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The impact of fixed links on population development, housing and the labour market: The case of Norway

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Abstract

This study compares 11 fixed link projects in Norway, linking islands to the mainland. The fixed links substantially increase the accessibility between the islands and the mainland. Thus, interaction between the islands and the mainland increases. Large infrastructure improvements may not only affect the transport patterns but also the population and companies in the connected areas. We apply a difference-in-difference method to analyse the impacts from the increased accessibility. The findings indicate growth in housing prices, population, commuting and employment on the islands. The growth rates of these variables depend on the case characteristics. Urban cases appear to promote larger growth on the island. The contribution of this paper to the literature is that while there have been several studies that have involved single projects, a comparison of several cases that combines assessments of housing and labour markets is still rare in the literature.

Keywords: Ferry replacement; fixed link; population; housing market; regional development

1. Introduction

Transport projects strive to improve economic and social conditions. Network improvements increase accessibility, as travel time and distance to surrounding areas decrease. According to Vickerman (1998), network improvements may promote regional development and cohesion as more jobs are within commuting distance. Reductions in travel time promote new opportunities for people, as communities become more integrated. Hence, the labour market widens and becomes more optimised (Louw et al., 2013). This finding provides the potential for more interactions between areas. The impact on society from transport investments, such as population development and labour market changes, has previously been recognised in the literature (Baldacchino, 2007; Banister and Berechman, 2001; Bråthen, 2001; Bråthen and Hervik, 1997; Coppola et al., 2013; Geurs and van Wee, 2004; Knowles, 2006; Wu et al., 2017). These impacts on society are of crucial importance when assessing the long-term effects of transport investments.

Wegener (2004) divides the urban change process of transport projects into four categories by how fast the changes occur. Goods transport and travel patterns may change immediately. The change in the number of people living and/or working in an area is a rapid process. The development of workplaces, such as factories and office buildings, and residential buildings changes slowly. The transport network and zoning change at a very slow pace. Banister and Berechman (2001) emphasise the importance of an increase in accessibility at a network scale as a key factor in promoting economic growth. Hence, projects linking two previously disjointed networks promote larger growth than an additional link in an established network. Fixed link projects are suitable examples of such projects.

Fixed link projects are defined as bridges or tunnels replacing a ferry service. Ferry services constitute barriers in the transport network. In contrast to the remainder of the road network, ferry connections are open for traffic only at scheduled arrival times. Thus, ferry connections are characterised by the inconvenience associated with low frequencies and waiting times, particularly outside peak hours. This circumstance provides less flexibility for the travellers who are dependent on the ferry. Furthermore, ferry services may involve capacity restraints, as the number of vehicles on each departure are limited. A fixed link removes these barriers, reducing travel time and substantially increasing capacity. Furthermore, flexibility increases as the fixed link is open 24/7 and is normally less influenced by bad weather conditions than the ferry. These special projects are very interesting to analyse due to the clearly defined affected area, as they involve islands that acquire a connection to the mainland.

The impact on fixed links has previously been studied in a number of papers. Díez Gutiérrez et al. (2015) analysed two Norwegian ferry replacement projects joining smaller towns/settlements to a city with more than 50,000 inhabitants. The connected areas experienced an increase in population and housing prices. However, four fixed link projects in rural areas observed by Andersen et al. (2016) did not have significant effects on population numbers and the labour market after opening. Engebretsen and Gjerdåker (2010) did not find a strong impact on settlement, trade and employment when analysing the Triangle link in Norway. However, the link had a strong impact on commuting. Meijers et al. (2012) analysed the Westerschelde tunnel in the Netherlands, finding impacts on both population and employment; however, the impacts are considered distributive effects rather than growth at the regional level. Matthiessen (2004) analysed the Öresund Bridge linking urban areas in Denmark and Sweden. This study reports slow development towards an integrated urban region. These studies show that fixed links contribute to changes in society to varying degrees.

This paper contributes to the research on the interactions between transport and the impacts on society, specifically for fixed link projects. While existing studies typically analyse only one or a few cases, this paper investigates and compares 11 fixed link projects in Norway regarding population development, housing and the labour market. Much of the previous research on this topic focuses on the regional scale, while our contribution lies in a more detailed, meso-level approach.

The study focusses on the changes experienced on the connected islands. The methods currently used in Norway to assess fixed link projects do not include changes in population due to infrastructure improvement. By analysing cases with different characteristics, this paper can also contribute with recommendations as to when changes to population development and labour market should be expected to occur in future fixed link projects. This paper empirically investigates whether transport investments affect the indicators of changes to society, in this paper defined as changes to the housing market, population development and the labour market. We address the following research questions in this paper:

1) How do fixed links affect population development and the labour market on the connected island?
2) How do the case characteristics influence these changes?

Norway has replaced many ferry connections with fixed links over the past 60 years along the whole coast of Norway. We have analysed 11 of these ferry replacement projects located along the western coast of Norway. The western coast of Norway has been chosen due to the plans for investing in many new fixed link projects in this part of the country (Statens vegvesen, 2018).

