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The Impact of Home Births on Infant Outcomes[*]

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Abstract

Many developed countries have recently experienced sharp increases in home birth rates. This paper investigates the impact of home births on the health of low-risk newborns using data from the Netherlands, the only developed country where home births are widespread. To account for endogeneity in location of birth, we exploit the exogenous variation in distance from a mother's residence to the closest hospital. We find that giving birth in a hospital leads to substantial reductions in newborn mortality. We provide suggestive evidence that proximity to medical technologies may be an important channel contributing to these health gains.

Keywords: Medical technology, birth, home birth, mortality
JEL Classifications: I11, I12, I18, J13

1 Introduction

Over the last few decades, many developed countries experienced sharp rises in home birth rates. While the number of home births in most of these countries remains low, the trends are striking. For example, home births in the United States increased by almost 30 percent between 2004 and 2009 (MacDorman et al., 2012). Similarly, the fraction of home births in the United Kingdom almost tripled between 1990 and 2006 (Nove et al., 2008) and out-of-hospital births in Canada more than quadrupled between 1991 and 2009.[1] In this paper, we investigate the impact of home births on the health (7-day and 28-day mortality and 5-minute Apgar score) of low-risk newborns using a unique confidential dataset covering the universe of births in the Netherlands for the period 2000–2008.

The Netherlands is an ideal setting to study this question for several reasons. First, it is the only developed country where home births are widespread: between 2000 and 2008, approximately 25 percent of births took place at home, leading to sample sizes large enough to examine causal effects on rare health outcomes such as perinatal mortality. This also implies that our findings apply to a potentially large fraction of the population. Second, the Dutch institutional setup allows us to identify place-of-birth effects (home versus hospital) abstracting from provider-effects (obstetrician versus midwife).[2] This is because Dutch maternity care is based on a system of risk selection where low-risk women (women without known medical risk factors throughout their pregnancy) can choose between a home or a hospital birth and in both cases the delivery is supervised by a midwife without a doctor being present.[3] Finally, the Netherlands is a country where childbirth technologies are a major policy issue because the Dutch perinatal mortality rate is one of the highest in Europe (Mohangoo et al., 2008) and the contribution of home births to this

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[1] Authors' calculation using data from Statistics Canada, CANSIM Table 1024516.

[2] The use of physician extenders is another important policy question that is examined elsewhere (e.g., Miller, 2006; Daysal et al., 2013).

[3] The remaining women (i.e., high-risk women) are always required to give birth in a hospital under the supervision of an obstetrician.

is hotly debated.

Location of delivery and newborn health outcomes seem to be related in the raw data. Historical data show that 7-day (28-day) mortality declined from 4.25 (5.35) deaths per 1,000 births in 1980-85 to 2.42 (3.18) deaths in 2005-09, while the share of hospital births increased from 61.25% to 72.06%. In addition, using a decomposition similar to Cutler and Meara (2000), we find that most of the mortality decline between 2000–2008 comes from newborns over 2,500 grams, who are more likely to be low-risk and thus eligible for home births. However, these raw correlations are tainted by the endogenous choice of location of birth: even among observably low-risk mothers, those who are at a higher risk of having an unhealthy infant for reasons unobservable to the midwife and to the researcher may choose to give birth in a hospital. In order to account for non-random selection into a home birth, we use an instrumental variables (IV) approach that exploits the exogenous variation in distance from a mother's residence to the closest hospital with an obstetric ward.[4]

Using the sample of low-risk women, all of whom are under the care of a midwife at the onset delivery, we find that distance is strongly negatively correlated with the likelihood of a hospital birth. For example, women residing within 2–4 km of a hospital are 6 percentage points (9% at the mean) more likely to deliver in a hospital than those living at least 11 km away from a hospital. Reduced form results also indicate a strong and almost monotonically increasing relationship between distance and infant mortality but no relationship with Apgar score. For example, we find that 7-day infant mortality is lower on average by 0.554 (31% at the mean) deaths per 1,000 births among individuals residing within 2–4 km of a hospital as compared to those who live at least 11 km away from a hospital. As a result, the IV estimates indicate that giving birth in a hospital leads to economically large reductions in perinatal mortality but has no effect on Apgar scores. Back-of-the-envelope calculations suggest that the rise in hospital births explains roughly 46%–49%

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[4]This strategy is similar to McClellan et al. (1994) who use the differential distance between alternative types of hospitals when examining returns to intensive heart attack treatments.

of the reduction in infant mortality in the Netherlands between 1980 and 2009.

In order to interpret these results as causal two conditions must be satisfied: distance must impact newborn health outcomes only through location of birth (excludability), and all women who are affected by the instrument must be less likely to choose a hospital birth as the distance to an obstetric ward increases (monotonicity). It is important to emphasize that these assumptions are ultimately untestable. As such, much of the results section is devoted to investigating the robustness of the results and to showing that endogenous residential sorting by distance is unlikely to drive the results. For example, we show that there is no reduced form relationship between perinatal mortality and distance among high-risk births, where there is no variation in location of birth (since all births have to occur in a hospital).

Our instrumental variable strategy identifies the local average treatment effect for the subpopulation of low-risk women who give birth in a hospital because they reside close enough to it, but would give birth at home if they lived farther away. Most of the characteristics of compliers are not associated with high risk but our results are entirely driven by births from lower-income postal codes. This is consistent with the previous literature documenting disparities in preventive behavior and quality of care by income and education (e.g., Smith, 1999; Cutler and Lleras-Muney, 2010). Unfortunately, data do not allow us to distinguish between these two channels.

The lack of an impact on the 5-minute Apgar score suggests that the general health of low-risk babies born in a hospital is similar to those born at home shortly after birth. Hence, any mortality reductions from a hospital birth are likely due to the medical care provided after delivery. A hospital birth may reduce infant mortality through various channels, such as the availability of better facilities and equipment, potentially better hygiene or the proximity to other medical services. While data limitations constrain our ability to investigate many important channels, we are able to examine whether giving birth in a hospital with or without a neonatal intensive-care unit (NICU) has differential effects on newborn health. We find slightly larger mortality reductions from births in hospitals with a NICU. We cautiously interpret this

as evidence that access to medical technologies may be one channel explaining the lower mortality among hospital births.

This paper adds to the large medical literature studying the effects of home births. As we detail in section 2.2, these studies exclusively rely on simple regression models comparing outcomes among subsamples of low-risk women who (plan to) give birth at home or in the hospital, after controlling for observable differences in pregnant women. The major drawback of these studies is a potential selection bias due to the endogeneity in (planned) location of birth. In addition, the power of most of these studies is limited due to their small sample size. Our paper is also related to the growing literature in economics evaluating returns to medical technologies. As we summarize in section 2.2, this literature almost exclusively focuses on returns to medical technologies for high-risk individuals (e.g., heart attack patients and at-risk newborns), while we focus on low-risk newborns.

Our results pertain directly to current policy debates on the health and safety of home births. For instance, the United Kingdom Department of Health now asserts that home births are safe for women who have been properly assessed for risks and explicitly states that "[f]or the majority of women, pregnancy and childbirth are normal life events requiring minimal medical intervention. These women may choose to have midwifery-led care, including a home birth." (Department of Health, 2004, p. 6) In a joint statement, Royal College of Obstetricians and Gynaecologists and Royal College of Midwives (2007, p. 1) declare that "[t]here is ample evidence showing that laboring at home increases a woman's likelihood of a birth that is both satisfying and safe, with implications for her health and that of her baby." In the Unites States, The American College of Obstetricians and Gynecologists (2011, p. 1) notes that "[a]lthough the Committee on Obstetric Practice believes that hospitals and birthing centers are the safest setting for birth, it respects the right of a woman to make a medically informed decision about delivery" and a special Home Birth Consensus Summit was held in Virginia as recently as October 2011. Under these circumstances, the issue of home births is likely to be increasingly prominent in policy debates in the coming years.

4

2 Background

2.1 The Dutch obstetric system

The current Dutch maternity care system has its origins in the 1950s (Amelink-Verburg and Buitendijk, 2010). In an effort to cut healthcare expenditures, the Dutch National Health Insurance Board issued in 1958 a list of conditions that were deemed necessary for a hospital admission during childbirth. This list set the foundation for risk selection, the principle that uncomplicated births should stay in the primary care provided by a midwife or a general practitioner, and that hospital admissions into the secondary care provided by an obstetrician are necessary only in case of deviations from the normal course of a pregnancy. This list was updated in 1973 and became the official "List of Obstetric Indications" (LOI), which determines when referrals are made from primary to secondary care.

Subsequent updates to the LOI kept the same underlying idea: that pregnancy, delivery and puerperium are all natural processes. As a result, women are referred to an obstetrician only in specific cases. The LOI lists four main types of reasons for referral: non-gynecological pre-existing conditions, ranging from asthma, diabetes, hypertension and epilepsy to alcoholism and psychiatric disorders; gynecological pre-existing conditions (e.g., pelvic floor reconstructions); obstetric anamnesis, including items such as a C-section or complications in a previous delivery, previous preterm births or multiple miscarriages; conditions arising or first diagnosed during pregnancy, such as infections, hyperemesis gravidarum, plurality, gestational hypertension, blood loss and (threat of) preterm or postterm birth, defined as before 37 and after 42 completed gestation weeks, respectively (CVZ, 2003). If only one of these reasons for referral occurs, referring is compulsory (i.e., there is no continuous risk scale). Referrals for reasons other than those detailed in the LOI are not allowed and insurance plans do not cover doctor fees in these instances (CVZ, 2003). In addition, women are not allowed to contact directly an obstetrician. Between 2000 and 2008, about 47 percent of all pregnant women were deemed to have an increased risk and were referred to an obstetrician before

the start of delivery. These high-risk women give birth in a hospital under the supervision of an obstetrician.

