Effects of Maternity Ward Closures on Maternal Health in Finland

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ABSTRACT

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The number of maternity wards in Finland has halved between 1987-2017, which has raised the question of whether the closures have had effects on the quality of care, which can be measured through changes in health. The main objective was to study how the closures have affected maternal health in total and in different areas.

The data used was micro-level data from the Medical Birth Register, with variables on maternal and child health from all births in Finland between 1987-2020. This thesis used a sample of the register from 2004-2017. The empirical analysis was conducted with a difference-in-difference method and was a replicate of Avdic et al. (2018).

The study showed a significant 1.8 percentage point increase in the probability of maternal complications in closure and inflow areas combined. Inflow areas were areas with a remaining ward and experiencing an inflow of mothers from closure areas. The study found significant negative health effects of closures in inflow areas. Causal interpretation of the results was challenged due to concerns of possible unparallel pre-trends between treatment and control groups.

Whereas it is easy to quantify the monetary savings induced by a ward closure, the health and quality effects often receive less attention. The results of this study indicate they should be studied further. If there is a negative connection between closures and health, it should be discussed whether the savings are enough to compensate for the worsened health.

TIIVISTELMÄ

ITÄ-SUOMEN YLIOPISTO
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Synnytyslaitosten määrä Suomessa on laskenut 53:sta 24:ään vuosien 1987-2018 välillä, mikä on nostanut esiin kysymyksen sulkemisten vaikutuksista terveydenhuollon laatuun. Tässä pro gradussa pyrittiin selvittämään, miten sulkemiset ovat vaikuttaneet synnyttävien äitien terveyteen. Lisäksi tutkittiin, miten vaikutukset eroavat eri alueilla.

Tutkimuksessa käytettiin anonymisoitua henkilötasoista dataa Syntyneiden lasten rekisteristä. Rekisteriin on kirjattu kaikki Suomessa tapahtuneet synnytykset ja niihin liittyvää tietoa synnyttäjistä ja syntyneistä lapsista vuodesta 1987 nykypäivään. Tässä pro gradussa käytettiin otosta rekisteristä vuosilta 2004-2017. Empiirinen analyysi tehtiin difference-in-difference-metodilla, replikoiden Avdicia ym. (2018).

Empiirisessä analyysissä havaittiin sulkemisten nostaneen äitien komplikaatioiden todennäköisyyttä merkitsevästi 1.8 prosenttiyksilöllä yhteensä sulku- ja virtausalueilla (inflow area). Sulkualueilla asuvien synnyttäjien siirtyessä synnyttämään jäljellä oleviin synnytyslaitoksiin siirtyy virtausalueita. Näillä alueilla sulkemiset nostivat komplikaatioiden todennäköisyyttä merkitsevästi. Yhteyttä ei voida tulkita kausaaliseksi mahdollisten eriävien ennakkotrendien vuoksi.

Sulkemisista aiheutuvia säästöjä on helppo mitata, mutta laatuvaikutukset ovat jääneet alan tutkimuskirjallisuudessa vähemmälle huomiolle. Tämän pro gradun tulokset indikoivat, että tutkimusta tulisi jatkaa. Jos sulkemisten ja terveystulemien välillä on negatiivinen yhteys, tulisi pohtia kuinka suurilla säästöillä voidaan kompensoida menetettyä terveyttä.

Contents

1 Introduction

The number of closures of specialized health care units have increased in Finland, as the government has struggled to cope with the increasing costs of health care and an expanding public sector. With a declining fertility rate, the closure policies have especially affected maternity wards. Between 1987-2018, the amount of maternity wards in Finland has decreased from 53 to 24 wards. With closures becoming more commonplace, it is important to assess their effects on the quality of care. A possible measure of quality is the health of the patients.

Wards are by law required to have a sufficient amount of births per year to operate. As less children are being born, maternity wards are unable to reach the required 1 000 yearly births. Simultaneously, maternity wards require multiple different specialists at all times, which makes them costly from the viewpoint of the health care providers.

Empirical research has concluded scale effects exist in health care. If a certain operation is performed multiple times in a given time frame opposed to being performed fewer times, it is likely the hospital with more operations will have a lower mortality rate associated with given operation (see e.g. Gaynor et al. 2005; Shahian et al. 2001; Birkmeyer et al. 2002; Halm et al. 2002). This thesis intends to examine the effects of the Finnish maternity ward closures on the health of mothers. When a maternity ward closes, the number of patients in near-by remaining wards increases as a result. If there is a positive, causal relationship between volume of births and health outcomes driven by increased learning-by-doing, the increasing number of births should have a positive effect on maternal health. If the same causal relationship is negative due to for example congestion in the remaining wards, the health effects should be negative. The net effect is determined by changes in health of two different groups of mothers: mothers living in closure areas and mothers living in inflow areas with remaining wards.

The empirical model is a replicate of a study from Sweden by Avdic et al. (2018). In this thesis, the analysis is carried out with a difference-in-difference model. In the model, there are essentially three different areas that need to be observed. Firstly, there is the treatment area, which is the catchment area of the maternity ward under closure. Secondly, there are inflow areas, which is the catchment area of the maternity ward that will accommodate the mothers coming from the closure or treatment area. Thirdly, there is a control area, unaffected by these changes. The study setting is based on an identifying assumption that health trends are similar in control and treatment areas prior to the treatment. The treatment inflicts a change on the health outcome variables, which is studied as the treatment effect.

This thesis study finds statistically significant effects of closures on maternal health. The net effect of the closures increases the probability of maternal complications by 1.8 percentage points. This corresponds to roughly a 10 percent increase in the amount of complications, when it is compared to the mean complications rate in control regions, where the average rate is roughly 20 percent. Similar results are attained through robustness checks and with other health outcome variables. The results are both aligned with the theoretical framework and the previous empirical literature.

This thesis begins with a brief introduction of the theoretical background of the research question and a short literature review on empirical literature on the health effects of maternity ward closures. It is followed by a detailed description of the institutional setting, which is needed to understand the empirical model used and the interpret the results. The study design is presented through the data and the model along with its most important components. Descriptive statistics illustrate the characteristics of the data, whereas studying common trends validates the empirical model. Certain limitations of the study are also addressed and accounted for. The thesis includes a description of the results from the model and a short discussion and analysis of the mechanisms driving the results. Finally, the conclusion reflects on the theoretical background and previous literature in light of my results.

2 Background

2.1 Theoretical background

The mergers and closures of maternity wards have been justified by minimizing costs and improving patient safety. Patient safety often goes hand in hand with quality of care. Although quality is undoubtedly hard to quantify, there are measures that have been taken to ensure a sufficient level of it. To have an operating maternity ward in a hospital, there must be a sufficient amount of births per year to maintain a sufficient level of learning-by-doing. The high number of births can be thought to create routine and keep the know-how of the staff at a sufficient level. This type of phenomenon has been described widely in health care. The so-called volume-outcome effects, scale economies and learning-by-doing have been associated with the fact that there seems to be a positive correlation between the number of times a health care unit performs a given operation and the rate of positive health outcomes of the patients. The positive correlation has been explained by "practice makes perfect" and "selective referral" hypotheses. The former includes effects of both learning-by-doing and scale economies, whereas the latter explains better quality with higher demand and a larger volume of patients. (Gaynor et al. 2005; Luft et al. 1987)

This has been a topic of discussion mainly due to its policy implications. Centralization policies attempting to improve quality may be feasible, if indeed a greater volume causes better health outcomes. If higher quality attracts more patients and the causality runs the other way, centralisation policies may not be relevant. Empirical research has indicated volume to affect outcome, which gives rise to quality being explained by either learning-by-doing or the pure volume-outcome effects. (Hata et al. 2016; Gaynor et al. 2005, 2004; Gowrisankaran et al. 2004)

Although the volume-outcome effects resulting from hospital closures have been observed in empirical studies, it should be noted they may vary significantly depending on the type of operation in question. Hata et al. (2016) study surgical outcomes of the Whipple procedure, a surgical operation on the pancreas and find volume to have positive effects. Avdic et al. (2019) study the causal effects of volume on survival rates from advanced cancer surgery. They find the volume has substantial positive effects on survival and also attribute learning-by-doing as one of the more prominent explanations for the finding. However, similar results are not observable in a study of the effect of surgery volume on hip-fracture patients. Hamilton and Ho (1998) found the significance of surgery volume on inpatient mortality and length of stay disappeared once hospital fixed effects were included in the regression. Similarly, Avdic et al. (2016) find that centralization of emergency care services temporarily worsened the survival rates from acute myocardial infarctions due to longer travel times to remaining hospitals. Thus the magnitude of volume-outcome effects may be rather procedure-specific. When considering whether centralization of procedures will improve health outcomes, the decisions should be based on outcomes observed in the specific procedures. Another factor to consider is whether the quality outcomes are more associated with hospital-wide levels of volume or the procedure volume per physician. A literature review by Chowdhury et al. (2007) on the relationship between surgical volumes and patient outcomes suggested the individual surgeon volume was a better predictor for the health outcomes rather than the cumulative volumes of the whole hospitals.

Whether the volume effects come through learning-by-doing or a static scale economy has policy implications. In the static case, increasing the volumes at any unit would improve the quality. Therefore it would not matter where the centralised functions would be located. In the learning-by-doing explanation, choosing the remaining hospital more carefully matters. The knowledge in the closure ward is thought to be in a sense lost. In the case of maternity ward closures, this would mean the expertise or knowledge in the closed wards could no longer be utilized. This may be true, but in the Finnish case the choices of remaining wards are determined by mostly the number of births, which already suggests the wards that have theoretically accumulated the most learning-by-doing over time will also survive the closures. (Gaynor et al. 2005) To answer more thoroughly the question of what actually happens to the expertise of the specialists working in the closure wards, mobility of doctors and other personnel would have to be studied closer. It is outside the scope of this study.

The determinants of quality have also been discussed. Gaynor and Town (2011, 560) present the quality of health care rather as a choice than an exogenous determinant. In different models, the hospitals choose the quality they provide, which further determines the amount of care provided as well as either profits or the prices. The level of quality chosen by the hospital is usually determined by aiming for a certain level of an outcome determined by the quality of services. In many cases, this is patient mortality, but quality could also be measured in other terms, such as waiting times, length of treatment or re-admission rates. In the case of maternity wards, a measure could also easily be also determined. In this thesis, quality is measured through acute maternal health outcomes in childbirth.

Gaynor and Town (2011, 560) also suggest the level of quality chosen is hospital-wide. The case of heart attack patients clarifies the situation: a patient suffering from a heart attack hardly chooses the hospital they are admitted to. Yet heart attack mortality has been studied to be lower in markets with low concentration and high competition. This is because although some services do not compete for patients, others do. It creates a uniform level of effort to acquire the quality wanted. (Kessler & McClellan 2000) This will affect even the specialized care treating acute illnesses. The same logic could be applied for maternal care, which can reliably be described as urgent care.

In addition to the quality being an exogenous choice, it is likely to also have to do with the level of competition. Although traditionally Finnish hospitals are not seen to compete with other hospitals or health care providers, studies from the United Kingdom, which uses a similar Beveridge system as Finland, indicate competition may affect quality. In the UK, competition has been seen to attribute to better quality in health care through various channels (see e.g. Cooper et al. 2011; Bloom et al. 2015). Mergers and closures tend to reduce competition in the market. A study by Gaynor et al. (2012) from the UK gives further insight into how the effect of mergers or closures on quality can be studied. In the paper, the effects of public hospital closures on financial performance, waiting times and clinical quality are studied. Measures of clinical quality included both waiting times and survival rates. The mergers reduced the capacity of the hospitals and decreased the admissions, but did not improve quality.

The cost issue has been a topic of research in several countries, although most research has studied hospital mergers in general, instead of mergers of specialized wards or operations. The cost topic will not be further looked into within this thesis, as the focus of the research question is in the effects of health outcomes. These outcomes are yet to be studied in the Finnish context. It is, however, essential to acknowledge reducing costs is a primary driver in the mergers and closures of maternity wards, afflicting the changes in health studied in this thesis.

2.2 Previous literature

A literature review was conducted in order to form a cohesive image of all the previous academic research literature published on the subejct. In all, the results were few, especially when restricting the articles to ones that display an attempt to estimate causal inference between centralization of operations and health.

The literature review search strategy is shown in Appendix A. After searching for articles, they were divided into different categories. Articles concerning health in general are about the health outcomes caused by mergers and closures in other areas of care than obstetrics. These articles provide useful insights into designing the empirical method and thinking about the possible issues in the design. Quite a few of the results were connected to the topic of access, use of care and distance. Although some issues related to distance are addressed in this thesis, a thorough and complete empirical analysis of it is outside its scope. Access to care is a large concern often associated with closures of maternity wards or hospitals in rural regions (see e.g. Buchmueller et al. 2006; Pilkington et al. 2008; Hung et al. 2017). Many of the closures of the Finnish maternity wards also have occurred in rural regions.

Articles on the determinants of mergers and closures help to pinpoint some recurring attributes and features of the closures, which should be taken into account in the empirical analysis. Understanding the determinants of closures and mergers also helps to understand possible underlying trends in the data. Lastly, articles about costs and efficiency help understanding differences and nuances between questions of efficiency and quality. As costs are often the main driver of unit closures, it is also important to understand how they affect operations in hospitals.

The literature search yielded a total of 25 results under the maternal and child health topic, out of which 23 are articles. The rest are a book chapter, a short survey and a working paper. In all, literature on public health mergers and their effects on health can be described as small, with the literature focusing specifically on maternity ward closures being even smaller. The oldest article was from 1986 and the newest 2018. In total, four of the articles were studies from Nordic countries (Sweden, Norway and Denmark), two from elsewhere in Europe, nine from North America and four from elsewhere in the world. After critical review, a total of 15 articles were accepted into the review. The detailed review of the chosen articles can be found in Appendix B.

In 14 of the 15 articles, the intervention that offset the changes in health were different types of closures of units or wards. One article did not have an intervention such as a closure, but attempted to nevertheless observe differences in health between similar individuals in areas with different levels or types of access to obstetric care. None of the articles reviewed used the Finnish Birth Register. In general, the Birth Register has not been used widely in health economics related research.

It is worth noting that very few of the studies attempted to draw conclusions about causality and were able to comment only on correlations. Furthermore, many of these correlations were weak. A common trait in many of the articles was the lack of addressing possible sources of bias and including necessary controls. Some of the articles also had data, which was not patient-level. These shortcomings are rather serious from the viewpoint of causality. In this thesis, the aim is to make observations about the causal link between closures and health, which can be done through reliable statistical method, as well as controlling for underlying characteristics and assuring the parallel trends assumption holds. The two most useful empirical works for the purposes of this thesis were by Avdic et al. (2018) and Grytten et al. (2014).