The analysed projects substantially improve accessibility between the islands and the mainland. The islands consist of one or more municipalities, which provide us access to data recorded at the municipality level. Other municipalities in the region may also be influenced by the fixed link, both for the mainland and the surrounding islands. However, the scope of this paper is limited to the islands that become connected to the mainland. This scope is limited to a focus on whether the fixed links will promote growth on the island, as is normally expected by decision makers in Norway.

An important feature when conducting case studies is to compare the case against an alternative path of development. What would occur if the fixed link had not been built? This comparison is often lacking in other case studies. In this paper, we utilise the difference-in-difference method (Lechner, 2011).

The analysed cases are presented in Section 2. Section 3 describes the data used in this study, and Section 4 describes the methods used in the analysis. The results are described in Section 5, with a discussion following in Section 6. Finally, the conclusions and policy implications are summarised in Section 7.

2. Description of the cases

Figure 1 shows the locations of the 11 ferry replacement projects studied in this paper. The cases have different characteristics regarding population on the island, population on the mainland, travel time reduction, travel time to the closest town after opening and a change in monetary cost. The differences in characteristics promote a better understanding of the impact that accessibility has on the population and the labour market. Table 1 presents the most important characteristics of each case.

The cases are located within four of the five counties on the western coast of Norway. Three of the largest cities in Norway are located in this area and are labelled with names in Figure 1.

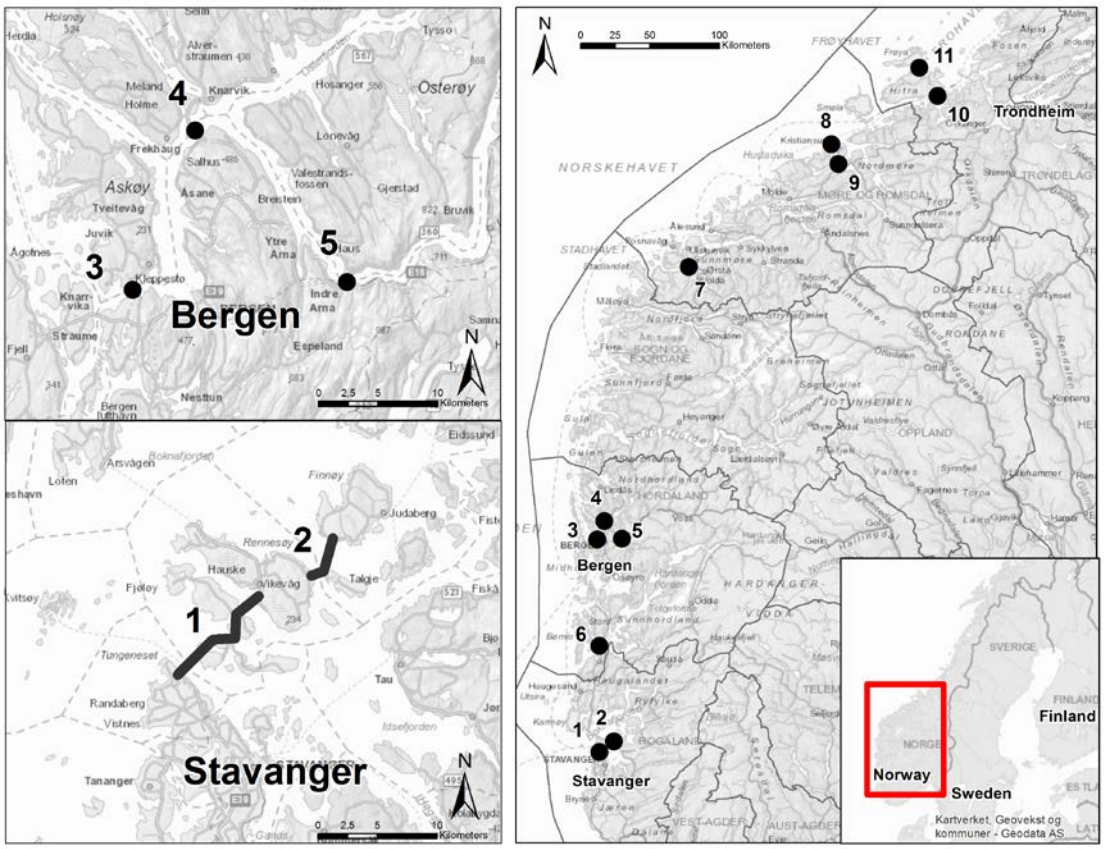


Figure 1 - Location of the cases in this study. The excerpts to the left show the projects around the cities of Bergen and Stavanger. County borders are also highlighted. Numbers in the maps according to Table 1.

Table 1 – Case characteristics. Population figures refer to the population at the time of the opening of the fixed link. Travel time is calculated between the closest towns on the mainland and the island, including the estimated waiting time for the ferry.