As long as there are no complications, women are not seen as patients and midwives supervise their entire pregnancy, perform all checks, and attend the birth (Bais and Pel, 2006). These low-risk women can choose the midwifery practice that cares for them as well as whether to deliver at home or in a hospital. It is important to emphasize that midwives are not allowed to administer any medical interventions and thus women receive the same set of services regardless of location of birth. In addition, hospital births supervised by midwives take place in a polyclinic setting with no obstetrician present and the midwives are the same persons as those who would otherwise have supervised the delivery at home.[5] At the onset of labor (when contractions occur with a certain frequency or there is loss of amniotic fluid), the woman contacts her midwife, who then either comes to the woman's home for a home birth or notifies the hospital that they will be arriving for a hospital birth. Thus, women choosing a hospital birth have to be transported to the hospital during the contraction phase and they have to arrange their own transportation.[6] If complications arise during delivery, the delivery takes too long, or the need for pain medication arises, the midwife refers the woman to an obstetrician. This can be a within-hospital transfer, if the woman was already there, or it could entail transport from home to the hospital in the case of a home birth. Around 31 percent of all women who started delivering with a midwife between 2000 and 2008 were referred to an obstetrician during delivery and about 12 percent of referrals were due to the need for pain relief medication.

Following a low-risk (uncomplicated) hospital birth, the woman is gener-

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[5]There are very few exceptions when a low-risk woman is not allowed to choose her place of (midwife-supervised) delivery. For example, she is not allowed to deliver at home if she cannot deliver on the ground floor and her floor can only be reached by a steep or narrow staircase, since labor laws would not allow ambulance personnel to carry her down.

[6]Moreover, women cannot go to the hospital until their midwife agrees to it. According to the Royal Dutch Organisation of Midwives (KNOV), "hospital deliveries start at home as well. You will consult with the midwife about the moment you will go to hospital. Usually this is when contractions are well underway. The midwife will join you at the hospital." (www.knov.nl/voor-zwangeren/zwanger/de-bevalling/thuis-of-in-het-ziekenhuis/, authors' translation, accessed on August 31, 2012).

ally discharged a few hours after delivery, irrespective of the time of the day. Postnatal care for both home births and hospital births is ensured by a system in which trained health workers intensively take care of the woman and child during home visits totaling three to eight hours per day (depending on personal and health circumstances) over a period of eight to ten days. This care includes prevention, instruction, detection of any (health) problems, ensuring good hygiene, verification that the child is properly cared for, and often even household chores.

It should be mentioned that midwives have no financial incentive to influence a woman's choice of delivery location. Midwifery practices are private independent entities usually including 2–3 midwives. The midwifery practice receives a fixed amount per delivery, which as of 2008 was 333.50 euros per birth (NZA, 2008). Most importantly, midwives are paid a fixed salary regardless of the number of births supervised or the location of delivery. On the other hand, there are differences between home and hospital births in terms of the out-of-pocket cost for the mother. The default types of delivery, at home for midwife-supervised low-risk births and in a hospital for obstetrician-supervised high-risk births, are fully covered by universal healthcare insurance. Hospitals charge an additional fee for low-risk deliveries in their polyclinics and for the use of their facilities. As of 2008, this fee was 468.50 euros (around 23% of the average monthly household income) and it is only partially covered by universal health insurance and by supplementary health insurance, if any (NZA, 2011a; Latta et al., 2011). In conclusion, the Dutch obstetric care system is designed around risk selection and encourages the use of home births for low-risk deliveries.

2.2   Previous Literature

This paper is at the intersection of three strands of research. The first strand includes the economic studies of returns to medical technologies, the majority of which examine treatments for heart attack patients (e.g., McClellan and Newhouse, 1997; Cutler et al., 1998; McClellan and Noguchi, 1998; Skinner

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et al., 2006). The handful of papers analyzing the returns to childbirth technologies focus almost exclusively on at-risk newborns, particularly those with low and very low birth weight (Cutler and Meara, 2000; Almond et al., 2010; Bharadwaj et al., 2013; Freedman, 2012). One notable exception is the study by Almond and Doyle (2011) on the health benefits of longer hospitalizations for newborns following uncomplicated births.

The second related line of literature examines the benefits of a hospital as compared to a home birth. The research comes entirely from medical studies using observational data as it proved impossible to randomize birth location (Dowswell et al., 1996; Hendrix et al., 2009). These studies generally compare average outcomes between samples of (low-risk) women *planning* to give birth at different types of location after controlling for observable characteristics. The use of planned rather than actual place of delivery is justified by the assumption that there is less endogeneity in planned than in actual birth place, since the actual birth place may deviate from the planned one due to changes in individual health and risk factors. The results, interpreted as an intention-to-treat effect, are mixed, with some studies showing higher perinatal mortality risk among home births (e.g., Bastian et al., 1998; Pang et al., 2002; Kennare et al., 2010; Malloy, 2010; Birthplace in England Collaborative Group, 2011; Grünebaum et al., 2013) and others finding no significant differences (e.g., Ackermann-Liebrich et al., 1996; Murphy and Fullerton, 1998; Janssen et al., 2002; Lindgren et al., 2008; de Jonge et al., 2009; van der Kooy et al., 2011).[7] However, as the medical literature acknowledges, planned birth place may be endogenous (Wiegers et al., 1998; Gyte et al., 2009). In addition, the small sample sizes in several of these studies pose statistical power problems. Unlike these studies, our paper analyzes the returns to *actual* (rather than planned) hospital birth using a large sample of low-risk births. We also explicitly correct for the endogeneity of birth location using distance to the nearest obstetric ward as an instrument.

Several other studies use distance as an instrument and they form the

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[7]The studies by de Jonge et al. (2009) and van der Kooy et al. (2011) use the same data as this paper and find no significant differences between home and hospital births.

third line of research related to our paper. Generally, these studies examine the return to a more intensive procedure while accounting for the endogeneity of access to this procedure. The particular instrument used is the relative distance between the closest provider of this procedure and the closest provider of a less intensive treatment (see, for example, McClellan et al., 1994 and Cutler, 2007 in the case of heart attacks, or Freedman, 2012 in the case of NICU intensity). The two technologies compared in this paper are home and hospital births. Therefore, our instrument, the distance between a woman's residence and the nearest hospital where she can give birth, also represents a relative distance.[8]

3   Empirical Strategy

We are interested in estimating the impact of type of delivery place (home versus hospital) on infant health outcomes. The structural equation of interest can be described as follows:

$$Y_{izt} = \beta_0 + \beta_1 Hospital_{izt} + \beta_2 X_{izt} + \epsilon_{izt} \tag{1}$$

where the unit of observation is infant i who is born in year t to a mother residing in postal code z. Y_{izt} is an outcome variable capturing infant health, $Hospital_{izt}$ is a dummy variable indicating that the birth occurred in a hospital, and X_{izt} is a set of control variables representing observable characteristics of the mother and of the infant. We provide detailed information on each of these variables in section 4, after describing the data sources.

The coefficient of interest in the structural equation, β_1, measures the average difference in the health outcomes of infants born in a hospital as compared to those born at home, after controlling for observed characteristics of the mother and the infant. The primary challenge in interpreting the ordinary

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[8]Although they do not use it in an instrumental variables framework, Ravelli et al. (2011) examine the relationship between travel time and infant health outcomes among all births in the Netherlands. Similar to our reduced form results, they find that longer travel times are associated with higher infant mortality.

least squares (OLS) estimates of β_1 as causal stems from the endogenous choice of location of birth: mothers who are at a higher risk of having an unhealthy infant (for reasons that are unobservable to the researcher) may choose to give birth in a hospital, leading to a biased estimate of β_1.

To address this endogeneity problem, we employ an instrumental variables approach. In particular, we estimate the causal effect of hospital births via two stage least squares (2SLS), instrumenting for $Hospital_{izt}$ with the distance between a mother's residence and the nearest hospital with an obstetric ward. Our instrumental variable strategy identifies the local average treatment effect (LATE) for mothers who give birth in a hospital only because they live "close enough" to it, but would give birth at home if they lived farther away. This population of "compliers" is likely not a random draw from the population and thus the effect of hospital births may not reflect the average treatment effect. However, since our paper is the first to convincingly identify the causal effect of place of birth, our results are relevant nevertheless. In addition, although we cannot identify individual compliers, in section 5.4 we compare their characteristics to those of the entire sample.

In order for the 2SLS method to yield consistent estimates of the parameter of interest, three conditions must be satisfied. First, the instrument should be a strong determinant of delivery location (the relevance condition). Intuitively, home and hospital births are alternative choices for the same final outcome — a healthy birth — and expectant mothers compare the costs and benefits of each of these options when choosing their delivery location. The distance to the nearest hospital with an obstetric ward impacts this cost-benefit calculation by changing the perceived costs of a hospital birth. This motivates the following first stage equation capturing the impact of the proposed instrument on the choice of delivery location:

$$Hospital_{izt} = \alpha_0 + \alpha_1 Distance_{izt} + \alpha_2 X_{izt} + u_{izt} \qquad (2)$$

and the following reduced form equation relating the instrument to health

outcomes:

$$Y_{izt} = \delta_0 + \delta_1 Distance_{izt} + \delta_2 X_{izt} + v_{izt} \qquad (3)$$

where $Distance_{izt}$ is a measure of the distance between a mother's residence and the nearest hospital with an obstetric ward. The relevance condition is easily tested using the results of the first stage equation. As a rule-of-thumb, if the first-stage F-statistic testing the significance of the instrument is greater than 10, then the instrument is considered strong.