Avdic et al. (2018) study the causal effects of maternity ward closures in Sweden on maternal and infant health. The closures studied have taken place between 1990 and 2004, when a wave of maternity ward mergers shut down smaller wards and merged them with larger ones. The data used is from the National Patient Register and the Medical Birth Registry, which account for the pre- and post-birth health variables, as well as the Intergenerational Register linking children to their parents and LOUISE register with socioeconomic and demographic data. The empirical method used is difference-in-difference with multiple treatment groups and differing times of treatments. The outcome variables are maternal trauma, different degree lacerations and a residual of other trauma. The study takes advantage of the Swedish policy automatically assigning mothers to their closest maternity ward for childbirth, which allows for very accurately determining different control and treatment groups. These groups are either unexposed or exposed to the closure to different extents. In addition to the control group, the treatment groups are defined by women living in closure areas and women living in areas with remaining wards and an inflow of patients from the closure areas. The study of Avdic et al. is used as a reference for the empirical method used in this thesis, as the maternity care system in Sweden is very similar to Finland and the model translates well, with certain adjustments, into the Finnish institutional setting.

Avdic et al. (2018) find the net effect of the closures is negative for mothers. The effects on newborns are small and insignificant. The negative effects for maternal health are driven by an increased trauma rate for mothers in inflow areas. The effects on the mothers living in closure areas are not significant. They hypothesize the possible positive effects of moving to larger wards with a higher level of learning-by-doing may be offset by any negative effects arising from increased distance or the adverse effects of an increasing caseload in the ward. They further study the mechanisms behind the health effects and find closures leading to a larger number of births per midwife, which may be an indication of increased congestion in remaining wards. They find no significant effects of the distance, although note the distances travelled even after closures are on average rather low (32 kilometres). Finally, they study the efficiency of allocation of care by looking at the treatment decisions concerning caesarean sections. They find cases they classify as high-risk are less likely to receive sections after the closures.

Grytten et al. (2014) use a similar setting of maternity ward closures in Norway, but instead studies the effect of regionalization and local hospital closures on infant health between 1980 and 2005. The health outcomes are neonatal and infant mortality. The data used is from the Medical Birth Registry of Norway. To account for the differences in case mix between local and central hospitals, they use propensity score weighing. This is followed by studying the analysis of mortality effects of closures through a difference-in-difference study. The study finds no significant effects of hospital type on neonatal or infant mortality.

3 Maternity ward closures

3.1 Institutional context

The maternity care system in Finland is quite extensive and reaches most of the expecting mothers. Roughly 99.8 percent of all pregnant mothers receive antenatal care from a prenatal clinic. Care is in general seen as reliable and accessible, and indicators, such as maternal mortality, also support this. In the recent years, there have only been approximately three early maternal deaths in Finland. (Palomäki 2019) In Finland, births mostly take place in the hospital. In 2017, there were a total of 50 151 births recorded and out of these births, 243 occurred outside the hospitals as either before arrival to the hospital, at home unplanned or at home planned. (National Institute for Health and Welfare 2019d)

In addition to the births mostly taking place in hospitals, mothers often also give birth in the closest maternity ward near them. Finland has a freedom of choice principle in health care, which was implemented in two parts in 2011 and 2014. In 2011, a new Health Care Act (L 1326/2010 2010) took a more patient-centered approach to care, allowing for the patient to choose the health care unit and the personnel in non-acute health care within their municipality of residence or larger specific catchment areas of expertise. In 2014, the choice was extended to cover the whole country. Before these reforms, the patients could not choose between providers. In spite of the freedom to choose where to give birth, most of the mothers give birth at their nearest hospital. Thus the effect of the freedom of choice principle on choice of the maternity ward is rather small.

Prenatal care is based on national treatment recommendations and laws. The aim is to have nationally equal care available for all pregnant mothers. Prenatal care is offered in prenatal clinics, which are operated by municipalities. (L 1326/2010 2010) During pregnancy, mothers are encouraged to visit a prenatal clinic, where they are offered the services of a nurse or midwife, and a doctor specialized in prenatal care. The first visits are scheduled around the 8–10 pregnancy weeks and these visits are especially important for prenatal screening, which helps to detect risks in the pregnancy. Nullipara (first-timers) are offered at least nine visits and primipara (given birth once) and multipara (given birth numerous times) at least eight visits. These visits include an extensive health check for the whole family as well as two doctor visits. First-timers are also offered a home visit from a nurse or midwife around the 30th week of pregnancy. A nurse visits all mothers within a week after being discharged from the hospital after giving birth and in addition there is a follow-up within 5–12 weeks of childbirth. If at any stage of the pregnancy there are abnormalities in the course of the pregnancy or the health of the mother or the fetus, the nurse or doctor can send the mother for further examinations. These examinations take place at a maternity clinic, which are generally located in larger hospitals with a maternity ward. (Palomäki 2019) Maternity care in Finland could best be described as a mutual effort of multiple health care professionals and providers.

According to the Constitution of Finland, everyone must be ensured adequate health and medical services to promote the health of the population (L 11.6.1999/731 1999). The health care services are funded and controlled by the state and operatively managed by municipalities. Municipalities are responsible for organizing care for its inhabitants and it can be done also in cooperation with other municipalities in local government co-management areas. Primary care must be organized in areas with over 20 000 inhabitants. In addition, the municipality must be a part of a hospital district to organize specialized medical care. (Ministry of Social Affairs and Health 2013, 10)

Whereas prenatal care is a part of primary care and is offered in hospital units of all size, perinatal care and childbirth are managed by maternity wards in larger hospital units. According to Finnish law, a hospital can have a maternity ward, if they have a sufficient amount of midwifes and staff to assist in emergency surgeries and the required facilities and equipment for it. They must also be able to monitor the health of the fetus, infant and the mother and evaluate their need for care. Required treatment must be given immediately, including laboratory examinations and blood transfusions. The patients should have immediate access to specialists in obstetrics or anesthesiology or physicians specialized in other fields, yet thoroughly familiar with obstetrics or anesthesiology. The hospital should also be able to provide a pediatrician or a physician with good knowledge of pediatrics and a possibility to receive advice from a specialized pediatrician. If the maternity ward in question is a centralized unit offering care for high-risk mothers, the hospital also needs to have a physician specialized in neonatal care. In addition, The Finnish Ministry of Social Affairs and Health along with the Finnish Government has issued a decree requiring a hospital with a maternity ward to have at least 1 000 births per year. The decree going by the name of the Centralization Decree was issued in the beginning of 2015, so it has only affected the latest ward closures in this sample. (D 782/2014 2014) The previous closures have been mostly driven by the need to reduce health care costs. Hospitals may be exempted from having the required amount of births per year, if there is a need for a maternity ward in the area based on ensuring patient safety or access to care. (D 583/2017 2017)

3.2 Centralization in Finland

The number of maternity wards in Finland has been decreasing steadily over the past 20 years. In 1987, there were 53 operating wards. In 2018, 24 wards were left. A few existing wards were operating under temporary licenses. (National Institute for Health and Welfare 2019b)

The decrease in the number of children born has not been overlooked by policymakers. The closures have been driven by the need to reduce costs as well as the decreasing number of births, presented in Figure 1. In practice, the legal requirement of having immediate access to specialists in obstetrics and anesthesiology, who can perform emergency operations such as the caesarean sections, is what makes having a maternity ward costly in a smaller hospital unit. This is because emergency procedures requires the input of several professionals. The closure of a small maternity ward has been approximated to result in savings worth roughly 4 million euros. However, the savings may be substantially larger, as closing a maternity ward can help to re-evaluate the need for several other operations within the hospital, such as laboratory or medical imaging services. Indeed, the closures of maternity wards in the latest years are a part of a larger effort to harmonize and centralize on call duty work between hospitals and within hospital districts to save costs. (Ministry of Social Affairs and Health 2014, 32; Ministry of Social Affairs and Health 2017, 1) The savings will be accumulated on a municipality or hospital district level, because the hospitals receiving the patients from the closed wards will usually already have the needed resources for care available (Nieminen 2015, 9).

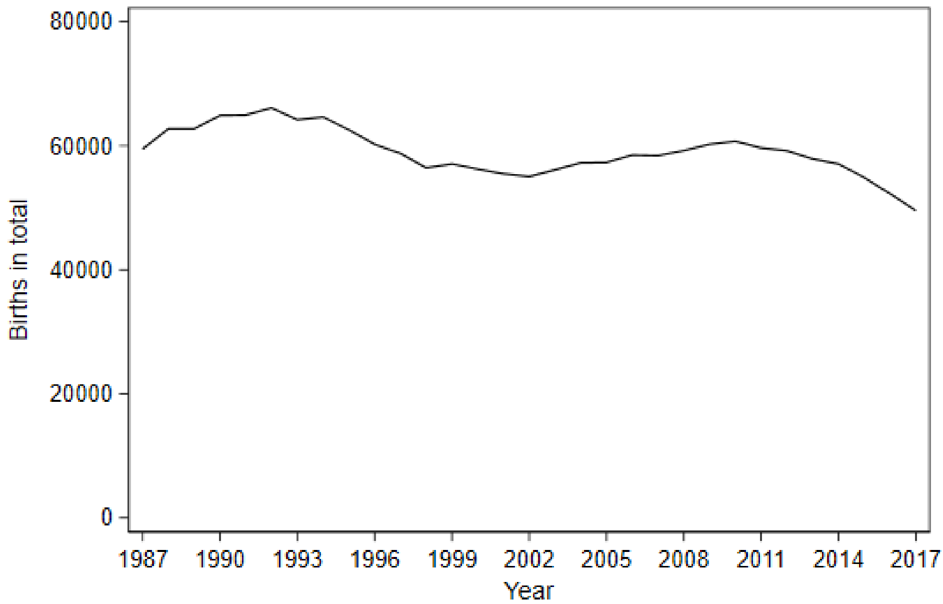

Figure 1: Total births in Finland between 1987-2017

The problem can be described as a cost minimization problem: there will, independent of any other factors, be an amount of births in a year and care for these patients must be provided. The governmental organizations overseeing the operations require certain quality requirements to be filled. The cost minimization problem attempts to solve how a certain amount of care of a certain quality can be supplied in the efficient way. What the cost minimization problems do not take into consideration, are the questions of quality perceived by the pregnant mothers. The National Advisory Board on Social Welfare and Health Care Ethics (2010, 1-2) describes pregnancy and delivery a profound experience for the mother. There is a two-way connection between giving birth and motherhood: the experience of giving birth will affect what type of a mother the woman becomes. Accepting the role of a mother will also affect the experience of giving birth. Although these factors are unmeasurable, they will also affect later outcomes of both the mother and the child. This is not studied in this thesis.

Another justification for centralization has been patient safety. Due to less births in some of the maternity wards, decision-makers feared the routine can deteriorate. On the other hand, only a small fraction of all births require immediate medical attention (Ministry of Social Affairs and Health 2017). For example in 2018, only

0.8 percent of births required emergency caesarean sections (National Institute for Health and Welfare 2019c). By centralizing the care involving these procedures, the government expects to both minimize costs and maximize patient safety. It should be noted that women belonging to risk groups have, even before the closures, been guided to give birth in larger hospitals. Assessing the risks involved with the pregnancy and going into labor is done through regular checkups pre-childbirth. (Ministry of Social Affairs and Health 2017) Factors that may contribute to the pregnancy being risky include a high or low BMI, old or young maternal age, substance abuse, various diseases and conditions, lack of social support, genetics, previous caesarean sections or previous poor obstetric history such as miscarriages, neonatal deaths or stillbirths (Attilakos & Overton 2012, 48; Dhanjal 2012, 36-40). The prevalence of some of these factors in the population is studied in the descriptive statistics of the population, found in Appendix D.

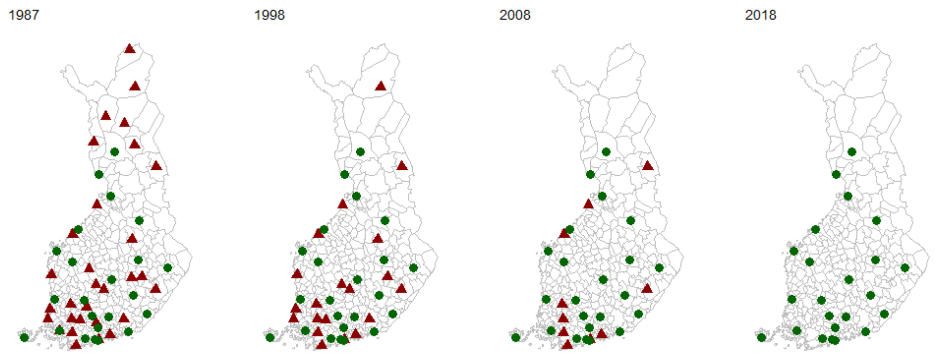

Figure 2: Locations of the maternity wards in 1987, 1997, 2007 and 2018 (National Institute for Health and Welfare 2019b)

In effort to minimize costs and improve patient safety, there have been a number of maternity ward closures. Figure 2 illustrates the development of the locations and numbers of maternity wards in Finland. The green circular markers indicate wards that were still operating in June 2019. Red triangular markers indicate wards that would be closed over time. The four maps show the locations of the wards in roughly 10-year intervals between 1987–2018. At the starting point of 1987, there were in total of 53 maternity wards. Many of the wards closed in the so-called first wave of closures were in Northern parts of Finland or located near other existing wards. In the second and third waves, the closed wards were often also located near to another larger maternity ward. For a more detailed view of the closed wards and closing years as well as the remaining wards closest to them, refer to Table 1. In this thesis, a ward is said to be closed if the amount of births decreases to ten or less or the amount has decreased 95 percent compared to the previous year.

