The Effect of Commuting Time on House Prices

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Abstract

Building on the theoretical framework of monocentric city theory, this thesis investigates whether the new E18 highway, reducing commuting time between Grimstad and Kristiansand, increased house prices in Lillesand, Grimstad and Arendal. The thesis first uses the synthetic control method to construct a projected price growth based on pre-treatment values on prices and macro-economic variables in a weighted set of comparable municipalities. The gap between the actual growth and the projected price growth, representing the effect of the new road, is found to be positive, implying that the road indeed had an effect on house prices. The significance of the findings is strengthened by running placebo tests on the other municipalities in the donor pool. Furthermore, by using data on roughly 9 000 house transactions in the affected areas the amplitude of the change of travel time on house prices is measured. The analysis finds the elasticity of house prices when changing travelling time to be approximately 0,15. Finally, the thesis explores whether the timing of the effect is relevant. By assigning the travel time using the new road to transactions done before the road opened, the thesis finds that the effect of the new road was actually largest at the year the construction works began. This implies that people were forward looking and took the reduced commuting time into account several years before the E18 actually opened. The finding is in line with other papers on comparable cases.

Preface

This thesis completes my period of studies at the University of Oslo and concludes a two-year master's degree in Economics. Working on the thesis has been both challenging and frustrating at times, but most of all inspiring. It has improved my understanding and enhanced my interest in this particular field of social science. First and foremost, I would like to express my gratitude towards my supervisor Edwin Leuven, for invaluable support and guidance. He has always offered his assistance when needed. Through a part time job at Eiendomsverdi I was introduced to the field of housing economics and the different aspects of this subject. My superiors gave me the possibility to do interesting analyses and dig into unlimited amounts of data. The thesis at present is based on data from their database, and I would like to thank my colleagues for good discussions and support throughout the process. Finally, I owe my fellow students, friends and family unlimited debts of gratitude for support, care and good times.

The regressions and estimates in this thesis is performed in STATA. Data sets and do-files are available upon request. Any errors or inaccuracies that might occur, are solely my responsibility.

Oslo, November 2016

Andreas Jensen

Contents

List of Tables

List of Figures

1. Introduction

The theory of monocentric cities describes a situation where people work in one central business district (CBD) and live in the surrounding areas (Alonso 1960). The theory is the basis of Alonso's idea that house prices, holding everything else constant, fall with distance from the centre. Since people have disutility of commuting, bids will theoretically rise until the savings provided by the location are fully capitalized into the price of the property. Based on this bid rent theory one could thus assume that reduced commuting time between the CBD and a housing area, leads to increased houses prices in the affected housing area. This thesis will investigate this prediction on a specific case. The opening of the new E18 highway between Grimstad and Kristiansand in southern Norway in 2009 reduced the commuting time between Grimstad to Kristiansand from roughly 45 to 30 minutes. According to Alonso's theory, this should lead to an increase in house prices in Grimstad, as well as in the neighbouring cities. In a time where several rails and roads specifically related to commuting are being improved in Norway, it is therefore of interest to investigate whether such improvements affect house prices. Previous research (Adolfsen and Grimstvedt 2011, Gonsholt 2013) found that the new road did increase house prices in the affected areas. Building on their findings, this thesis first investigates whether the effect still holds when controlling for changes in macro-economic variables typically affecting the house prices. By using the synthetic control method, a contrafactual trend is constructed based on pre-treatment developments in prices and macro variables in a weighted average of control municipalities. This gives a measurable effect of the new road. Micro data on house transactions in the treated areas are then used to measure the exact effect of reduced commuting time on house prices.

The structure of the thesis will be the following: section 2 will provide some general background of the area and the road, while section 3 gives a summary of the existing research on the topic as well as an introduction to Rosen's (1974) theory on hedonic models, used in the regression. Section 4 explains the data used in the thesis and section 5 an explanation of the two methods used. Section 6 provides the results from the regressions as well as a discussion of potential extensions. Concluding remarks and suggestions for future research will be covered in section 7.

2. Background

2.1 Regional information

The case studied in this paper is the new E18 highway, connecting the cities in the Agder area, also known as *Sørlandet*. This area consists of the two counties Aust- and Vest-Agder, together home to approximately 300 000 inhabitants. Sørlandet has traditionally been characterized by fishing and agriculture as well as maritime industry. In the later years, different service industries have, as in all parts of the country, however increased.

Fig. 1 – *The cities in the Agder area. The black line is the new E18 highway.*

The map in figure 1. shows the main cities in the region. With its 88 000 inhabitants Kristiansand is by far the biggest city in the area. Arendal and Grimstad follow with 44 000 and 22 000 (SSB table 06913). The three cities, together with Lillesand, form an important axis as most of the population in the Agder region is based here. The distance between Arendal and Kristiansand is about 64 km, approximately 45 minutes by car on the new E18 highway. One can thus conclude that these four municipalities are within the same working area.

2.2 The new E18 highway

After much political debate, the plans for the new E18 were officially approved in December 2004 (Draft resolutions and bills – Nr.33). Works began in June 2006 and the road was finished in August 2009. The new road reduced the travelling time between Grimstad and Kristiansand from 45 to 30 minutes, also affecting the rest of the municipalities in the study.

There were several aims of building the new E18 between Grimstad and Kristiansand. One was to improve the main road between Oslo and Kristiansand. Numerous cabins and summer houses are located in the Agder area. Many of these are owned by people living in the Oslo area, so the traffic on the road increases during the summer months. Being one of the main roads between the eastern and western parts of Norway, improvements would also facilitate better transportation possibilities for both commodities and personal transport. In addition to reducing the transport time, increasing road safety was high on the agenda. However, developing the Agder area as a working and living region was the most important objective. A new road, with increased capability and the possibility for higher speed limits would facilitate economic cooperation and trade within the region. The project was financed by transfers from the Government and toll plazas. Today there are three toll plazas on the road. Although one could assume that the location of these plazas could give some local differences in house prices, this will not be analysed in depth in this thesis.

2.3 Migration and commuting in the area

The new E18 was meant to influence the whole Agder region. With 44 000 inhabitants, Arendal might be regarded a commuting destination itself. It can therefore be discussed whether Sørlandet is not monocentric, but rather a two-centre region. In figure 2, the net immigration to the treated areas (Lillesand, Grimstad and Arendal) and Kristiansand are shown.

Fig. 2 - *Net immigration to the treated areas and Kristiansand. The vertical lines mark when the road was decided, initiated and opened respectively.*

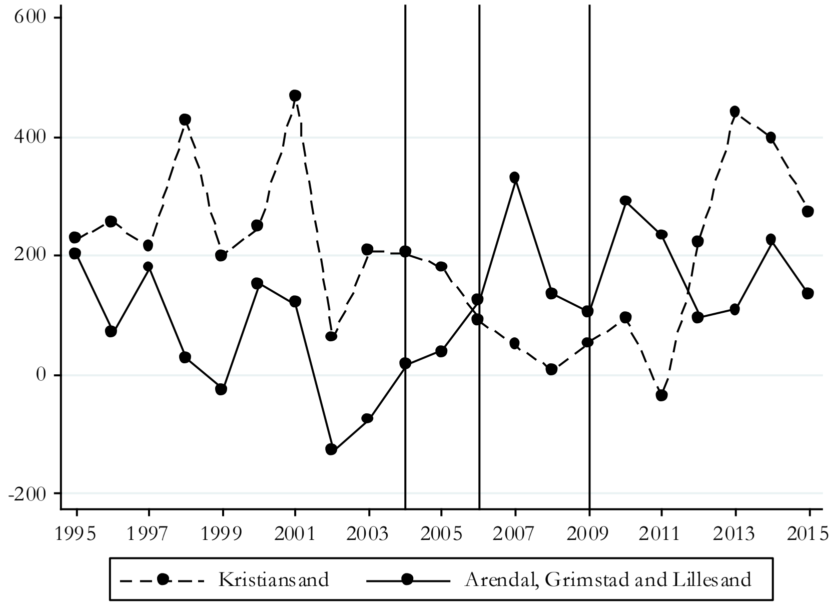


Figure 2 shows the net immigration to the treated areas, Arendal, Grimstad and Lillesand as well as Kristiansand between 1995 and 2015. One can observe a period of high net immigration to the treated areas in the years connected to the opening of the road. Coinciding with this is a period of low net immigration to Kristiansand. This might indicate that people are moving from the CBD to the treated areas, but also that people moving to the region choose the treated areas instead of the CBD. The hypothesis of increased house prices when the commuting time goes down is also depending on the fact that people living in the treated areas have utility of reduced travelling time to Kristiansand. Table 1 shows the level of commuting, in 2000 and 2014 (Knutepunkt Sørlandet, 2014). From 2000 to 2014 the level of commuting between the four cities has increased in all cases. The largest increase by far has been in the number of commuters from Arendal, Grimstad and Lillesand to Kristiansand. The increased net immigration to the treated areas as well as increased commuting to the CBD, might thus be a result of the new E18 highway.

