Health Care Regionalization and Birth Outcomes: Evidence from Maternity Clinic Closures*

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Abstract

Concentrating health care resources creates a potential trade-off between increased productivity and decreased access. We study how mergers of Swedish maternity clinics in the 1990s affected the quality of maternal care received by mothers and newborns using register data on all births in Sweden over two decades. To account for endogenous sorting to clinics we exploit closures of maternity clinics, which generates exogenous variation in distance to and size of clinics. We find that closures affected the health of newborns positively but increased the risk of maternal trauma, suggesting that regionalization policies may cause a trade-off between infant and maternal health.

Keywords: Quality of care, regionalization, hospital closure, birth outcomes, maternal care

JEL Classifications: D24; I11; I18; J13; R41

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1 Introduction

Medical expenditures are high and increasing in many countries and how to organize health care more efficiently is a question of key importance. In public health care systems, one cost-control policy has been to merge hospitals and concentrate health care to a smaller number of (larger) hospitals. Such regionalization policies are often unpopular among the public but policy-makers commonly argue that it cut costs through scale economics while improving the quality of the care through learning-by-doing effects. Reduced access could in principle also affect patient outcomes negatively, and especially so for conditions that require immediate care, such as child births and heart attacks. However, despite the important policy implications, there is limited evidence on the effect of hospital mergers on patient outcomes.[1] This is partly due to selection problems arising from that patient groups exposed to a merger may differ in unobservable dimensions from those not exposed. Moreover, the patient composition at remaining hospitals is likely to change after a merger. To identify the causal effect of mergers it is important to adjust for such differences.

In this paper we provide new evidence on the health effects of hospital mergers in a publicly financed health care system. In particular we study the effect of a series of mergers of maternity ward clinics in Sweden on mothers' and babies' health outcomes. The mergers took place between 1990 and 2005 and was intended to cut costs and increase efficiency. The mergers was implemented by shutting down smaller clinics, leading to an increased regionalization of maternity clinics in Sweden. To study the effects of the mergers, we use rich administrative, individual-level data on the universe of births in Sweden. The data includes detailed information on birth outcomes, birth technologies, and maternal health outcomes. Moreover, the data allows us to construct measures of the case load at all maternity wards and the driving distance to the maternity clinics, allowing us to conduct detailed analyses on the role of congestion and distance when clinics merge.

Our empirical design helps us to overcome some of the empirical challenges mentioned above. First, the Swedish institutional context allows us to define clear treatment and control groups who were either exposed to a merger or not. We are able to do this because patients in Sweden are assigned to hospitals based on their geographical location and not by choice.

[1] We review the existing literature below.

We can then compare changes in outcomes between treatment and control groups, allowing us to difference out the influence of unobservable factors at the group level. Second, since we know the catchment area of each hospital, we can deal with changes in the patient composition by focusing our analysis on patients who resided in the same catchment area both before and after any merger. Third, we provide evidence in favor of our empirical strategy. In an event study analysis we show that the closures of clinics led to substantial increases in case load per clinic and average driving distance for those exposed to a closure there were no effects on the characteristics of those giving birth in terms of maternal age or in the number of births. In addition, we observe no pre-closure effects for any of the outcomes we study, including maternal and newborn health indicators, suggesting that areas that experienced a merger follow similar trends as the other areas.

Our detailed data allows us to perform different analyses in order to understand the effects of mergers of maternity wards on health outcomes of babies and mothers. Initially, we focus on the overall effect of a maternity ward closure, comparing changes in health outcomes of newborns and mothers in areas experiencing a merger to the corresponding changes in "control" regions where no merger took place. We then focus on effects for two subgroups. First, we focus on the women that experienced a closure of their ward. This group are affected in several ways. The distance to their nearest clinic increases as well as the case load at that clinic, but they also transfer to a larger ward of, presumably, higher quality than the old birth ward. Second, we focus on women who did not face a closure of their nearest birth clinic but who were exposed to an additional inflow of pregnant women from other areas in the same region where a closure of a birth clinic took place. This group of women face no change in the distance to or quality of their nearest birth clinic but face an increased case load at their ward. By analysing the two groups of women separately we are able to assess which women that gained and who lost from the mergers.

Our main findings are that mothers who were directly exposed to a closure were not worse off in terms of health and nor where their babies, suggesting that the positive effect of giving birth at a larger clinic instead of at a small rural ward cancels any negative effects from reduced access to due increased case load or distance. For the group who were indirectly affected by the closure we find negative effects on APGAR scores for newborns as well as a thirty percent increase in the risk of obstetric trauma among women giving birth. To the extent that the increased case load causes congestion and therefore affect mothers and newborns health outcomes negatively, this result pattern is expected. The overall net effect from the mergers is thus negative in terms of quality of care.

We also use additional data to study the mechanisms in more detail. To study congestion effects, we hypothesize that the increased case load led to an increased work load among the medical staff in the referral clinics. We find supporting evidence for this claim by adding information on the number of midwives employed in each maternity clinic over time to our analysis data. Specifically, our results confirm that the maternity clinic closures led to a substantial increase in the number of deliveries per midwife at the birth clinics. In other words, the clinics did not fully compensate for the increased birth case load by employing additional midwives. We also explore the impact of the distance to the maternity ward. To this end, we use geocoded data for each sampled individual's place of residence and information to the location of each maternity ward. We explore different distance measures, but find no effect of increased distance to the maternity ward.

As a final piece of the puzzle, we study whether the increased workload implied an increase in the probability of administering inappropriate treatments by comparing how sensitive treatments are to the patient's health history before and after the increased case load. To this end, we categorize mothers into different risk types and then examine which treatment mothers of similar risk, based on a large set of observable characteristics, were administered in inflow wards before and after the inflow of additional mothers. The results indicate that women whose appropriate treatment should have been a Cesarean section were much less likely to have this treatment after a nearby maternity ward was closed.

Our paper also relates to several strands of literature. A small literature has studied the effect of hospital closures in publicly finance health care system on the health of patients, using quasi-experimental designs, finding mixed results. Avdic (2016) estimates the effect of hospital closures in Sweden on deaths from heart attacks and finds that an increased distance following closures increases mortality. Similar findings have been obtained in Taiwan Shen and Hsia (2012). Avdic *et al.* (2014) report improvements in cancer surgery survival after closures of cancer surgery clinics. Gaynor *et al.* (2012) study hospital mergers in the UK but find no evidence that the mergers affected patient outcomes, however. Related to our study, Grytten *et al.* (2014) study the effect of local hospital closures in Norway and find no significant effects on neonatal and infant mortality.

Furthermore, our paper relates to the literature that studied the effect of mergers in competitive health care systems, such as in the U.S. Merger decisions in such contexts reflect private decisions by firms and affects the level of competition in the market. The results may therefore not be directly transferable to public health care systems. Most of the literature finds limited effects of the mergers on costs and prices (see, e.g., Dranove, David and Lindrooth, Richard, 2003; Harrison, 2011; Vogt and Town, 2006; Dafny, 2009). Joynt *et al.* (2015) report that hospital closures in the U.S. led to decreases in the use of inpatient care but did not affect mortality or hospitalization rates. Buchmueller *et al.* (2006) estimates the effect of hospital closures in Los Angeles county on deaths from heart attacks and injuries and finds that an increased distance following closures increase deaths, however. Lorch *et al.* (2013) studied the effect of obstetric unit closures on neonatal and perinatal mortality in Philadelphia and found short-term adverse effects that faded out over time.

At a more general level, our paper relates to the literature on disparities in health at birth. A recent literature highlights the long-term economic implications of such disparities (see, e.g., Heckman, 2007; Currie and Almond, 2011). Early life health interventions, such as improved prenatal and neonatal care, have shown effective in improving short and long-run outcomes (see, e.g., Almond *et al.*, 2010; Bharadwaj *et al.*, 2013). There is less evidence on how the organization of maternal care health in itself matters for early child and women health outcomes. Understanding the effect of organizational changes is important for policy, as an inefficient organization means that there are potentially unrealized gains in health that do not necessarily rely on investments in new and expensive technology.