No.	Name	Year of opening/toll removal	Population in opening year		Travel time between island and closest town on the mainland		Ferry ticket	Toll fee on fixed link
			on the island	of the closest town on mainland (name of town)	before opening	after opening		
1	Rennfast	1992/ 2006	2,600	135,500 (Stavanger)	150 min	25 min	€16.40	€15.50
2	Finnfast	2009	2,800	190,000 (Stavanger)	90 min	50 min	€8.54	€23.30/ 17.80
3	Askøybrua	1992/ 2006	18,500	191,000 (Bergen)	30 min	15 min	€9.20	€6.40
4	Nordhord-landsbrua	1994/ 2005	21,400	195,000 (Bergen)	40 min	30 min	€7.80	€7.20
5	Osterøybrua	1997/ 2015	7,000	200,000 (Bergen)	96 min	42 min	€7.00	€7.00
6	Trekant-sambandet	2001/ 2013	10,800	11,000 (Stord)	60 min	30 min	€8.54	€11.20
7	Eiksund-sambandet	2008/ 2014	22,500	5,500 (Volda)	50 min	30 min	€7.00	€8.54
8	Krifast	1992/ 2012	22,500	20,600 (Molde)	145 min	78 min	€4.40	€8.70
9	Atlanterhavs-tunnelen	2009	5,400	17,000 (Kristiansund)	45 min	20 min	€10.90	€10.30
10	Hitratunnelen	1994/ 2010	4,200	6,000 (Orkanger)	152 min	88 min	€8.50	€5.30
11	Frøya-tunnelen	2000/ 2010	4,100	6,000 (Orkanger)	212 min	116 min	€18.40	€5.30

Most of the fixed link projects connect sparsely populated areas on the islands to more dense areas on the mainland. However, there are exceptions. In case 8, the city is located on the island, while the mainland is more rural. This finding may provide different results, as the fixed links open for more interaction with the surrounding rural areas, and the results may provide indications regarding whether redistributive effects from the city to the surrounding rural areas appear. In this case, the closest city is used in Table 1. Case 6 and case 8 are also part of a triangular connection, connecting islands and the national road network. In these two cases, the affected areas are defined as the island that obtained a fixed link. Cases 10 and 11 can be characterised as rural areas on both the island and the mainland.

Travel times were reduced substantially in all cases. The fixed links connected many islands to the town on the mainland within a reasonable commuting time of 45-50 minutes. However, cases 8, 10 and 11 have a travel time of more than 60 minutes to the closest town.

A toll fee as part of financing the investment costs normally replaces the ferry ticket. The relative change in direct cost varies from 0.62 to 2.72 times the corresponding ferry ticket. The toll period normally ends after 10-15 years, depending on the time needed to repay the investment cost. Despite the toll fee, fixed links represent a substantial increase in accessibility, as time savings are large. Thus, areas connected by a fixed link serve as excellent cases to study the joint interaction between transport investments and changes to society.

3. Data

The analysis of the cases is based on multiple data sources, which are presented in Table 2 and described in the following text.

Table 2: Variables and observed period

	Variable	Observed period
1	Traffic volumes	(1989 – 2015)
2a	Population	(1985 – 2015)
2b	Population relocation patterns	(1985 – 2014)
3	Housing market (square metre price)	(1993 – 2014)
4a	Employees	(2000 – 2015)
4b	Commuting patterns	(2000 – 2015)

3.1. Traffic volume data

Average annual daily traffic (AADT) was collected before and after the opening of the projects. The before data were based on counts provided by the ferry companies, while the after data were collected from counts on the fixed links by the Norwegian Public Road Administration. The traffic volumes used are the sum of all vehicle types.

3.2. Population data

Population data consisted of the total number of people residing in each municipality who are registered in the national database. People residing temporarily and thus not registered in the correct municipality may influence the data. However, these errors are considered minor errors (Statistics Norway, 2016). We analysed changes in the total population. We also observed migration and population relocation patterns. The latter consist of the total number of people moving from one municipality to another.

3.3. Housing data

Housing market data consisted of registered sold dwellings, collected from the Land Registry and Cadastre. A possible source of error was that the properties were registered after the sale occurred; therefore, for sales late in the year, they may have been registered in the following year. In addition, a low percentage of the properties lacked information about the size and/or the sale price. The average annual prices presented fluctuations. To observe potential trends, we used the central moving average method with three values to reduce the sensitivity of the data.

3.4. Employee and commuting data

Commuting data consisted of the number of people residing in one municipality and working in another within Norway. The population of the register-based employment statistics consisted of persons between 15 and 74 years

old, with one or more working hours per week, including the self-employed. Employee data use the same data source. The dataset has several data sources; therefore, it is possible to observe the consistency. Nonetheless, a possible source of error is delays in the registration of the self-employed. Additionally, employees working for companies with several locations may be incorrectly registered as employed by the wrong establishment (Statistics Norway, 2015).