In this thesis, hospital is used as an umbrella term for health care providers. Hospitals include university hospitals, central hospitals, regional hospitals and smaller health centers. Hospitals in Finland are divided into different categories. The largest

Table 1: Maternity wards closed between 1988–2018 (National Institute for Health and Welfare 2019b)

Closed ward	**Hospital type**	**Closing year**	**Closest ward**	**Hospital type**	**Distance (km)**
Sodankylä	HC	1988	Lapland	CH	160
Pello	HC	1988	Lapland	CH	77
Kittilä	HC	1989	Lapland	CH	141
Riihimäki	RH	1990	Hyvinkää	RH	18
Pieksämäki	HC	1991	Varkaus*	RH	49
Valkeakoski	RH	1991	TAYS	UH	32
Ähtäri	RH	1991	South Ostrobothnia	CH	68
Kemijärvi	HC	1994	Lapland	CH	65
Heideken	HC	1995	TYKS	UH	<1
Mänttä	H	1998	Jokilaakso*	RH	49
Inari	HC	1999	Lapland	CH	246
Selkämeri	H	1999	Satakunta	CH	99
Jokilaakso/Jämsä	RH	1999	Central Finland	CH	47
Rauma	RH	2001	Satakunta	CH	49
Varkaus	RH	2001	KYS	UH	76
Kuusankoski	RH	2002	Kymenlaakso	CH	52
Lounais-Häme	RH	2002	Loimaa*	RH	32
Iisalmi	H	2003	KYS	UH	86
Vakka-Suomi	H	2003	TYKS	UH	71
Kuusamo	HC	2008	Lapland*	UH	162
Loimaa	RH	2008	TYKS	UH	69
Västra Nyland	H	2010	Lohja	H	49
Raahe	HC	2012	OYS	UH	68
Vammala	RH	2013	TAYS	UH	52
Savonlinna	CH	2014	Mikkeli*	CH	86
Pietarsaari	H	2014	Central Ostrobothnia*	CH	28
Salo	RH	2015	TYKS	UH	48
Porvoo	RH	2016	HYKS	H	58
Kätilöopisto	H	2017	Jorvi	H	3
Oulaskangas	CH	2018	OYS	UH	101

hospitals are university hospitals. Current university hospitals are located in Helsinki, Turku, Tampere, Kuopio and Oulu, and there is an operating maternity ward in each of them (Ministry of Social Affairs and Health 2019a). The university hospitals may also foster some smaller units elsewhere, which should be taken into consideration, when examining their statistics. The second largest hospitals are central hospitals, some of which have maternity wards. The third category is other hospitals, which includes regional hospitals and smaller units such as health centers. Only a small fraction of current maternity wards are located in these types of hospitals. (National Institute for Health and Welfare 2019a)

Table 1 provides a more detailed, chronological list of the closed maternity wards and the closest existing wards near them. The types of hospitals in the table are, from smallest unit type to largest, health center (HC), hospital (H), regional hospital (RH), central hospital (CH) and university hospital (UH). The average distance to the closest remaining ward was 70,3 kilometers. Most of the new nearest wards were located in central hospitals (N=12) or in university hospitals (N=10).

Some of the closest wards listed may have been closed at a later stage and therefore were the closest ward in this case was determined at the time, not today. Throughout the years, there have also been changes in the hospital districts. These changes have also affected hospitals and health centers that have had and still have maternity wards. Jokilaakso hospital located in Jämsä in Central Finland belonged to the Hospital District of Central Finland, when it had a maternity ward, but was later moved under the administration of the Pirkanmaa Hospital District.

Most of the closest wards are in the same hospital district. The closed wards with a closest existing ward in another hospital district are marked with an asterisk (*) in Table 1. The closest wards within the same hospital district in these cases are shown in Table 2.

Table 2: Closed maternity wards and closest wards within the same hospital district National Institute for Health and Welfare 2019b

Closed ward	Closest maternity ward in same hospital district	Hospital type	Distance (km)
Pieksämäki	Mikkeli	CH	49
Mänttä	TAYS	UH	86
Forssa	Kanta-Häme	CH	54
Kuusamo	OYS	UH	205
Pietarsaari	Vaasa	CH	101
Savonlinna	-	-	-

The hospital district of Itä-Savo has not had a hospital with a maternity ward after the ward in Savonlinna was closed. It is the only hospital district without a maternity ward. Mothers living in the region are advised to choose to give birth in one of the maternity wards in central hospitals of Mikkeli, North Karelia or South Karelia or the Kuopio University Hospital (KYS). (Sosteri 2001)

As mentioned earlier, most births in Finland take place in hospitals. However, the proportion of out-of-hospital births has increased between 1990 and 2020. Closures of maternity wards have resulted in discussion of the risks associated with it. One concern has been the increased travel distances to the wards, which may be resulting in more unplanned out-of-hospital births. Babies born outside a hospital environment have an increased risk of conditions such as hypothermia, hypoglycaemia and jaundice (McLelland et al. 2018). Births taking place outside the hospital can be categorized to three categories. Born-before-arrival (BBA) births are births that occur on the way to the hospital. Unplanned home births are births that take place at home, but accidentally. Planned homebirths happen at home planned. There has been research that may indicate increased travel time having implications on health. Weaknesses of many of the studies is, that due to data restrictions, the above mentioned different types of out-of-hospital births cannot be distinguished from each other. Combier et al. (2013) found a small positive, but non-significant correlation between closures and increased travel time. Kildea et al. (2015) study closures and the rate of BBA births and finds they were significantly associated. However, an increased distance does not necessarily causally imply a higher rate of out-of-hospital births. BBA births may be associated with for example multiparous mothers, who after previously having given birth are not as precise about getting to the hospital on time (Loughney et al. 2006;Haloob & Thein 1992).

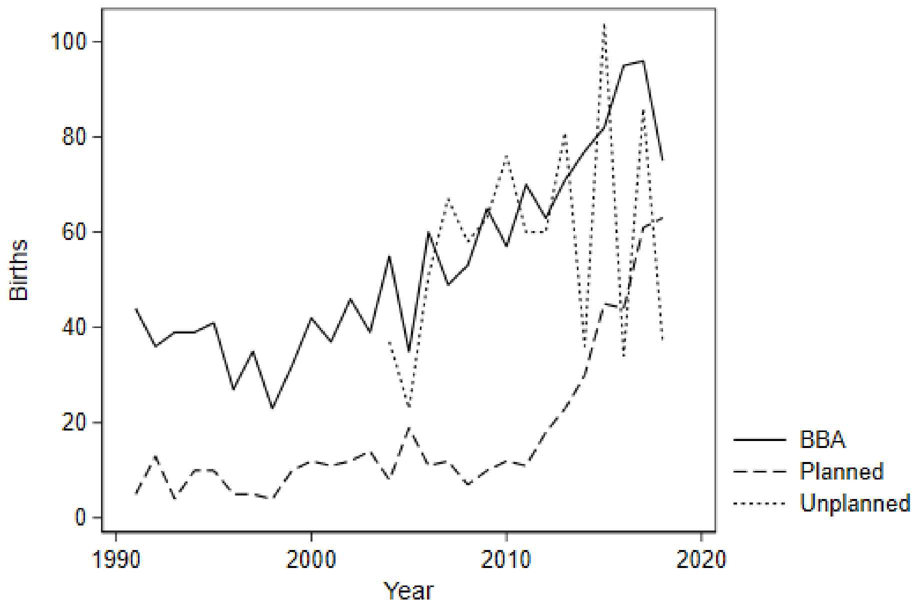

Figure 3: Out of hospital births by type (National Institute for Health and Welfare 2019d)

Figure 3 indicates all measured out-of-hospital births in Finland between 1991-2017. The figure indicates that especially the number of planned home births has experienced growth since 2010, whereas the number of BBA births has been growing at a more constant rate. Documenting unplanned births began in 2004. In Finland, the number of out of hospital births has increased over time, yet the overall number of them has remained relatively low. In 2018, roughly 0.2 percent of births were BBA, 0.2 percent unplanned home births and 0.1 percent planned home births. Drawing conclusions about possible implications on health is challenging due to the restricted samples and will therefore not be further commented on in this thesis.

4 Study design

4.1 Data

This thesis is based on novel empirical work with data, that is also being used in other studies with different types of research questions within the same research project. The data on mothers has been provided by the National Institute for Health and Welfare's Medical Birth Register. Before using the data, Statistics Finland has encrypted the social security numbers of the individuals in the data, so that the researcher or the reader cannot recognize any individuals. The permits for use of this data were applied with the VATT Institute for Economic Research. All analysis was conducted using Stata 16.0 in the remote access portal Fiona supplied by Statistics Finland.

The complete Medical Birth Register covers all births (N=1 846 098) in Finland between 1987–2017. The register gathers together data on all the live births and stillbirths of infants over the birth weight of 500 grams or over 22 weeks of gestational age stillbirths in Finland. The register also contains data on the mothers of these children. The purpose of the register is statistics and research. (National Institute for Health and Welfare 2019e)

The data set used in this thesis study is a sample (n=550 062) of the register data set (N=1 846 098). The time frame is restricted to 2004-2017. This is because recording maternal ICD-10 diagnoses associated with child birth began only at the beginning of 2004. Before this, there were certain variables available indicating acute maternal birth complications, such as a variable for placental abruption. However, this, among the other early variables available, is a rare complication and only occurred for on average 0.2 percent of the women giving birth. To ensure there is enough data on the complications, the late part of the entire data set was chosen for analysis. A complete list of variables in the Medical Birth Register can be found in Appendix C.

In addition, the data was restricted to chosen areas of closure. This was due to overlaps in treatment periods and treatment classes. The areas were chosen to simplify the model: one area will be only subject to one treatment over the time period studied and will also remain classified in the same control or treatment group over the entire time. The wards chosen for analysis are presented in Table 3. It should be noted the individuals in the model are not assigned to control and treatment groups depending on the ward they gave birth in, but according to the catchment area they live in. A more detailed description of this can be found in Section 4.2.2.

The data was cleaned by looking for missing values or obvious errors in the variables defining which maternity wards the mothers gave birth in. Removed data included observations with Finnish or foreign mother without residence in Finland, homebirths and births without location information. The sample was restricted to mainland Finland, so all births in Åland were removed.

The data was further cleaned to account for administrative changes. There were some maternity wards in the same cities or the same municipality having undergone administrative changes during the period examined. Births in the town of Pietarsaari have been filed under Jakobstad sjukhus until 2004 and under Malmi hospital after that. These separate statistics have been merged into one series, because the change

Table 3: Maternity wards in sample

Maternity ward	**Class**
Kuusamo Health Center	Treatment
Loimaa Hospital	Treatment
Västra Nylands Hospital	Treatment
Raahe Health Center	Treatment
Vammala Hospital	Treatment
Savonlinna Central Hospital	Treatment
Pietarsaari Hospital	Treatment
Oulu University Hospital	Inflow
Turku University Hospital	Inflow
Salo Hospital	Inflow
Lohja Hospital	Inflow
Jorvi Hospital	Inflow
Oulaskangas Hospital	Inflow
Tampere University Hospital	Inflow
Satakunta Central Hospital	Inflow
Mikkeli Central Hospital	Inflow
Kuopio University Hospital	Inflow
North Karelia Central Hospital	Inflow
South Karealia Central Hospital	Inflow
Central Ostrobothnia Central Hospital	Inflow
Vaasa Central Hospital	Inflow
Hyvinkää Hospital	Control
Lappi Central Hospital	Control
Porvoo Central Hospital	Control
Kainuu Central Hospital	Control
Kanta-Häme Central Hospital	Control
Central Finland Central Hospital	Control
South Ostrobothnia Central Hospital	Control

has been purely administrative. Similarly births in Jämsä's Jokilaakso hospital until 1993 and Jämsä health center from 1994 have been merged. In Lapland, the Inari-Utsjoki health center had a maternity ward until 1993 and continued operations under the name of Inari health center between 1993–1999. In the data, births at Raahe hospital and Raahe health center were categorized under the same ward code.

The data also includes entries of hospitals without maternity wards that mothers have nevertheless given birth in. This group of births mostly consists of births in private hospitals and emergency deliveries. Typically, there have not been over 10 births in these units, so they are omitted from the data. These units were located in Parkano, Posio, Ranua, Rovaniemi mlk, Salla, Utsjoki, Muonio-Enontekiö, Hamina, Riihimäki, Orimattila, Harjavalta and Imatra.

To form the catchment areas, the municipal reforms over the time period had to be taken into account. In the span of the data, there had been 158 municipal reforms. The disbanded municipalities were merged with the remaining ones in the data. This was done, because the difference-in-difference method requires observations both before and after the treatment. In this case, as the municipalities had ceased to be, they did not have both types of observations. By forming larger municipality areas and merging the data from different postal codes, the sample could be kept as representative as possible.

Certain variables were added to the data, namely dummy variables indicating types of hospital and variables indicating occurrence of certain characteristics or complications in the childbirth. These complications were sought from the data by filtering ICD-10 classified diagnoses. ICD-10 is the most recent international statistical classification of diseases and related health problems, and it was last updated in 2016 (World Health Organization 2016). The ICD-10 classification was implemented in Finland in 1996, which means part of the complete data set is outside the span of the classification. For the years in the sample, ICD-10 codes have remained the same. If one wanted to include the years before ICD-10 diagnoses, one could use the Finnish national diagnose codes. Dummies were created for complications such as haemorrhage, lacerations, anesthesia-related complications, obstruction related to the pelvic abnormalities, abnormalities in forces of labour, obstruction due to malposition or malpresentation of fetus, prolonged labour as well as unclassified and other obstetric complications. In addition, dummy variables concerning pre-birth health characteristics were formed, including variables on overweightedness and smoking during pregnancy. To look at general characteristics of the wards chosen for analysis, continuous variables for distance to ward, length of stay and length of stay after the childbirth were formed.

Table 4 shows the descriptive statistics on the variables used in the analysis. A similar table for the whole population from the cleaned register data set can be found in Appendix D. In Appendix E, the shares of maternal complications over groups and over time have also been tested. The shares differ in the groups and can be seen to have changed due to the closures.

The data was merged with Statistics Finland's FLEED and FOLK data sets on socioeconomic control variables for the mothers. The merged variables were earnings, marital status, education and home language. The variables were retrieved for the

Table 4: Descriptive statistics

	All	Control	Treatment	Inflow
Maternal characteristics				
Age	29.65	30.48	29.5	29.36
Married (%)	62.1	65.02	63.04	59.39
High school degree (%)	52.77	57.86	53.28	49.39
Taxable income	19923	23054	19371	18849
Finnish or Swedish speaking (%)	93.53	89.15	93.86	95.51
Overweight (%)	33.81	30.87	32.87	36.52
Obese (%)	12.27	10.8	11.76	13.68
Smoker (%)	14.78	12.39	14.49	16.45
Diabetes (%)	0.66	0.64	0.75	0.55
General care specific indicators				
Distance to ward	38.85	21.14	60.81	22.83
Length of stay	3.79	3.54	3.95	3.73
Length of stay after delivery	3.11	2.93	3.22	3.09
Pregnancy-related visits	16.19	15.97	15.95	16.61
Visits to maternity polyclinic	3.22	3.31	2.74	3.8
Pregnancy and delivery specific characteristics				
First-timers (%)	40.42	41.22	40.82	39.52
Earlier births	1.12	1	1.16	1.13
Miscarriages (%)	22.72	20.62	23.42	23.05
Earlier pregnancies	1.61	1.44	1.67	1.64
Miscarriages	0.32	0.28	0.33	0.32
Abortions	0.16	0.14	0.15	0.17
Ectopic pregnancies	0.02	0.02	0.02	0.02
Caesarean sections	0.11	0.12	0.1	0.11
Young mother (under 18) (%)	0.9	0.78	0.86	1
Old mother (over 35) (%)	18.91	22.71	18.05	17.82
Diabetes in pregnancy (%)	7.41	7.66	7.74	6.15
Anemia (%)	2.77	4.05	2.85	1.98
Care for risk of prematurity (%)	1.91	1.88	1.48	2.45
Care for high blood pressure (%)	2.04	3.51	1.42	1.96
Placenta praevia (%)	0.31	0.35	0.3	0.3
Long labour (%)	4.52	5.53	4.06	4.5
Maternal outcomes				
Maternal complications (%)	16.4	19.59	14.75	16.58
Bleeding (%)	3.63	4.15	2.67	4.47
Lacerations (%)	3.74	4.1	4.28	2.9
Other trauma (%)	0.72	1.1	0.56	0.7
Number of births	550 062	111 090	236 947	202 025

year the mothers gave birth. As many mothers gave birth multiple times, they may have been included in the sample more than once with the control variables from each year they gave birth.