Tab. 1 – *Share of commuters in each municipality and where they commute. The difference is measured in percentage points. Source: Knutepunkt Sørlandet 2015*

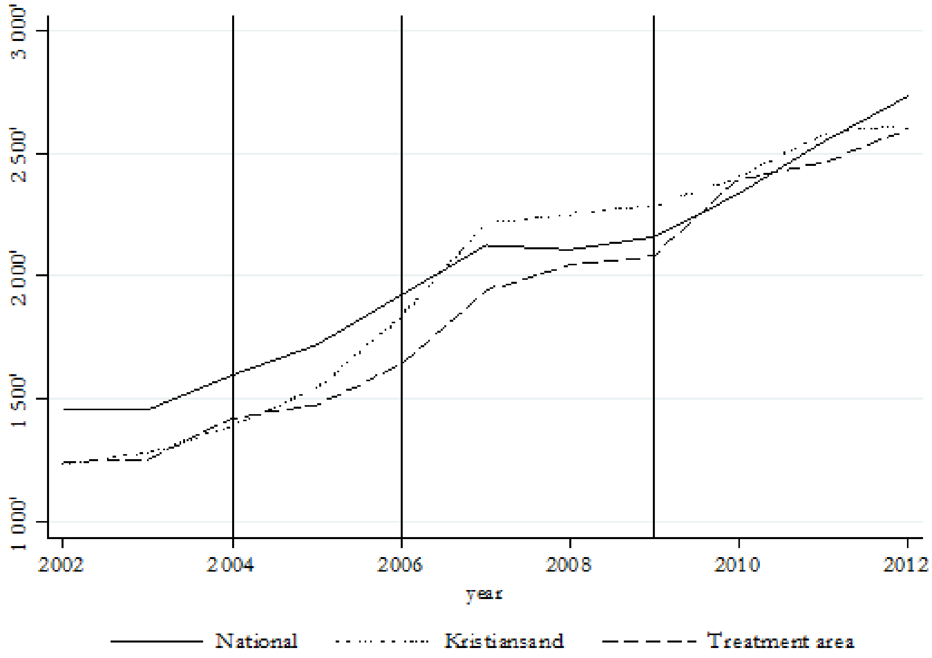
2000		Living municipality			
		Grimstad	Arendal	Lillesand	Kristiansand
Working municpality	Grimstad	62 %	7 %	5 %	0 %
	Arendal	20 %	77 %	3 %	0 %
	Lillesand	3 %	1 %	55 %	1 %
	Kristiansand	3 %	2 %	23 %	85 %

2014		Living municipality			
		Grimstad	Arendal	Lillesand	Kristiansand
Working municpality	Grimstad	54 %	7 %	5 %	1 %
	Arendal	21 %	75 %	4 %	1 %
	Lillesand	4 %	1 %	50 %	1 %
	Kristiansand	9 %	4 %	29 %	83 %

Difference		Living municipality			
		Grimstad	Arendal	Lillesand	Kristiansand
Working municpality	Grimstad	-8 %	0 %	0 %	1 %
	Arendal	1 %	-2 %	1 %	1 %
	Lillesand	1 %	0 %	-5 %	0 %
	Kristiansand	6 %	2 %	6 %	-2 %

The main hypothesis in this thesis is that the new road led to increased house prices in the area, investigating whether the prices actually increased or not is therefore vital. Figure 3 shows the development in average house prices in the treated municipalities, Kristiansand and the national average. The treated municipalities experienced higher growth than the national average from around 2006 and onwards. This effect accelerated towards the time of the opening. In Kristiansand, house prices rose even earlier (from 2004 and onwards), but then followed a path similar to the national development after a while. Based on this, it should be plausible that the road could have been a reason for the increased house prices.

Fig. 3 – *Developments in average house prices in the different areas. The vertical lines mark when the road was decided, initiated and opened respectively.*



3. Literature and theoretical framework

3.1 Previous literature

The idea that house prices decrease with distance from the centre is the foundation for the works of Alonso (1960) and Mills (1967). Their model is based on the idea of a monocentric city, where people work in one centre and live in the surrounding areas. Since people value their time and hence have disutility of commuting, house prices, holding everything else constant, will be higher closest to the centre. In a market setting, bids will theoretically rise until the cost savings provided by the location are fully capitalized into the price of the property. The model has later been extended by for example Muth (1969) who showed that the result is consistent also in a polycentric setting, an idea also pursued by Wheaton (2004). Alonso and Mills' model predicts that areas closer to the CBD have higher prices than those further away. This could, however, merely be an observation of the situation at a given point of time. The introduction of a dynamic aspect, namely a *change* in travelling time, is therefore of interest. This idea has been studied by several authors. Dewees (1976) inspected the effect of a new subway line on residential property values in Toronto, Henneberry (1998) examined the impact of the introduction of a tram on house prices in Sheffield and Yiu and Wong (2005) studied how a new cross-harbour tunnel affected housing prices in Hong Kong. These studies all found that reduced transport time indeed gave higher house prices in the affected areas. This thesis does the same type of analysis on a Norwegian case, namely the new E18 between Grimstad and Kristiansand.

To my knowledge there are two other papers that have studied this. Adolfsen and Grimstvedt (2011) studied the effect of the road on house prices in Lillesand, and found that the house prices did increase. Gonsholt (2013) later found that the road also gave increased prices in Grimstad and Arendal, but without checking the amplitude of the increase. This thesis expands their findings by first looking at how the treated areas performed compared with the rest of the country, taking possible changes in macro variables into consideration. Secondly, the magnitude of the effect in all the treated areas is measured through a difference-in-differences analysis on micro data. Including Arendal and Grimstad in the study is of interest since Arendal to some degree also can be regarded as a centre on its own.

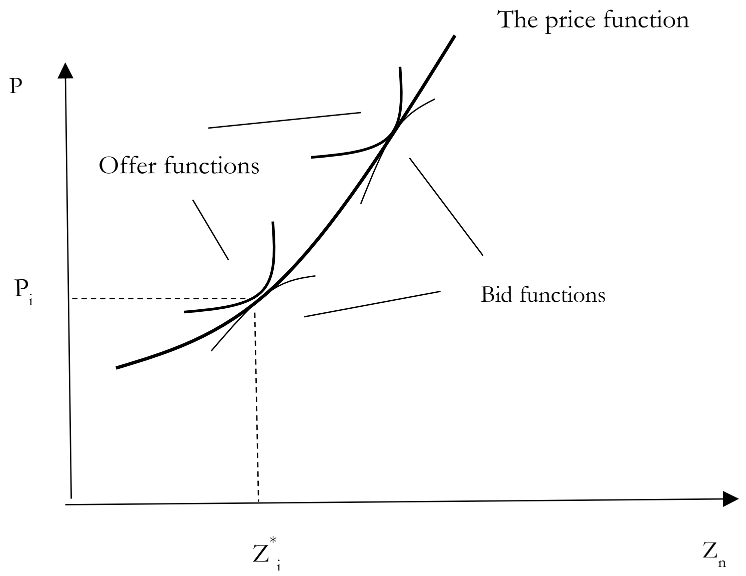
3.2 Hedonic pricing

Houses differ from ordinary economic goods in a range of aspects. Houses are immovable. Thus, when buying a house one also buys a location. This also emphasizes the exclusivity of the good, there is only one winner of the bidding. And when the demand for ice cream quite quickly can be met by producing more ice cream, a sudden increase in supply of houses is difficult, implying a low supply elasticity. Complicating the picture even more is the fact that a house can be treated both as a necessary good and an investment good.

The most significant aspect of houses however is the heterogenetic character of it, all houses are different. This is the basis of the model developed by Sherwin Rosen in 1974. Rosen based his model on Kelvin J. Lancaster's view (1966) on goods as consisting of several attributes each giving utility to the buyer. Rosen's static model connects the hedonic price function with the adjustments of the agents on both sides of the market. A more thorough explanation of the Rosen model can be found in the appendix, but the main idea is the following.