4. Method

The analysis uses the difference-in-difference method (DiD-method) to analyse the impact of the fixed link. First, the DiD-method will be described; this will be followed by a description of how control areas used in the DiD-method are selected.

4.1. Difference-in-difference

The variables in this paper are analysed using the principle of the non-parametric difference-in-difference method (DiD-method) (Lechner, 2011). This method compares the development of an affected area to a control area, assuming that the development of the variables was similar in both areas before the project. The benefit of the method is to explain external factors that may influence the development, such as interest rates or gross domestic product (GDP). Hence, the results from the analysis could be related to the actual infrastructure improvement.

Equation 1 shows the formula used to calculate the DiD-values.

Equation 1 - Calculation of difference in-difference values

$$DiD = \left|Y_t^A - Y_{t_0}^A\right| - \left|Y_t^C - Y_{t_0}^C\right| \qquad (1)$$

Y_t is the variable analysed in the affected area (A) or in the control area (C). t_0 relates to the opening year of the fixed link, and t is the number of years after opening. In this study, when data were available, we observed the opening of the ferry replacement projects at six time intervals: immediate (t: 1), short term (t: 3), medium term (t: 5) and long term/toll removal (t: 10, 15 and 20).

Furthermore, the analysis also includes a test to determine if the affected area or control area experiences a trend break in the analysed variables at the time of opening. We used the hypothesis in Equation 2 with time series data five years prior to opening to test whether the assumption of similar trends was met. The hypothesis was tested using the test statistic described in Equation 3.

Equation 2 - Null hypothesis used to test for similar trends prior to opening of the fixed links and for trend breaks after opening

$$\boldsymbol{H_0}: \boldsymbol{\beta_1} = \boldsymbol{\beta_2} \ \boldsymbol{i.e.}\ \boldsymbol{\beta_1 - \beta_2} = \boldsymbol{0}$$

Equation 3 - Test statistic used to test for similar trends and trend breaks

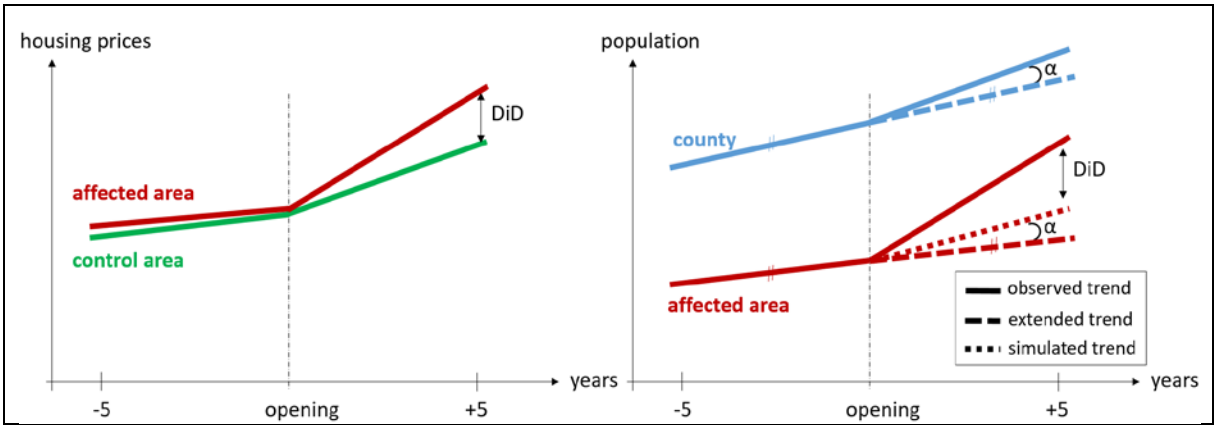
$$\boldsymbol{t} = \frac{\boldsymbol{b_1 - b_2}}{\sqrt{\boldsymbol{s_{b_1}^2 + s_{b_2}^2}}} \sim \boldsymbol{T(n_1 + n_2 - 4)}$$

where:

b_1 is the slope of group 1
b_2 is the slope of group 2
s_{b1}^2 is the standard error of b_1
s_{b2}^2 is the standard error of b_2
n_1 is the number of observations in group 1
n_2 is the number of observations in group 2

4.2. Selection of control groups

The DiD-method uses control areas to control for an alternative development without the infrastructure improvement. An important assumption of the DiD-method is that the affected areas and control areas have similar developments before the opening of the fixed links. Control areas were defined using two different approaches. The variables housing prices, employment and commuting use a control group, while traffic volumes and population development use a simulated trend. The two approaches are described in Figure 2.



a) b)

Figure 2: Difference-in- difference using a) a control group or b) a simulated trend. The control group here is the adjusted trend in Figure b.

The control group method uses the development on islands with similar characteristics such as industry composition and a ferry connection to the mainland during the whole period of analysis. Furthermore, the municipalities are selected from different islands in the same county as the affected area. The control groups consist of 1-4 municipalities with similar development to the affected area in the five years prior to opening. The test in Equation 2 is used to test for similar development between the affected area and the control group prior to opening. This approach is described in Figure 2a).