The locations of the mothers were retrieved from population grid data. The data set from Statistics Finland includes 1km x 1km population grid data for years 2004-2016. The data was matched to the individuals with the encrypted social security numbers. As year 2017 was not included in the data, the coordinates for these mothers were determined through using the coordinates of the geographic centers of the municipalities they lived in. This was also done for the mothers missing from the general population grid data. They may have been missing due to living in rural areas with too few people to form a 1km x 1km grid. These coordinates determined by the municipality centres may have a substantial error margin and the problem may be more persistent in rural areas, where people live further away from the municipal centres. It should, however, also be noted the number of mothers in these types of rural areas is small, so although there may be error, the sources are likely to be few. To minimize errors for the coordinates of the mothers not included in the population grid data, the municipality coordinates were retrieved with the old municipality codes rather than the coordinates of merged municipality centers.

To determine the mothers' distance to the wards, coordinate data was also retrieved for the maternity wards. This data was from the National Institute for Health and Welfare's TOPI register from the year 2019. The TOPI register includes data on producers of the health services and the postal code of the units, in addition to other variables. The locations of the closed maternity wards were retrieved from various versions of the TOPI registers, if needed. However, in many cases even after closing the maternity ward, some other operations have still continued in the hospital units and were therefore detectable in the later versions of the TOPI register. Each postal code was assigned coordinates with the EUREF-FIN datum. These coordinates were from Statistics Finland's Paavo database. (Statistics Finland 2019b)

With the coordinates of the maternity wards and the mothers, the travel distances could be calculated. By using the ETRS-TM35FIN coordinate system under the geodetic datum EUREF-FIN, the distance could be calculated by simply using the Pythagorean theorem. All the coordinates are in an x,y plane with the origo located in Åland. The average travel distance for the mothers was roughly 38 kilometers. It should be noted that whenever conducting calculations based on these types of coordinates, there is an error margin in them. All distance measures are, for the sake of simpler calculations, geodesic and may therefore differ from the actual distances travelled to the maternity wards. The problem may be more persistent in distance measures in Eastern Finland, where large water areas like the Saimaa, may make routes to the hospital via roads and such longer than the geodesic distances used in the measurements of this study. For further study and more accurate analysis of the effects of distance to the maternity ward, one would need to look at actual travel times instead of geodesic distances or determine a more sophisticated method of analyzing geodesic distances or spatial access.

4.2 Empirical model

The effects of maternity ward closures are studied through a difference-in-difference (hereafter DiD) setting, by replicating the method used by Avdic et al. (2018). DiD is suitable for this particular setting, because in a policy intervention such as closing certain maternity wards, we are interested in the broader effects of the health of a certain group, mothers giving birth.

DiD has been widely used for estimating causal inference, because it aims to study the differential effect of an intervention on two groups: the unaffected control group and the affected treatment group. The key identifying assumption in any DiD model is that the groups being compared have parallel trends before the treatment, in this case closures. When trends are similar in both groups prior to the treatment, the treatment will result in a single-sided deviation from the trend. The name difference-in-difference hence results from deducing the difference between time periods for control and treatment groups separately (first difference) and then between the two groups (second difference). The outcomes are studied before and after the intervention of choice, but the method does not require panel data. Regressors of interest vary on an aggregate level. For example, the closures of maternity wards may result in health varying between different areas after the closures, but not within the areas due to the closure. (Angrist & Pischke 2009, 169)

The DiD method has had its share of critique. Firstly, the challenge is to isolate the effect of the treatment from all underlying trends and characteristics. This is usually tackled by including rigorous sets of control variables and testing for similar underlying pre-trends. The simpler DiD designs have also been criticized to suffer from the fact the outcomes are only measured few times. If there is much noise and little autocorrelation in the data, measuring outcomes at few instances in time may not be a very powerful tool of portraying changes. Increasing the number of measurements increases the explanation power. (McKenzie 2012) In addition, treatments may not occur in a short time instance, but may be closer to continuous. DiD models have thus evolved from the simpler and earlier models such as the classic example of the study of the effect of the minimum wage on employment by Card and Krueger (1994), taking into consideration both the noise and different intensities in differing times as well as the possibility of continuous treatments (see e.g. Goodman-Bacon 2018; Dafny et al. 2012; Jackson et al. 2016).

In this DiD model, an assumption we must have is that mothers are assigned to the maternity wards based on the area of their residence. This is the typical case, as a pregnant mother normally gives birth in the maternity ward closest to them. This is further supported by childbirth often having an urgent nature. Finland has a freedom of choice principle, which allows one to choose their health care provider. Within specialized care, a patient can request to give birth in a hospital further away from them. In this case, the patient needs a referral from their own doctor. (Suomi.fi 2019) In some cases, it is possible that due to need for special medical attention, the patient is instead unwillingly assigned to a maternity ward further away. Previous research has shown in the case of a low-risk birth, women are likely to choose an obstetric ward closest to them, which makes the assumption of giving birth in a ward that is closest plausible (Pilkington et al. 2012, 1). This is also confirmed by the data used in the thesis.

Much like Avdic et al. (2018, 9), I also use different types of catchment areas to determine the treatment and control groups in the difference-in-difference analysis. They determine three catchment areas: closure areas, inflow areas and control areas. Closure areas include areas, which were affected by the maternity ward closures. Inflow areas are areas with a remaining ward subject to the inflow of patients from the closure areas. Control areas are unaffected by the closures. Defining the difference between closure and inflow areas is important, because the implications on patient health are likely to be different for patients in these areas. As mentioned earlier, mothers in closure areas may be affected positively by increased learning-by-doing, but negatively through longer travel times or more congested wards. Mothers in inflow areas, too, experience more congestion, but depending on the size of the ward, may either benefit or suffer from the increased caseload.

In a sense, one can think of the maternity ward having an optimal number of births n^*. This n^* assures that learning-by-doing knowledge is at a sufficient level, which will be enough to minimize risks to health. Due to Finnish regulations, we can assume the yearly n^* to be over 1 000. However, it is possible that once the number of births exceeds n^* to a certain extent, the patient caseload becomes too large and begins to have negative effects on health. This could be caused by a number of reasons. Possible suggestions include overcrowding of hospital spaces or a too large number of patients per midwife or obstetrician. Therefore, the final net health effects are priori ambiguous and will be determined by which group of patients the closures affect more and through which channels the effects are realized.

I start with a baseline model, where I compare mothers subject to closures (this including both closure and inflow areas) to mothers in control areas. Baseline in this context refers to the regression studying the net effect of the closures. The model includes all controls, fixed effects and time trends, further explained below. To be sure of parallel trends before the closures, I compare the before and after closure health outcomes of interest. This is done in Section 5.2.

The baseline model can be formulated as

$$y_{iadt} = \alpha + \beta_C C_{at} + \lambda_a + \lambda_t + (t \times \lambda_d) + X'_{it}\beta_X + Y'_{i\,t}\beta_Y + \epsilon_{iadt}, \qquad (1)$$

where i indicates the individual living in catchment area a within hospital district d at time t. C_{at} indicates whether the catchment area was subject to closure (in either the form of a closure area or an inflow area) at time $t \geq T_c$, where T_c indicates the year the maternity ward was closed. The model uses a fixed effects framework. It is used to control for differences between catchment areas, that do not vary with time. These fixed effects are accounted for with λ_a. Similarly, there are larger scale trends in maternal health, which are accounted for by yearly fixed effects with λ_t. The term $(t \times \lambda_d)$ accounts for hospital district level time trends. As suggested by Angrist and Pischke (2009, 239), one needs to have a sufficiently long period of data both before and after the treatment, which is why I include a minimum data span of six years for each closure studied.

The baseline model, as do all the other models used in this thesis, includes controls and trends. In order to account for mothers having different types of general maternal characteristics (i.e. the case mix of mothers), I include a vector X'_{it}. These variables include age, marital status, earnings and home language. In addition, I include a vector of pre-birth health characteristics Y'_it, which include obesity, diabetes and smoking. One must be sure to include only controls that are not affected by the treatment, in other words are not "bad controls" (Angrist & Pischke 2009, 47). Avdic et al. (2018) use as their controls age, cohabiting, earnings, tumor, substance dependence, obesity, heart disease, respiratory disease and diabetes. The Finnish Medical Birth Register does not include ready variables for tumors, substance dependence, heart diseases or respiratory diseases. These are typically also not diagnosed at the pregnancy stage, which is why they do not show in the ICD-10-classified pre-birth diagnoses.

After the baseline, a second-stage regression is estimated. The aim is to further understand the mechanism behind the changes in health and how the net effect is driven by changes in closure and inflow areas. As said earlier, the hypothesis is the effects differ. The second-stage regression shows the magnitudes and the direction of the effect in the two areas. I therefore separately compare closure areas to control areas and inflow areas to control areas. The models are identical to Model 1 and the only difference is that C_{at} indicates if the area is a closure area for closure area estimations or an inflow area for inflow area estimations. Understanding differences in the health changes of the patients in different areas provides valuable insights at later stages, when trying to determine the mechanisms behind inflicted changes in health. The mechanisms are discussed in Section 5.3.

The basic estimations will be made using OLS, but due to the outcome variable being binary, I also run the same models in a logistic regression and show the discrete effects for those regressions. This is due to the fact that estimating a binary outcome with an OLS model is not ideal, and the logistic regression models may be superior (Pohlman & Leitner 2003). The logit model is appropriate, because complications are occurring rather rarely. Avdic et al. (2018) also use OLS and logit, and justify the consistency of OLS by stating similar results are also obtained by using a non-linear logit model. This is the case in my study too: OLS and logit yield very similar results. The OLS estimators should, however, be treated with certain caution due to their possibly poor prediction power over probabilities of occurrence of binary outcomes.

With the use of OLS, there is bound to be heteroskedasticity, which is why robust standard errors are used in the analysis. The need for robust standard errors is also supported by the analysis being based on a sample of the whole population. Lechner (2011) notes the consistency of OLS may not be valid if the number of observations in a regression with covariates is too small. This may result in there being too few interactions. The model will not be saturated because of the chosen specification. In this thesis, I assume index function beneath the parametric regression to be linear. The covariates are assumed to linearly influence the outcomes. This may result in heterogeneity problems. (Angrist & Pischke 2009; Lechner et al. 2011) Assessing how serious the bias induced by heterogeneity is not easy.

The standard errors will be clustered at the hospital district level. Clustered standard errors are used to account for certain variables being possibly similar with each other within same regions. There are less than 30 hospital districts in Finland, so I use the wild bootstrap method to account for the small number of clusters. The method is appropriate for when large-sample assumptions are not satisfied due to for example too few clusters, few treated clusters or weak instruments. (Roodman et al. 2019) Clustering may be feasible due to either a sampling design reason or an experimental design reason. If the data used has been sampled from a population, but one would like to generalise results to a larger population, clustering can be justified. In experimental design, treatment may be assigned in clusters. In this thesis study setting, the reason is the former. In addition in my thesis study, the treatment is not assigned on an individual level, but to clusters, which is why clustering in standard errors is needed. Avdic et al. (2018) cluster their standard errors by parishes. Clustering based on a geographical location, but not in addition based on for example age, may be hard to justify, as correlations may exist in several different aspects and variables. (Abadie et al. 2017)

4.2.1 Outcome variables

The changes in the outcome variables in this study aim to measure changes in acute maternal health. They have been chosen on the basis of previous literature and discussions with obstetricians. Moore et al. (2006) studied the different complications of vaginal deliveries in the US. The most common complications in vaginal delivery were perineal lacerations of the 1st and 2nd degree. In addition, the study listed bleeding, different types of obstruction and complications from prolonged labour as common complications.

The outcome variables had to be chosen to reflect acute changes in health, determined as little as possible by pre-birth health or behaviour in pregnancy. On the basis of this, the outcome variables used in this study are

- Maternal complications, consisting of lacerations (O70), bleeding (O67 & O72), anesthesia-related complications (O74), obstruction related to the pelvis (O65), abnormalities in forces of labour (O62), obstructions due to malposition or malpresentation of fetus (O64), prolonged labour (O63) and unclassified and other obstetric trauma (O75)
- Lacerations (O70)
- Haemorrhage (O67 & O72)
- Other obstetric trauma (O75).

Essentially, all of the above mentioned outcome are such that can be avoided or at least reduced with the appropriate measures. They are therefore suitable for measures of quality of care. (OECD 2011, 112) Perineal lacerations (1st and 2nd degree) are widely used in different countries to measure quality of care. (OECD 2017, 118) The more severe lacerations are also used as a quality measure by the Agency for Health Care Research and Quality, which is an organization working under the U.S. Department of Health and Human Services. (Russo & Andrews 2009) As Table 4 indicated, bleeding is as common in the sample as lacerations. In addition, postpartum haemorrhage, just like lacerations, can be prevented or reduced by taking certain measures during labour. Therefore, it is also a suitable measure for quality of care and studied separately.

The outcome variables are deduced from the data. From 2004, the register has included ICD-10 diagnoses on maternal health in pregnancy and childbirth. Each patient entry may include up to ten different labour-specific ICD-10 diagnoses. This allows for dummies to be formed for all the outcome variables. The ICD-10 codes are presented above. Some of the outcome variables are similar to what Avdic et al. (2018) use. I use the total maternal complications, haemorrhage and lacerations as main indicators. Avdic et al. (2018) use a composite of trauma and perineal lacerations of 1st and 2nd degree as the main indicators of obstetric trauma. The composite variable holds trauma resulting from the rupture of uterus, laceration of cervix, haematoma of pelvis and other obstetric injury to the pelvic organs.