Second, the instrument should be conditionally uncorrelated with the error term in the structural equation (the excludability condition). Intuitively, the excludability condition states that distance affects infant health outcomes only through its impact on the likelihood of a hospital birth. This is a non-trivial assumption and it would be violated if, for example, mothers whose infants have better expected health outcomes select their residential location based on the distance to the hospitals with an obstetric ward. Similarly, distance to the nearest obstetric ward may directly impact the health outcomes of infants born to mothers who experience complications and need to be transferred during delivery. While the excludability condition cannot be tested directly, in section 5 we bring several pieces of suggestive evidence on its plausibility.

The final assumption needed for the 2SLS to yield consistent estimates is monotonicity. This assumption states that while the instrument may not impact all individuals, those who are impacted by it are all impacted in the same way. In particular, it rules out a scenario where living closer to a hospital makes some mothers more likely to give birth in a hospital while making others less likely to do so. Similar to the excludability assumption, monotonicity cannot be tested formally but we provide empirical evidence suggesting its plausibility in section 5.

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4 Data

4.1 Data Sources

Our primary data comes from the Perinatal Registry of the Netherlands (Perinatale Registratie Nederland, PRN) and covers the period 2000–2008. PRN is an annual dataset that links three separate datasets of individual birth records collected separately by midwifes (LVR-1), obstetricians (LVR-2) and paediatricians (LNR). It covers approximately 99 percent of the primary care and 100 percent of the secondary care provided during pregnancy and delivery in the Netherlands (de Jonge et al., 2009).[9] The data includes detailed information on the birth process including delivery place (home or hospital), birth attendant (midwife or obstetrician) and method of delivery (natural birth, C-section, labor augmentation, induction, etc.) as well as on the presence of any complications during pregnancy or delivery. For each newborn, PRN also provides rich data on demographics such as gender, gestational age in days, birth weight, parity and plurality, on short term health outcomes including mortality and the Apgar score, as well as limited information on diagnosis and treatment such as NICU admission within the first 7 days of life. While the PRN data includes basic demographic characteristics of mothers (age, ethnicity, residential postal code), it does not provide information on education or income. For that reason, we complement this individual-level data with postal code-level data published by Statistics Netherlands (Kerncijfers postcodegebieden 2004), providing a snapshot of postal codes characteristics as of January 1, 2004. Our main analysis uses the average household income in the postal code of residence of the mother and some of our robustness checks use additional variables from this data source. Finally, we use the 2005 Dutch National Atlas of Public Health to obtain the exact address and the availability of an obstetric ward for each hospital in the Netherlands. This information is

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[9]As discussed in section 2.1, the primary care in the Netherlands is provided by midwives and qualified general practitioners. PRN data does not include information on births supervised by general practitioners. These are a very small share of all primary care deliveries (Amelink-Verburg and Buitendijk, 2010).

used in combination with geocode data on the latitude and longitude of the centroid of each postal code to construct the instrument.

Our outcome variables include three measures that capture the short term health of newborns: 7- and 28-day mortality and 5-minute Apgar score.[10] The observable characteristics included in the regressions can be classified in four groups. The first group (time effects) includes fixed effects for the year, month and day of the week of the birth. The second group (maternal characteristics) includes mother's age and ethnicity.[11] The third group (infant characteristics) includes birth weight, gestational age, and indicators for gender, plurality, type of birth attendant and birth position.[12] Finally, we include the average household income in the postal code of residence of the mother.[13]

Our instrument is based on the straight-line distance between mother's residence and the nearest hospital with an obstetric ward with both locations defined using the centroids of their respective postal codes.[14] To allow for potentially non-linear effects of distance, we construct our instrument as a set

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[10]We do not have information on longer term mortality rates. The Apgar score summarizes the health of newborns based on five criteria: appearance (skin color), pulse (heart rate), grimace response ("reflex irritability"), activity (muscle tone), and respiration (breathing rate and effort). Newborns are usually evaluated at 1 and 5 minutes after birth. The score ranges from zero to 10 with higher scores indicating better health. Common reasons for a low Apgar score include a difficult birth (e.g, a fast delivery, a prolapsed cord, preterm birth, maternal hemorrhage), C-section, and amniotic fluid in the baby's airway.

[11]We include indicators for six maternal age categories (less than 20, 20–24, 25–29, 30–34, 35–39, 40 and above) and three maternal ethnicity categories: Dutch, Mediterranean and others (Moroccans and Turks, commonly identified as "Mediterraneans," represent the majority of the immigrant population in the Netherlands).

[12]Specifically, we include indicators for male, multiple birth, obstetrician supervision, breech birth, and a third degree polynomial in birth weight. Gestational age is included as a continuous variable but in some of the robustness checks we include additional indicators for preterm or late births.

[13]Some of the control variables (newborn gender and birth weight, mother's age, and average household income) are missing for a very small number of observations (less than 0.3 percent). We replace these missing values with the sample average of the corresponding variable and we include as additional controls indicators for missing values for each variable.

[14]Our data includes 6-digit postal codes for hospitals and 4-digit postal codes for mothers. Postal codes in the Netherlands have 6 digits and are much smaller than zip codes in the United States. The average 6-digit area has only 40 inhabitants and a land surface of 0.078 square kilometers (0.030 square miles); the average 4-digit area has 4075 inhabitants and a land surface of 8.5 square kilometers (3.28 square miles).

of six mutually exclusive dummy variables indicating distances less than 1 km, 1–2 km, 2–4 km, 4–7 km, 7–11 km, and more than 11 km. The lower cutoffs of these categories correspond approximately to the 10th, 25th, 50th, 75th and 90th percentiles of the distribution of the distance variable, respectively.

The analysis sample is constructed as follows. The initial sample includes data on 1,630,062 newborns. First, we exclude observations for which the mother's residential postal code, the type of birth location and the type of birth attendant are missing. Second, we exclude stillbirths, planned C-sections and infants with congenital anomalies. The resulting sample of 1,478,187 births can be divided into two groups based on the perceived risk of the birth. We define high-risk mothers ($N = 689,844$) as those who start their perinatal care directly with an obstetrician or are referred to an obstetrician during pregnancy (before delivery) due to newly found risk factors. These women are required to give birth in a hospital under the supervision of an obstetrician and thus are excluded from our analysis sample.[15] In our main analysis, we only consider low-risk mothers, who start their deliveries under the supervision of a midwife. We further restrict our analysis to low-risk mothers at their first birth because it is likely that mothers who gave birth before have additional information on their own risk and preferences that is unobserved to the researcher but that is used in their choice of location of birth. This leaves us with a final sample of 356,412 observations.[16,17]

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[15]One concern is the violation of the exclusion restriction due to a correlation between distance and the probability of being classified as a high-risk pregnancy. This could happen, for example, if midwives are more likely to refer women who reside farther away from an obstetric ward to obstetricians. Indeed, when we use an indicator for being classified as high-risk as the dependent variable in our reduced form equation, we do find a positive but economically small relationship between distance and high-risk classification (results available upon request). As a result, we would expect that in our sample of low-risk women those who live closer to the hospital are on average "unhealthier" than those who live farther away. Since our first stage results indicate that women are more likely to give birth in a hospital when they live closer to it, this selective referral strategy would bias our results in such a way that any health gains from a hospital birth likely represent lower bounds.

[16]In the rest of the paper, we refer to the sample consisting of the 1,478,187 observations described above as the "full sample" and the final sample consisting of the 356,412 observations as the "analysis sample".

[17]There are slight differences between the estimating samples for mortality indicators and for the Apgar score because the Apgar score is missing for a small number of observations

4.2 Descriptive Statistics

Table 1 provides descriptive statistics for the overall analysis sample, as well as by type of location of birth. Around 68 percent of all infants in the analysis sample are born in a hospital. Panel A lists the outcome variables and shows that there are substantial differences in mortality rates by location of birth. Low-risk babies who are born in a hospital are approximately four times more likely to die within a week and about 3.5 times more likely to die within 28 days than babies born at home. Similarly, babies born in a hospital have lower Apgar scores, on average, than those born at home. Panels B–D show that with the exception of birth weight and gestational age the observable characteristics of mothers and infants differ according to birth location in important ways. For example, over 90 percent of the infants born at home have a Dutch mother, in contrast to 79 percent of the babies born in a hospital. Children of Mediterranean mothers, on the other hand, tend to be born at the hospital rather than at home. Infants born in a hospital are also more likely to come from more densely populated postal codes with slightly lower average monthly income.

The differences in characteristics and health outcomes between hospital and home births have two likely causes. First, low-risk mothers who suspect themselves to be of increased risk for reasons unobserved to the midwife (and to the researcher) may self-select into a hospital birth. Second, all women who need to be referred to an obstetrician during delivery (either because of complications, slow progression, or the need for pain relief medication) have to give birth in a hospital. As the Table shows, these referrals make up over 70 percent of hospital births.