The simulated trend extends the trend line from the five years before opening through the period of analysis. To explain external factors, we use the development in the county as a whole. The change in trend between the six years before and six years after was analysed (α in Figure 2b), and the extended trend was adjusted according to this trend change to provide a simulated trend as described in Figure 2b). Traffic volumes uses only the extended trend, due to a lack of data on regional traffic development.

The motivation behind the use of a simulated trend was the lack of a control group with a similar trend before the opening of the fixed link as shown in Figure 2a). The synthetic control group method, as described by Abadie et al. (2010), was tested as a third alternative. However, this method did not provide better results than the control group method.

5. Results

5.1. Traffic data

Table 3 shows the development in traffic volumes. The table also shows the AADT on the ferry the year immediately before the opening to provide the magnitude of the traffic volumes on the stretch.

Table 3 – Traffic volumes, DiD-values compared to extended trend.

	Fixed link project	AADT on the ferry, the year before opening	DiD-values Years after opening of the fixed link					
			1	3	5	10	15	20
1	Rennfast	260	265	198	225	374	1,003*	1,384*
2	Finnfast	396	59	88	108	-	-	-
3	Askøybrua	2,970	72	92	111	183	416*	569*
4	Nordhordlandsbrua	4,760	20	47	62	90	198*	233*
5	Osterøybrua	560	183	204	251	377	474	-
6	Trekantsambandet	942	89	85	106	144	-	-
7	Eiksundsambandet	960	112	124	153	-	-	-
8	Krifast	1,490	35	46	50	78	59	123
9	Atlanterhavstunnelen	890	132	160	176	-	-	-
10	Hitratunnelen	940	355	390	418	564	861	-
11	Frøyatunnelen	340	33	21	103*	143*	191*	-

* = observed after toll closure

All cases experienced a substantial increase in traffic during the first years after opening. The immediate increase ranged from 20% to 285%. This immediate increase may be caused by the large increase in accessibility, which may trigger changes in the destination patterns. An example of this may be more private trips from the island to the mainland. Case 1 experienced a slight decrease from year 1 to year 2 after opening, but the reason for this is not clear.

After the initial years, the traffic growth stabilises at a higher growth rate than before the opening. The changes may be due to long-term factors other than changes in the destination pattern. These changes may be due to factors such as growth in population and employment. An increase in the population provides a higher potential for interactions with the mainland and hence may explain the further growth in traffic.

Toll removal also induces a second impact on the traffic volumes for those cases with available data. This removal may further promote the changes observed during the toll period, due to the reduction in generalised cost represented by the toll removal.

5.2. Housing market

Table 4 presents the DiD-values for housing price development. Cases 1, 8 and 10 are not analysed due to limitations in the data.

Table 4 - Development in housing prices

	Fixed link project	Similar trend before? (t-value)	Trend break in affected area? (t-value)	Trend break in control area? (t-value)	DiD-values Years after opening					
					1	3	5	10	15	20
1	Rennfast	Not analysed due to data limitations								
2	Finnfast	Yes (1.05)	No (1.32)	No (1.08)	1.0	15.6	33.7	-	-	-
3	Askøybrua	Yes (0.51)	Yes (10.96)	No (-1.28)	-11.5	36.1	53.5	128.9	294.1*	159.7*
4	Nordhord-landsbrua	Yes (-1.98)	No (1.19)	Yes (-3.96)	7.0	16.7	35.0	78.2	62.3*	-96.1*
5	Osterøybrua	No (2.60)	Yes (3.15)	Yes (3.64)	*24.5*	*44.3*	*-8.1*	*-23.2*	*-61.1*	-
6	Trekant-sambandet	No (3.93)	Yes (4.82)	Yes (6.69)	*-13.1*	*-7.1*	*-4.0*	*-6.9*	-	-
7	Eiksund-sambandet	Yes (2.11)	No (0.78)	No (-1.28)	6.1	14.3	22.1	-	-	-
8	Krifast	Not analysed due to data limitations								
9	Atlanterhavs-tunnelen	Yes (0.90)	No (-0.29)	No (-1.31)	-18.2	-1.6	5.5	-	-	-
10	Hitratunnelen	Not analysed due to data limitations								
11	Frøyatunnelen	No (-2.74)	Yes (3.24)	No (-2.17)	*5.8*	*41.9*	*24.1*	*-4.4*	-	-

* = observed after toll closure
Numbers in italic = Assumption of similar development before has not been met

All cases except case 6 experienced a positive development in the square metre price. However, case 6 did not satisfy the similar trend assumption, which made the DiD numbers uncertain. Furthermore, this case involves a triangular connection also linking two parts of the mainland together. This finding may make the areas on the mainland more attractive regarding the expense of growth on the island. Case 4 experienced a decrease in the DiD-values in years 19 and 20 after opening. This finding may be due to a large growth in the control group and is considered to have been caused by a trend change in the control group. The negative DiD-value for case 3 in year 1 is due to a peak in the housing prices for the control area.