Often in empirical studies, mortality is used as an indicator for either health or quality of services. It is, indeed, an easy indicator, which is usually measured quite reliably. However, in the case of maternal health, using mortality as a health measure is not feasible as maternal mortality tends to be very low (Avdic et al. 2018, 12). In Finland, maternal mortality accounts for roughly three yearly deaths. (Palomäki 2019) The more minor complications, which are more commonplace, are better variables for measuring health.

4.2.2 Catchment areas

The model is based on the assumption that patients are directed to designated wards after closures. These wards are the closest ones to the patient. In spite of the Finnish freedom of choice in health care, most of the births still take place at the nearest ward.

In the study by Avdic et al. (2018), the catchment areas were pre-determined. Finland does not have such a system, so the catchment areas of each ward had to be determined manually. This was done by manually tracking the patient flows from each municipality. The mothers are not assigned to control, inflow or treatment groups based on the maternity ward they gave birth in, because it would make the DiD setting impossible to use. Instead, they are assigned to the three different groups based on their area of residence and whether that area was a part of the catchment area of a closed or remaining maternity ward.

After determining the catchment areas of each ward, the wards had to be labeled as either control, treatment or inflow. Assigning treatment wards was trivial. Control wards were the ones unaffected by the treatment. Inflow wards were determined by tracking patient flows in catchment areas. A detailed process of tracking these flows allowed for recognition of all the inflow wards instead of just one main ward. There were many cases of closures, where a couple of near-by wards received patients from a closing ward. This also explains why in Table 3 there are more inflow wards than treatment wards. In some cases patients were flowing to two or three remaining wards instead of one.

Inflow areas can be studied by looking at the caseloads, i.e. numbers of births, in maternity wards close to closed wards. Figure 4 depicts four examples of remaining maternity wards and the number of births yearly in these wards. Vertical lines indicate years a maternity ward close to the ward in question has closed. TYKS is an abbreviation for Turku University Hospital and OYS for Oulu University Hospital.

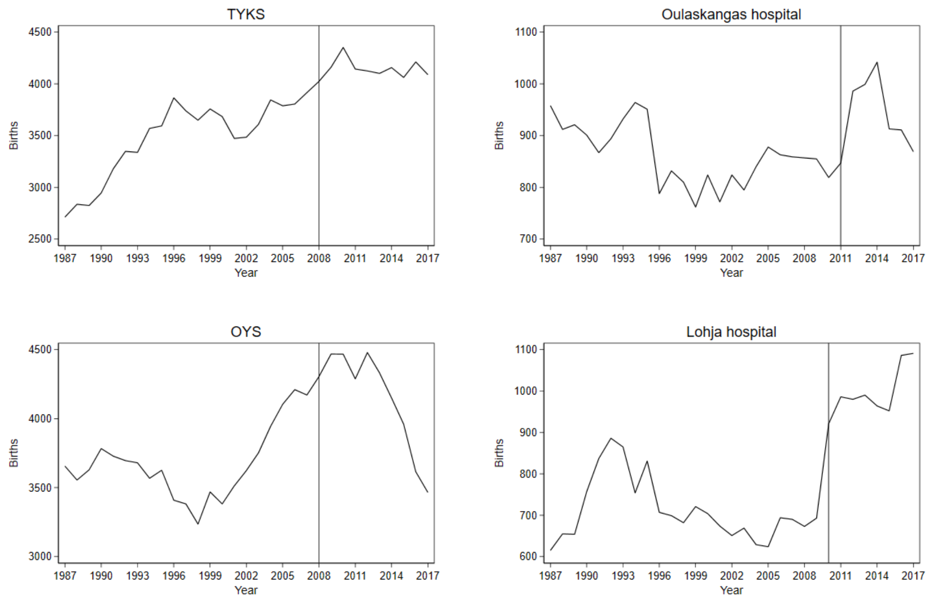

Figure 4: Total births at maternity wards between 1987-2018 with indicators of closures (National Institute for Health and Welfare 2019b)

The figures indicate some visible inflows of patients. However, sometimes the closure wards have been quite small and the effects may not be clearly visible in the graphical presentations. It is also visible from some of the graphs that there may have been inflows of patients from the to-be closure wards already before the actual closure years. This is likely to be the case with for example Lohja hospital. For the DiD results, this would make the coefficients likely to be underestimated.

The graphical method is not reliable for the actual analysis of patient flows, so as said, they were tracked by looking at the numerical amounts of births. In the numerical, more precise comparison, it is easy to observe where the patient flows are directed after closures. By looking at yearly numbers of births in each municipality and categorizing them by which ward they took place at, one can determine which inflow wards are associated with each closure ward. This was done for all of the closures, where the closure date has allowed for a sufficiently long post-treatment period.

4.3 Limitations of the study

Due to this research project being a Master's thesis, not all possible considerations have been able to be implemented into the research design. I discuss the limitations of the study and the model as well as their implications on the results.

Although not a limitation of the model per se, the timing of the closures and the locations of the closure wards create challenges in forming the empirical model. For the sake of simplicity, in this thesis study, I have chosen to include closures taking place only between 2004-2017. This is due to two main reasons. Firstly, as mentioned before, the Medical Birth Register began using ICD-10 variables for diagnoses during childbirth from the beginning of 2004. Although there were other variables recording maternal complications in birth before that, they were significantly fewer than the ICD-10 codes. Secondly, the timings of the closures and the locations of the closure wards create overlap in the treatment periods as well as the treatment classes. For example, inflow wards may be subject to new inflows of patients from different closures areas in consecutive or nearly consecutive years. By definition, this complicates using a simple difference-in-difference model. In addition, in some cases, an inflow ward may become a closure ward. This means the ward will have a different treatment class in period t and $t+1$. This complicates building the model effectively. The overlaps in treatments and classes were a problem especially in the 1990's and the early 2000's. To deal with this, these years and the wards changing class have been excluded from the sample used for analysis in this thesis. Without the thorough understanding of the dynamics of the effects on health, building a model with multiple treatments is difficult. However, after the dynamics have been studied through the more simplified model in this thesis, it can be executed by using extensions of the staggered DiD model.

In Avdic's et al. (2018) model, the maternal pre-birth controls included are age, cohabiting, earnings, tumor, substance dependence, obesity, heart disease, respiratory disease and diabetes. The Finnish Medical Birth Register does not allow for the exact same set of controls. For the socioeconomic controls, I am able to include similar variables, but for the pre-birth health characteristics I need to control with other types of variables. The register includes ICD-10 classified diagnoses from the pregnancy period, but does not include earlier diagnoses from basic diseases. These illnesses include for example respiratory diseases, heart diseases and earlier tumours, used as control variables in the replicated study. With access to the full Care Register for Health, an even more rigorous set of control variables could be included.

Another shortcoming of this model is the lack of information on staffing in the hospital. The closures of certain wards increase the number of patients admitted to near-by wards. The effects this has on the staffing in the remaining maternity wards should ideally be controlled for. If the remaining maternity wards in the inflow areas increase their staffing due to closures of other wards, this can be seen to increase the quality of care provided in the inflow ward. The staffing can increase already before the closure, which would create a bias: the quality could increase before inflow patients start arriving and then decrease due to an increased caseload. It is also possible the staffing increases with a lag, which challenges the persistence of the health effects inflicted. The staffing question is not limited to only hospital-wide considerations. As staffing and therefore perceived quality of care may also vary between different times of the day, this should also be accounted for in the model. The Medical Birth Register does not include data on staffing, because hospitals collect it themselves.

Another factor to consider is, that not all the closures of maternity wards are similar. In some cases, it is easier to identify to which operating maternity ward the patients of a closed maternity ward would be directed. These cases are characterized by the closed maternity wards being close to one existing ward or within the same hospital district. This was the case with Raahe Health Center regional hospital, where the maternity ward closed in 2012. The patients were being directed to the Oulaskangas Hospital. On the other hand, in some cases the patients from closure areas were directed to multiple wards. For example, in the case of closing the Savonlinna Central Hospital in Eastern Finland, the patient flow was divided between Mikkeli Central Hospital, Kuopio University Hospital, North Karelia Central Hospital and South Karelia Central Hospital. If these flows did not have to be manually determined and there was ready-made information on the catchment areas like in the study by Avdic et al. (2018), the results may be even more precise.

Selection of patients to each maternity ward can be described as rather random. It is a fair assumption that a to-be mother does not choose to live in a city based on whether it has a maternity ward or not. However, there is a possibility of a selection bias. What we observe in the results may be biased by selection of mothers with high risks in the delivery into the larger university hospitals or central hospitals, already before closure of smaller maternity wards. This is known to be true, as mothers with risk factors affecting their pregnancy are both being monitored and often placed in the hospitals or hospital hotels well before going into labor to minimize risks, although it should be noted the proportion of these expecting mothers is small (Palomäki 2019). This is somewhat tackled by adjusting for the case mix of mothers with maternal pre-birth health and socio-economic control variables. While in some countries for example c-section rates may be higher amongst women of high socio-economic status, in Finland the need-based system should eliminate these kinds of trends. Therefore including the riskiness of the birth through the health controls should be a reliable control for selection into larger maternity wards (OECD 2014; Räisänen et al. 2014). This can of course be debated, for there have been studies (see e.g. McCallum et al. 2013; Keskimäki 2003; Hetemaa et al. 2004) arguing differences in use of services between socioeconomic groups in Finland. This also has to do with the problem also pointed out by Avdic et al. (2018), where patient groups exposed to the mergers may be affected by unobservable factors that differ from the ones affecting mothers in areas without mergers.

Another problem discussed also by Avdic et al. (2018) is the changes in patient composition afflicted by closures and new patient inflows to existing maternity wards. If a closure of a maternity ward, for example in a rural area, increases the perceived risk of giving birth, this may have implications on the number of children born in the region. Although a problem of this magnitude would pose a serious threat to the empirical model, it can be argued unlikely for women behave in this way. This is supported by Figure 5, which shows trends in fertility have been similar during 1990-2018 in all regions in Finland despite a larger amount of closures in certain regions compared to others.

It should also be discussed, whether the dependent variables are good indicators for the health outcomes. Another possibility would be to look at different characteristics of the mothers and look at whether they, after the merger, were treated according to the risks they have due to their characteristics. As an indicator of quality, one could also look at the operations done and attempt to determine whether they were targeted efficiently and fairly to the patients most in the need of them. The hypothesis

Figure 5: Total births in hospital districts by area

of smaller hospitals not having enough learning-by-doing activity due to a low level of births may bear issues. Mainly, due to the complicated nature of childbirth, it is possible certain low-grade, non-fatal complications are not diagnosed correctly or at all. As some of the health indicators are dummies deduced from ICD-10 diagnoses, there may be some inaccuracies in them. In general, using the ICD-10-classified diagnoses assumes all of the diagnoses are recorded into the register.

5 Results

5.1 Main results

When closures occur, the caseloads in the remaining wards can change. As Figure 6 indicates, the closure wards are rather small in size. After closures, the patients go to give birth in remaining inflow wards, which are much larger in size. The wards the mothers living in closure areas give birth in after closures have more average yearly births than the closure wards. As mentioned before, some of the closure wards may not close down strictly at one point in time, but are shut down gradually. This can be also seen in Figure 6, as the curve for treatment areas begins to increase slightly already one year before the closure. This should be taken into account when interpreting the results: because of this phenomenon, the DiD effects on the closure and inflow wards may be slightly underestimated. As expected, inflow or control areas do not experience a similar change in the average caseload.

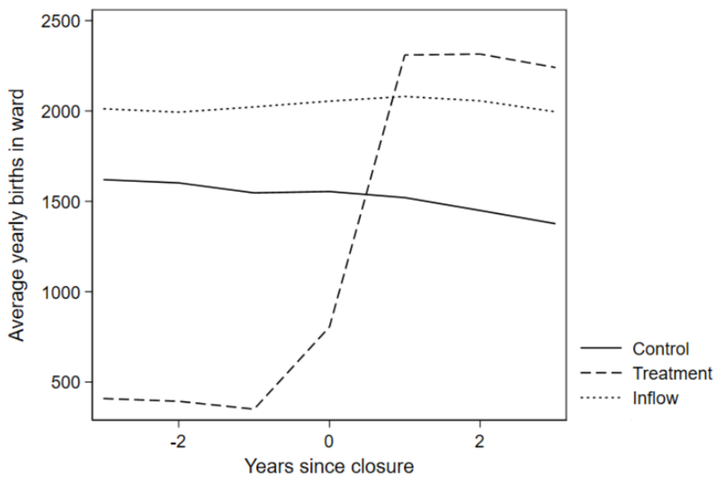

Figure 6: Average caseloads of treatment and control groups by time since closure

In addition, one can observe an increase in the average distance travelled to the ward in closure areas. Mothers in closure areas travel on average a longer distance after the closure. Such changes can not be observed in control or inflow areas, which is an important observation for the identifying assumption. There is thus no observed movement from the inflow areas to other wards as a result of closures of near-by wards. As mentioned earlier, the population grid data was only available for until 2016. The noise at the end of the curves is likely to be due to the distance measures in 2017 being calculated with the municipal center coordinates rather than population grid data.

The main results from Model 1 are the effects of closures on maternal health presented in Table 5. The complete regression tables are found in Appendix F.1. The discrete effects for the logit regression are shown in Table 6. Table 5 presents the regression coefficients of the baseline model with trends in (1), no trends in (2) and a logit regression in (3) as well as the results from the second-stage regression of individual models of closure in (4) and inflow areas in (5). All the results in the table include the controls and fixed effects, adjusting for area fixed effects, year fixed effects as well as maternal socioeconomic characteristics and pre-birth health characteristics (for further details see Table 4). Apart from regression (2) in Table 5, the models also adjust for regional linear time trends in health. The standard errors are clustered at the hospital district level.

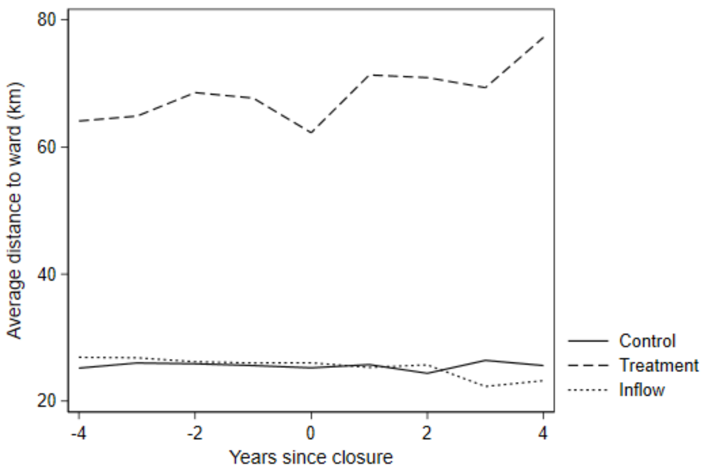

Figure 7: Average distance to ward by group and time since closure

Table 5 presents the coefficients for the regressions of the main outcome variable, maternal complications, are significant for the main, no trend and logit models. The net effect from the main regression in column (1) is positive, with a sizable effect of 1.8 percentage points of increased maternal trauma. With the mean complication rate of the control group in the sample being roughly 20 percent, the probability increase of 1.8 percentage points corresponds to a 10 percentage increase in the complication rate, compared to control group rates. The models in (2) and (3) support the findings of the main regression as they do not differ from it greatly.