The paper proceeds as follows. The next section describes our data. Section 3 describes the relevant institutional framework in Sweden. Section 4 outlines our empirical strategy and specification of our econometric model. Section 5 presents our main results from estimation together with some robustness checks. Section 6 analyzes the mechanisms of the estimated effects more in detail. Section 7 concludes.

2 Institutional background

The Swedish system of maternal and perinatal care is different to the system practiced in some other countries. In particular, planned home births are rare and almost all births takes place in one of the approximately 80 hospitals located around the country[2]. Birth deliveries, basic neonatal care and postnatal monitoring of mothers and newborns are performed in hospital maternal wards. If the delivery is carried out without complications, the mother and her newborn child are transferred to a post-natal ward (BB-avdelning) where hospital staff perform a health examination and assist with information on, for example, breastfeeding, before mother and child are allowed to return home (typically within a day).

A midwife typically assists the birth without the active involvement of a physician, unless a delivery is expected to involve significant complications or surgery. The midwife occupation in Sweden is, since the 1950's, a licensed nurse education with an orientation in reproductive and perinatal care. To become a midwife in Sweden, a prospect first has to complete a three year general post-secondary education and, after completing one year of vocational training, an additional 1.5 years specialist education. Provided that these qualifications are met, a certificate to practice midwifery can be obtained by submitting an application to the Swedish Board for Health and Welfare.

Prior to birth, pregnancies are continuously monitored through visits of the expecting mother to midwife clinics located in health care centers in each of the 290 municipalities of Sweden. The monitoring consists of a set of systematic health check-ups (medical examination, anamnesis, ultrasound etc.) at different stages of the pregnancy and complemented with information and consulting for both parents to prepare for the birth and parenthood. If potential complications or other types of risk births are detected, such as, e.g., preeclampsia, maternal diabetes or multiple births, the pregnant mother can be referred to a maternity clinic at a nearby hospital for specialist care to be examined by an obstetrician.

Swedish hospitals are owned, managed, and financed by the public sector which comprises three tiers; the national, the regional and the local level. The responsibility for health care, regulated by the Swedish Health Services Act (1982:763), generally takes place on the

[2] Lindgren *et al.* (2008) notes that from over 1.2 million births over the time period 1992–2004, only 1,600 births were planned home deliveries. The main reason is that home deliveries are neither recommended by health care authorities or covered by the public health insurance.

regional level. The regional county councils are the major financiers (via direct taxes raised from the residents) and providers of Swedish health care. There are 21 county councils in total, and each council is obliged by law to provide its residents with equal access to health services and quality of care. Each county council is free to set its own patient fees, which are typically low, but a national cap on co-payments limits the total amount that a patient has to pay out-of-pocket each calendar year.[3] As a consequence, patient fees account for only around three percent of total health care revenues. The county councils have, since the end of the 1990's, been allowed to contract with private providers in so-called purchaser-provider split (PPS) models, but most inpatient health care services, including birth deliveries, are still performed by public agents.

3 Empirical framework

3.1 Maternity clinic closures

During the 1990's and early 2000's, a wave of closures of maternity clinics swept over Sweden as a part of a general reorganization of the inpatient health care system and an alleged need to cut costs and increase efficiency. The reorganization was triggered by the economic crisis starting in 1991 and further reinforced by a new law that stipulated that counties were not allowed to run deficits in their annual budgets. These factors pressured the counties to explore new cost control strategies, including the transferring of many specialized services from, smaller, rural to, larger, regional hospitals. The hospitals in which the closing maternity clinics were located did not close entirely. Instead, they were typically reformed into health care centers providing medical services for common diseases and elective standardized treatments that require additional resources compared to a general practitioner. As a consequence, the number of maternity clinics in Sweden was reduced by around one-third over a period of 15 years (FFCC, 2002).[4] Figure 1 indicates geographically and over time the location and time pattern of the closures.

[3] In Stockholm, a visit to a doctor in primary care costs 200 SEK as of 2017 ($25)).

[4] We classify a clinic as closed if the yearly number of births at the hospital decreased by more than 90 percent during a single year. Applying this rule, we identify a total of 17 closures of maternity clinics between 1994 and 2004. To externally validate that the closures were not simply an artifact of incomplete data, we further complement this information with other closure sources such as official documents, media coverage and research reports.There were no new maternity clinics established during the studied time window.

[Figure 1 about here]

Closing a maternity clinic may theoretically impact maternal and neonatal health in several ways: First, a closure leads to an increase in the average clinic distance in the catchment area where a clinic closed since expecting mothers now have to resort to a clinic further away for giving birth. Particularly in cases when the onset of labor comes unexpectedly, longer travel times may increase riskiness of the delivery (see, e.g., Viisainen *et al.*, 1999).

Second, closing a maternity clinic implies that other nearby clinics must absorb patients initially assigned to the closed clinic and therefore should experience an increase their case load of births. This may impact the quality of care received by expecting mothers in a number of ways: The positive volume-outcome relationship in health care, where larger units typically perform better than smaller units, has been explored in detail by Halm *et al.* (2002), suggesting productivity channels such as learning-by-doing, specialization and economies of scale. Furthermore, one general reason for closing a maternity clinic could be that it performs poor in terms of quality of care. Hence, transferring patients from lower-quality to higher-quality clinics would improve outcomes for patients who resided in catchment areas of closing maternity clinics.

Third, an inflow of additional patients after a closure may also lead to congestion in referral clinics if staffing and facilities are not scaled up proportionally. This may lead to adverse health outcomes for patients from increased waiting times in order to receive appropriate treatments or from increased work load of medical staff who may more prone to make mistakes.[5]

3.2 Catchment areas and clinic closures

One important institutional feature of the Swedish inpatient care system is that patients have little discretion in their choice of health care provider. Since health care in Sweden is mainly funded by direct taxes, there exist no individual contractual agreements between providers and recipients of care. Instead, place of residence via mutually exclusive catchment areas determines the hospital a patient will be admitted to when needing health care. The size of a

[5] Since health monitoring of the expecting mother and the fetus typically takes place in primary care centers outside of the hospital, this diagnostic procedure should not be significantly affected the maternity clinic closures.

catchment area is a function of the underlying population density and hospital capacity. This setting ensures that each patient always has a designated "home hospital", which can be identified by using hospital admission data linked to information on the patient's registered home. The fact that area of residence to a very large extent determines which hospital and birth clinic each mother is referred to will be important for the empirical analyses as it allows us to divide mothers into different treatment and control groups depending on in which catchment area they reside in when a maternity ward closure occurred.

Figure 2 provides a map of Sweden reporting the share of mothers in each municipal who are admitted to their designated maternity clinic. As can be seen from the figure, the overwhelming majority (municipal median 93%) of patients visit their designated hospital. This is reassuring as it implies that our method of mapping mothers to clinics works well.[6,7]

[Figure 2 about here]

Given that we are able to map patients to hospitals over time with high precision, we exploit this feature in combination with the data on maternity clinic closures to propose counter-factual treatment situations, i.e., what would have happened if the closed clinic remained active, from which we can estimate closure effects. Specifically, within each administrative health care region (county), we define three types of catchment areas: (i) closure areas, which were subject to a maternity clinic closure, (ii) referral areas, which were subject to an inflow of patients from the closing areas, and (iii) control areas, which were entirely unaffected by a closure in the region. To separate between referral and control catchment areas, we simply track the post-closure patient flows in our data.

3.3 Econometric model

In the econometric analyses, we initially focus on pooling individuals in both closure-affected groups (i.e., closure and referral catchment areas) and comparing them to individuals in the

[6]The few individuals who are observed to be admitted to another hospital than their designated do not follow a systematic pattern and most likely due to temporary departures from home, such as, for example, vacationers. These observations are therefore excluded from our analysis sample.