Because of the heterogeneity of houses as a good, the price of a house can be regarded as the sum of implicit prices for a range of attributes. These attributes are variables such as size, age of the house, view or distance to the city centre. To simplify, it is assumed that prices are increasing in all attributes. On the demand side, there is an indefinite range of households which have utility functions defined by housing attributes, other goods as well as a preference parameter. Their incomes are spent on housing and other goods. Each household maximize their utility given their budget restriction. Since all houses are different, every transaction includes a bidding process. Each household's bid functions are thus important when solving for the market equilibrium. This function is defined as the marginal willingness to pay for different compositions of attribute vectors, holding utility level and income constant. The bid function is deduced through the optimal values of the utility function. The different households maximize their utility by finding the composition of attributes which gives the lowest possible bid function along the price function. Because there are many households, the hedonic price function entails all households' bid functions.

Fig. 4 – *Market equilibrium in Rosen's model on hedonic pricing*



The supply side consists of an indefinite range of agents, taking costs and prices as given. These agents can be regarded as producers, which can adjust the number of units and the number of attributes of their products. The profit expression on the supply side is given by the aggregate profit for the sellers. Their profit is defined by the number of houses being sold of a given composition of attributes as well as a convex cost function of the number of houses and their attributes. Parallel to the bid function on the demand side is an offer function on the supply side.

Market equilibrium is achieved when the bid function of the households and the offer functions of the producers are tangent. As figure 4 shows, the hedonic price function is given by the bid function of the households and the offer functions of the producers.

4. Data and descriptive statistics

All the data on prices in this thesis are provided by Eiendomsverdi AS, a commercial company gathering data and developing statistics on the Norwegian real estate market. Eiendomsverdi's data, covering most house transactions in Norway, are based on the official cadastre. Through cooperation with all real estate agencies in Norway, all house transactions are automatically uploaded to the database and connected with the corresponding address. The data is cleaned and controlled against the official registry, reducing, although not eliminating, the chance of errors.

The dataset is limited to transactions on houses and apartments excluding estate types such as cabins and farms, as the price of these will be less affected by changes in commuting time. In addition, it only includes sales done through a real estate agent, since the data on transactions done privately (without an agent) are typically between relatives or of similar arrangements, making the sales price not representative.

4.1 Macro-economic data

The macro variables included are the ones assumed to be the most influential to house prices, based on the following intuition. Like any other market, the house market is driven by supply and demand. Regarding *this* market, the most relevant supply variable is the number of new dwellings, assuming that the number of houses being taken out of the market (demolished) every year is limited. On the demand side, several variables are of interest. Income and unemployment might indicate each individual's purchasing power, while population and GDP describe more aggregate aspects. The data sources of the variables are described below.

Increased supply of houses, through building activity, might reduce the house prices. Therefore, one could think that a reduction in building activity could be a reason for increased house prices. In this thesis, SSB's numbers on initiated houses are used. In their registry, a house is counted as initiated when the building permit is given (Statistics Norway – Table 05940). Increased income makes people able to spend more on housing and is thus a relevant parameter for the housing market. The data for median income is from

Statistics Norway's (SSB) tax statistics. It shows the median income for people above 17 (Statistics Norway - Table 05671). Since a secure income is vital for getting a loan, it is reasonable to assume that when more people get employed, these people move from the rental market to a position where they can get a loan and hence buy a house. Reduced unemployment therefore increases the demand side of the market. The unemployment numbers used in this analysis show the share of registered unemployed of the total workforce (between 15 and 74) on municipality level. The numbers are based on the Norwegian Labour and Welfare Administration's (NAV) register of unemployed (Statistics Norway – Table 06900). Population growth could imply increased demand for houses, which through the price mechanism should increase prices. The population data is from SSB and shows the annual number of inhabitants per municipality (Statistics Norway – Table 06913). The data on GDP shows development in production per county from 2002 to 2012 (Statistics Norway – Table 09391 and Table 05560). Production is defined as the value of goods and services from domestic production, including production for sale as well as public sector and organizations (SSB - Concepts and definitions in national accounts 2014).

The data set covers the years from 2002 to 2012. The road was started in 2006, and finished in 2009, so both potential expectation effects as well as effects on longer term should be covered by this time span. During this period, there has been some changes in municipality structure. All municipalities with missing observations on one or more variables are therefore excluded, as well as municipalities with no registered transactions in a year. As these municipalities are excluded merely due to changes in municipality structure, there should be no reason to expect selection bias. After the exclusions, the data set consist of observations on 274 municipalities.

4.2 Micro-economic data

The data used in the difference-in-differences analysis is on house level and covers transactions in Arendal, Grimstad and Lillesand between 2002 and 2012. Eiendomsverdi registers a set of variables on all house transactions in Norway, but this analysis will only include some of them. The variables included in the thesis are the following: sale date, sale price (included common debt if it is part of a housing cooperative), estate type (detached, attached or apartment), build year (decoded to age at sale date), living area and ownership type.

Regressing house prices on travelling time to CBD requires numbers on travelling time from each house to the CBD. Since the dataset contains nearly 9 000 observations, distance is measured from the geographical centre of the post or sub-council number area. Post number areas are used for Grimstad and Arendal, and sub-council numbers for Lillesand. This gives 22 different areas in Arendal, 9 in Grimstad and 21 in Lillesand. For the CBD, Kristiansand town hall is chosen as the geographical centre point. The travelling time between each area and the CBD is measured by using the route planner tool in Google maps. The travelling time reported using this tool might be different from the time it actually takes. However, since all times are measured in the same way, it should at least give similar bias and will thus not matter when using the difference in differences method. Each transaction in the panel data is assigned either the old or the new travel time, depending on the time of the transaction.

Some areas have been excluded from the analysis because of few observations or no natural centre. These are the ones situated in sub-council number 224, 220, 204 and 223 in Lillesand, and in post number area 4900 and 4820 in Arendal. These restrictions lead to omitting 162 observations. Registered transactions lacking numbers on living area, price or year of construction are also excluded.

Tab. 2 - *Summary statistics*

	Mean	Std.dev.	Min	Max
Sale year	2007.4	3.17	2002	2012
Age of house	42.4	44.9	0	404
Apartment	0.22	0.41	0	1
Detached house	0.63	0.48	0	1
Attached house	0.15	0.36	0	1
Cooperative	0.098	0.30	0	1
Price	1 786 305	912 747	350 000	23 000 000
New time	43.8	10.6	24	69
Old time	58.2	12.7	28	84
Relative time diff.	0.25	0.059	0.13	0.36
Observations	8908	8908	8908	8908

5. Empirical approach

5.1 Synthetic control method

When measuring the potential effect a treatment can have on price developments, a plausible pitfall are other factors that change at the same time as the treatment. To address this potential bias, the synthetic control method described in (Abadie and Gardeazabal 2003; Abadie, Diamond and Hainmueller 2010) will be used. This method constructs a counterfactual trend based on a weighted average of comparison units. The so-called synthetic control is estimated by minimizing the pre-treatment distance between the treated and the weighted average of potential controls for the outcome of interest (Almer, Boes and Nüesch 2013). In that way, one can compare the actual developments in the post-treatment period with the counterfactual projection. The difference between these two will represent the effects that are not explained by the included variables. In the case of this thesis, the technique can therefore be used to measure the effect of the new road.

Important assumptions in the synthetic control method are that the treatment has no effect before the implementation and that there is no interference between units. The former assumption is in the case of this thesis quite strong and will be discussed in section 6.3. In the following, the assumption will however be regarded as met. The latter should be unproblematic for most of the municipalities in the donor pool, but it may be that some of the neighbouring municipalities are affected by the road. To avoid this, the municipalities neighbouring the treated ones are excluded from the pool. These are Tvedestrand, Kristiansand, Froland and Birkenes.

The basis for the synthetic projection are the macro variables; production, unemployment, initiated buildings, population and median income, together with observations on the dependent variable, average house prices, at some points of time in the pre-treatment period. A more detailed explanation of the synthetic control method is included in appendix II.