The results from Table 4 show that most of the islands had a higher square metre price than before, suggesting that the increased accessibility provided by the fixed link matters in terms of residential location attractiveness. All the cases appear to have a positive effect as well, but the size of these effects varied among the cases. The cases that experienced the highest increase in housing prices are localised close to large cities (on a Norwegian scale). Cases 2, 3, and 4 obtained fixed link connections to the second or third largest city regions in Norway, while case 7 obtained a connection to two smaller cities.

5.3. Population

Table 5 presents the DiD-values and trend breaks for population development.

Table 5 - Population development

	Fixed link project	Trend break simulated trend (t-test)	Trend break observed trend (t-test)	Population numbers in the closest town on the mainland in opening year	DiD-values Years after opening					
					1	3	5	10	15	20
1	Rennfast	No (0.804)	Yes (4.461)	135,500	0	2.4	6.1	16.0	21.5*	49.8*
2	Finnfast	Yes (2.868)	Yes (10.971)	190,000	1.6	7.0	11.5	-	-	-
3	Askøybrua	No (0.370)	No (0.603)	191,000	-0.7	-0.9	0.3	5.7	16.2*	30.7*
4	Nordhord-landsbrua	No (0.036)	Yes (3.201)	195,000	0.3	1.4	2.2	5.0	12.1*	20.8*
5	Osterøybrua	No (-0.655)	Yes (2.150)	200,000	0.3	0.5	2.2	4.2	9.9	-
6	Trekant-sambandet	No (0.388)	Yes (-5.886)	11,000	-1.0	-2.4	-3.2	-1.7	-	-
7	Eiksund-sambandet	Yes (33.232)	Yes (15.648)	5,500	0.1	3.2	4.2	-	-	-
8	Krifast	No (2.093)	No (1.938)	20,600	0.5	0.2	0.2	0.9	2.3	8.2*
9	Atlanterhavs-tunnelen	Yes (5.304)	Yes (7.485)	17,000	0.1	1.2	1.9	-	-	-
10	Hitratunnelen	No (0.373)	No (-0.121)	6,000	-0.3	-0.3	-0.3	2.5	6.2	17.5*
11	Frøyatunnelen	Yes (2.577)	No (-1.836)	6,000	-0.6	-0.8	-2.7	-0.5	4.7*	-

* = observed after toll closure

Most of the cases experienced a growth in population after the opening of the fixed link. The DiD-values show that the increase differs between the cases. Cases 6 and 11 did not experience extra growth in population during the toll collection period because the population growth was lower than the growth for the entire county.

After toll removal, all cases with sufficient data experienced an additional growth in population compared to the simulated trend. This additional growth may indicate that the tolling suppresses some of the potential growth that the fixed link represents.

We also analysed relocation patterns for the cases with population growth. For the cases close to cities, a large proportion of people move from the nearby municipalities to the islands. For the remainder of the fixed links, a larger proportion of the people moving to the areas came from municipalities that were farther away from the affected areas. The reason why more people move from the mainland in cases close to cities may be due to access to new residential areas and lower housing prices on the island than the city area on the mainland. This finding is supported by the cases close to Stavanger (1 and 2) and Bergen (3, 4 and 5), where average square metre prices on the islands were 40-80 % of the equivalent prices in the cities in the period of analysis. Conversely, the more rural cases reported similar prices on the island and mainland.

5.4. Employment

Data on the number of employees and on commuting to and from the affected area are available only for cases 2, 7 and 9 due to data being available only from 2000. The DiD-values for employment are presented in Table 6, while data for commuting from and to the affected area are presented in Table 7 and Table 8, respectively. Note that similar trends are only found in some of the observations.

Table 6 - Development in number of employees (Source:(Nilsen et al., 2017))

	Fixed link project	Similar trend before? (t-value)	Trend break in affected area? (t-value)	Trend break in control area? (t-value)	DiD-values Years after opening		
					1	3	5
2	Finnfast	No (-3.389)	Yes (-2.752)	Yes (-2.954)	*2.3*	*-5.7*	*6.1*
7	Eiksundsambandet	No (-3.220)	No (-2.006)	Yes (-5.740)	*2.4*	*8.1*	*11.4*
9	Atlanterhavstunnelen	Yes (-0.478)	No (-0.558)	No (-0.797)	-0.6	3.0	-1.1

Numbers in italic = Assumption of similar development before has not been met

Table 7 - Commuting from the island to the mainland. (Source:(Nilsen et al., 2017))

	Fixed link project	Similar trend before? (t-value)	Trend break in affected area? (t-value)	Trend break in control area? (t-value)	DiD-values Years after opening		
					1	3	5
2	Finnfast	No (-5.518)	Yes (-2.649)	No (-0.420)	*5.2*	*10.3*	*19.6*
7	Eiksundsambandet	No (-3.046)	No (-1.356)	No (-0.701)	*-2.9*	*-7.1*	*3.4*
9	Atlanterhavstunnelen	No (-4.343)	No (-0.966)	Yes (-5.950)	*7.5*	*22.8*	*24.2*