The last panel of Table 1 (Panel E) provides descriptive statistics on the instrument. The average mother resides in a postal code that is 4.8 kilometers away from the nearest hospital with an obstetric ward. The distance from a woman's residence to the nearest hospital is correlated with the type of her delivery location: those who give birth in a hospital reside in postal codes

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(less than 0.2 percent of the sample).

that are on average closer to hospitals (4.6 km) than those who give birth at home (5.3 km). Overall, the evidence presented in Table 1 is consistent with riskier births selecting into hospitals and with a negative correlation between distance and the likelihood of a hospital birth.

5   Results

5.1   Baseline Estimates

Table 2 reports the results of our main specifications controlling for time effects, maternal and infant characteristics, as well as the average household income. Panel A provides estimates from OLS models which suggest that giving birth in a hospital is not associated with lower infant mortality but that it is associated on average with a 0.06-point lower Apgar score. However, online Appendix Table A1 shows that the results are highly sensitive to the set of control variables included in a way suggestive of selection of riskier births into hospitals. Online Appendix Table A2 further shows that these findings are robust to using non-linear models.

In the remainder of the section we turn to the causal effect of a hospital birth on newborn outcomes. We begin by examining the first stage relationship between distance and the likelihood of a hospital birth. Figure 1 shows that the risk-adjusted probability of a hospital birth declines as the distance to the closest obstetric ward increases and that this relationship is indeed non-linear. In Panel B of Table 2 we present the estimated coefficients of the distance indicators from the first stage equation (2). The results confirm that the distance between an expectant mother's home and the closest hospital with an obstetric ward is a strong predictor of whether she gives birth in a hospital or at home. For example, women living within 1 km of a hospital with an obstetric ward are 7.5 percentage points (11% at the mean) more likely to deliver in a hospital than those living at least 11 km away from a hospital. Although this effect diminishes as the distance between the mother's residence and the nearest hospital goes up, women located within 7–11 km of

an obstetric ward are still 3 percentage points (4% at the mean) more likely to deliver in a hospital than those living farther away. The F-statistic testing the joint significance of the distance indicators is equal to 28, indicating that the instrument is strong. Online Appendix Table A3 shows that these results hold regardless of the set of control variables included.

Panel C of Table 2 presents the reduced form relationship between the outcomes and the instrument, which is also plotted in online Appendix Figure A1. The results indicate a strong and almost monotonic relationship between the distance indicators and infant mortality. For example, we find that 7-day (28-day) infant mortality is lower on average by 0.701 (0.853) deaths per 1,000 births among individuals residing within 1 km of a hospital as compared to those who live at least 11 km away from a hospital. This is a large effect when compared to a sample mean of 1.779 (1.978) deaths per 1,000 births. Online Appendix Table A4 shows that this relationship tends to grow stronger as more controls are added, suggesting negative selection of mothers into postal codes closer to hospitals. In addition, Table A5 in the online Appendix confirms the robustness of these findings to non-linear specifications.

The last panel of Table 2 presents the instrumental variable estimates. In sharp contrast to OLS estimates, the 2SLS results point to significant reductions in mortality and no effects on Apgar score from a hospital birth. In particular, we find that giving birth in a hospital reduces infant mortality by 8 to 9 deaths per 1,000 births. These reductions are large when compared to sample means of 1.779 and 1.978 for 7-day and 28-day mortality, respectively. To put them into context, consider historical data over the period 1980–2009. These data show that 7-day (28-day) mortality declined from 4.25 (5.35) deaths per 1,000 births in 1980-85 to 2.42 (3.18) deaths in 2005-09. During the same period, the share of hospital births increased from 61.25% to 72.06%. Our IV results suggest that a 10.81 percentage point increase in the share of hospital births reduces 7-day (28-day) mortality on average by 0.89 (0.99) deaths per 1,000 births. This represents about 49% (46%) of the reduction in infant mortality between 1980 and 2009.

Two points are worth emphasizing when thinking about the magnitudes

of the effects. First, the 2SLS estimates have wide confidence intervals that include much smaller but still economically important effects. For example, the lower bounds of a 95-percent confidence interval indicate 2.1 and 2.6 fewer infant deaths per 1,000 births, respectively, for 7-day and 28-mortality. Second, as noted in section 3, our instrumental variable strategy identifies a LATE and thus our results apply to a population of compliers: mothers who are induced to give birth in a hospital because they live "close enough" to it. We describe the characteristics of this compliant population in section 5.4 after demonstrating the robustness of our estimates to various checks.

5.2 Instrument Validity

As discussed in section 3, the instrumental variable method yields consistent estimates if the instrument satisfies the relevance, the excludability and the monotonicity conditions. The first stage results presented in Table 2 show that the relevance condition is satisfied. While excludability and monotonicity cannot be tested directly, in this section we bring suggestive evidence on their plausibility.

The specific institutional setup of the Netherlands allows us to perform an intuitive validity check of the excludability condition. As discussed in section 4, we define high-risk mothers as those who are under the care of an obstetrician at the start of delivery and have to give birth in a hospital. This means that there is no variation in type of delivery place in this sample (and so no relationship between the instrument and birth location). Hence, evidence of a relationship between distance and newborn health in this sample would indicate a violation of the excludability assumption. Table 3 reports the estimated coefficients of the distance indicators from the reduced form equation (3) among high-risk women. We find no relationship between distance and infant health, both in the sample of first-born children and in the sample of all children born to high-risk mothers. The coefficient estimates are always statistically insignificant and small relative to the mean of the outcome variable. In addition, F-tests reject the joint significance of the distance indicators at

p-values ranging from 0.521 to 0.769.

Online Appendix Table A6 provides further suggestive evidence on the plausibility of the excludability assumption by examining whether the observable characteristics are balanced across the distribution of our instrument. While many observable characteristics are balanced, we find some evidence that infants residing in areas close to a hospital are somewhat riskier in terms of observable characteristics (see the last panel of the Table which shows the average predicted newborn health based on a regression model including all the observable characteristics).[18] It is worth emphasizing that this *negative* selection combined with our first stage results imply that any bias in our 2SLS estimates would be in the direction of finding negative health effects from a hospital birth. Therefore, our findings likely represent lower bounds of the true effect.[19]

In our context, the monotonicity assumption states that all women who are affected by the instrument are less likely to choose a hospital birth as the distance to an obstetric ward increases. This is a non-trivial assumption because women choose their type of delivery location. Suppose women make their choice by comparing the comfort of a home birth to the risk of a negative outcome due to complications during delivery. As distance to an obstetric ward goes up, the risk of a negative outcome increases due to longer travel times to a hospital. In this case, it is possible that women who live far away from a hospital prefer a hospital birth, violating the monotonicity assumption. Intuitively, we do not expect such a violation to be present in our sample for several reasons. First, the fact that women can only go to the hospital after contractions reach a certain frequency makes the trip increasingly uncomfortable for women living farther away from a hospital. Second, the fact that we observe a positive relationship between distance and the probability of be-

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[18]Previous studies that use distance as an instrument when examining returns to heart attack technologies or NICUs also find some evidence of residential sorting based on ethnicity and average urbanization (McClellan et al., 1994; Cutler, 2007; Freedman, 2012).

[19]We confirm this conjecture using the method suggested by Altonji et al. (2005). We estimate the bias in our 2SLS results when the instrument is a binary indicator for distance less than the median and find that it is indeed positive (1.526 for 7-day mortality and 2.104 for 28-day mortality).

ing classified as high-risk suggests that midwives might refer more risk-averse women to an obstetrician in order to ensure a hospital birth.

Online Appendix Table A7 provides suggestive evidence on the plausibility of the monotonicity assumption by comparing the means of selected covariates among women who deliver in a particular type of location by distance to the nearest obstetric ward. To the extent that women who choose a hospital (or home) birth have similar observable characteristics across distance categories, we may be less concerned about them responding in different ways to the instrument. As the Table shows, the relationships between distance and observable characteristics closely mimic those found in the overall sample, regardless of location of delivery. These findings may not be surprising given that 98 percent of the Dutch population lives within a 30-minute drive from an obstetrics ward (Nationale Atlas Volksgezondheid, 2011).[20]

It is important to emphasize that the key identifying assumptions of IV are ultimately untestable and there may be scenarios under which they are violated that cannot be ruled out by our checks. Similarly, none of these tests are individually sufficient to claim the validity of the 2SLS assumptions. However, taken together they provide consistent evidence that these assumptions are likely to hold in our context.

5.3 Robustness Checks

Online Appendix Table A8 presents our robustness checks. In Panel A, we show that our results are not driven by the exclusion of newborns with congenital anomalies or stillbirths. When we add higher order low-risk births, we still find substantial reductions in mortality. The estimated effects are somewhat smaller, consistent with the idea that women use information on their unobserved health risk from previous births to better select their delivery lo-

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[20]We provide additional evidence on the plausibility of the monotonicity assumption in section 5.3 by showing that our 2SLS results are robust when the sample is split by average car ownership per capita in the postal code, a factor likely to directly impact the choice of type of delivery location.

cation.[21] We also provide results from the full sample which are statistically indistinguishable from the baseline estimates.

In our empirical strategy, we define birth location according to where the birth occurred rather than where the delivery started because this information is not available in our data. Instead, we use information on midwife-to-obstetrician referrals (which include home-to-hospital transfers and within-hospital referrals) to investigate the sensitivity of our results. We obtain similar results to the baseline both when we re-classify all referrals as home births instead of hospital births and when we replace the actual birth place of referrals with the planned place of birth if this was provided (see Panel B).[22]

In Panel C, we revisit the plausibility of the monotonicity condition. We use information on car ownership, which arguably has a direct impact on the cost-benefit calculation of a hospital birth.[23] When we split the sample using the median number of cars per person in the postal code, the results are statistically indistinguishable between the two subsamples and suggest again mortality reductions from a hospital birth.