[7]A few municipalities with inconsistent home hospitals are removed from our sample. This refers predominantly to cases where a municipal is split into two neighboring catchment areas. Furthermore, for individuals living in municipals with multiple hospitals (in the metropolitan areas of Stockholm, Göteborg and Malmö), the geographically closest unit is defined as the designated hospital.

control group to study the overall closure effect on a set of health outcomes for mothers and newborns. One empirical problem in estimating such effects is that individuals in the different catchment areas may vary with respect to observed and unobserved characteristics correlated with the outcomes we analyze; more health conscientious women might for instance reside in areas where the average distance to maternity clinics is shorter, thereby creating a spurious positive relationship between distance and treatment quality. Using the longitudinal features of our dataset we are able to tackle this selection problem by comparing changes in outcomes of women and newborns residing in closure areas to the corresponding changes for individuals in control areas. We also adjust for a rich set of covariates which are known to be related to birth outcomes and especially complications at birth. This way, we control for both observed covariates and unobserved time-invariant systematic differences between mothers in different catchment areas.

Specifically, our baseline model for a specific health outcome for individual i, in area s in region r in year t is estimated with OLS as

$$y_{isrt} = \alpha + \beta_C C_{st} + \lambda_s + \lambda_t + t \times \lambda_r + X'_{it}\beta_X + \varepsilon_{isrt} \tag{1}$$

C_{st} in is closure dummy as in indicator variable for whether the individual was affected by a closure in year t or before t, so that β_C captures the average closure effect for the closure year and all subsequent years. We control for local area fixed effects, λ_s, which controls for all time-invariant differences between mothers in areas where a maternity clinic was closed and mothers in areas unaffected by closures. We also adjust for general changes to maternal and infant health by including calendar year fixed effects, λ_t. Our model also include a large set of pre-birth health characteristics, defined by the vector X'_{it} and reported in Table 1. Finally, we also control for regional time trends, which adjust for differential trends in health in regions with and without closures.

As a second step we exploit that individuals residing in different catchment area types were differentially affected by a closure to study the mechanisms underlying our net effects from estimating Equation 1. Specifically, individuals residing in closure catchment areas were affected by both an increased distance and an increased inflow of patients while individuals in the referral areas were only subject to the increased patient volume. By utilizing spatial variation across catchment areas and time variation around the time of clinic closure we are able to analyze each mechanism separately, as well as their net impact, on the outcomes we study.

The main identifying assumption for consistent estimation of the closure effects from model (1) is that patients in different catchment areas should, after covariate adjustment, be comparable in terms of changes in maternal and infant health. We perform several checks of this. These checks include examining trends in the number of births and maternal age. Using data for several years before the closures we are also able to examine pre-treatment trends to validate our approach. These tests may reveal endogeneneity problems with respect to underlying health trends and across catchment areas.

4 Data

In our analyses we use data from several Swedish population-based administrative registers; the Intergenerational Register (IGR), containing linked data between parents and children up to three generations for the entire Swedish population; the National Patient Register (NPR), containing detailed information on all publicly provided inpatient care episodes in Sweden; the Clinical Birth Registry (CBR), containing detailed health information on mothers and newborns for all births in Swedish hospitals; and a longitudinal register, LOUISE, containing annual information on socioeconomic and demographic background characteristics such as marital status and earnings. All registers are available for the full study period, 1994–2004.

The NPR contains individual-level information on the date and hospital of admission and discharge and the nature of the visit. The latter category includes length of stay, detailed medical information on cause for admission and any co-morbidities (through the International Classification of Diseases, ICD), and information on any medical procedures undertaken, such as type of surgery and complementary treatments (through the National Classification of Surgical Procedures, NCSP13). The CBR provides complementary health information, mainly on the infant, such as APGAR scores, birth weight and birth traumas. It also includes information on the main and co-morbidities for both the mother and the infant.

The population of interest for our analysis is the universe of births in Sweden for years 1994–2004. Importantly, since essentially all births in Sweden occur in hospitals, the NPR and the CBR will cover the entire population. Thus, we extract from our data all inpatient records with a main diagnosis of O80-O84, referring to a single spontaneous, assisted (via forceps or vacuum extractor), cesarean section, other assisted birth, and multiple delivery, respectively. These observations are subsequently linked to the other datasets using individual identifiers for the mothers.

Catchment areas may be heterogeneous in terms of underlying health and other characteristics. We therefore control for a rich set of covariates known to be related to birth outcomes in our analysis (see, e.g., Dubay *et al.*, 1999, 2001; Currie and MacLeod, 2006) and Shurtz (2014). To this end, we compute the medical history of all mothers in our sample dating back to 1987 (the first year for which we have inpatient data). These variables include socioeconomic characteristics (e.g., age, foreign born and marital status), medical history (e.g., tumors, obesity and heart diseases), pregnancy-specific conditions (e.g., diabetes, anemia and early onset birth) and delivery specific conditions (e.g., incorrect fetal position and prolonged delivery).[8]

Geocoding data for each sampled individual's place of residence are added to our sample of births by linking coordinates included in LOUISE. This information is used to compute the distance from an individual's home to their designated hospital for each year in the data. We apply three distinct distance measures: minimum distance, travel distance, and travel time. The first measure is simply computed using the coordinates, while the two latter ones are measured using the Google® Maps API software.[9,10]

As outcome measures of infant health we use information on APGAR score after one, five and ten minutes, infant mortality and commonly occurring birth traumas. The APGAR

[8] We have also validated this information from official Swedish health records.

[9] The coordinates are based on the RT-90 standard and computed using the transverse mercator map projection. In contrast to the standard projection, the transverse projection takes into account that the world is shaped as an ellipsoid by using so-called geodetic datums in order to deliver improved accuracy positioning measurements. According to the Swedish Ordnance Survey, the RT-90 measurements cover approximately 3,800 triangular points over the country with a relative distance accuracy of 1-2 ppm (mm/km).

[10] The coordinates used in the analysis are midpoints in the Small Areas for Market Statistics (SAMS) classification, created by Statistics Sweden in January 1994 and last revised in 2003. The classification is based on registered property names (NYKO) in the larger municipalities and on electoral districts in the smaller. The total number of SAMS districts in Sweden are about 9,200. The SAMS division has remained largely intact over time and any revisions are minor adjustments have been made to adjust the boundaries of updated municipal borders.

score is based on the heart rate, respiratory effort, reflex irritability, muscle tone and the color of the infant. For each sign the baby is given a rate of either 0, 1 or 2 from worst to best which is then summed up to a total value between 0 to 10. A rule of thumb is that scores of 7 and below is considered as low (see, e.g., Carlo, 2011). For infant mortality we analyze neonatal and perinatal death probabilities which refers to deaths within the first seven and first 28 days of life, respectively. Regarding birth traumas we include on scalp and brachial plexus injuries and clavicle fractures. Scalp injuries are relatively common among newborns, especially Cephalohematoma, which is caused by a collection of blood underneath the skin in the tissue enveloping the infant's skull bone. The second most common trauma is a Clavicle (collar bone) fracture. It usually occurs when the shoulder of the newborn becomes stuck during the delivery. Related to this are Brachial plexus injuries, including Erb's palsy, which is a paralysis of the arm caused by damage to the nerves in the baby's upper arm. It generally occurs during a difficult labor if the baby passes the birth canal at an awkward angle due to excessive pulling of the shoulders (Kaplan *et al.*, 1998).