5.2 Difference in differences

While the synthetic control method shows the effect of the road, it does not provide an estimate of how much people are willing to pay for shorter commuting time. House prices are higher in downtown city areas, than in the suburbs, thus prices are falling with distance to the centre. However, this could simply be a result of differences between houses at different locations. This makes a simple comparison difficult. To answer whether travelling time affects house prices it is therefore vital to control for every attribute of each house. For this kind of analysis, a hedonic pricing model, where each attribute of the house is given value, is a good tool. The attribute of interest in this thesis is commuting time to the central business district. To deal with the potential problem that commuting time simply correlates with different characteristics of each sub-area one must exploit an exogenous change in commuting time. This was exactly what happened when the new E18 was built.

The hedonic model, founded on the ideas of Lancaster (1966) and Rosen (1974), is based on the realization that some goods are heterogenous and differ in numerous characteristics (Palmquist 1991). Therefore, for these goods the consumer is buying a *bundle* of characteristics in every transaction. A hedonic model, for say a house, decomposes the price and gives all the different attributes of the house, such as size and build year, a value. The value of the attributes is however only observable indirectly, through the sales price. The attribute price or shadow price is therefore defined as the increase in sales price when marginally increasing one attribute. This makes the hedonic price function a function of all the different attributes:

$$P(Z) = P(Z_1, Z_2, \ldots, Z_n),$$

where n is the number of attributes, which in theory could be infinite. A more detailed explanation of Rosen's model can be found in appendix I.

The data used in this analysis is a panel data set of house transactions in the treated municipalities (Lillesand, Grimstad and Arendal) for the time period 2002-2012. Using the calculated travelling times from each transaction area to Kristiansand at the time of sale, sales prices are regressed on commuting time. This is done to measure how big the effect of the changed travelling time was. One could say that the ideal way to set up the analysis would be to compare treated with untreated areas. In the case under scrutiny this is however not that simple, since most of the commuting to Kristiansand are from the cities affected by the new E18 highway.

The variables included are both house specific, previously called micro variables, as well as variables related to the location of the house and time of sale. Some of the independent variables related to the house, living area and age, are continuous variables. Estate type and ownership status are coded as dummies. In the regression detached houses are used as the basis, since this is the most frequent estate type. Lastly, the geographical and time variables are also denoted as dummies.

Four different regression specifications are tested:

Model 1: $lnvalue_i = \alpha + \beta_1 lntime_{it} + \varepsilon$

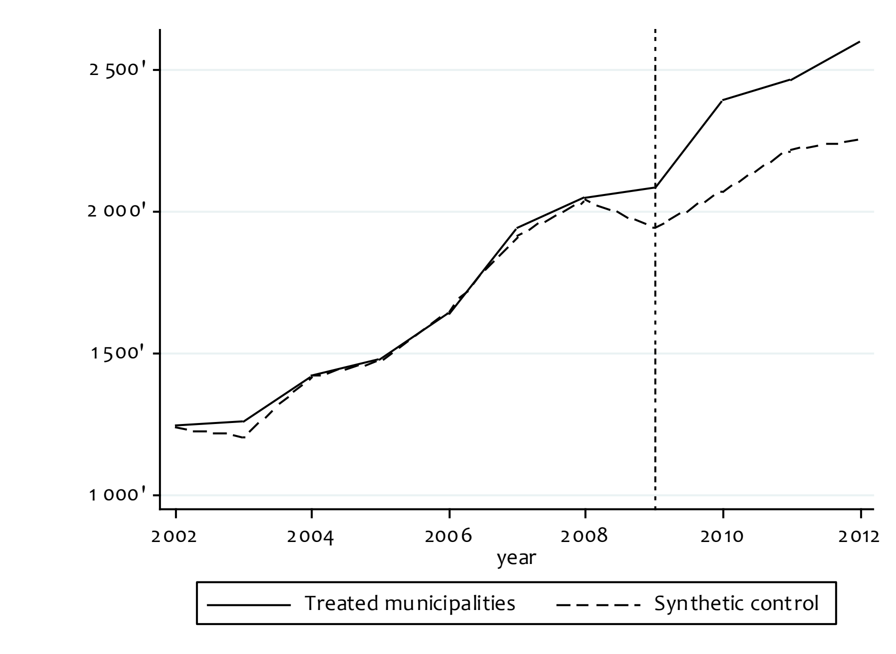
Model 2: $lnvalue_i = \alpha + \beta_1 lnlivarea_i + \beta_2 lnage_i + \beta_4 attached + \beta_5 apartment + \beta_6 cooperative + \varepsilon$

Model 3: $lnvalue_i = \alpha + \beta_1 lnlivarea_i + \beta_2 lnage_i + \beta_3 lntime + \beta_4 attached + \beta_5 apartment + \beta_6 cooperative + \partial_1 2002 + \ldots + \partial_{12} 2012 + \pi_1 Jan + \ldots + \pi_{12} Dec + \varepsilon$

Model 4: $lnvalue_i = \alpha + \beta_1 lnlivarea_i + \beta_2 lnage_i + \beta_3 lntime + \beta_4 attached + \beta_5 apartment + \beta_6 cooperative + \delta_1 Geo_1 + \ldots + \delta_n Geo_n + \partial_1 2002 + \ldots + \partial_{12} 2012 + \pi_1 Jan + \ldots + \pi_{12} Dec + \varepsilon$

6. Results

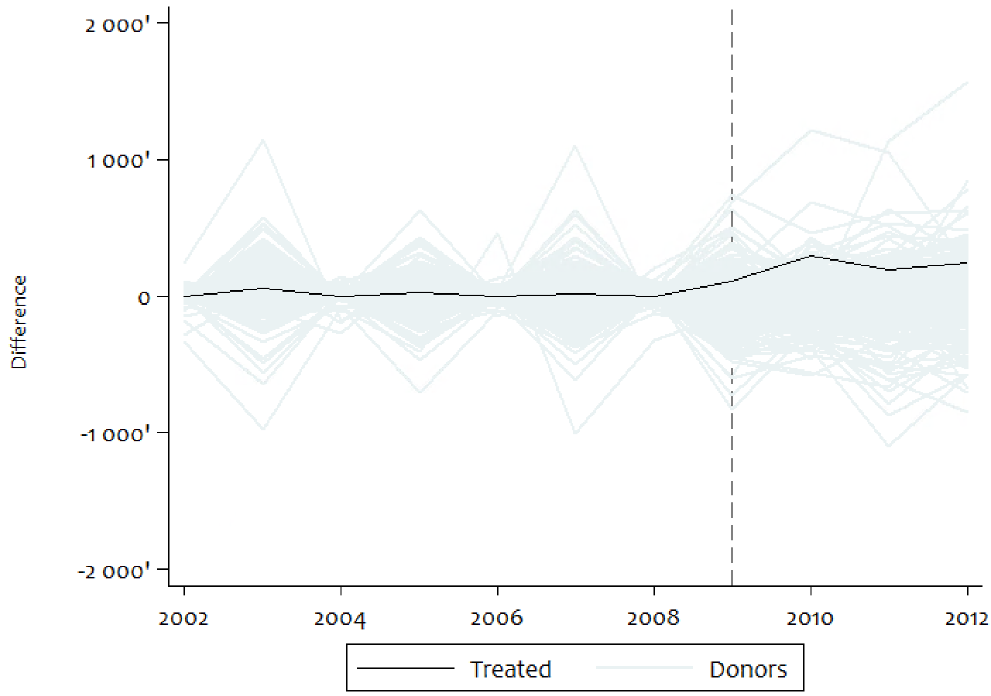
Fig 5: *The projected and actual price development for the treated municipalities*



6.1 The effect of the road on prices

Figure 5. displays the price developments in the treated areas as well as the synthetic prediction between 2002 and 2012. The synthetic prediction is a weighted average of the untreated municipalities. The municipalities in this case were Tjøme (25,5%), Risør (8,1%), Evje og Hornnes (23,1%), Flora (11,1%), Tromsø (17,0%) and Alta (15,2%). One can see that the synthetic control fits well throughout the pre-treatment period, suggesting that the synthetic projection provides a sensible approximation to the price development had the new E18 not been built. After the treatment, the synthetic control projects a much lower trajectory than what actually happened. The estimate of the effect of the new road is thus the difference between the two graphs, after the treatment. Where the synthetic graph implies a moderate development after the treatment, the actual growth was far bigger. The discrepancy between the two graphs is approximately NOK 250 000 in 2012, a substantial difference. This gap fits well with the reduced difference between the national average and the average of the treatment areas after 2006 shown in figure 3.