The results are also similar when we include additional control variables (Panel D), when we define the instrument based on continuous straight-line distance or driving distance categories (Panel E), when we cluster the standard errors at different aggregation levels (Panel F), and when we use limited information maximum likelihood (Panel G).

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[21]Mothers who have a risky first birth (and thus possibly worse unobserved risk) may become "always-takers" and always choose a hospital birth in subsequent pregnancies. As a result, the compliant population among higher-order births may have lower health gains from a hospital birth, leading to lower coefficient estimates among all low-risk births.

[22]The planned place of birth is recorded by midwives at any time during pregnancy, and in a significant number of cases not at all or after delivery, making the variable potentially endogenous.

[23]We have data from Statistics Netherlands (CBS Statline, accessed on June 11, 2012) on the average car ownership per citizen in each postal code dating from January 1, 2004. The median number of cars per person is 0.435.

5.4 Heterogeneous Effects and Complier Characteristics

To the extent that there is heterogeneity in the effect of a hospital birth, our 2SLS results represent a local average treatment effect that applies to the subpopulation of compliers: women who give birth in a hospital *because* of the particular distance between their residence and the closest hospital with an obstetric ward. Online Appendix Table A9 examines the heterogeneity in the 2SLS effects by selected observable characteristics of mothers and their newborns (online Appendix Table A10 reports the corresponding first stage results). We find that the 2SLS estimates are similar when the sample is split by maternal ethnicity, median age (29 years), median gestational age (280 days) or median birth weight (3,410 grams). However, there is substantial heterogeneity with respect to the average monthly income in the postal code of the mother's residence. In particular, our baseline results are driven entirely by births to mothers residing in postal codes with less than the median of the average monthly household income in the postal code (1,929 euros).

In the remainder of this section we focus on the compliant subpopulation. While it is not possible to identify individual compliers, we can calculate their share among the analysis sample as well as the distribution of their characteristics (Imbens and Angrist, 1994; Angrist and Imbens, 1995). When the instrument consists of a set of mutually exclusive indicators, as in our case, the estimated LATE is a weighted average of the LATEs using each indicator one at a time. In particular, there is a distinct compliant subpopulation corresponding to each distance indicator. Therefore, the size and characteristics of compliers can be calculated separately for each indicator.

Online Appendix Table A11 shows that compliers represent approximately 10.6 percent of all low-risk first births. In addition, compliant mothers have observable characteristics not generally associated with higher risk: they are more likely to be Dutch and younger than the median age of 29, and their pregnancies are more likely to be within the normal range (i.e., gestational age between 37 and 42 weeks).[24]

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[24]Although complier newborns tend to be lighter than the median newborn in the analysis sample (3,410 grams), the vast majority of babies in our sample are above the medical at-risk

In conclusion, we find that compliers do not have higher observable risk but our results are entirely driven by births from lower-income postal codes. This is consistent with the previous literature documenting disparities in preventive behavior and quality of care by income and education (e.g., Smith, 1999; Cutler and Lleras-Muney, 2010). Midwives serving lower-income postal codes frequently argue that expectant mothers residing in these areas have poorer health education and life styles, suggesting worse unobserved preventive behavior.[25] The tendency among complier newborns to be lighter and among complier mothers to be younger also fits with the poorer preventive behavior explanation (maternal age is strongly positively correlated with education in the Netherlands; van Agtmaal-Wobma and van Huis, 2008). However, we emphasize that we do not have data that allow us to distinguish between unobserved preventive behavior and quality of care as the driver of our results.

5.5 Mechanisms

Our 2SLS results indicate that the broadly measured general health condition of children born in different locations is similar shortly after birth, as captured by the 5-minute Apgar score. This indicates that the mortality reductions observed in the first 7 or 28 days of life following a hospital birth come from medical care provided after delivery. There are many channels through which a hospital birth may reduce infant mortality, such as the availability of better facilities and equipment, potentially better hygiene (sterility) or the proximity to other medical services. Unfortunately, our data does not allow us to identify the precise mechanism. Instead, we use information on a specific type of treatment for which reliable information is available: admission to a NICU

threshold of 2,500 grams because fetal growth retardation is one of the reasons for referral to an obstetrician (only 2.7 percent of the newborns in our sample weigh less than 2,500 grams).

[25] A recent survey by the Royal Dutch Organisation of Midwives reports that midwives needed on average 23 percent extra time when caring for lower-income women, leading to a 2009 policy change that increased the reimbursement for midwives by 23 percent in selected postal codes (NZA, 2011b). According to the report, the need for extra time was due to the difficulties in collecting relevant (medical) data, additional education on prevention, lifestyles and risk, more frequent home visits, consultations to exclude uncertainties, etc.

within the first seven days of life.[26]

In particular, we investigate whether giving birth in a hospital with or without a NICU has differential effects on newborn health. Following a strategy similar to our baseline model (1), we include two indicators for birth in a hospital with and without a NICU. We then use the distance between a mother's residence and the nearest hospital of each type as instruments. The results, provided in Table 4, indicate substantial mortality gains from both types of hospitals. While the two estimates are statistically indistinguishable, they bracket the baseline estimate: giving birth in a hospital with a NICU leads to slightly larger mortality gains while a birth in a hospital without a NICU has somewhat smaller mortality benefits. We cautiously interpret this as evidence that access to medical technologies may be an important channel in explaining the lower mortality among hospital births.

6   Conclusions

In this paper, we examine the impact of home births on the health outcomes of low-risk newborns. We implement an instrumental variables strategy that exploits the exogenous variation in distance between a mother's residence and the nearest obstetric ward. Using data from the Netherlands for the period 2000–2008, we find that giving birth in a hospital leads to substantial reductions in infant mortality but has no effect on Apgar scores.

Our results represent a local average treatment effect that applies to the subsample of low-risk women who give birth in a hospital because they reside close enough to it, but would give birth at home if they lived farther away. We show that compliers have observable characteristics that are not generally associated with higher health risks — they are younger, more likely to be native, and more likely to give birth within the normal gestational age interval — but our results are entirely driven by those residing in below-median postal codes.

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[26]Evidence on the health benefits of NICUs is mixed. Some papers find that NICUs significantly improve the health and survival of at-risk newborns (e.g., Cutler and Meara, 2000), while others find evidence of a negative correlation between availability of NICU and newborn health outcomes (e.g., Goodman et al., 2002).

Data limitations do not allow us to investigate many potentially important channels that may facilitate these health gains but our finding that mortality gains are slightly larger in hospitals with a NICU suggests that proximity to medical technologies may be one of these channels.

As high health care costs persist and out-of-hospital births keep rising sharply in many developed countries, understanding the impact of home births on newborn outcomes becomes even more important. Taken together, our results suggest that giving birth in a hospital leads to economically large mortality reductions even in a health care system that is specifically geared toward risk selection and home births.

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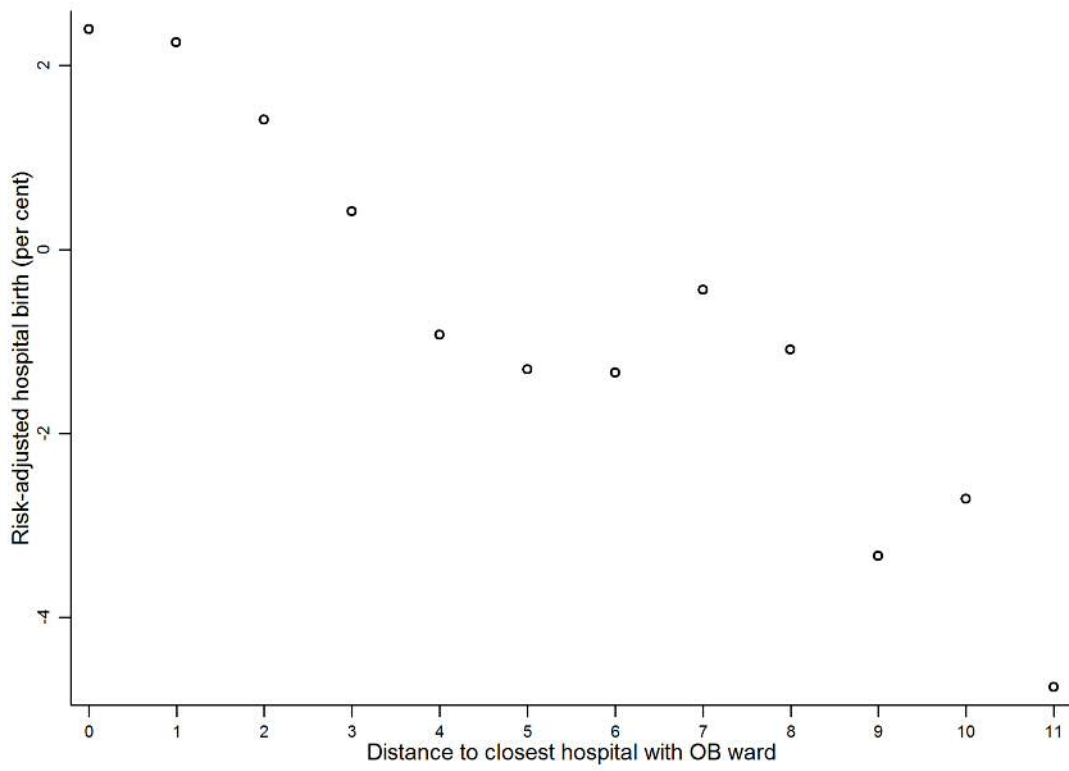
Figure 1: Risk-adjusted fraction of hospital births by distance to the nearest hospital