The main maternal health outcomes we include in the analysis are different types of obstetric trauma, capturing the severeness and prevalence of complications at birth (see, e.g., Iizuka, 2013). Perineal lacerations are a common indicator for comparing health care quality across countries (cf., OECD, 2011). Perineal lacerations are classified into four categories of increasing severity. According to the Agency for Health care Research and Quality (AHRQ), first and second degree perineal lacerations were the most common complicating condition for vaginal deliveries in the U.S. among women with health insurance in 2011 (cf., Moore *et al.*, 2014). The more severe third and fourth degree lacerations are used as indicators for patient safety by the AHRQ. We include other obstetric trauma as a residual residual category.[11]

We also collect information on the type of birth, in particular whether the birth was assisted by instrumental or surgical means. Assisted births are defined by the use of an instrument to assist the delivery; typically a vacuum extractor or the use of forceps.[12] If there are serious concerns about the mother's and/or infant's health, a cesarean section may in-

[11]This group includes rupture of uterus, laceration of cervix, haematoma of pelvis and other obstetric injury to the pelvic organs. We do not consider maternal mortality here as it is an extremely uncommon outcome in Sweden during the time period we study.

[12]Reasons for the decision to instrumentally assist the birth are, for example, concerns about the infant's heart rate, if the infant is in an awkward position, if the patient is too exhausted or if she is a first-time mother.

stead be considered. Emergency cesareans are needed when complications develop during pregnancy or labor and delivery needs to be quick. A cesarean is elective if it is planned in advance. Table 1 shows descriptive statistics of the variables used in the analyses.

[Table 1 about here]

5 Results

We next present our main results. We start with a set of event study analyses in order to illustrate our main findings graphically. First, we study the consequences of the closures in terms of distance to maternity wards and case load at wards. Second, we perform an event study analysis on the effect of closures on child and maternal outcomes. This analysis serves both the purposes of illustrating our main findings as well as allowing us to examine the parallel trend assumption in more detail. Third, we present our regression results on our main outcomes, including APGAR scores, infant mortality, and maternal trauma. We then perform various analyses with the aim to examine these different mechanisms in more detail.

5.1 Closures, distance, and clinic size

Figure 3 illustrates an event-study analysis on the effect of a closure on the driving distance to the nearest clinic and clinic size. The analysis is performed on the individuals living in an area in which a closure occurred and is performed by running our empirical specification above complemented with a set of dummy variables indicating years before and after the closure (with t-1 as reference category). The graph shows a jump in the distance in the year of the closure and thereafter but show no effects before the closure. The distance more than doubles between t-1 and 0 and increases from 14 to 32 kilometers on average.

[Figure 3 about here]

The other major change following a closure of a clinic is that the remaining clinics in the region needs to take on the additional women giving birth from the now closed clinics. While the distance change following a closure only affects women in areas with a closure the change in case load affects all women in a region. Figure 3 shows an event study analysis on the effect of a closure on the case load at birth clinics for the group of women in areas where a closure took place. There is a clear jump in the graph and the average case load more than tripled between the year before the closure and the year of the closure. We can do the same type of event study analysis for women not residing in closure areas but who were affected by an increased case load at their clinics. The jump is then smaller since the closed clinics were typically smaller in size than the remaining ones.

The analyses show that the closures generated sharp changes in the driving distance to clinics and to the case load at clinics. An additional possibility is that the closures affected fertility patterns. If women respond to the closures by for instance giving less births or by moving to other regions the sample composition of children born and mothers giving birth might change, making it difficult to interpret any health effects of the closures. In order to check this, Figure 4 display event studies on the number of births and maternal age before and after the closure, showing no evidence of any changes over time for mothers directly exposed to a closure. We can perform the same analyses on mothers in referral areas who did not face any changes in distance but who faced an additional inflow of mothers from other areas. Again, we see no effects on any of the outcomes.

[Figure 4 about here]

5.2 Graphical evidence

We next perform a set of event study analyses on the effect of closures on child and maternal outcomes. Figure 5 illustrates the effect on APGAR scores of newborns for women residing in closing areas. We see no evidence of any pre-trends in APGAR scores, thus supporting the underlying assumption of our difference-in-differences model. Figure 5 provide similar exercises for maternal trauma where we, again, see no evidence of any pre-trends. There are no important changes in the trauma rates after the closure for the closure group. We can also run the same analyses on the group of women who are not exposed to a closure but who face an increased case load at their clinics. Figure 5 show no effect of APGAR scores but for birth trauma we see a upward jump.

- No pre-trends.

- Effect on trauma in the referral group.

- Indication of small effect on APGAR score for the referral group.

5.3 Regression results

- For closure areas no effects, neither for mothers nor for children.

- Before we had an effect for low birth-weight babies, but only in the upper part of the distribution. If we give all three APGAR scores equal weight and only study the effects on average scores we no longer find any significant effects for low birth-weight babies. I think this is the way we should go.

- For referral areas: negative effects for both mothers and babies.

This section reports regression results on our main outcomes, including APGAR scores, infant mortality, and maternal trauma. We also study potential mechanisms through which the estimated effects arise, including effects due to changes in distance, case volume, clinic quality and medical technology.

Columns 1 and 4 of Table 2 gives the pooled results from estimating the closure effects for both the closure and referral catchment areas jointly. This gives the total effect of the closures for the entire population of mothers and children that are affected by the closures. For this full group we find adverse effects on maternal outcomes, suggesting that the inflow of additional births at the remaining clinics induce substantial crowding effects, which we study next. For babies, we find no significant negative effects.

Columns 2 and 5 of Table 2 contain regression estimates for women in closure areas; i.e., women living in catchment areas subject to a maternity clinic closure. The upper and middle panels give results for the infant health outcomes while the bottom panel gives results for maternal outcomes.

Table A.1 in the appendix for the low-birth weight group. We report separate estimates for all children and the subgroup of children with low birth weight (below 2500g), respectively. Two important reasons for studying children with low birth weight separately are that a premature delivery or other in-utero complications, which in both cases means that the delivery is associated with greater risks. By examining effects on the subsample of children with low birth weight we are, thus, able to study the effects of maternity clinic closures on high-risk deliveries.

[Table 2 about here]

The upper panel of Table 2 reports estimates for APGAR score at 1, 5 and 10 minutes, respectively. For the full sample we find no significant effects on any of the three Apgar scores. The same holds for the low birth weight sample. The middle panel of Table 2 reveals no significant effects on infant mortality. The bottom panel gives the results for the maternal birth outcomes, but we find no significant effects for mothers in closure areas (columns 1 and 4). In sum, for closure areas we see no effects neither for children nor for the mothers.

Column (2) and (5) of Table 2 reports the estimated effects for mothers and children living in catchment areas subject to an inflow of births after the closure of a nearby maternity clinic. Interestingly, for this group we find negative effects on all three APGAR scores. The effects for the full sample of children is significant, while the effects for the low birth weight sample are insignificant. As for children in closures areas, we find no effects on infant mortality. The bottom panel of Table 2 reveals that mothers in these inflow areas had a significantly higher probability of obstetric trauma, and the effects are sizable. For the full sample of mothers the risk of obstetric trauma increases by 2 percentage points, corresponding to a 30 percent increase. The increased probability of obstetric trauma is mainly explained by a increased likelihood of less severe (degree 1 and 2) perineal lacerations.

5.4 Mechanisms

- Evidence of crowding based on that births/midwife ratio goes up.
- No evidence of any distance effects
- Removed the table on selective closures. Unclear.
- Removed the previous Tables 4 as it was unclear (as suggested by Petter).

In the previous section, we documented an interesting pattern. For closure areas, where mothers are relocated from a closed clinic to a remaining clinic, we see some evidence of positive effects on infant health, especially for children with low birth weight, but no effects on maternal health. In inflow area, where mothers remain at the same clinic but where the clinic experience a inflow of additional births, we find negative effects on both infant health and maternal health. These patterns provide initial information about the importance of different mechanisms, since the hypothesized negative crowding effect and the volume effect affects both the inflow and the closure group, whereas the distance and clinic quality effect only affects the closure group. The fact that we find negative effects for the inflow group indicates that crowding effects are important, leading to adverse effects in the inflow group. The closure group are also affected by any negative crowding effects at the remaining clinics as well as possible distance effects, but still we observed positive effects for the closure group. This suggest that there are important positive clinic quality effects as the mothers in closure areas are relocated to a better clinic. This is consistent with the fact that mainly smaller clinics in rural areas offering maternal care of lower quality are closed. In this section, we perform additional analyses with the aim to examine these different mechanisms in more detail.