Numbers in italic = Assumption of similar development before has not been met

Table 8 - Commuting to the island from the mainland. (Source:(Nilsen et al., 2017))

	Fixed link project	Similar trend before? (t-value)	Trend break in affected area? (t-value)	Trend break in control area? (t-value)	DiD-values Years after opening		
					1	3	5
2	Finnfast	Yes (-1.459)	No (-1.521)	No (-2.128)	2.6	-13.4	7.9
7	Eiksundsambandet	No (-3.349)	No (-1.465)	No (-1.361)	*0.1*	*2.5*	*5.0*
9	Atlanterhavstunnelen	Yes (-0.384)	No (-1.833)	No (-0.798)	6.2	40.8	12.1

Numbers in italic = Assumption of similar development before has not been met

Cases 2 and 7 experienced an increase in the number of employees five years after opening. Only case 2 experienced extra growth in the number of employees; however, the results are uncertain due to the development not being similar to the control group before the opening.

The commuting patterns show an increase in commuting both to and from the islands in all cases after five years, which may indicate a widening of the labour market. However, the similar trend conditions were only met for commuting to the island in cases 2 and 9.

6. Discussion

The cases in this paper represent a large increase in the accessibility between the islands that the projects connect and the mainland. The improvement in accessibility provides more opportunities for people to interact between the newly connected areas. The question raised in this paper is how this substantial increase in accessibility may affect the society on the island, represented by growth in population and the housing and labour markets. Furthermore, we question how the characteristics of the connected areas and travel time reductions influence the magnitude of these changes.

6.1. How do fixed links affect population development and the labour market on the connected island?

The results from the analysis show immediate growth in traffic the first year after the opening. These results were expected, as the increased accessibility provides easier access across the fjords. However, the more interesting part in this setting is the change from low or no annual growth to a large growth rate in the years after the opening. This increased growth rate indicates that long-term processes may be present since the traffic continues to grow. Similar changes are also found in previous studies including a few of the same cases (Andersen et al., 2016; Díez Gutiérrez et al., 2015).

The housing market experienced an increase in housing prices after 3 years, in all the cases with sufficient data. This increase in housing prices on the connected islands indicates an increased demand for housing on the island, as the islands become more attractive for residential settlements. The growth is also larger in the cases connected to cities. These findings are also in line with previous studies (Andersen et al., 2016; Christophersen et al., 2000; Díez Gutiérrez et al., 2015; Laakso, 1997). The importance of accessibility with respect to housing prices and residential location has been highlighted in numerous studies (e.g., (Osland, 2010; Wegener, 2004)). The growth in housing prices may have started even before the opening. However, the smoothing method used also averages out a bit of the trend break observed in the raw data in some of the cases.

Additional population growth due to the opening of a fixed link is not evident in all the analysed cases. Only the cases connecting the islands to the most populated areas experienced additional population growth according to the results. This finding is in accordance with the findings in previous studies (Andersen et al., 2016; Díez Gutiérrez et al., 2015; Meijers et al., 2012).

We also find indications of growth in employees and commuting to and from the island due to the fixed link. However, similar trends before are only found for commuting to the island. The data do not provide an explanation of the reasons for this growth. However, various factors may cause this growth in commuting. People may move from the mainland and retain their job there. In addition, people on the island may get new jobs on the mainland or vice versa. Furthermore, firms may establish new or increase the activity on the island, attracting more workers from the mainland. These findings support that fixed links appear to connect the labour market closer to the mainland. This finding is also in accordance with interviews with firms on these islands, reported in (Nilsen et al., 2017).

The toll removal provides an additional impact on the analysed variables. Both the traffic volumes and population growth are affected by the toll removal. Traffic volumes get another immediate increase, and the annual growth rate is higher than the situation with toll collection. Population development also experiences additional growth due to the toll removal. However, the toll removal did not influence housing prices as much as expected. The two cases with sufficient data did not experience further growth in the housing prices due to the fixed link. This finding may indicate that much of the potential growth effect from the fixed link was realised within the tolling period. The findings are also uncertain due to potential external effects in the control groups, as one of the control areas experienced sudden growth in the last two years. Overall, the cases with available data experience additional growth to both population and traffic when removing the toll. This finding may indicate that the full potential of growth is restricted to an extent during the tolling period.

6.2. How do the case characteristics influence the changes?

Combining the results from the housing prices and population growth may explain the causal relationship in the cases close to a city. A fixed link connects new areas to the city, available for residential or commercial development. The housing prices on the newly connected island tend to be lower than those on the mainland, providing new opportunities for cheaper housing on the island. However, the people moving to the island need to travel longer distances to be able to work in the city or utilise services only found in the city centre. This relationship is supported by the commuting results, which indicate an increase in commuters from the island to the mainland. Furthermore, the moving patterns also show that much of the population growth originates from the mainland in these cases. This finding is also in accordance with the mechanisms described in Wegener (2004).