Fig. 6 – *Differences between projected and actual price developments for all 273 municipalities in the donor pool*



Having observed an estimated effect of the new road, a placebo test is done to evaluate the significance of the estimate. The placebo test implies running the synthetic control method on the other (untreated) municipalities in the control pool and comparing the effect found in the treated areas with the distribution of the placebo effects (Abadie, Diamond & Hainmueller 2010). If the placebo effects create similar gaps to the one estimated for the treated areas the analysis cannot be treated as significant evidence of an effect of the new E18 on house prices. The result of the placebo test is shown figure 6. The grey lines show the gaps between the predicted and actual price developments for each of the 272 municipalities in the donor pool. The black line shows the gap predicted for the Arendal, Grimstad and Lillesand. The line for the treated areas is in the upper segment of the distribution. Since there are many municipalities in the donor pool, it is only natural that some of them will give differences. To correct for this, those municipalities that have more than the double the preintervention mean squared prediction error (MSPE) as the one constructed for the treated areas, are excluded. The result of this is shown in figure 7.

Fig. 7 – *Differences between projected and actual price developments with 68 municipalities in the donor pool*

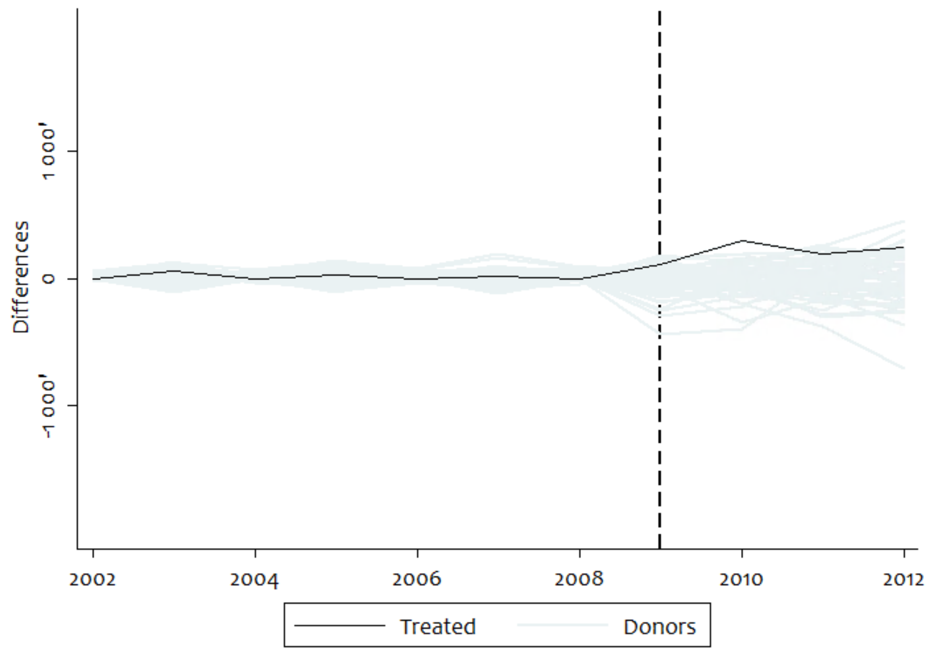
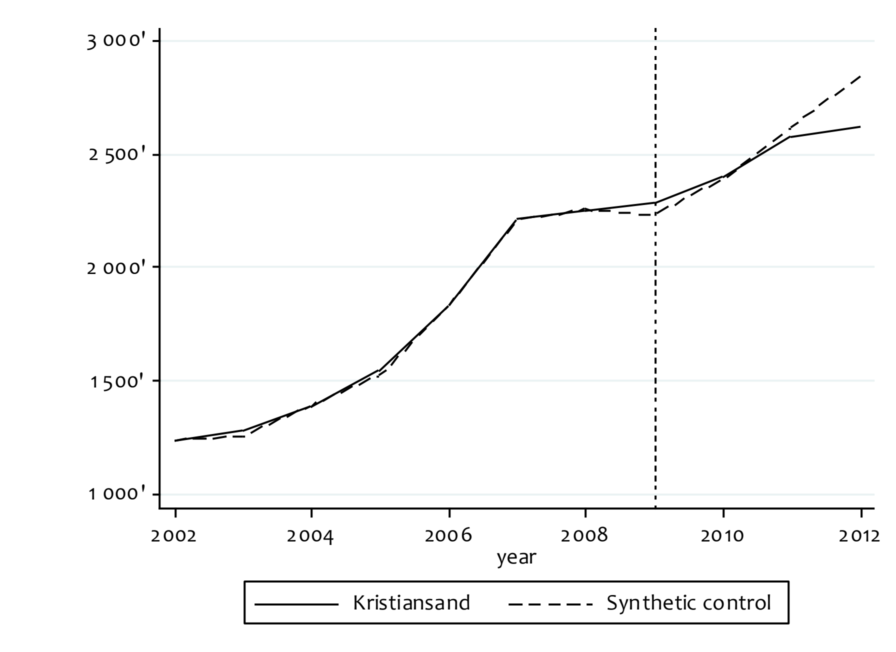


Figure 7 shows the differences between the synthetic projections and the actual development for the municipalities with less than the double MSPE of the treated ones. From this graph, one can clearly see that the effect found for Arendal, Grimstad and Lillesand through the synthetic design method cannot be by chance.

Finally, the synthetic control method is run on Kristiansand. This is also of interest to the analysis since one could assume that the demand for housing in Kristiansand should fall, since the travelling time to the treated areas is reduced. The result of the synthetic regression with Kristiansand as the treated unit are shown in figure 8.

Fig 8. - *The projected and actual price development for Kristiansand*



The synthetic Kristiansand was based on the following municipalities: Oslo (3,6%) Tjøme (6,3%), Risør (24,4%), Stavanger (40,3%), Bjerkreim (4,0%), Meløy (2,4%), Vestvågøy (4,2%), Alta (13,5%) and Sør-Varanger (1,4%). The figure show that the price development in Kristiansand did not differ much from the one projected by the synthetic control method, if anything it fell. This should support the findings on E18's effect on the house prices.

6.2 The willingness to pay for commuting time

Tab. 3 - *Regressions results*

	(1) lnprice	(2) lnprice	(3) lnprice	(4) lnprice
Ln(Comm. time)	-0.5546***	-0.5167***	-0.2573***	-0.1490**
	(0.0149)	(0.0121)	(0.0102)	(0.0497)
Ln(Living area)		0.6182***	0.6232***	0.6148***
		(0.0116)	(0.0088)	(0.0175)
Ln(Age)		-0.0464***	-0.0532***	-0.0661***
		(0.0033)	(0.0025)	(0.0066)
Attached house		-0.1197***	-0.1135***	-0.0949***
		(0.0109)	(0.0083)	(0.0141)
Apartment		0.1163***	0.0479***	-0.0029
		(0.0142)	(0.0108)	(0.0275)
Cooperative		-0.0562***	-0.0554***	-0.0171
		(0.0148)	(0.0112)	(0.0281)
Constant	16.4725***	13.5476***	12.1264***	11.8776***
	(0.0588)	(0.0770)	(0.0630)	(0.2047)
Year and month dummies	No	No	Yes	Yes
Geographical dummies	No	No	No	Yes
Observations	8908	8768	8768	8768
Adjusted R^2	0.13	0.46	0.69	0.73

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The results found in the previous section proved that the new road affected house prices in the treated areas. The next task will be to use the change in commuting time to measure people's willingness to pay for this change. The results of the regression in shown in table 3.

The first model, model (1), is simply a log-log regression of commuting time on prices. Since the coefficient is negative and statistically significant it implies that increased commuting time, not controlling for any other variables, reduces house prices.