One interpretation of the adverse effects on maternal trauma for mothers in inflow areas is that the inflow of additional births leads to crowding and/or stress among midwifes at the remaining clinics after a closure. In Figure 6 we provide event study graphs illustrating changes in the number of births at clinics in referral areas. Figure 15 shows that the number of births per midwife increased as well suggesting that the workload for midwifes indeed increased.

[Figure 6 about here]

We next study the importance of the distance to the maternity clinic in more detail. While we did not find any adverse effect on mothers and babies that were directly affected by a closure, longer travel times may be particularly acute for risky pregnancies and for cases where the childbirth occurs very rapidly (see, e.g., Viisainen *et al.*, 1999). There may thus be heterogeneity in the effects.

To check for heterogeneity, we exploit detailed geographical information on the area of residence of the mothers. We use the fact that the increase in distance to the nearest clinic after a closure depends on where the mothers live, i.e. mothers in the same closure area will experience differential distance increases, depending on their area of residence around the two clinics. To control for pre-existent differences between mothers in different areas we use local area fixed effects. Since we will compare mothers in areas giving birth at the same clinic both before after the closure we are able to control for other effects of closures, such as case volume effects, that are the same for all mothers giving birth at a specific clinic. This is achieved by including both local area fixed effects and hospital fixed effects in our model. Note that it is the closures that allow us to include both local area fixed effects and hospital fixed effects in the same model. The hospital fixed effects will capture all general differences between the hospitals as well as any closure effects that are unrelated to the distance to the clinic.

[Table 3 about here]

The estimated distance effects are presented in Table 3. These estimates reveal no important effects of the distance to the clinic. However, note that we capture an average effect for the sample of all mothers. There might still be important distance effects for certain types of deliveries. In robustness checks we have dropped individuals whose distance decrease after the closure, leading to similar results.

Midwife quality:

[Figure 7 about here]

5.5 Medical technology

Another possible mechanism through which closures can affect outcomes of mothers and babies is through changes in medical technology. If a closure, for instance, leads to increased crowding at remaining clinics, the medical staff may fail to administer appropriate treatments. To investigate this we analyze whether patients are optimally treated given their medical history. We do so by first applying a propensity score method to categorize patients into high and low risk patients and then study how the treatments of observationally equivalent patients fare before and after a maternity clinic closure took place. For this exercise we focus on Cesarean sections.

Specifically, we use a two-stage estimation procedure: first, we estimate the probability (or risk) of being subject to a Cesarean section by means of a binary logistic regression model using data from all control hospitals, including all known risk factors at our disposal. In a second step, we predict each individual's risk of a Cesarean section who gave birth in referral hospitals (i) years just before the year of closure of a nearby clinic and (ii) years just after the same closure for affected patients. Finally, we relate these predictions to the actual treatment outcome and compute the deviations from the reference risk (as estimated by the logistic model) for the pre- and post-closure periods separately. The relative difference in treatments between pre- and post-closure births from the reference treatment probability, given the predicted risk, give us some information on whether administered treatments were improved or deteriorated after the closures.[13]

Figure 8 relates the fraction of administered Cesarean sections before (circles) and after (triangles) the closures to the predicted risk of having a Cesarean section, based on the pre-closure data, in bins of 0.05. The reference point is the 45 degree line mapping the predicted risk to the fraction of Cesarean sections one-to-one which would be the optimal treatment outcome for each bin (based on the control hospitals). By analyzing the relative deviation of the risk-specific fractions of Cesarean sections before and after the closures we can therefore assess how the match of patients to treatments changed due to the maternity clinic closures. The observed pattern is quite striking: while the relation between the 45 degree line and the realized treatments in referral hospitals before a nearby hospital closed are highly correlated over the predicted risk, the relationship becomes gradually worse with risk after the closure as shown. Hence, this implies that women who had the highest need for a Cesarean section based on their observed characteristics, were considerably less likely to have this treatment after a nearby maternity clinic closed compared to before the closure. This may have affected the mothers health outcomes adversely by for example an increased risk of obstetric trauma as found in Table 2.

[Figure 8 about here]

[13]This procedure should be valid under the assumption that the control hospitals are comparable to the referral hospitals in terms of mapping risk factors to treatments.

6 Concluding remarks

This paper studies how concentration of maternity clinics affect the outcomes of mothers and their babies. To account for endogenous sorting to clinics, we exploit closures of maternal clinics that occurred in Sweden in the 90 that gave generates exogenous variation in distance to clinics and in their case volume. Our empirical design allows us to analyze the impact of both changes in distance and in maternity clinic characteristics, as well as the overall impact from both factors. In addition, we can analyze the effect of closures separately for those directly exposed to a closure and for those indirectly exposed through an increase in case volume at their clinics.

We find some evidence that concentrating the number of maternity clinics have positive health effects for children with low birth weight in areas exposed to a closure. Although distance to the nearest maternity clinic increased these babies had significantly higher APGAR scores. This is in contrast to the outcome of babies born in referral areas, i.e. who were not directly exposed to a closure but who faced a greater case load at their clinics, where we find negative effects on APGAR scores. When we study the two groups together, the net effect is small and insignificant suggesting that the opposite effects in the two groups cancel each other out.

For mothers we find that obstetric trauma increased significantly for mothers in referral areas who experienced an inflow of patients to their clinics. We find no such effect among mothers in closure areas but when we study the two groups together the net effect of the closures is that obstetric trauma increase.

In order to understand the effects we provide evidence on a number of possible mechanisms. First we show that closures leads to larger patient volumes at remaining clinics in a region and that the number of births per midwife increases. Second, we show that closures leads to less flexibility in treatments where mothers experiencing high risk births are less likely to receive a Cesarean section after the closures.

Concentrating health care resources creates a potential trade-off between increased productivity and decreased access. Our results provide little evidence of any such tradeoff and, instead, showed that the net effect of the closures was negative. Somewhat unexpected, the negative effects did not arise due to increased distance to clinics but rather through potential crowding effects at remaining clinics. We believe this is an important lesson when assessing the costs and benefits of concentration policies.