When decomposing the maternal complications into smaller parts, it is seen the increased complications are mainly from the less severe types of complications, which include haemorrhage. The haemorrhage variable shows an increase of 1.0 percentage points, corresponding to almost a 25 percent increase in the amount of complications compared to the mean complications rate in control areas.

The changes in the laceration variable in my model are very small and insignificant. The outcome of other trauma is very small, but significant. Furthermore, when trends are removed from the model, the coefficient becomes insignificant and also changes sign. Therefore, the results can be considered somewhat unreliable and should not be used for any generalizations.

In addition to the results of the estimations of the net effect of closures, the table also indicates the results for treatment group specific estimations. These are shown in column (4) for closure areas and column (5) for inflow areas. The main finding is, that the results are similar within the groups for the different health outcomes.

The coefficients for closure areas are negative, which indicates a lower probability of complications and improved health outcomes. However, none of the results are significant. The coefficients of inflow areas are positive, which indicates a higher probability of complications and worsened health outcomes. The coefficient for the maternal complications in inflow areas is significant at 90%-CI.

Table 5: Estimated impacts of maternity ward closures on maternal health

	Closure and Inflow			Closure	Inflow
	Main	No trends	Logit		
	(1)	(2)	(3)	(4)	(5)
Maternal complications	0.018***	0.017***	0.090***	-0.050	0.038*
	(0.001)	(0.021)	(0.009)	(0.030)	(0.019)
Haemorrhage	0.010***	0.014***	0.244***	-0.004	0.008
	(0.001)	(0.011)	(0.026)	(0.014)	(0.008)
Lacerations	-0.002	0.004	-0.175***	-0.036	0.019
	(0.001)	(0.013)	(0.037)	(0.045)	(0.029)
Other trauma	0.003***	-0.001	0.353***	0.002	0.001
	(0.000)	(0.002)	(0.010)	(0.001)	(0.001)
Time trends	✓		✓	✓	✓
Observations	438 972	438 972	438 972	236 947	202 025

NOTE. *p<0.1 **p<0.05 ***p<0.01.

As mentioned before, the outcomes are binary and should also be assessed more carefully through the logit regression. Table 6 shows the dy/dx factors for the logit regressions of different maternal health outcomes. The factors indicate the discrete change from the base level, which in this case is the DiD term. They can be thus interpreted as the change in probability of the complications, when the mother is being affected by closures. In the logit model, all the net effects (closure and inflow) are significant. The effects on maternal complications are more modest than in the OLS model, but they are same in direction. In addition, they are all statistically significant, unlike in the OLS regression, where only the net effect and the effects in inflow areas were significant to some degree. The margins for haemorrhage, lacerations and other trauma are also similar to those in the OLS model.

The results in Tables 5 and 6 of the closure and inflow estimations provide more information about the possible mechanisms affecting the health outcomes. As Figure 6 indicated, closure wards had much fewer average yearly birth and were small in size. Mothers moving to give births in larger wards may benefit from the better learning-by-doing in the remaining inflow wards. At the same time, they must travel slightly longer distances to the ward. Since the overall effect on the closure areas

Table 6: Estimated discrete effects from logit model for effect of maternity ward closures on maternal health

	Dy/dx margins		
	Closure & Inflow	Closure	Inflow
Maternal complications	0.012***	-0.025**	0.022**
	(0.001)	(0.009)	(0.007)
Observations	548 495	547 623	547 623
Haemorrhage	0.009***	-0.007	0.009
	(0.001)	(0.010)	(0.007)
Observations	545 355	544 485	544 485
Lacerations	-0.005***	0.004	-0.005
	(0.001)	(0.007)	(0.004)
Observations	546 093	545 224	545 224
Other trauma	0.003***	0.002	0.001
	(0.000)	(0.002)	(0.001)
Observations	539 013	537 254	537 254
Time trends	✓	✓	✓

NOTE. *p<0.1 **p<0.05 ***p<0.01.

is negative, indicating less complications, it is likely the effect of distance is very small and insignificant. Similarly, the increased probability of complications in inflow wards can indicate there are congestion effects. According to the results presented here, they may be sizeable. Overall, the net effect of increased probability of maternal complications is driven by the increased probability of complications in inflow areas.

5.2 Parallel trends assumption

For the DiD model to produce valid results, the underlying trends should be similar. The identifying assumption is that the treatment results in a deviation from the trend, which is similar in both the control and treatment groups before treatment. (Angrist & Pischke 2009) To observe the yearly dynamics and possible pre-trends, I look at the dynamics of the effect of closures both three years prior and after the treatments in closure and inflow areas. This estimation allows for observing treatment effects separately for each year both before and after the closure. Figure 8 shows the event studies for the second-stage regression of maternal complications, haemorrhage and lacerations in closure and inflow areas. The models used adjust for the local area fixed effects, year fixed effects and regional linear trends as well as the maternal characteristics. Errors are clustered at the hospital district level. The coefficients have been indexed on the year prior to the closure.

In an ideal case indicating no pre-trends, all the years before the closure would be insignificant. In the case of maternal complications in closure areas, we already know from the regression results, that the effects were not significant. The yearly dynamics make it clearer. The year after the closure, there is an insignificant drop downwards, followed by a significant increase in the second year. Furthermore, the third year before closure seems to exhibit a statistically significant coefficient. The pre-closure coefficients in closure areas do, however, look similar to those in inflow areas. In the inflow areas, there seem to be no pre-trends and after the closure, there is an increase in the probability of maternal complications, that is statistically significant. The effect evens out in the second year, but is then followed by significant increases. It is hard to estimate what could cause such a drop. A possible, but completely hypothetical, explanation could be the worsened outcomes have been noticed in the ward and acted upon temporarily.

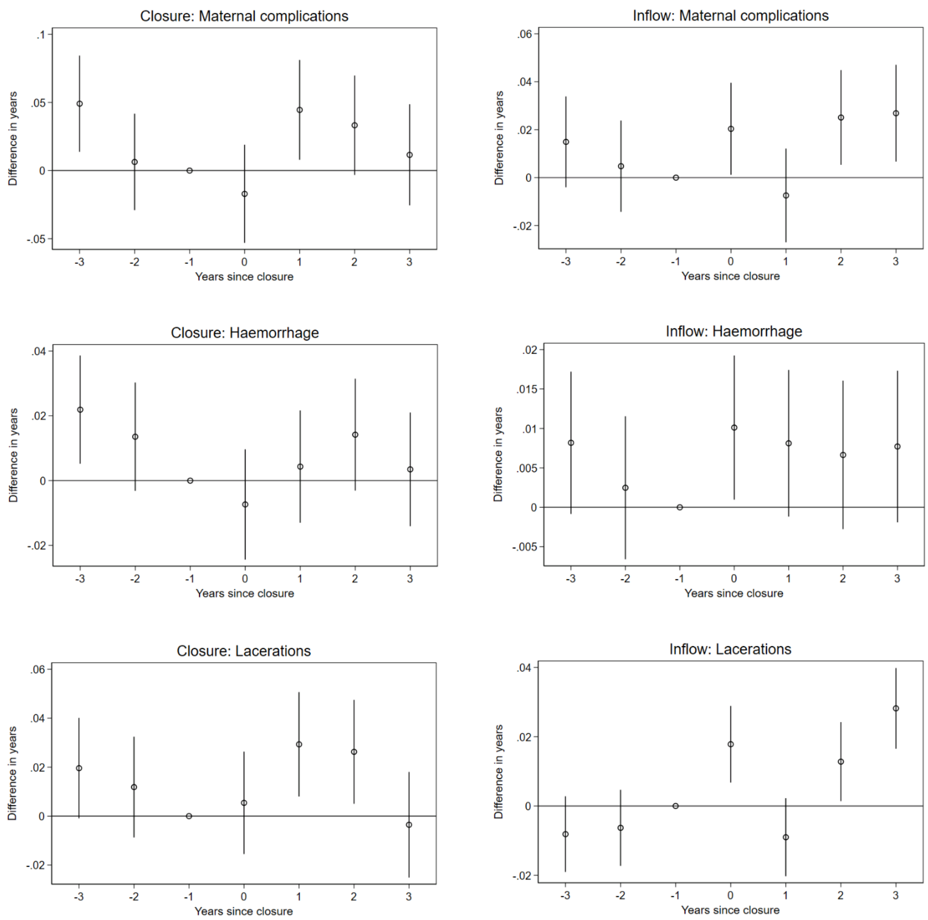

Figure 8: Event studies of maternity ward closures on maternal health

For haemorrhage, the results are and show similar types of problems as the maternal complications estimates. For closure areas, there tends to be an insignificant drop, after which the probabilities grow. These dynamics are insignificant. In the inflow areas, there is a significant increase in the closure year and the level tends to be higher in post-years.

With lacerations, the pre-trend assumption seems to be violated. Closure areas and inflow areas display opposites types of coefficients for closure and inflow areas. Furthermore, there seems to be very large difference between the yearly coefficients.

Essentially, we learn two things from the figures. Firstly, it seems the dynamics of the effects vary between indicators. This is not necessarily a sign of faulty modelling, as it may well be the effects only realize into health outcomes after some time has passed after the closure. It could be explained by for example temporary higher staffing. Second, there are some significant coefficients prior to the closure years, which raises some concern for existing pre-trends. For the main health indicators, we can conclude the parallel trends assumption to hold for most part.

To understand better whether there are significant time trends before the closures, I regress maternal complications on time in event studies. These results can be found in Appendix F.3. The control areas do not show strong signs of pre-trends, but in some of the regressions, the closure and inflow areas display significant pre-trends. By a strict definition, the results of the study should therefore not be interpreted as causal.

5.3 Mechanisms

Avdic et al. (2018) include a discussion of the mechanisms driving the changes in maternal health. As discussed, there are several channels through which the closures may affect health. In this section, I study the effects of congestion and the effects of increased distance. These two drivers are derived from the analysis in Section 5, where Figure 7 showed the closure increased the average distance to ward for mothers in closure areas and Figure 6 showed the mothers residing in closure areas gave birth in larger wards after the closures.

Distance to the ward should be studied, as it is a common topic of discussion related to health care unit closures. Increased distance is often being single-handedly attributed as a significant factor for worsened health, although evidence from studies is not unanimous. Furthermore, it is often being referred to as a contributor to more BBA births and unplanned out-of-hospital births. From Figure 3 with the yearly BBA births as well as unplanned and planned hospital births, we have already concluded those births have increased to some extent, but still remain on a very low level overall. The following regressions and figures do not study the effects of out-of-hospital births.

Table 7 shows the estimated impact of distance to the maternity ward on maternal health. The sample includes only mothers from closure areas, using the variation of their locations within the closure area. The measure of distance is used as a continuous independent variable and a categorical variable in the regression model. The outcome variable used, in this case, is the overall measure of maternal complications introduced earlier in Section 4.2.1. The regression includes hospital and time fixed effects as well as area fixed effects, which are used to account for differences in mothers in different areas as well as differences between the wards. The results are displayed on the overall level and with the mothers divided into bins based on the distance. None of the results

Table 7: Estimated impact of distance to ward on maternal health

	Maternal trauma
Distance (km)	-0.00006
	(0.00013)
Distance in categories	
10-40 km	-0.012
	(0.007)
41-70 km	0.008
	(0.015)
70+ km	-0.018
	(0.017)
Time trends	✓
Observations	236 947

NOTE. *p<0.1 **p<0.05 ***p<0.01.

are significant. The complete regression results (excluding dummies) can be found in Appendix F.2.

The finding of distance not having an effect on maternal complications is important, because it may partially explain why the earlier model indicated the closure areas may have benefited from the closures through improved health outcomes. However, as the regression coefficients shown in Table 5 were not significant for closure areas, estimating the effect of distance is mostly for descriptive purposes. In addition, as mentioned before, the distance measures are geodesic. They do not measure travel time, which could be a more accurate measure.

Congestion or crowding effects are another possible driver of the changes in health outcomes. Avdic et al. (2018) study the caseloads and the staffing of the inflow wards to study the number of births per midwife. For I do not have data about the staffing in the hospitals, I cannot study the effects in a similar setting. I therefore have chosen to describe the effects through the number of women giving birth on the same day before and after closures. These results should be taken as descriptive evidence rather than any type of definitive answer.

Figure 9 plots the average daily births in inflow wards in the year prior to the closure and the year of the closure. It seems as the daily averages are slightly higher in the post-closure graph than the pre-closure graph. This could hint of more crowding in the wards. However, without knowing the ratios of staff and births, it is difficult to comment on whether these factors actually transpire into real health effects. For example, in the pre- and post-closure groups, one can observe the average length of stay and the average length of stay after childbirth have slightly decreased from the pre-closure year to the post-closure year.

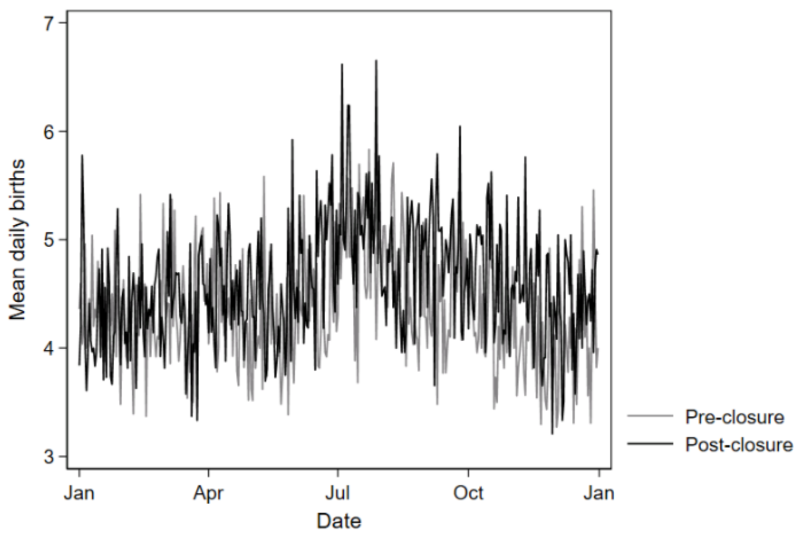

Figure 9: Daily births one year prior and after closures in inflow wards

This may suggest that even though there are more daily births, the patients stay at the ward for shorter times, which decreases the congestion effect. Therefore making any consistent conclusions regarding the magnitude or perhaps even the direction of crowding effects is not possible from this data.