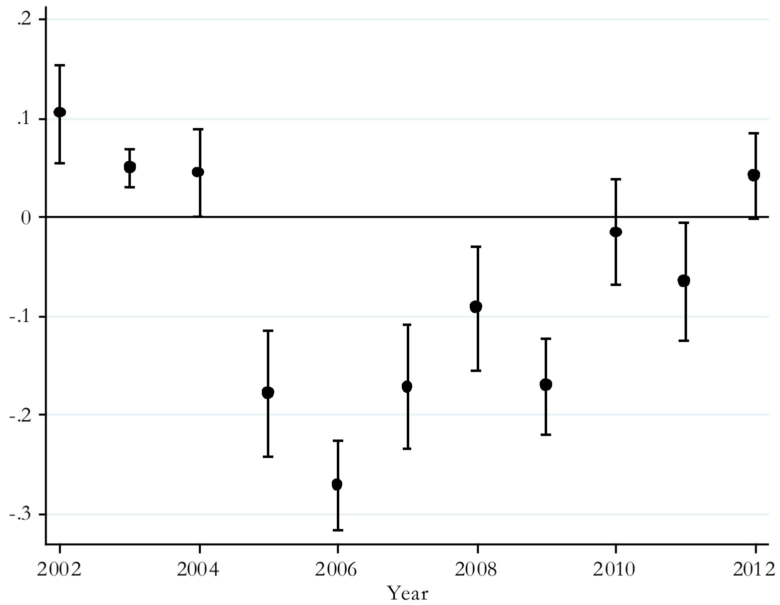
The next model, model (2), includes the micro variables describing the transaction object. Sale year and geographical location are still not included at this point. The figure shows that travelling time still has a negative coefficient. This is also the case for age, implying that houses lose value as they get older. The coefficient on living area is positive, as one should expect. Bigger houses give higher prices. Finally, when using detached houses as base, attached houses have negative and apartments positive coefficients. This implies that apartments are more and attached houses less expensive. One should however be careful of putting too much into this result, as location has not yet been controlled for. It is reasonable to assume that there are more apartments in the central areas, which could implicate that this effect is driven mainly by location.

Model (3), includes dummies on sale year and sale month as continuous variables. As the figure shows, adding time variables dramatically increase the adjusted R-squared of the regression. This implies that the time of sale is important for explaining the variations in price, as one should expect. The coefficients for the different sale years and months are not included in the table, simply because their coefficients and significance are all as one should expect. More importantly, the figure shows that none of the other variables change their signs when time variables are included.

The last model, model (4), includes the geographical areas as dummies. Their coefficients are not included in the table as they are not of interest for the result. Including them in the regression model is however important because there could be aspects about the geographical areas that are the reason for the positive coefficient on travelling time. By including both dummies for geographical areas as well as for sale year and month in the regression most of the underlying factors should be accounted for. The coefficient on travelling time in model (4) is thus the effect of the changed travelling time the new road facilitated.

6.3 What if the effect occurred at another time point of time?

Figure 9 – *The coefficient of travelling time on house prices for different years*



Based on the regression results in the previous section, one can conclude that the reduced travelling time the new E18 gave, contributed to increased house prices in the affected areas. Is it however given that the effect happened as the road opened or could it be that the effect appeared already when the decision was taken or when construction works began?

To check whether this is the case, new variables are constructed for the timing of the effect. Using the first of June as the impact point in every year, and running regressions for every year in the data set returns the values shown in figure 9 for the change in travelling time.

Figure 9 shows the coefficients of travelling time on house prices for each year in the dataset. Standard errors are shown by the bars surrounding the marks. The figure shows that there are statistically significant observations at several years. Two "peaks", in 2006 and 2009, can however be observed. As described in section 2.2, 2006 was the year the building started, while 2009 was the year the road opened. This implies that the road indeed gave an effect on the house prices, and that this effect was biggest when the construction works started.

7. Conclusion

This thesis investigated whether a reduction of commuting time between a CBD and a commuting area can increase house prices in the commuting area. Alonso's monocentric theory, describing house prices as falling with distance from the centre, has been found applicable to a Norwegian example, namely the new E18 between Grimstad and Kristiansand. By using the synthetic control method, it has been shown that the price increase in the treated areas, Arendal, Grimstad and Lillesand, cannot be explained by any typical house price driving macro-economic variable. Supported by placebo tests on the untreated municipalities, one can therefore conclude that the reduced commuting or travelling time given by the new E18 did increase the house prices. The difference-in-differences analysis has also measured the size of the effect, and found that the elasticity of prices with regards to commuting time was approximately 0,15. This implies that a 30 percent decrease in commuting time, as was the case for some of the areas, is associated with an almost 5 percent increase in house prices. Finally, the thesis has shown that the effect of the new road was largest when the construction of the road started. This suggests that agents are forward looking and take the price increase into account already before the road is finished. This corresponds to the findings of Yiu and Wong (2005) who studied the effect of a new harbour tunnel in Hong Kong.

Based on these findings, one should expect that similar results might be found on other ongoing infrastructure projects. For future research, it could therefore be of interest to check whether this actually is the case. Yiu and Wong (2005) concluded that part of the infrastructure projects could be financed by selling land in the areas that would be affected by the project. Such ideas could possibly also be applicable to a Norwegian setting, and it should thus be of interest to investigate whether future infrastructure projects in Norway could be financed through such arrangements.

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9. Appendices

I. A description of Rosen's model for hedonic pricing

The hedonic model used in this thesis is founded on the model developed by Sherwin Rosen in 1974. The presentation given here is based on a paper by Liv Osland (2001). Rosen based his model on Kelvin J. Lancaster's view (1966) on goods as consisting of several attributes each giving utility to the buyer. Rosen's static model connects the hedonic price function with the adjustments of the agents on both sides of the market. There are several important assumptions in this model, the most important are the following. There are many houses on the market, making the choices between the different attribute vectors continuous. There also many agents which individually are not able to influence neither the market nor prices. Finally, there are no searching, moving or transaction costs and all information is fully available for everyone.

The demand side

On the demand side of the market, each household maximize their utility with a given non-linear budget restriction:

$$U_j = (Z, X, \alpha_j), \text{ given } Y_j = X + P(Z) \tag{1}$$

where X is a vector of all goods other than housing. Y_j measures household j's income, measured in X. α_j is a vector of parameters characterising all the preferences. Every household buys one house, considered a consumption good. The utility function is concave, implying that households have decreasing utility of attributes. In optimum, the marginal substitution rate between Z_i and X will equal the partial derivative of the price function w.r.t. the different housing attributes:

$$\frac{\frac{\partial Uj}{\partial Zi}}{\frac{\partial Uj}{\partial X}} = \frac{\partial P}{\partial Zi} \tag{2}$$

The right side of this equation shows the marginal implicit or hedonic price for attribute i, and gives the inclination of the price function in different points of optimal amounts of Z_i.

The bid functions on the demand side in a hedonic model is important when solving for the market equilibrium. This function is defined as the marginal willingness to pay (WTP) for different estate types or compositions of attribute vectors, holding utility level and income constant. The bid function is deduced through the optimal values of the utility function in the following way:

$$U_j = (Z^*, X^*, \alpha_j) \tag{3}$$

Inserting the rewritten budget restriction gives:

$$U_j = (Z^*, Y_j - P(Z^*), \alpha_j) = U_j^* \tag{4}$$

If utility level and income are kept constant, the WTP for the household will equal the price they actually pay. Remember, there are many agents or house buyers, all maximizing their utility. The optimized utility function can thus be rewritten:

$$U_j = (Z^*, Y_j - \Theta_j), \alpha_j) = U_j^* \tag{5}$$

Rewriting this gives the bid function, with attributes, income, utility level and preferences as depending variables:

$$\Theta_j = \Theta\ (Z, Y_j, U_j, \alpha_j) \tag{6}$$

Note here that if utility level (U_j) and income (Y_j) are held constant, the WTP is only determined by different attributes and personal preferences. Taking the derivative of the utility function with regards to the attributes

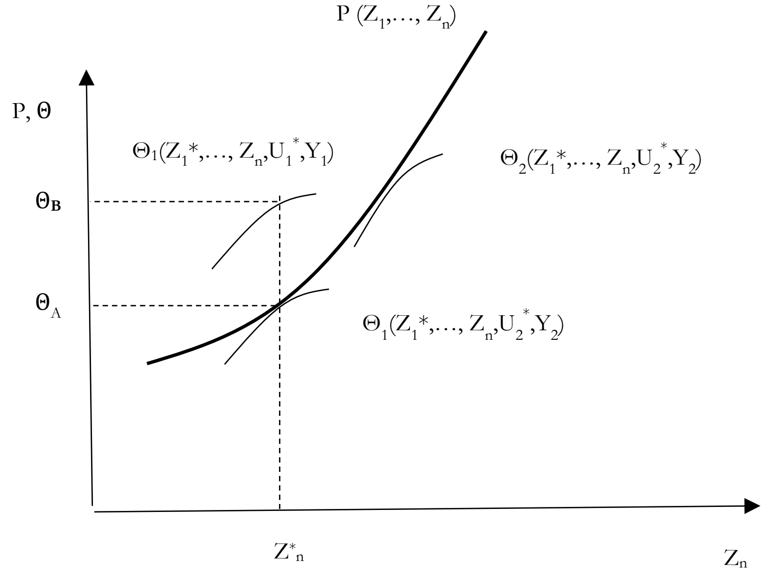
$$\frac{\partial Uj}{\partial Zi} = \frac{\partial Uj}{\partial Zi} + \frac{\partial Uj}{\partial X}\frac{\partial \Theta j}{\partial Zi} = 0$$

and rewriting this expression gives:

$$\frac{\partial \Theta j}{\partial Zi} = \frac{\frac{\partial Uj}{\partial Zi}}{\frac{\partial Uj}{\partial X}} > 0 \tag{7}$$

which is the WTP for a partial increase in one of the attributes. The result of this can be illustrated graphically:

Fig. A – *The demand side in Rosen's model*



Since the utility level in this diagram increase as one moves further down, $\partial\Theta_j/\partial U_j < 0$. Utility maximisation is thus achieved by finding the composition of attributes which gives the lowest possible indifference curve. For household 1, this is achieved on the indifference curve in Θ_A. Household 2, with Θ_2, have a higher need for attributes, but can pay more for housing as well. In the case at present, one can think of the deciding attribute being distance to the CBD. Thus household 2 can be regarded as a couple with high paid jobs and thus high alternative cost of commuting, while household 1 might be someone with lower paid jobs who cannot afford to live at a more central location.

The different households thus maximize their utility by finding the composition of attributes which gives the lowest possible bid function (highest possible utility), along the price function. The hedonic price function $P(Z_1,\ldots, Z_n)$ can accordingly be regarded as an envelope of all the different households' bid functions.

The market equilibrium condition is found by combining equation (2) and (7):

$$\frac{\partial \Theta j}{\partial Zi} = \frac{\frac{\partial Uj}{\partial Zi}}{\frac{\partial Uj}{\partial X}} = \frac{\partial P}{\partial Zi} \tag{8}$$

When utility is maximized, the marginal WTP therefore equals the implicit price of the attribute. Market equilibrium also demands that $\Theta\ (Z^*, Y_j, U^*_j, \alpha_j) = P(Z)$, since

Θ (Z, Y_j, U_j, α_j) shows the maximal amount of what the specific household are willing to pay and P(Z) the minimum of what they must pay. Because there many households, the hedonic price function P(Z) entails all households' bid functions.

The supply side

The supply side in Rosen's model does also consist of many small agents. An important feature of his model is that he regards the supply side exclusively as the production of new dwellings. This might be an unrealistic assumption, but is done to simplify the analysis. The producers can adjust the number of units and the number of attributes of their products. The aggregate profit function to the sellers together can be defined as:

$$\Pi = M \bullet P(Z) - C\ (M, Z, \beta) \tag{9}$$

Here M describes the number of houses being sold of a given composition of attributes Z to the price P(Z). All agents take the price as given. The cost function is a convex increasing function of the number of houses for sale. β is a vector of shift parameters representing things such as the price of capital or production technology.

The first order conditions are found by taking the derivative of the profit function of the sellers with regards to attributes (Z) and then to the number of houses (M):

$$0 = \frac{\partial \Pi}{\partial Zi} = M\frac{\partial P}{\partial Zi} - \frac{\partial C}{\partial Zi}$$

which rearranged gives:

$$\frac{\partial P}{\partial Zi} = \frac{\frac{\partial C}{\partial Zi}}{M} \tag{10}$$

And:

$$0 = \frac{\partial \Pi}{\partial M} = P(Z) - \frac{\partial C}{\partial M}$$

which rearranged gives:

$$P(Z) = \frac{\partial C}{\partial M} \tag{11}$$

Equation (10) shows that each producer should select the composition of attributes which gives an implicit price for an attribute equal to the marginal cost per house when marginally increasing the number of attributes. In words; the increase in price when increasing the number of attributes should equal the increase in marginal cost per house when increasing the number of attributes marginally. Equation (11) is the standard market FOC which says that the price of a good, in this case a house, should equal the marginal cost of adding a new house to the market.

Mirroring the bid function on the demand side, is an *offer function* on the supply side. This function, $\Phi = \Phi\ (Z, \pi, \beta)$, defines the smallest amount or price the producers are willing to accept on various attribute compositions at constant profit given optimal number of houses being produced. As on the demand side, the optimized profit function is used as the starting point:

$$\pi^* = M^* \bullet P(Z^*) - C\ (M^*, Z^*, \beta) \tag{12}$$

Keeping the profit constant and inserting the offer function for the price gives:

$$\pi^* = M^* \bullet \Phi\ (Z^*, \pi^*, \beta) - C\ (M^*, Z^*, \beta) \tag{13}$$

The first order conditions are found by taking the derivative of the profit function with regards to M and Z_i:

$$0 = \frac{\partial \pi *}{\partial M} = \Phi\ (Z^*, \pi^*, \beta) - \frac{\partial C}{\partial M}$$

which rearranged gives:

$$\Phi\ (Z^*, \pi^*, \beta) = \frac{\partial C}{\partial M} \tag{14}$$

And:

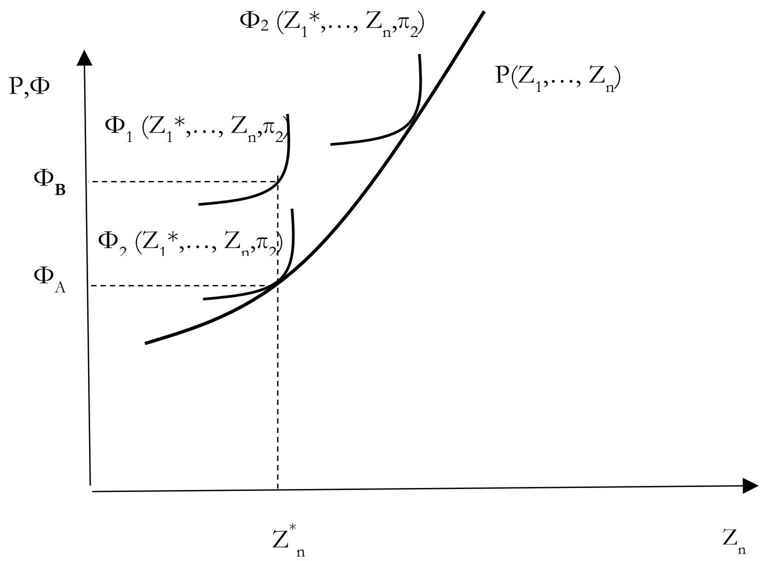
$$0 = \frac{\partial \pi *}{\partial Zi} = M * \frac{\partial \Phi}{\partial Zi} - \frac{\partial C}{\partial Zi}$$

which rearranged gives:

$$\frac{\partial \Phi}{\partial Zi} = \frac{\frac{\partial C}{\partial Zi}}{M} \tag{15}$$

Equation (14), paralleling equation (11) on the demand side, shows that in equilibrium, the amount the bidder is willing to accept for a unit equals the marginal cost of producing one more unit. Equation (15) corresponds to (10) on the demand side, and shows that the marginal gain of increased number of attributes should equal marginal costs of the same increase per unit.

Fig. B – *The supply side in Rosen's model*



This graph shows different iso-profit curves. The curves are convex and the companies' profit increase when moving upwards in the diagram implying $\partial\Phi/\partial\pi > 0$. Producers with different β-values will adjust on different places along the price function. One example is producers specializing in building flat in locations near the centre, where site prices are high, will adjust further up (to the right) on the price function.

Market equilibrium is secured by combining the FOC's (10) and (15):

$$\frac{\partial P}{\partial Zi} = \frac{\frac{\partial C}{\partial Zi}}{M} = \frac{\partial \Phi}{\partial Zi} \tag{16}$$

In addition, the offered price has to equal the exogenously given price in equilibrium, Φ (Z*, π*, β) = P(Z*).