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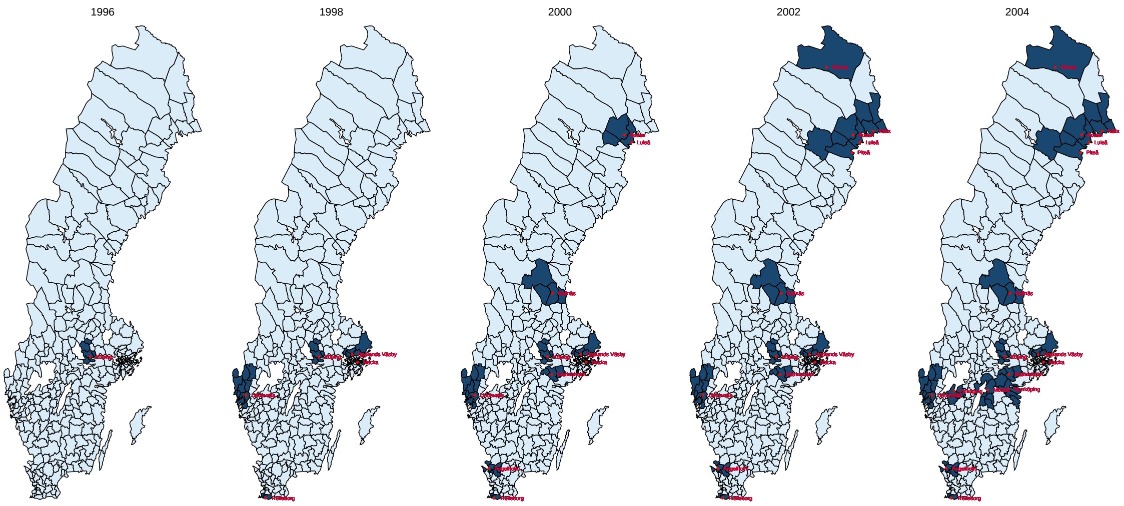
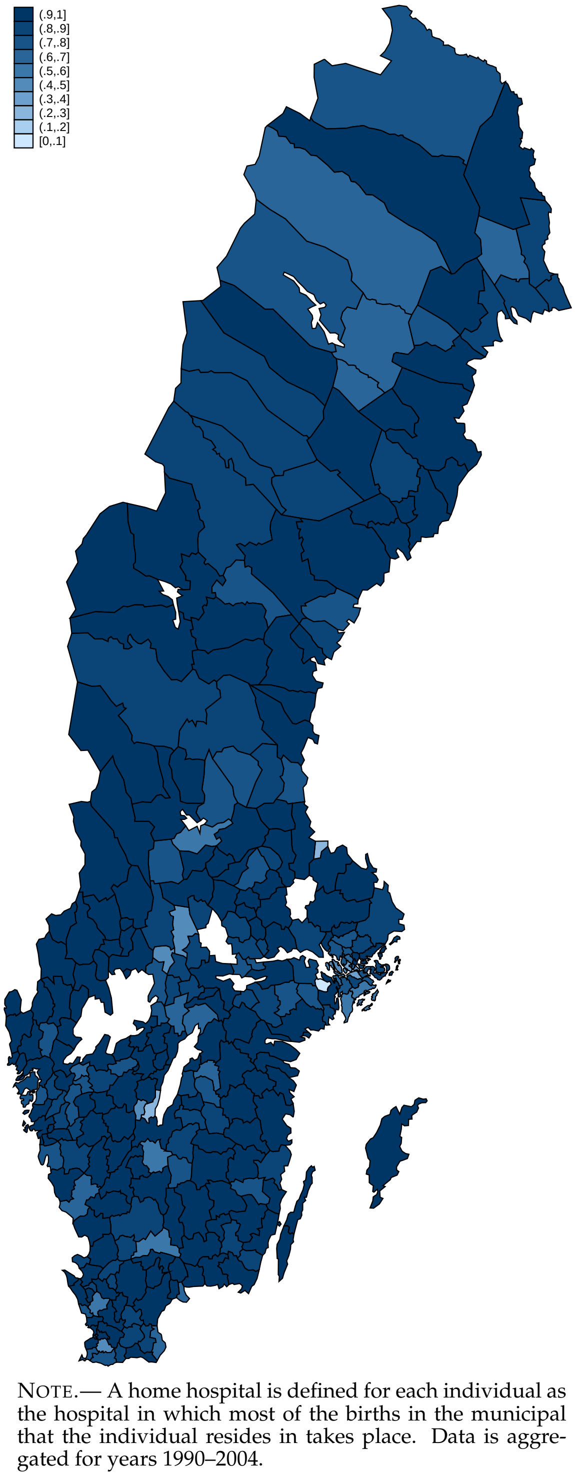
Tables and Figures

FIGURE 1.
Municipals affected by maternity clinic closures, 1990–2004



NOTE.— Dark blue areas correspond to municipals affected by a nearby maternal clinic closure. The red text indicate the location and name of the closed clinic.

FIGURE 2.
Share of births occurring at designated home hospitals in Sweden by municipal



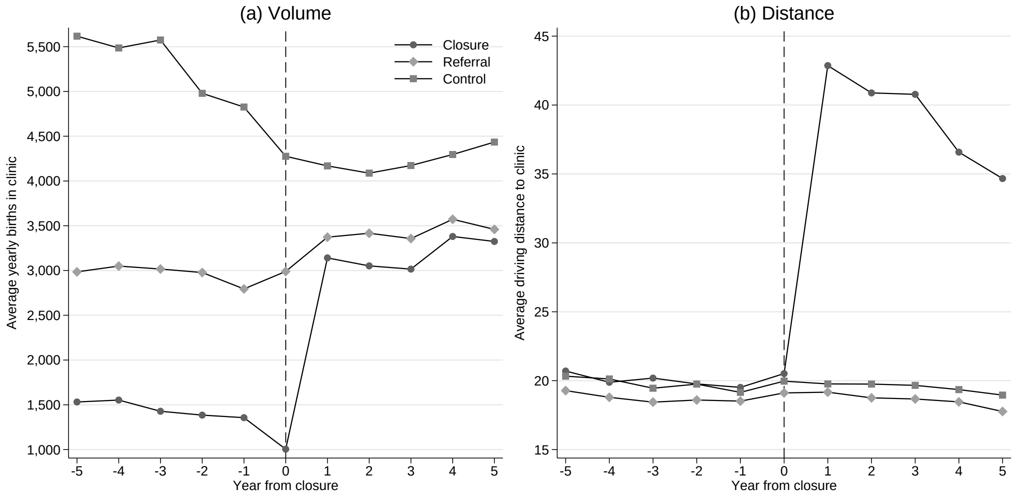
NOTE.— A home hospital is defined for each individual as the hospital in which most of the births in the municipal that the individual resides in takes place. Data is aggregated for years 1990–2004.

TABLE 1.
Sample statistics

Variable	Sample All	Control	Referral	Closure
Maternal characteristics				
Age	29.13	28.90	29.52	28.89
Cohabiting (%)	88.25	89.10	87.20	88.17
Earnings before tax	58,696.90	54,789.04	64,310.12	56,552.91
Tumor (%)	0.03	0.03	0.03	0.02
Substance Dependence (%)	0.00	0.00	0.01	0.00
Obesity (%)	0.03	0.04	0.02	0.03
Heart Diseased (%)	0.11	0.12	0.10	0.10
Respiratory Disease (%)	0.17	0.20	0.16	0.14
Diabetes (%)	0.78	0.87	0.73	0.67
Pregnancy- and delivery-specific conditions				
STD (%)	0.05	0.04	0.06	0.04
Rhesus Incompatibility (%)	0.11	0.11	0.11	0.12
Umbilical Cord (%)	0.42	0.37	0.44	0.51
Anemia (%)	3.30	3.36	3.51	2.70
Early Onset delivery (%)	5.00	5.11	4.94	4.70
Prolonged Pregnancy (%)	3.60	3.45	3.80	3.36
Labor Dystocia(%)	9.15	9.	9.18	9.25
Placenta (%)	2.55	2.62	2.55	2.42
Hypertension (%)	4.45	4.50	4.50	4.31
Child outcomes				
Apgar at minute 1	8.70	8.71	8.69	8.70
Apgar at minute 5	9.73	9.72	9.74	9.76
Apgar at minute 10	9.87	9.86	9.87	9.88
Infant mortality 0-7 days (%)	0.23	0.23	0.23	0.24
Infant mortality 0-28 days (%)	0.29	0.29	0.28	0.29
Maternal Outcomes				
Trauma during Delivery (%)	7.73	6.95	9.04	7.11
1st or 2nd Deg. Perinea (%)	4.21	3.59	5.19	3.84
3rd 4th Deg. Perineal (%)	2.46	2.33	2.71	2.20
Other Trauma (%)	1.18	1.10	1.29	1.18
Number of Births	1,322,967	586,337	516,783	219,847