6 Conclusion

The objective of this thesis study was to estimate the effects of maternity ward closures on maternal health in Finland. The research question stems from the fact there have been multiple maternity ward closures in Finland between 1987-2017. In addition, a study by Avdic et al. (2018) has found closures to affect maternal health outcomes related to maternal complications in Sweden.

This study studied the effects of the closures that took place between 2004-2017 with the maternal health outcomes being an overall measure of maternal trauma, haemorrhage, lacerations and other trauma. The data used for the analysis combined data from the Medical Birth Register, FLEED and FOLK data sets and the PAAVO data set. The empirical part of the thesis study is a replicate of Avdic et al. (2018).

The empirical method used was a difference-in-difference setting with multiple treatment periods and multiple treatment groups. More specifically, the treatment groups were divided between closure areas and inflow areas. The closures occurred in different years, which caused there to be multiple time periods. The regressions were run with an OLS model including fixed effects and linear time effects. In addition, there were robustness checks with the same model without time trends and a logit regression, for the maternal trauma is a binary outcome, that is relatively rare. The analysis included a model measuring the net effect of health changes in the affected areas (closure and inflow) together as well as separate models for assessing the effects separately in closure and inflow areas. The common trends assumption was tested for closure and inflow areas with the different health outcomes used. For the main health indicators, the results seemed to mostly comply with the parallel trends assumption, but there were some unparallel pre-trends present in the data. By strict definition, this prevents from interpreting the results causally.

The results of the study are aligned with previous research and theory. In my study, the probability of maternal complications was observed to increase by 1.8 percentage points, which adds to roughly a 10 percent increase in the amount of complications, when compared to the mean rate of complications in the sample control group. The result is considerably large and also similar to the result of Avdic et al. (2018), who found the probability of maternal trauma to increase 2.0 percentage points, corresponding to a 30 percent increase in the amount of trauma. I also found significant effects for haemorrhage, but no significant effects for the lacerations Avdic et al. (2018) too studied.

The margins from the logit regression also gave very similar results to those of the main OLS estimations. In the logit results, the discrete effects were significant for all the complication outcomes in the baseline level (closure and inflow areas). The main indicator for maternal complications was significant also for the separate closure and inflow estimations.

The findings in the closure and inflow area estimations of both my OLS and logit models contradict the findings of Avdic et al. (2018) slightly, but are still explainable within the same framework. Avdic et al. find positive coefficients for both areas in their main trauma estimator. The closure area exhibits a very small and insignificant increase of 0.1 percentage points, where as the inflow areas exhibit a larger and significant increase of 2.0 percentage points in their study. In my study, the closure coefficient is negative and the inflow coefficient positive. The changes in the inflow areas were significant.

I also shortly studied the effects of distance and congestion. Similar to what Avdic et al. (2018) found, there were no significant effects for the whole sample or the binned samples regarding the distance. The data showed some mild evidence of possible increases in congestion. However, it could not be studied further due to lack of data. Avdic et al. (2018) found evidence of increased crowding in the inflow wards after closures.

In spite of the results from my model being statistically significant, one should be careful when making generalizations from the data. In event studies, there was evidence of possible pre-trends, which prevents the results from being interpreted as causal. Although the model is built to give generalizable results, it should be kept in mind, the analysis was conducted with a sample of the whole population. Comparing the descriptive statistics in Table 4 and Appendix D indicates the sample is somewhat representative of the population, but there are differences in the rate of complications. Namely, the complications seem to be more commonplace in the sample.

The study gives way to many other interesting lines of research. Whereas this study was aimed at studying the net changes in health resulting from closures, another important question is also whether there were changes in how the care being provided was targeted. Currie and MacLeod (2017) have developed an index for the risk of C-section consisting of various medical risks. With this index, one could study with a propensity score estimator how many patients predicted to be in the risk group actually received a C-section. The risk index can be compared to the actual sections before and after the closures, similar to what also Avdic et al. (2018) have done in their paper.

Avdic et al. (2018) also study the effects of the closures on child health, although find nothing significant. The reason analysis on the effects of the closures on child health is important is, that several studies have concluded the in utero and neonatal health interventions have effects in the short- and long-term. These outcomes include for example health and education (see e.g. Currie & Almond 2011; Almond & Currie 2011; Almond & Doyle 2011; Currie & Rossin-Slater 2015). The importance of neonatal care is recognized by policymakers as well. The Ministry of Social Affairs and Health (2014, 25) states mistakes in care of a fetus or newborn will have persisting effects on the whole lifespan of the child. The Medical Birth Register has a rigorous set of variables on child health, which makes it very suitable for this type of analysis. Other Finnish data sets, including the FOLK and FLEED, would also allow for a research study on the long-term effects of closures on child health. The children from the Birth Register could be easily paired with data on their education and employment as adults for the earliest closures. In addition, if the Birth Register was paired with the Inpatient Care Register and the Outpatient Care Register, the long-term health outcomes could be studied.

Finally, as the closures are almost always associated with the intent to lower health care expenditure, one could try to quantify the changes in health in monetary terms and compare them to the actual savings. This could be done through simple cost-benefit analysis. This line of research was not pursued in this thesis, because ready estimates of the effects of closures on maternal health did not previously exist for the Finnish institutional setting. For communicating the results to policy-makers, a cost-benefit analysis may be useful.

It is easy to quantify the monetary savings generated by health care unit closures. While harder to quantify, the quality effects may also have important implications. As Avdic et al. (2018) note, understanding the real effects of organizational changes is important especially because they may affect efficiency. For policy, understanding the potentially unrealized gains or losses in health is important. These gains may be realized without costly investments, which should be noted in times of expanding health care costs.

As the results indicate the closures may have negative overall effects on maternal health, there are essentially two questions policy-makers need to consider. Firstly, if closures induce savings, but also result in worse health, what is the amount of health we are willing to give up to save in expenses? Secondly, the effects of the closures seem to distribute very differently on the areas affected by them. If there are major improvements in some areas, will they be enough to justify the worsened outcomes elsewhere? Are all areas treated equally or is the well-being of individuals in one region preferred over another? These are not simple questions to answer, which is why further work on the topic is called for.

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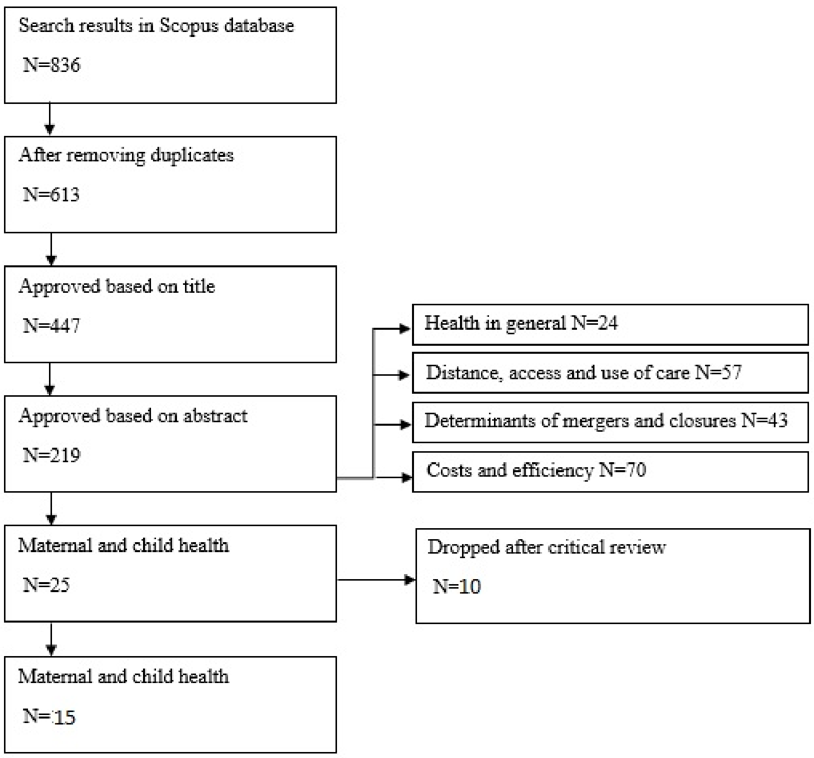
A Literature review search strategy



B Literature review summary

Authors	Study design	Objective	Intervention	Outcome	Results	Comments
Avdic et al. 2018	Retrospective cross-sectional study with register data. Difference-in-difference.	Assessing whether ward closures affected mothers who gave birth and their children in Sweden.	Maternity ward closures	Lacerations, obstetric trauma	Closures affected mothers negatively, mainly because of crowding effects in remaining wards. Effects on infants were insignificant.	Assumes women are automatically assigned to closest ward and that closures don't affect fertility patterns or composition of mothers giving birth.
Kozhimannil et al. 2018	Retrospective cohort study with birth certificate and survey data. County-level regression models with an annual interrupted time series approach.	To assess the relationship between loss of obstetric services and birth outcomes in rural US counties.	Loss of hospital-based obstetrical services	Rates of out-of-hospital births, birth in hospitals without obstetric services, preterm births	Rural counties nonadjacent to urban areas had increases in all the health outcomes considered.	Health measures were not on an individual level. Counties may differ in size and distribution of residents.

Pearson et al. 2018)	Retrospective cross-sectional study with quantitative and qualitative survey data. Generalized estimating equations.	Assessing whether changes in obstetric care affected mental health and birth experience of mothers giving birth in the US	Closures of obstetrical units	Birth experience, expectations, anxiety	Birth experiences remained positive or extremely positive, but anxiety about getting to the hospital increased.	Dependent variables are not objective.
Nethery et al. 2018	Retrospective cross-sectional study with register data for low-risk women. Multivariable logistic regression.	Assessing whether a limited access to obstetric care affected maternal and neonatal outcomes in the US	Limited access to care due to living in rural area	Mode of delivery, blood transfusions, severe events, lacerations	Among the sample of low-risk women, there was not a significant increased risk determined by rural versus nonrural status.	Births in rural area may be home births due to not only access, but cultural or religious reasons, which should be considered in the analysis.
Powell et al. 2018	Retrospective cross-sectional study with register data. Comparison of differently affected counties without controls.	To assess if closure of obstetrics units had implications on access to care and health indicators of the infant in Alabama.	Closure of obstetric units	Access to prenatal care	Closure of the maternal care units coincided with an over 50 percent increase in the infant mortality rate(IMR)	The study cannot be used to make conclusions about causality due to the lack of controls of factors affecting the IMR.

Hamlin 2018	Retrospective cross-sectional study with birth certificate data. Before-and-after study.	To see whether closures of inpatient obstetric units affected perinatal outcomes in New Hampshire in the US.	Closure of inpatient obstetric units	Prenatal care visits, birth weight, gestational age	There were no changes in perinatal outcomes due to closure of obstetric units.	The study did not include analysis on where the care providers were located or how many of them there were.
Hutcheon et al. 2017	Retrospective cross-sectional study with Perinatal Data Registry. Fixed effects framework.	Assessing whether reduced obstetric services in British Columbia, Canada influenced labor and delivery outcomes of women.	WService closures of obstetric care in smaller hospitals	Composite measure of labor and delivery safety, maternal or newborn transfer, use of obstetric interventions.	Closures were not associated with an increase or decrease in the frequencies of severe events in the delivery.	Causal conclusions based on FE within communities may be difficult. Some of the severe outcomes were rare, which is likely to make detecting real changes more difficult.

Kildea et al. 2015	Retrospective study with perinatal data. Linear regression.	Assessing whether closure of maternity units in Queensland and Australia has increased number of babies born before arrival (BBA), often associated with increased risks.	Closures of maternity units	BBA rate	Closures of units were significantly associated with increased BBA rates	The study assumes all out of hospital births are BBA births and there are no voluntary home births. This is likely to induce bias.
Grytten et al. 2014)	Retrospective study with perinatal registry data. Propensity score weighing (PSW), difference-in-difference.	Assessing whether the type of hospital had implications for neonatal and infant mortality. The study is from Norway.	Limited access to care in different types of hospitals	Neonatal and infant mortality	Neonatal or infant mortality were not affected by the types of hospitals.	Using PSW includes a risk of choosing correct risk factors: omitted risk factors affecting health and the "choice" of the hospital can cause bias.

Poeran et al. 2014	Retrospective study with cohort data. Multilevel logistic regression model.	To assess if centralization of acute obstetric care had implications on infant health in the Netherlands.	Closure of hospitals with obstetric care (i.e. centralization of services)	Intrapartum and neonatal mortality	Closure of 10 smallest hospitals increased mortality. Closure of 10 smallest, non-adjacent hospitals did not increase mortality as much.	Some important maternal health controls like smoking were not present in the data. Study also assumes no changes in performance or operations of hospitals after centralization.
Combier et al. 2013	Retrospective cross-sectional study with register data. Hierarchical logistic regression.	To see whether maternity unit closures in France increased travel time for pregnant mothers, often associated with increased risks.	Maternity unit closures	Stillbirths, fetal heartrate abnormalities, meconium-stained amniotic fluid, hospitalization during or before pregnancy	A positive, non-significant gradient existed between increased distance because of the closures and perinatal mortality.	Risk births are likely to be recognized before giving birth in controls, which may reduce complications for mothers travelling long distances.

Lorch et al. 2013	Retrospective before-and-after study with birth and death certificate data combined with maternal and neonatal hospital discharge records.	Observe association between obstetric unit closures and maternal and infant health in Philadelphia in the US.	Obstetric unit closures	Neonatal mortality, perinatal mortality	The neonatal mortality and perinatal mortality increased compared to the control groups. The effects, however, evened out over time.	Study did not address why units were closed, which may reveal more about possible differences between control and treatment groups.
Grzybowski et al. 2011	Retrospective study with maternal and newborn data and geographic catchment data. Hierarchical logistic regression.	Assessing whether closures of small maternity services in British Columbia, Canada affected travel to care and thus also newborn and maternal outcomes.	Closures of small maternity services	Mother: Induction of labor, c-sections, unplanned deliveries. Child: Perinatal mortality, prematurity, admission to ICU.	Women who had to travel longer distances to maternity services had higher rates of adverse perinatal outcomes. Newborns had more NICU treatments of 2 and 3 days.	Study did not include data on ethnicity or socio-economic status due to privacy constraints. British Columbia is home to aboriginals and not controlling for ethnicity is likely a problem.