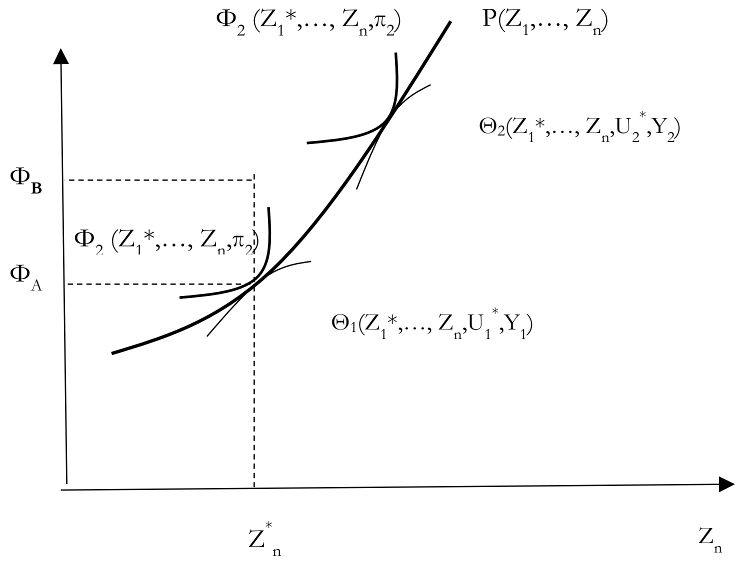
Market equilibrium

Market equilibrium is achieved when the bid function of the households and the offer functions of the producers are tangent. This is where

$$\frac{\partial \Theta}{\partial Zi} = \frac{\partial P}{\partial Zi} = \frac{\frac{\partial C}{\partial Zi}}{M} = \frac{\partial \Phi}{\partial Zi}$$

As can be seen in the next figure, the hedonic price function is a mix of the bid function of the households and the offer functions of the producers:

Fig. C – *Market equilibrium in Rosen's model*



II. A description of the synthetic control method

The following model presents an explanation of the synthetic control method in detail. The presentation is based on Abadie, Diamond and Hainmueller's paper on the effect of California's tobacco control program (2010). Suppose the dataset consists of J+1 units, in this case municipalities. Since this thesis concentrates on Grimstad, Arendal and Lillesand, the values for these municipalities are first aggregated and then treated as one municipality. This gives one unit, unit 1, which receives a treatment after some initial intervention period, as well as J untreated municipalities, which can be described as the donor pool. P_{it}^N is the outcome that would be observed for region i at time t in the absence of the intervention for units i = 1,...,J+1, and time periods t = 1,…,T. T_0 is the number of pre-intervention periods, with $1 \leq T_0 \leq T$. Let P_{it}^I be the outcome for unit i at time t if the unit receives the treatment at some time between T_0+1 and T.

A dummy variable, D_{it}, takes the value 1 if the unit i is exposed to the intervention at time t, and zero otherwise. This implies that $D_{it} = 1$ only if i = 1 and $t > T_0$. Let α_{it} be the effect of the intervention for unit i at time t, implying that $\alpha_{it} = P_{it}^I - P_{it}^N$. The observed outcome for unit i at time t is thus

$$P_{it} = P_{it}^N + \alpha_{it}D_{it} \tag{17}$$

The aim is to estimate α_{1t}. Since $\alpha_{1t} = P_{1t}^{I} – P_{1t}^{N}$ for $t > T_0$ and P_{1t}^{I} is observed one simply have to estimate P_{1t}^{N}. Suppose P_{1t}^{N} is given by an autoregressive model with time-varying coefficients:

$$P_{it+1}^{N} = \delta_t P_{it}^{N} + \beta_{t+1} Z_{it+1} + u_{it+1}$$
$$Z_{it+1} = \gamma_t P_{it}^{N} + \prod_t Z_{it} + v_{it+1}$$

where Z_{it+1} is a (r×1)-vector of observed covariates at time t, β_{t+1} and $\prod_t$ are (1×r)-vectors of unknown parameters at period t+1 and t respectively, and u_{it+1} and v_{it+1} have mean zero conditional on $\Omega t = \{P_{js}, Z_{js}\}_{1\leq j\leq N,\ s\leq t}$.

Let $W = (w_2,\ldots, w_{I+1})'$ be a (I×1) vector of weights allocated to the control cities, with $w_{i\geq 0}$ for i= 2, …, I+1 and $\sum_{i=2}^{I+1} w_t = 1$. The goal is to find the optimal weight matrix W = $(w_2^{*},\ldots, w_{I+1}^{*})'$ to construct the synthetic control for P_{1t}^{N} such that

$$\hat{}P_{it}^{N} = \sum_{i=2}^{I+1}(w_i \times P_{itN}) = \sum_{i=2}^{I+1}(w_i \times P_{it}) \tag{18}$$

The next step is to estimate W*. Let $\sim P_i^{K} = \Sigma_{s=1}^{T0-1} k_s P_{is}$ be a linear combination of the pre-intervention housing price, where $K = \{k_1, \ldots, k_{T0-1}\}$ is a vector of weights allocated to the sample periods before the treatment. This gives M possible values of K, defined by $K_1,\ldots, K_M$. Denote $X_1 = (Z'_1, \sim P_1^{K1},\ldots, -P_i^{KM})$ a vector of pre-treatment characteristics for the treated municipality, and similarly X_0 for the group of control municipalities. The vector W* is estimated by minimizing the distance between X_1 and X_0W before the treatment:

$$|X_1 – X_0E|_V = \sqrt{(X1 - X0W)'\ V\ (X1 - X0W)}$$

Here V is a (k×k)-symmetric matrix (k = r + M). The value of V is chosen to minimize the mean squared prediction error of P_{1t}^{N}, in the pre-treatment period. Given W*, following from (17) and (18), the estimated impact of the treatment is

$$\hat{}\alpha_{1t} = P_{1t} – \hat{}P_{1t}^{N} = P_{1t} - \Sigma_{i=2}^{I+1} w_i^{*} P_{it},\ \text{for } t > T_0$$

III. The geographical areas and their travel times using the old and new road

Post number or sub-council area		Post area/Grunnkrets	Old time	New time	Saved time	Saved time as percent
	4810	Eydehavn	78	63	15	0,19
	4812	Kongshavn	77	62	15	0,19
	4815	Saltrød	73	58	15	0,21
	4816	Kolbjørnsvik	66	51	15	0,23
	4817	His	61	46	15	0,25
	4818	Færvik	72	57	15	0,21
	4821	Rykene	56	41	15	0,27
	4823	Nedenes	57	42	15	0,26
	4824	Bjorbekk	61	46	15	0,25
	4825	Arendal	64	49	15	0,23
Arendal	4836	Arendal	65	50	15	0,23
	4838	Arendal	66	51	15	0,23
	4839	Arendal	65	50	15	0,23
	4841	Arendal	69	54	15	0,22
	4842	Arendal	68	53	15	0,22
	4843	Arendal	68	53	15	0,22
	4844	Arendal	65	50	15	0,23
	4846	Arendal	65	50	15	0,23
	4847	Arendal	63	48	15	0,24
	4848	Arendal	61	46	15	0,25
	4849	Arendal	65	50	15	0,23
	4920	Staubø	84	69	15	0,18
	4870	Fevik	58	39	19	0,33
	4876	Grimstad	51	34	17	0,33
	4877	Grimstad	50	33	17	0,34
	4878	Grimstad	55	35	20	0,36
Grimstad	4879	Grimstad	48	34	14	0,29
	4885	Grimstad	53	36	17	0,32
	4886	Grimstad	51	33	18	0,35
	4887	Grimstad	47	34	13	0,28
	4888	Homborsund	44	36	8	0,18
	204	Sangereid	29	25	4	0,14
	205	Luntevik/Bergshaven	30	26	4	0,13
	206	Grøgårdsmyr	30	26	4	0,13
	207	Furulia/Borkedalen	28	24	4	0,14
	208	Rosenberg/Sandsnes	29	25	4	0,14
	209	Solgård/Bellevue	29	25	4	0,14
	210	Vesterskauen	29	25	4	0,14
	211	Lillesand 1	30	26	4	0,13
	212	Lillesand 2	30	26	4	0,13
	213	Lillesand 3	30	26	4	0,13
Lillesand	214	Lillesand 4	30	26	4	0,13
	215	Lillesand 5	30	26	4	0,13
	216	Øvreberg/Fagertun	30	26	4	0,13
	217	Lofthus/Møglestu	30	24	6	0,20
	218	Solheim/Ørving/Bergstø	32	27	5	0,16
	219	Stykkene/Tingsaker	31	25	6	0,19
	221	Heldal/Gitmark	33	26	7	0,21
	222	Tingsaker/Ålebekk/Gaupemyr	33	26	7	0,21
	225	Tunveien	29	25	4	0,14
	226	Hestheia	30	26	4	0,13
	227	Engekjerr	29	25	4	0,14