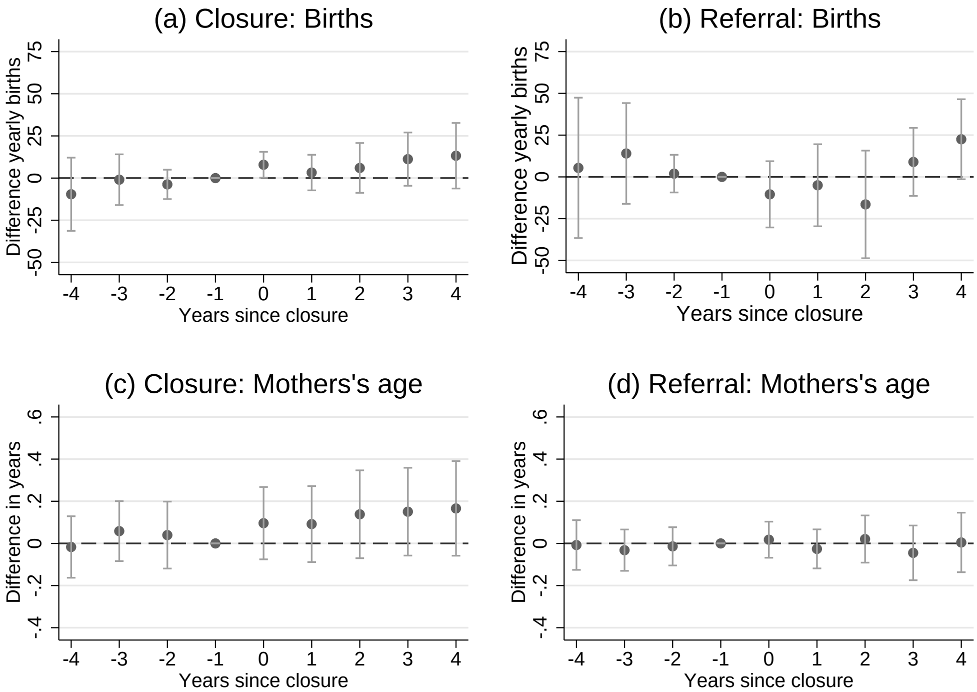
NOTE.— The table reports mean values for each variable by sample. See the text for variable and sample definitions. Earnings are measured in Swedish crowns (SEK). One crown corresponds to around 0.1 euro in 2015.

FIGURE 3.
Maternity ward closures, ward size and distance to the ward



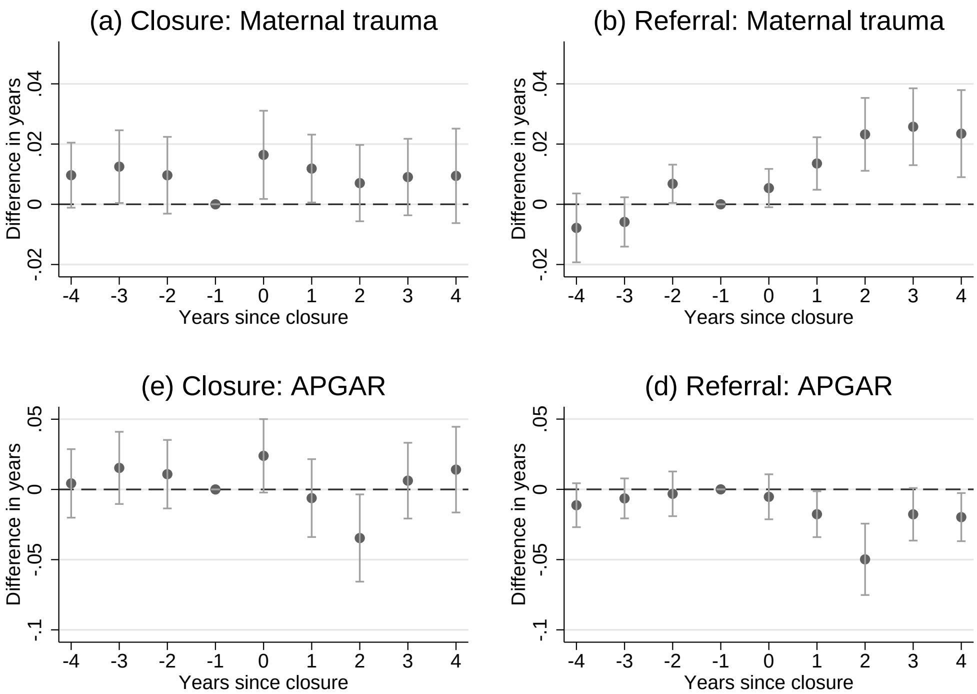
NOTE.— Lines refer to group averages for closing, referral and control catchment areas by time from closure (see text for definitions).

FIGURE 4.
Maternity ward closures, number of births and mother's age



NOTE.— Event study estimate for the difference between (affected) mothers in a closing or a referral areas compared to (unaffected) mothers in control catchment areas, adjusting for local area fixed effects, year fixed effects and regional linear trends. Swedish data for the period 1990-2004.

FIGURE 5.
Effects of maternity ward closures on health outcomes



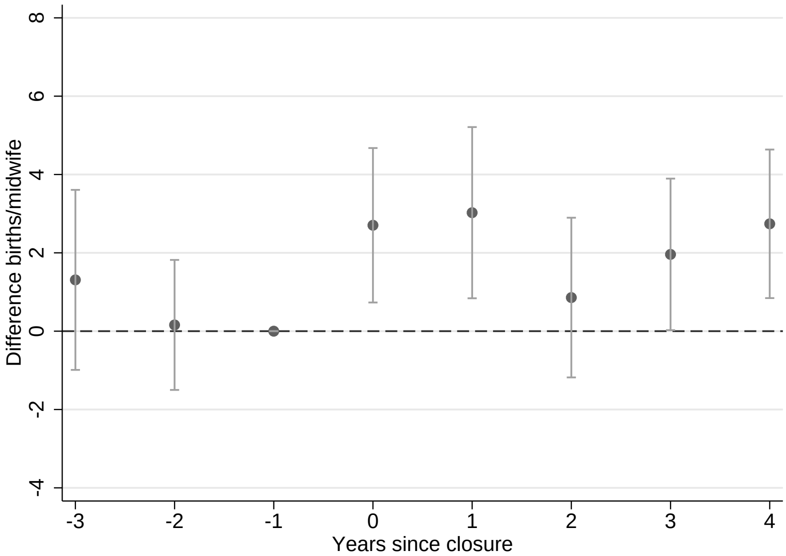
NOTE.— Event study estimate for the difference between (affected) mothers in a closing or a referral areas compared to (unaffected) mothers in control catchment areas, adjusting for local area fixed effects, year fixed effects and regional linear trends. Swedish data for the period 1990-2004.

TABLE 2.
Maternity clinic closures, infant health and maternal health

	Total (1)	Closure (2)	Referral (3)
		Infant health	
APGAR 1	0.011	0.0067	-0.012*
	(0.0087)	(0.016)	(0.0069)
Control mean:	8.71	8.71	8.71
APGAR 5	-0.0019	-0.0088	-0.019***
	(0.0059)	(0.0094)	(0.0051)
Control mean:	9.72	9.72	9.72
APGAR 10	-0.0084	-0.0067	-0.018***
	(0.0058)	(0.0077)	(0.0045)
Control mean:	9.86	9.86	9.86
Child mortality	-0.00041	-0.00033	0.000022
	(0.00039)	(0.00033)	(0.00027)
Control mean:	0.0029	0.0029	0.0029
		Maternal health	
Trauma	0.021***	0.0011	0.020***
	(0.0038)	(0.011)	(0.0048)
Control mean:	0.069	0.069	0.069
1-2 degree Rupture	0.015***	0.0013	0.018***
	(0.0032)	(0.011)	(0.0039)
Control mean:	0.035	0.035	0.035
3-4 degree Rupture	0.0021*	-0.0010	-0.0011
	(0.0012)	(0.0027)	(0.00099)
Control mean:	0.023	0.023	0.023
Other trauma	0.0043***	-0.00036	0.0030**
	(0.0011)	(0.0016)	(0.0013)
Control mean:	0.011	0.011	0.011
Observations	507,229	755,241	1,107,495

NOTE.— Swedish data for the period 1990-2004. All models include local area fixed effects, year fixed effects, regional linear trends, maternal socioeconomic characteristics and maternal pre-pregnancy health measures. Standard errors clustered at the parish level in parentheses. *p<0.1 **p<0.05 ***p<0.01.

FIGURE 6.
Births/midwife at clinics in inflow areas.