Table 1: Descriptive Statistics

	Analysis Sample		Hospital		Home	
	Mean (1)	Sd (2)	Mean (3)	Sd (4)	Mean (5)	Sd (6)
A. Outcome Variables						
7-Day Mortality (per 1,000)	1.779	42.139	2.335	48.268	0.609	24.676
28-Day Mortality (per 1,000)	1.978	44.431	2.575	50.683	0.722	26.868
Apgar Score	9.660	0.818	9.585	0.898	9.818	0.586
B. Mother's Characteristics						
Age	28.380	4.652	28.332	4.828	28.482	4.255
Ethnicity: Dutch	0.827	0.378	0.786	0.410	0.913	0.281
Ethnicity: Mediterranean	0.064	0.246	0.082	0.274	0.029	0.166
C. Infant Characteristics						
Boy	0.509	0.500	0.519	0.500	0.488	0.500
Birth weight	3413	480	3416	503	3408	429
Gestational Age (days)	279	11	279	12	279	8
Obstetrician Supervision	0.482	0.500	0.712	0.453	0.000	0.000
Multiple Birth	0.001	0.023	0.001	0.028	0.000	0.000
Breech Birth	0.011	0.103	0.015	0.123	0.001	0.025
D. Average Postal Code Characteristics						
Monthly Household Income (euro)	1975	313	1970	322	1987	292
Density	1969	1889	2053	1907	1793	1840
Percent 0–15 years old	18.750	4.447	18.609	4.440	19.045	4.447
E. The Instrument						
Distance (km)	4.803	4.041	4.558	3.930	5.317	4.217
< 1 km	0.092	0.289	0.099	0.298	0.079	0.269
1–2 km	0.225	0.418	0.240	0.427	0.194	0.395
2–4 km	0.243	0.429	0.250	0.433	0.226	0.419
4–7 km	0.198	0.399	0.191	0.393	0.214	0.410
7–11 km	0.139	0.346	0.129	0.335	0.159	0.365
≥ 11 km	0.103	0.304	0.091	0.288	0.129	0.335
Observations	356,412		241,519		114,893	

Notes: The first two columns provide sample means and standard deviations for the full analysis sample. The remaining columns provide descriptive statistics by location of birth.

Table 2: Infant health, hospital births, and distance to the nearest hospital

	7-Day Mortality (1)	28-Day Mortality (2)	Apgar Score (3)
A. OLS (dependent variable: newborn health)			
Hospital	−0.001	−0.072	−0.061***
	(0.155)	(0.163)	(0.004)
B. First Stage (dependent variable: hospital birth)			
Distance: < 1 km	0.075***	0.075***	0.074***
	(0.009)	(0.009)	(0.009)
Distance: 1–2 km	0.073***	0.073***	0.073***
	(0.008)	(0.008)	(0.008)
Distance: 2–4 km	0.060***	0.060***	0.060***
	(0.007)	(0.007)	(0.007)
Distance: 4–7 km	0.037***	0.037***	0.036***
	(0.007)	(0.007)	(0.007)
Distance: 7–11 km	0.030***	0.030***	0.030***
	(0.008)	(0.008)	(0.008)
F-statistic	27.979	27.979	28.031
C. Reduced form (dependent variable: newborn health)			
Distance: < 1 km	−0.701**	−0.853**	0.020**
	(0.324)	(0.341)	(0.009)
Distance: 1–2 km	−0.702**	−0.770***	−0.003
	(0.282)	(0.299)	(0.008)
Distance: 2–4 km	−0.554**	−0.718**	0.006
	(0.276)	(0.293)	(0.007)
Distance: 4–7 km	−0.330	−0.500*	0.004
	(0.286)	(0.301)	(0.008)
Distance: 7–11 km	−0.548*	−0.629**	0.016**
	(0.294)	(0.309)	(0.008)
D. IV (dependent variable: newborn health)			
Hospital	−8.287***	−9.219***	−0.018
	(3.157)	(3.353)	(0.088)
Observations	356,412	356,412	355,761
Mean fraction hospital birth	0.678	0.678	0.678
Mean health outcome	1.779	1.978	9.660

Notes: Each column in each panel lists estimates from separate regressions. All regressions control for year, month and day-of-week of birth, maternal age, ethnicity, gestational age, a third degree polynomial in birth weight, newborn gender, multiple birth, obstetrician supervision, breech birth, and average income in the postal code of mother's residence (see section 4). The excluded distance category comprises postal codes at least 11 km away from an obstetric ward. The F-statistic corresponds to a test of joint significance of the distance indicators. Robust standard errors clustered at the postal code level are shown in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3: Distance and Infant Outcomes in the High-Risk Sample

	First Births			All Births		
	7-Day Mortality (1)	28-Day Mortality (2)	Apgar Score (3)	7-Day Mortality (4)	28-Day Mortality (5)	Apgar Score (6)
Distance: < 1 km	0.058	0.321	0.003	0.102	0.127	0.009
	(0.615)	(0.601)	(0.013)	(0.414)	(0.409)	(0.010)
Distance: 1–2 km	−0.089	0.013	−0.011	−0.068	−0.063	−0.008
	(0.475)	(0.488)	(0.010)	(0.314)	(0.324)	(0.008)
Distance: 2–4 km	0.054	0.133	−0.008	−0.150	−0.169	−0.004
	(0.488)	(0.493)	(0.010)	(0.313)	(0.316)	(0.008)
Distance: 4–7 km	−0.430	−0.308	−0.007	−0.091	−0.069	−0.005
	(0.480)	(0.489)	(0.010)	(0.307)	(0.311)	(0.008)
Distance: 7–11 km	0.402	0.524	−0.009	0.279	0.270	−0.007
	(0.525)	(0.528)	(0.010)	(0.320)	(0.323)	(0.008)
P-value for joint significance	0.555	0.521	0.769	0.729	0.725	0.575
Observations	329,598	329,598	329,204	689,893	689,893	689,108
Mean of dependent variable	7.497	8.152	9.426	6.881	7.500	9.499

Notes: Each column in each panel lists estimates from separate regressions. The dependent variable is the newborn health outcome listed in the column. All regressions control for year, month and day-of-week of birth, maternal age, ethnicity, gestational age, a third degree polynomial in birth weight, newborn gender, multiple birth, obstetrician supervision, breech birth, and average income in the postal code of mother's residence (see section 4). P-values from F-tests of joint significance of the distance indicators are listed along with the mean of the outcome variables. Robust standard errors clustered at the postal code level are shown in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: Effect of a Hospital Birth With and Without a NICU

	7-Day Mortality (1)	28-Day Mortality (2)	Apgar Score (3)
A. First stage, dependent variable: birth in hospital w/ NICU			
Distance to closest hospital w/o NICU	0.002***	0.002***	0.002***
	(0.001)	(0.001)	(0.001)
Distance to closest hospital w/ NICU	−0.004***	−0.004***	−0.004***
	(0.000)	(0.000)	(0.000)
B. First stage, dependent variable: birth in hospital w/o NICU			
Distance to closest hospital w/o NICU	−0.008***	−0.008***	−0.008***
	(0.001)	(0.001)	(0.001)
Distance to closest hospital w/ NICU	0.004***	0.004***	0.004***
	(0.000)	(0.000)	(0.000)
C. IV			
Birth in hospital w/o NICU	−7.599**	−8.917**	0.031
	(3.301)	(3.548)	(0.091)
Birth in hospital w/ NICU	−8.907***	−10.117***	−0.083
	(3.443)	(3.682)	(0.091)
Observations	356,412	356,412	355,761
Mean of dependent variable	1.779	1.978	9.660
Kleibergen-Paap F statistic	67.541	67.541	67.281

Notes: Each column in each panel lists estimates from separate regressions. The dependent variable in Panel C is the newborn health outcome listed in the column. All regressions control for year, month and day-of-week of birth, maternal age, ethnicity, gestational age, a third degree polynomial in birth weight, newborn gender, multiple birth, obstetrician supervision, breech birth, and average income in the postal code of mother's residence (see section 4). The Kleibergen-Paap F statistic corresponds to the test of weak instruments. Robust standard errors clustered at the postal code level are shown in parentheses. * $p <$ 0.10, ** $p < 0.05$, *** $p < 0.01$.