Sontheimer et al. 2008	A retrospective cross-sectional study with quantitative register data.	2-sided significance testing.	Assessing whether closed services affected baby weight in rural Missouri in the US.	Closures of local obstetrical services. Frequency of low birth weight in infants	There was an increase in LBW births and no effects on live births or VLBW infants.	Study lacked proper statistical methods and analysis and was a case study with nongeneralizable results.
Merlo et al. 2005	Retrospective cross-sectional study with data from the Swedish Birth Register.	Risk-stratified multilevel logistic regression. To assess the effects of regionalization and centralization of neonatal services in Sweden on low-risk delivery outcomes.	Centralization and regionalization of obstetric services	Mother: multiple births, pregnancy complications Child: Neonatal mortality, mortality risk score, gestational age, weight	In low-risk births, the mortality rates decreased with better access to care.	The results between the different risk groups were large between different types of hospitals, but rather small on interhospital level.

C Variables in Medical Birth Register

Table 9: Data content of mothers, in **bold** data content added in 2017 (National Institute for Health and Welfare 2017)

Type	Content
Personal data	Personal identity code, **surname** and **forenames**, profession, municipality of residence, nationality, marital status, cohabiting
Previous episodes	Previous pregnancies (miscarriages, abortions, ectopic pregnancies), previous deliveries (live and stillbirths)
Present pregnancy and monitoring	Check-ups during pregnancy, date of first check-up visit, mother's weight and height before pregnancy, mother's smoking habits during pregnancy, **regular use of folic acid before week 12 of pregnancy**, various variables of **infertility treatments in current pregnancy**, **prenatal defect screening and follow-ups**, various **results of screenings**, **screening of infectious diseases**, **screening for Group B Streptococcus**, risk factors and interventions relating to pregnancy (**circumcision, additional diabetes care**), diseases during pregnancy, hospital care during pregnancy
Delivery	Maternity hospital, place of birth, best estimate of gestational age at the time of delivery, onset of last period, **date of rupture of amniotic membrane (water breaking)**, duration of delivery (**length of stages**), method of delivery, pain relief in labour (**use of intravenous patient-controlled analgesia, no pain relief and info missing**), other procedures relating to delivery (**puncturing of the amniotic sac, oxitocyn, prostaglandin, Foley bulb for starting and availment, blood sample, lactate evaluation, GBS-profylaxis, ST analysis, prescribed antibiotics, hysterectomy, embolisation**), **estimate of bleeding in millilitres**, diagnoses relating to pregnancy and delivery, mother's diagnoses during delivery

D Descriptive statistics

Table 10: Descriptive statistics of population

Maternal characteristics	
Age	29.35
Married (%)	66.4
High school degree (%)	47.97
Taxable income	10926
Finnish or Swedish speaking (%)	94.85
Overweight (%)	14.3
Obese (%)	5.16
Smoker (%)	15.03
Diabetes (%)	0.28
General care specific indicators	
Distance to ward	38.14
Length of visit	4.35
Length of visit after delivery	3.58
Pregnancy-related visits	15.91
Visits to maternity polyclinic	2.99
Pregnancy and delivery specific characteristics	
First-timers (%)	40.78
Earlier births	1.05
Miscarriages (%)	20.57
Earlier pregnancies	1.51
Miscarriages	0.27
Abortions	0.13
Ectopic pregnancies	0.02
Caesarean sections	0.09
Young mother (under 18) (%)	1.12
Old mother (over 35) (%)	17.41
Diabetes in pregnancy (%)	3.25
Anemia (%)	1.3
Care for risk of prematurity (%)	2.22
Care for high blood pressure (%)	2.82
Placenta praevia (%)	0.25
Long labour (%)	2.05
Maternal outcomes	
Maternal complications	7.61
Bleeding	1.71
Lacerations	1.65
Other trauma (%)	0.36
Number of births	**1 830 070**

E Outcome tests

Table 11: T-test with unequal variances (Control & Closures, total)

H0: diff = 0			
Group	Observations	Mean	Std.error
Control	111 090	0.195	0.001
Closure	236 947	0.148	0.001
Combined	348 037	0.163	0.001
Difference		0.048	0.001
			t=34.69

Table 12: T-test with unequal variances (Control & Closures, before treatment)

H0: diff = 0			
Group	Observations	Mean	Std.error
Control	34 167	0.169	0.002
Closure	69 484	0.125	0.001
Combined	103 651	0.140	0.001
Difference		0.044	0.002
			t=18.60

Table 13: T-test with unequal variances (Control & Closures, after treatment)

H0: diff = 0			
Group	Observations	Mean	Std.error
Control	40 275	0.219	0.002
Closure	82 219	0.167	0.001
Combined	122 494	0.183	0.001
Difference		0.052	0.002
			t=21.51

Table 14: T-test with unequal variances (Control & Inflow, total)

H0: diff = 0			
Group	Observations	Mean	Std.error
Control	74 442	0.196	0.001
Inflow	118 352	0.192	0.001
Combined	192 794	0.194	0.001
Difference		0.004	0.002
			t=1.9115

Table 15: T-test with unequal variances (Control & Inflow, before treatment)

H0: diff = 0			
Group	Observations	Mean	Std.error
Control	34 167	0.169	0.002
Inflow	60 257	0.177	0.002
Combined	94 424	0.174	0.001
Difference		-0.008	0.003
			t=-3.09

Table 16: T-test with unequal variances (Control & Inflow, after treatment)

H0: diff = 0			
Group	Observations	Mean	Std.error
Control	40 275	0.219	0.002
Inflow	58 095	0.208	0.002
Combined	98 370	0.212	0.001
Difference		0.010	0.003
			t=3.90

F Regression results

F.1 Maternal health

$$Maternalcomplications = time + class + time * class +$$
$$areaFE + timeFE + timetrends +$$
$$maternalcontrols + \epsilon$$

Table 17: Estimates of maternal complications without FE and time trends estimates

	Closure and inflow			Closure	Inflow
	Main	No trends	Logit	Main	Main
	(1)	(2)	(3)	(4)	(5)
time	-0.009*	0.047**	-0.042	0.012**	-0.019
	(0.005)	(0.020)	(0.034)	(0.004)	(0.015)
class	-0.086***	0.005	-0.477***	0.111***	-0.104***
	(0.002)	(0.022)	(0.011)	(0.015)	(0.009)
did	0.018***	0.017***	0.090***	-0.050	0.038*
	(0.001)	(0.021)	(0.009)	(0.030)	(0.019)
age	-0.001***	-0.001**	-0.005***	-0.001***	-0.001***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
maritalstatus	-0.029***	-0.036***	-0.218***	-0.028***	-0.029***
	(0.002)	(0.005)	(0.025)	(0.002)	(0.002)
income	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
language	-0.031***	-0.062***	-0.224***	-0.031***	-0.031***
	(0.005)	(0.013)	(0.049)	(0.005)	(0.005)
obesity	0.023***	0.023***	0.171***	0.023***	0.023***
	(0.003)	(0.003)	(0.022)	(0.003)	(0.003)
diabetes	-0.015*	-0.009	-0.115**	-0.015*	-0.015*
	(0.008)	(0.008)	(0.055)	(0.008)	(0.008)
smoking	-0.010***	-0.008***	-0.075***	-0.009***	-0.009***
	(0.002)	(0.003)	(0.014)	(0.002)	(0.002)
Time trends	✓		✓	✓	✓
Observations	438 972	438 972	438 972	236 947	202 025

$$Haemorrhage = time + class + time * class +$$
$$areaFE + timeFE + timetrends +$$
$$maternalcontrols + \epsilon$$

Table 18: Estimates of haemorrhage without FE and time trends estimates

	Closure and inflow			Closure	Inflow
	Main	No trends	Logit	Main	Main
	(1)	(2)	(3)	(4)	(5)
time	-0.010***	0.008***	-0.266***	-0.002	-0.008
	(0.003)	(0.002)	(0.100)	(0.005)	(0.009)
class	-0.034***	0.000	-0.736***	-0.039***	0.037***
	(0.000)	(0.004)	(0.010)	(0.006)	(0.004)
did	0.010***	0.014***	0.244***	-0.004	0.008
	(0.001)	(0.011)	(0.026)	(0.014)	(0.008)
age	0.000***	0.001***	0.014***	0.000***	0.000***
	(0.000)	(0.000)	(0.003)	(0.000)	(0.000)
maritalstatus	0	-0.001	0.004	0	0
	(0.000)	(0.001)	(0.014)	(0.000)	(0.000)
income	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
language	0	-0.007**	-0.007	0	0
	(0.001)	(0.003)	(0.019)	(0.001)	(0.001)
obesity	0.001	0.001	0.02	0.001	0.001
	(0.001)	(0.001)	(0.024)	(0.001)	(0.001)
diabetes	-0.015***	-0.014***	-0.488***	-0.015***	-0.015***
	(0.005)	(0.005)	(0.126)	(0.005)	(0.005)
smoking	-0.003**	-0.003**	-0.098***	-0.003**	-0.003**
	(0.001)	(0.001)	(0.027)	(0.001)	(0.001)
Time trends	✓		✓	✓	✓
Observations	438 972	438 972	438 972	236 947	202 025

$$
\begin{gathered}
Lacerations = time + class + time * class + \\
areaFE + timeFE + timetrends + \\
maternalcontrols + \epsilon
\end{gathered}
$$

Table 19: Estimates of lacerations without FE and time trends estimates

	Closure and inflow			Closure	Inflow
	Main	No trends	Logit	Main	Main
	(1)	(2)	(3)	(4)	(5)
time	-0.010***	0.008***	-0.266***	-0.002	-0.008
	(0.003)	(0.002)	(0.100)	(0.005)	(0.009)
class	-0.034***	0.000	-0.736***	-0.039***	0.037***
	(0.000)	(0.004)	(0.010)	(0.006)	(0.004)
did	0.010***	0.014***	0.244***	-0.004	0.008
	(0.001)	(0.011)	(0.026)	(0.014)	(0.008)
age	0.000***	0.001***	0.014***	0.000***	0.000***
	(0.000)	(0.000)	(0.003)	(0.000)	(0.000)
maritalstatus	0	-0.001	0.004	0	0
	(0.000)	(0.001)	(0.014)	(0.000)	(0.000)
income	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
language	0	-0.007**	-0.007	0	0
	(0.001)	(0.003)	(0.019)	(0.001)	(0.001)
obesity	0.001	0.001	0.02	0.001	0.001
	(0.001)	(0.001)	(0.024)	(0.001)	(0.001)
diabetes	-0.015***	-0.014***	-0.488***	-0.015***	-0.015***
	(0.005)	(0.005)	(0.126)	(0.005)	(0.005)
smoking	-0.003**	-0.003**	-0.098***	-0.003**	-0.003**
	(0.001)	(0.001)	(0.027)	(0.001)	(0.001)
Time trends	✓		✓	✓	✓
Observations	438 972	438 972	438 972	236 947	202 025

$$Othercomplications = time + class + time * class + areaFE + timeFE + timetrends + maternalcontrols + \epsilon$$

Table 20: Estimates of other complications without FE and time trends estimates

	Closure and inflow			Closure	Inflow
	Main	No trends	Logit	Main	Main
	(1)	(2)	(3)	(4)	(5)
time	-0.002**	0.004**	-0.155***	0.001	0.000
	(0.001)	(0.002)	(0.056)	(0.000)	(0.001)
class	-0.014***	0.003	-1.616***	-0.007***	0.006***
	(0.000)	(0.002)	(0.026)	(0.001)	(0.001)
did	0.003***	-0.001	0.353***	0.002	0.001
	(0.000)	(0.002)	(0.010)	(0.001)	(0.001)
age	-0.000*	-0.000*	-0.019***	-0.000*	-0.000*
	(0.000)	(0.000)	(0.007)	(0.000)	(0.000)
maritalstatus	-0.001***	-0.001**	-0.105***	-0.001***	-0.001***
	(0.000)	(0.000)	(0.022)	(0.000)	(0.000)
income	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
language	0.000	-0.001	0.052	0.000	0.000
	(0.000)	(0.001)	(0.064)	(0.000)	(0.000)
obesity	0.002***	0.002***	0.226***	0.002***	0.002***
	(0.001)	(0.001)	(0.039)	(0.001)	(0.001)
diabetes	-0.002**	-0.002**	-0.333***	-0.002**	-0.002**
	(0.001)	(0.001)	(0.107)	(0.001)	(0.001)
smoking	-0.001***	-0.001	-0.140***	-0.001***	-0.001***
	(0.000)	(0.000)	(0.040)	(0.000)	(0.000)
Time trends	✓		✓	✓	✓
Observations	438 972	438 972	438 972	236 947	202 025

F.2 Distance

$$Maternal complications = distance + \\ ward time trends + area FE + time trends + \\ maternal controls + \epsilon$$

Table 21: Estimated impact of distance to ward on maternal complications without FE and time trends

	Maternal health
distance	-0.00006
	(0.0001)
age	-0.001
	(0.001)
marital status	-0.028**
	(0.004)
income	0.000***
	(0.000)
language	-0.027**
	(0.007)
obesity	0.019**
	(0.003)
diabetes	-0.016
	(0.027)
smoking	-0.007
	(0.006)
Time trends	✓
Observations	236 947

$$Maternalcomplications = D * distance + \\ wardtimetrends + areaFE + timetrends + \\ maternalcontrols + \epsilon$$

Table 22: Estimated impact of distance in bins to ward on maternal complications without FE and time trends

	Maternal health
Distance in categories	
10-40 km	-0.012
	(0.007)
41-70 km	0.008
	(0.15)
70 km	-0.18
	(0.017)
Controls	
age	-0.001
	(0.000)
marital status	-0.028***
	(0.004)
income	0.000***
	(0.000)
language	-0.027**
	(0.007)
obesity	0.019**
	(0.003)
diabetes	-0.016
	(0.027)
smoking	-0.007
	(0.006)
Time trends	✓
Observations	236 947

F.3 Parallel trends

$$Maternal complications = year + areaFE + timeFE + timetrends + maternalcontrols + \epsilon$$

Table 23: Estimations of pre-closure trends by event studies

	Control	Closure	Inflow
Closure in 2008			
Time	0.015*	0.002	-0.004
	(0.006)	(0.004)	(0.008)
Observations	14 354	57 349	6 311
Closure in 2010			
Time	0.006	-0.008	0.033***
	(0.004)	(0.014)	(0.009)
Observations	34 292	3 827	6 634
Closure in 2012			
Time	0.003	0.047***	0.051***
	(0.009)	(0.010)	(0.008)
Observations	4 984	3 067	5 692
Closure in 2013			
Time	0.005	-0.003	0.007
	(0.009)	(0.003)	(0.005)
Observations	6 260	33 674	9 712
Closure in 2014			
Time	0.010*	-0.007	0.007
	(0.003)	(0.013)	(0.008)
Observations	31 777	18 031	38 733