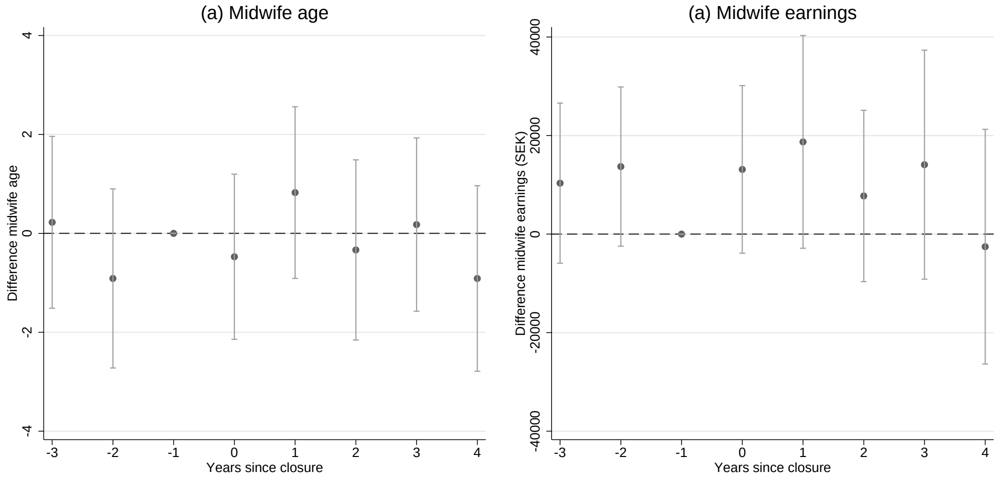
NOTE.— Event study estimate for the difference between (affected) mothers in a closing or a referral areas compared to (unaffected) mothers in control catchment areas, adjusting for area fixed effects, year fixed effects and regional linear trends. Each municipality/year is one observation. Swedish data for the period 1990-2004.

TABLE 3.
Distance to the maternity clinics, maternal health and child health

	Apgar score		Maternal trauma	
	All	Low birth weight	All	Low birth weight
	(1)	(2)	(3)	(4)
		Distance in kilometers		
Distance (km)	0.0048*	-0.0037	0.00012	-0.0098
	(0.0025)	(0.018)	(0.0021)	(0.0064)
		Distance in categories		
10-30 kilometers	0.0013	0.010	-0.0078*	-0.011
	(0.0050)	(0.029)	(0.0044)	(0.0091)
30-60 kilometers	0.014**	0.046	-0.00080	0.0025
	(0.0073)	(0.047)	(0.0058)	(0.018)
60+ kilometers	0.020	-0.099	-0.0013	0.040
	(0.018)	(0.12)	(0.012)	(0.033)
Observations	757,159	32,099	757,159	32,099

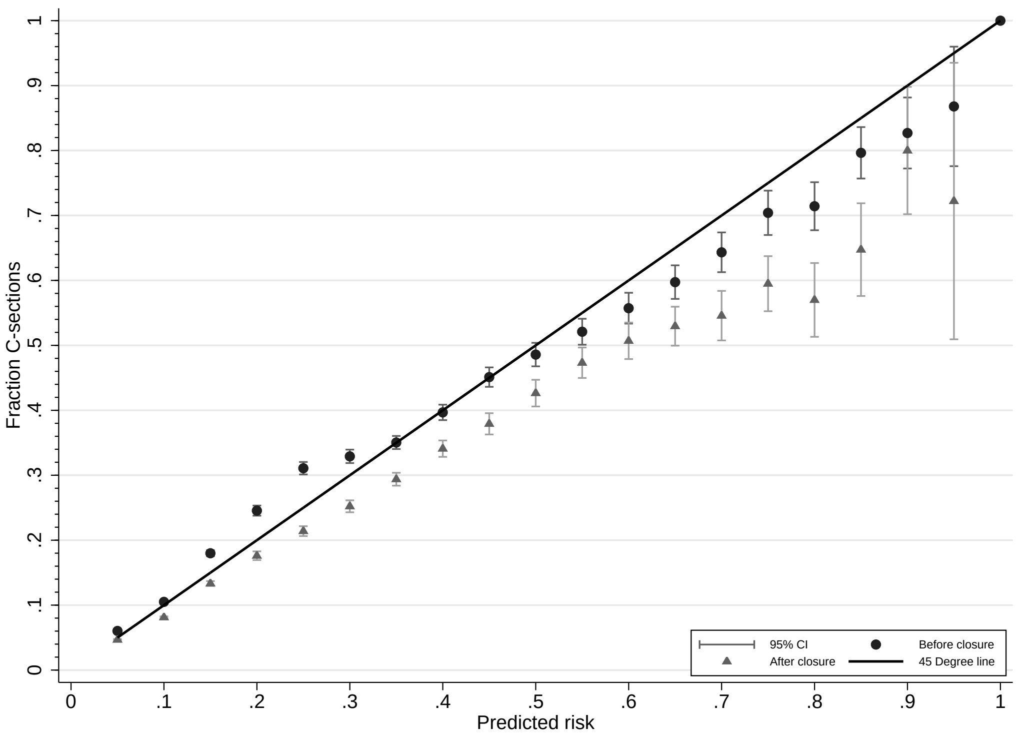
NOTE.— In Panel A the explanatory variables is the distance to maternity clinic in kilometers. In Panel B the individual distances are divided into three categories. Swedish data for the period 1990-2004. All models include local area fixed effects, hospital fixed effects, year fixed effects, regional linear trends, maternal socioeconomic characteristics and maternal pre-pregnancy health measures. Standard errors clustered at the parish level in parentheses. *p<0.1 **p<0.05 ***p<0.01

FIGURE 7.
Maternity ward closures midwife quality



NOTE.— Event study estimate for the difference between (affected) mothers in a closing or a referral areas compared to (unaffected) mothers in control catchment areas, adjusting for local area fixed effects, year fixed effects and regional linear trends. Swedish data for the period 1990-2004.

FIGURE 8.
Fraction actual Cesarean section by predicted risk



NOTE.—The propensity score estimation is performed using a logit model with the full set of regressors in Table (summary statistics) for individuals belonging to the closed hospitals before and after they were closed.

Appendix: Additional Tables and Figures

TABLE A.1.
Children with low birth weight and the effects of maternity clinic closures

	Total (1)	Closure (2)	Referral (3)
		Infant health	
APGAR 1	0.083	0.088	0.0050
	(0.083)	(0.056)	(0.057)
Control mean:	7.86	7.86	7.86
APGAR 5	0.042	0.011	-0.0092
	(0.061)	(0.034)	(0.042)
Control mean:	9.14	9.14	9.14
APGAR 10	0.027	0.016	-0.026
	(0.045)	(0.036)	(0.032)
Control mean:	9.48	9.48	9.48
Child mortality	-0.00041	-0.00033	0.000022
	(0.00039)	(0.00033)	(0.00027)
Control mean:	0.037	0.037	0.037
		Maternal health	
Trauma	-0.00053	-0.0024	0.0042
	(0.0059)	(0.0049)	(0.0042)
Control mean:	0.020	0.020	0.020
1-2 degree Rupture	-0.00088	-0.0015	0.0053
	(0.0042)	(0.0042)	(0.0034)
Control mean:	0.011	0.011	0.011
3-4 degree Rupture	-0.000015	-0.0030***	-0.00053
	(0.0028)	(0.0011)	(0.0018)
Control mean:	0.0029	0.0029	0.0029
Other trauma	0.00019	0.0018	-0.00100
	(0.0024)	(0.0017)	(0.0021)
Control mean:	0.0053	0.0053	0.0053
Observations	21,915	32,758	48,124

NOTE.— Swedish data for the period 1990-2004. All models include local area fixed effects, year fixed effects, regional linear trends, maternal socioeconomic characteristics and maternal pre-pregnancy health measures. Standard errors clustered at the parish level in parentheses. *p<0.1 **p<0.05 ***p<0.01.