Saving Lives at Birth:

The Impact of Home Births on Infant Outcomes

Online Appendix

N. Meltem Daysal
University of Southern Denmark

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Reyn van Ewijk
University Medical Centre Mainz and University of Mainz
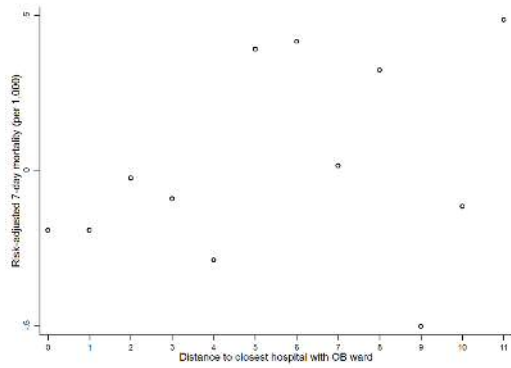
(a) 7-day mortality
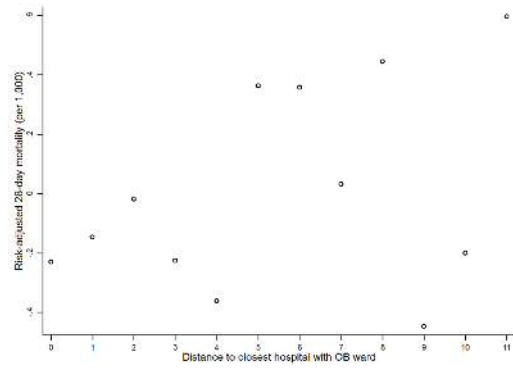
(b) 28-day mortality
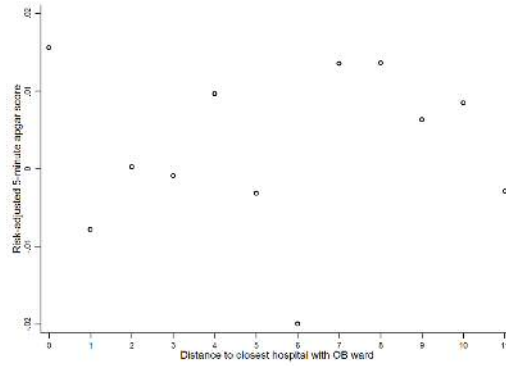
(c) Apgar score

Figure A1: Risk-adjusted newborn health outcomes by distance to the nearest hospital

Table A1: OLS Estimation of the Effects of Hospital Births on Infant Outcomes

	(1)	(2)	(3)	(4)	(5)
Dependent Variable: 7-Day Mortality (per 1,000; N=356,412)					
Hospital	1.726***	1.721***	1.644***	−0.003	−0.001
	(0.129)	(0.131)	(0.133)	(0.155)	(0.155)
Dependent Variable: 28-Day Mortality (per 1,000; N=356,412)					
Hospital	1.853***	1.835***	1.754***	−0.074	−0.072
	(0.135)	(0.137)	(0.141)	(0.163)	(0.163)
Dependent Variable: Apgar Score (N=355,761)					
Hospital	−0.233***	−0.228***	−0.231***	−0.061***	−0.061***
	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)
Time Effects		X	X	X	X
Mother's Char.			X	X	X
Infant Char.				X	X
Average HH Income					X

Notes: Each cell represents the estimated effect of a hospital birth on the health outcome indicated in the panel. Time effects include indicators for year, month and day-of-week of birth. Mother's characteristics include indicators for maternal age and ethnicity groups. Infant characteristics include gestational age, a third degree polynomial in birth weight and indicators for male, multiple birth, obstetrician supervision and breech birth. Average household income refers to the average income in the postal code of mother's residence. For more information, see section 4. Robust standard errors clustered at the postal code level are shown in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A2: Hospital Birth and Infant Outcomes – Probit Models

	(1)	(2)	(3)	(4)	(5)
Dependent Variable: 7-Day Mortality					
Hospital	0.002284***	0.002266***	0.002195***	0.000300	0.000302
	(0.000234)	(0.000234)	(0.000235)	(0.000234)	(0.000233)
N	356,412	356,412	356,331	356,331	356,331
Dependent Variable: 28-Day Mortality					
Hospital	0.002409***	0.002371***	0.002298***	0.000240	0.000242
	(0.000237)	(0.000236)	(0.000239)	(0.000244)	(0.000244)
N	356,412	356,412	356,331	356,331	356,331
Time Effects		X	X	X	X
Mother's Char.			X	X	X
Infant Char.				X	X
Avg. HH Income					X

Notes: Each cell presents the average marginal effect of a hospital birth from a different regression and corresponds to the effects in Table A1 divided by 1,000. Time effects include indicators for year, month and day-of-week of birth. Mother's characteristics include indicators for maternal age and ethnicity groups. Infant characteristics include gestational age, a third degree polynomial in birth weight and indicators for male, multiple birth, obstetrician supervision and breech birth. Average household income refers to the average income in the postal code of mother's residence. For more information, see section 4. Robust standard errors clustered at the postal code level are shown in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A3: Distance and Type of Location of Birth – First Stage Estimates

	(1)	(2)	(3)	(4)	(5)
Dependent Variable: Hospital					
Distance: < 1 km	0.127***	0.128***	0.087***	0.075***	0.075***
	(0.011)	(0.011)	(0.010)	(0.009)	(0.009)
Distance: 1–2 km	0.124***	0.125***	0.082***	0.074***	0.073***
	(0.009)	(0.009)	(0.009)	(0.008)	(0.008)
Distance: 2–4 km	0.100***	0.100***	0.071***	0.060***	0.060***
	(0.009)	(0.008)	(0.008)	(0.007)	(0.007)
Distance: 4–7 km	0.053***	0.055***	0.047***	0.037***	0.037***
	(0.009)	(0.008)	(0.008)	(0.007)	(0.007)
Distance: 7–11 km	0.032***	0.036***	0.033***	0.030***	0.030***
	(0.010)	(0.009)	(0.009)	(0.008)	(0.008)
F-statistic	62.051	64.510	28.002	27.966	27.979
N	356,412	356,412	356,412	356,412	356,412
Time Effects		X	X	X	X
Mother's Char.			X	X	X
Infant Char.				X	X
Average HH Income					X

Notes: Each column lists estimates from separate regressions of the main independent variable (an indicator for a hospital birth) on the instrument. The excluded distance category comprises postal codes at least 11 km away from an obstetric ward. Time effects include indicators for year, month and day-of-week of birth. Mother's characteristics include indicators for maternal age and ethnicity groups. Infant characteristics include gestational age, a third degree polynomial in birth weight and indicators for male, multiple birth, obstetrician supervision and breech birth. Average household income refers to the average income in the postal code of mother's residence. For more information, see section 4. The F-statistic refers to the test of joint significance of the distance indicators. Robust standard errors clustered at the postal code level are shown in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A4: Distance and Infant Outcomes – Reduced Form Estimates

	(1)	(2)	(3)	(4)	(5)
A. Dependent Variable: 7-Day Mortality (per 1,000)					
Distance: < 1 km	−0.286	−0.290	−0.492	−0.725**	−0.701**
	(0.342)	(0.342)	(0.344)	(0.324)	(0.324)
Distance: 1–2 km	−0.501*	−0.505*	−0.718**	−0.724**	−0.702**
	(0.288)	(0.288)	(0.292)	(0.282)	(0.282)
Distance: 2–4 km	−0.459	−0.466	−0.607**	−0.592**	−0.554**
	(0.289)	(0.289)	(0.288)	(0.276)	(0.276)
Distance: 4–7 km	−0.317	−0.323	−0.366	−0.383	−0.330
	(0.295)	(0.295)	(0.296)	(0.286)	(0.286)
Distance: 7–11 km	−0.574*	−0.578*	−0.594**	−0.572*	−0.548*
	(0.301)	(0.301)	(0.302)	(0.294)	(0.294)
B. Dependent Variable: 28-Day Mortality (per 1,000)					
Distance: < 1 km	−0.403	−0.405	−0.620*	−0.873**	−0.853**
	(0.365)	(0.365)	(0.368)	(0.341)	(0.341)
Distance: 1–2 km	−0.550*	−0.552*	−0.779**	−0.789***	−0.770***
	(0.311)	(0.311)	(0.315)	(0.299)	(0.299)
Distance: 2–4 km	−0.608*	−0.613**	−0.762**	−0.751**	−0.718**
	(0.311)	(0.311)	(0.310)	(0.293)	(0.293)
Distance: 4–7 km	−0.474	−0.478	−0.524*	−0.545*	−0.500*
	(0.315)	(0.316)	(0.316)	(0.301)	(0.301)
Distance: 7–11 km	−0.650**	−0.652**	−0.669**	−0.649**	−0.629**
	(0.325)	(0.325)	(0.326)	(0.309)	(0.309)
C. Dependent Variable: Apgar Score					
Distance: < 1 km	0.006	0.006	0.006	0.013	0.020**
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Distance: 1–2 km	−0.014*	−0.014*	−0.014*	−0.007	−0.003
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Distance: 2–4 km	−0.003	−0.003	−0.003	0.001	0.006
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Distance: 4–7 km	−0.002	−0.002	−0.002	−0.001	0.004
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Distance: 7–11 km	0.014*	0.014*	0.014*	0.015*	0.016**
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Time Effects		X	X	X	X
Mother's Char.		X	X	X	X
Infant Char.			X	X	X
Average HH Income					X

Notes: Each column lists estimates from separate regressions of the outcome variable indicated in the panel on the instrument. The excluded distance category comprises postal codes at least 11 km away from an obstetric ward. Time effects include indicators for year, month and day-of-week of birth. Mother's characteristics include indicators for maternal age and ethnicity groups. Infant characteristics include gestational age, a third degree polynomial in birth weight and indicators for male, multiple birth, obstetrician supervision and breech birth. Average household income refers to the average income in the postal code of mother's residence. For more information, see section 4. Robust standard errors clustered at the postal code level are shown in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A5: Distance and Infant Outcomes – Reduced Form Estimates, Probit Models

	7-Day Mortality (1)	28-Day Mortality (2)
Distance: < 1 km	−0.000896***	−0.000988***
	(0.000320)	(0.000335)
Distance: 1–2 km	−0.000777***	−0.000804***
	(0.000288)	(0.000302)
Distance: 2–4 km	−0.000703**	−0.000799***
	(0.000283)	(0.000296)
Distance: 4–7 km	−0.000502*	−0.000627**
	(0.000295)	(0.000307)
Distance: 7–11 km	−0.000690**	−0.000787**
	(0.000302)	(0.000311)
N	356,331	356,331