The cases around the cities of Bergen and Stavanger (cases 1-5) experience significantly larger growth in population, housing prices and traffic volumes than the more rural cases in this analysis. Two characteristics appear to influence this additional growth. First, the connected island is located close to a large city, and the travel time between the city and the island is within an acceptable commuting time of approximately 45 minutes. Thus, the fixed links connect the island to the larger labour market on the mainland. The second characteristic is the relative difference between housing prices on the island and the mainland before opening. The fixed links joins the island with lower housing prices, providing access to more land for development close to the city. These two case characteristics contribute to the understanding of the differences observed between rural and urban cases in this paper.

The rural cases did not experience growth of the same magnitude as those close to cities. The fixed links positively affected growth in housing prices, while the results indicate only small or no additional population growth due to the fixed link during the tolling period. However, after the tolling period ended, these cases also experienced an additional increase in population. Much of the same process as described above for the urban cases may explain these findings but with lower magnitude than projects close to cities.

If we draw a line between cases close to cities or rural areas, the general trend is that fixed links promote growth in housing prices and population. The magnitude of the changes varies according to the characteristics of the fixed link and surrounding areas and appears to be affected by the population level on the mainland. However, other parameters may also influence the magnitude. The difference in square metre price between the mainland and the island can also influence the attractiveness of the island for development and population growth, as the housing costs are initially lower on the island. Travel time to the closest town on the mainland may also influence growth, and the availability of jobs may affect the attractiveness of an area.

6.3. Limitations and further research

Suitable cases for this analysis are limited in the Norwegian context due to data being available only on a municipality scale and due to limited availability of older time series. The method used assumes that the control group can represent how the development would have been without a fixed link. To meet this assumption, the development before the opening needs to be similar in the affected area and the corresponding control area. However, the control area may be affected by other factors than the affected area due to different characteristics. To avoid this issue, we chose control areas with similar population levels and industry composition in the same county. Furthermore, control areas close to the affected area may mutually influence one another, and this situation will exclude certain municipalities as control groups. Therefore, we consider the control areas as a suitable fit for the alternative development.

We also consider the simulated trend as a suitable alternative path of development for population. The population development changes more slowly, and the method provides indications of whether the affected island attracts a larger proportion of the population growth than the remainder of the county. Furthermore, the use of the county in the simulated trend also involves the affected municipality. This use may provide a bias in the results. However, the proportion of population in the affected municipality is less than 5 % for all cases except case 8 (9 %). Due to this low proportion of the county population, we consider this to be a minor bias in the results. Furthermore, a positive DiD-value in the population variable shows that the island attracts a larger proportion of the population in the county than before the fixed link was built.

The construction time for these projects are normally 3 to 5 years. This finding may provide an anticipatory effect on the region, resulting in the development beginning prior to opening. Indications were found for the population in (Díez Gutiérrez et al., 2015). This finding may underestimate the DiD-values to an extent due to the contingent growth prior to the opening not being represented.

The cases in this study provide valuable information on some of the impacts fixed links have on the society on the connected islands. The transport model currently used in assessment in Norway does not include the impact from transport investments on society (e.g. population and employment numbers). Thus, the findings in this paper suggest that the methods should be expanded to include these impacts in future assessments of large projects such as fixed link projects. However, development of such a method is outside the scope of this study and remains for future research.

The scope of this study is to analyse the changes to society on the islands that obtain a fixed link connection. Our focus is on how the connected islands are affected by a fixed link connection. However, how these projects affect the surrounding areas and the region may be an interesting topic for future research. Engebretsen and Gjerdåker (2010) argue that these effects are redistributive effects rather than growth on a regional level. We agree that this may be the case on a regional scale, as the analysis of population relocation indicates that the observed population growth originates from the mainland. This finding may be analysed more in depth through the movement patterns in future studies. During our work with these cases, it appears that the cities expand towards the newly connected areas. This finding is also relevant to studies in the future. However, this paper will provide a strong foundation for further analysis on whether the growth on the islands happens at the cost of less growth elsewhere in the region or is actually additional growth for the region.

7. Conclusion

This study analyses changes in population, housing and the labour market due to a fixed link replacing a ferry service. The large impact on accessibility represented by the fixed link induces traffic growth, both immediate growth and a higher growth rate in the following years. The results show that one of the underlying reasons for this increased annual growth rate is that the islands become more attractive as residential locations. This finding

is reflected by the large growth in housing prices and population on the connected islands. Furthermore, we find indications of increased commuting to and employment on the connected islands. The magnitude of these changes may vary according to the characteristics of the connected mainland. We find that islands close to cities experience larger growth in population and housing prices than islands connected to rural areas. Based on these findings and our knowledge of the Norwegian assessment methods, we recommend developing these methods to explain changes to society in future assessments of fixed link projects, particularly for projects close to cities.

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