrøm, J.F, Ulstein, H., Holmen, R.B., Iversen, E.K., Høiseth-Gilje, K., Gulbrandsen, M.U., & Grünfeld, L. 2013. Investment in roads – Does the business sector become more productive? (in N*orwegian*), Menon Publication 36/2013. URL: https://www.menon.no/wp-content/uploads/Rapport-Investeringer-i-vei.-Blir-n%C3%A6ringslivet-mer-produktivt..pdf

Strand, A. 1983. The county distribution for national route grants (in *Norwegian*). Samferdsel, 5/1983. Contact information for access: hse@toi.no

Strand, A. 1993. Commitment to transportation - urban policy or rural policy? (in *Norwegian*). Regionale trender, 1/93. URL: https://www.nb.no/nbsok/nb/ee283d6a3fb37c4bf62a7255b6093c15

Strand, A., Olsen, S., Leiren, M. D., & Halse, A. H. 2015. Norwegian highway planning: What considerations govern the recommendations? (in *Norwegian*), Concept report no. 43. URL: https://www.ntnu.no/documents/1261860271/1262010703/131659_Concept_43_web_norsk+NY.pdf/b2d2e89b-74c1-471e-aad3-7306ad033f4b

Straub, S. 2011. Infrastructure and development: A critical appraisal of the macro-level literature. *J. Develop. Stud*., 47(5), 683-708. https://doi.org/10.1080/00220388.2010.509785

Transportation and Communications Committee at the Storting 2002. Recommendation of the Transportation and Communications Committee on a number of remits on the Ministry of Transportation and Communications' Area (in *Norwegian*), recommendation to the Storting no. 227 (2001-2002), belonging to Proposition to the Storting no. 60 (2001-2002), 6 June 2002, Oslo. URL: https://stortinget.no/no/Saker-og-publikasjoner/Publikasjoner/Innstillinger/Stortinget/2001-2002/inns-200102-227/

Transportation and Communications Committee at the Storting 2005. Recommendation of the Transport Committee on the implementation of E18 Grimstad – Kristiansand PPP pilot project with partial toll financing (in *Norwegian*), recommendation to the Storting no. 107 (2004-2005), belonging to Proposition to the Storting no. 33 (2004-2005), 3 February 2005, Oslo. URL: https://stortinget.no/no/Saker-og-publikasjoner/Publikasjoner/Innstillinger/Stortinget/2004-2005/inns-200405-107/

Tveter, E. 2021. Transport network improvements: The effects on wage earnings. *Regional Science Policy & Practice*, 13(3), 478-491. https://doi.org/10.1111/rsp3.12235

Tveter, E., & Mørkrid, G. V. 2018. Estimation methodology for wider economic impacts of transport investments. Review of previous research and applications and recommendation of method (in *Norwegian*). Møreforsknings Molde, Cowi and Høgskolen i Molde. Rapport No. 1813. URL: https://www.moreforsk.no/download.aspx?object_id=977BD3FC015A4E88A8474D9ECD04115F

Van Beveren, I. 2012. Total factor productivity estimation: A practical review. Journal of economic surveys, LICOS Discussion Paper Series, 26(1), 98-128. DOI: https://doi.org/10.1111/j.1467-6419.2010.00631.x

Venables, A. J. 2007. Evaluating Urban Transport Improvements: Cost-Benefit Analysis in the Presence of Agglomeration and Income Taxation. *Journal of Transport Economics and Policy*, 41, 173-188. URL: https://www.ingentaconnect.com/content/lse/jtep/2007/00000041/00000002/art00002

Vickerman, R. 2007. Recent evolution of research into the wider economic benefits of transport infrastructure investments, Joint transport research centre, OECD and International Transport Forum, OECD discussion paper no. 2007-9, December 2007. https://doi.org/10.1787/9789282101834-en

Vickerman, R., Spiekermann, K., & Wegener, M. 1999. Accessibility and economic development in Europe. *Regional Studies*, 33(1), 1-15. https://doi.org/10.1080/00343409950118878

Wangsness, P. B., Rødseth, K. L. and Hansen, W. 2017. A review of guidelines for including wider economic impacts in transport appraisal. *Transport Reviews*, 7 (1), 94-115. https://doi.org/10.1080/01441647.2016.1217283

Wooldridge, J. M. 2009. On estimating firm-level production functions using proxy variables to control for unobservables. *Economics Letters*, 104(3), 112-114. https://doi.org/10.1016/j.econlet.2009.04.026

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Supplementary Material: With the article follows on-line comprehensive appendixes with background material on the study region and a wide range of robustness checks https://zenodo.org/record/7276788#.Y2OtpeRBxPY. Otherwise, the article is closely related to the work in Holmen (2022a).

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