Notes: Each column represents a different regression. The dependent variable is the probability of death in the first 7 days (column 1) or 28 days (column 2) after birth. All specifications include our baseline set of controls. Each cell presents the average marginal effect of the corresponding variable and corresponds to the effects in Table A4 divided by 1,000. The excluded distance category comprises postal codes at least 11 km away from an obstetric ward. Robust standard errors clustered at the postal code level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A6: Average Observable Characteristics by Distance to the Nearest Hospital

	Distance to the nearest hospital					
	< 1km (1)	1–2 km (2)	2–4 km (3)	4–7 km (4)	7–11 km (5)	≥ 11 km (6)
A. Mother's Characteristics						
Age	28.287	28.255	28.275	28.635*	28.560	28.253
Ethnicity: Dutch	0.739	0.728	0.794***	0.897***	0.923***	0.933***
Ethnicity: Mediterranean	0.105	0.114	0.073**	0.031***	0.023***	0.022***
B. Infant Characteristics						
Boy	0.509	0.509	0.508	0.510	0.507	0.508
Birth weight	3,400	3,400	3,404	3,424***	3,425***	3,437***
Gestational Age (days)	278.84	279.02*	278.83	278.79	278.80	278.82
Obstetrician Supervision	0.493	0.487	0.490	0.482*	0.467***	0.463***
Multiple Birth	0.00058	0.00070	0.00046	0.00047	0.00049	0.00046
Breech Birth	0.010	0.009	0.010	0.012***	0.012**	0.012**
C. Average Postal Code Characteristics						
Monthly HH Income (euro)	1,943	1,935	1,997	2,057*	1,970	1,892
Density	3,338	3,532	1,957***	1,110***	746***	660***
Percent 0–15 years old	16.116	16.578	19.056***	20.453***	20.072***	20.067***
D. Predicted Outcomes						
Predicted 7-Day Mortality	2.205	1.799***	1.780***	1.759***	1.671***	1.652***
Predicted 28-Day Mortality	2.429	2.003***	1.981***	1.955***	1.868***	1.843***
Predicted Apgar Score	9.652	9.655	9.658***	9.663***	9.665***	9.664***
N	32,887	80,193	86,430	70,619	49,446	36,837

Notes: For a description of the variables, see section 4. Stars indicate significance of t-tests for the equality of means with distance category "< 1km" * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A7: Average Observable Characteristics by Distance and Location of Birth

	Hospital Birth						Home Birth					
	< 1 km (1)	1–2 km (2)	2–4 km (3)	4–7 km (4)	7–11 km (5)	≥ 11 km (6)	< 1 km (7)	1–2 km (8)	2–4 km (9)	4–7 km (10)	7–11 km (11)	≥ 11 km (12)
A. Mother's Characteristics												
Age	28.136	28.077**	28.177*	28.685**	28.666**	28.425	28.685***	28.720***	28.504***	28.541***	28.377***	27.997
Dutch	0.694***	0.681***	0.752***	0.870***	0.900	0.913	0.856***	0.851***	0.891***	0.949***	0.962	0.963
Mediterranean	0.124***	0.136***	0.090***	0.041***	0.031	0.028	0.055***	0.055***	0.034***	0.013	0.009	0.013
B. Infant Characteristics												
Boy	0.517	0.519	0.516	0.521	0.520	0.519	0.488	0.483	0.490	0.490	0.484	0.491
Birth weight	3,399***	3,399***	3,405***	3,430***	3,435**	3,447	3,402***	3,404***	3,400***	3,413*	3,406***	3,423
Gestational Age	279	279**	279	279	279	279	279	279	279*	279	279*	279
OB/GYN Supervision	0.680***	0.674***	0.701***	0.740***	0.741***	—	—	—	—	—	—	—
Multiple Birth	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Breech Birth	0.013***	0.012***	0.014***	0.018	0.018	0.019	0.001	0.000	0.001	0.001	0.001	0.001
C. Average Postal Code Characteristics												
Avg. HH Income	1,934	1,927	1,989***	2,055***	1,971***	1,891	1,967**	1,958***	2,017***	2,061***	1,968***	1,892
Density	3,387***	3,539***	1,979***	1,132***	765***	650	3,209***	3,513***	1,907***	1,067***	714	675
Percent 0–15 y.o.	16.069***	16.670***	19.011***	20.336	19.924	19.884	16.242***	16.340***	19.160***	20.673	20.326	20.340
D. Predicted Outcomes												
7-Day Mortality	2.744	2.257	2.248	2.315	2.265	2.352	0.817	0.640	0.675	0.643	0.667	0.677
28-Day Mortality	3.014	2.505	2.493	2.563	2.524	2.607	0.921	0.728	0.772	0.743	0.758	0.773
Apgar Score	9.599***	9.602***	9.599***	9.591***	9.587***	9.577	9.793	9.793	9.796	9.798**	9.798***	9.794
N	23,859	57,942	60,413	46,039	31,202	22,064	9,028	22,251	26,017	24,580	18,244	14,773

Notes: For a description of the variables, see section 4. Stars indicate significance of t-tests for the equality of means with distance category "≥ 11km." $* \ p < 0.10$, $** \ p < 0.05$, $*** \ p < 0.01$.

Table A8: Robustness Checks

	7-Day Mortality (1)	28-Day Mortality (2)	Apgar Score (3)
A. Alternative Samples			
Adding Congenital Anomalies	−8.474***	−9.489***	−0.033
	(3.282)	(3.460)	(0.088)
Observations	360,817	360,817	360,151
Mean of dependent variable	1.918	2.123	9.658
Adding Stillbirths	−10.862***	−11.742***	0.010
	(3.791)	(3.905)	(0.090)
Observations	356,817	356,817	356,166
Mean of dependent variable	2.912	3.111	9.649
All Low-Risk Births	−3.650**	−4.369***	0.005
	(1.483)	(1.567)	(0.061)
Observations	788,294	788,294	787,010
Mean of dependent variable	1.348	1.483	9.723
All Births	−5.253*	−5.971*	0.012
	(3.161)	(3.245)	(0.116)
Observations	1,478,187	1,478,187	1,476,118
Mean of dependent variable	3.930	4.291	9.618
B. Reclassifying Referral Patients			
As home births	−9.098***	−9.886***	−0.073
	(3.450)	(3.658)	(0.098)
Observations	356,412	356,412	355,761
Mean of dependent variable	1.779	1.978	9.660
According to planned location	−3.965**	−4.486***	−0.049
	(1.555)	(1.648)	(0.044)
Observations	356,412	356,412	355,761
Mean of dependent variable	1.779	1.978	9.660
C. Car Ownership			
Car ownership < median	−7.698**	−9.050**	0.113
	(3.543)	(3.827)	(0.099)
Observations	263,854	263,854	263,359
Mean of dependent variable	1.781	1.994	1.934
Car ownership > median	−6.407	−8.780	−0.296
	(6.944)	(7.145)	(0.214)
Observations	92,558	92,558	92,402
Mean of dependent variable	1.772	9.658	9.665

	7-Day Mortality (1)	28-Day Mortality (2)	Apgar Score (3)
D. Additional Controls			
Postal Code Characteristics	−6.364	−7.890*	−0.046
	(3.917)	(4.138)	(0.115)
Observations	356,412	356,412	355,761
Mean of dependent variable	1.779	1.978	9.660
Prematurity and late term	−8.729***	−9.670***	0.837
	(3.164)	(3.366)	(0.765)
Observations	356,412	356,412	355,761
Mean of dependent variable	1.779	1.978	9.660
E. Alternative Definitions of the Instrument			
Continuous straight-line distance	−7.999**	−9.284***	−0.004
	(3.308)	(3.555)	(0.088)
Observations	356,412	356,412	355,761
Mean dependent variable	1.779	1.978	9.660
Driving distance categories	−6.343**	−6.910**	−0.029
	(3.132)	(3.304)	(0.088)
Observations	356,411	356,411	355,760
Mean dependent variable	1.779	1.978	9.660
F. Clustering Standard Errors at Different Levels			
Municipality	−8.287**	−9.219**	−0.018
	(4.013)	(4.365)	(0.157)
Observations	356,412	356,412	355,761
Mean dependent variable	1.779	1.978	9.660
Distance category	−8.287**	−9.219**	−0.018
	(1.788)	(2.128)	(0.134)
Wild bootstrap p-value	0.044	0.028	0.900
Observations	356,412	356,412	355,761
Mean dependent variable	1.779	1.978	9.660
G. Limited Information Maximum Likelihood	−8.297***	−9.229***	−0.017
	(3.161)	(3.357)	(0.090)
Observations	356,412	356,412	355,761
Mean dependent variable	1.779	1.978	9.660

Notes: Each cell represents the effect of hospital birth on the health outcome listed in the column from an IV specification that includes our baseline set of controls. For a description of the robustness checks in each Panel, see section 5.3. In Panel E, we lose one observation on an island unconnected to the mainland when driving distance is used to construct the instrument. Robust standard errors clustered at the postal code level are shown in parentheses except in Panel F. Wild bootstrap p-values from 500 replications. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A9: Heterogeneous Results

	7-Day Mortality (1)	28-Day Mortality (2)	Apgar Score (3)
A. Mother's ethnicity			
Dutch	−8.219**	−9.336**	0.003
	(3.412)	(3.648)	(0.093)
Observations	294,671	294,671	294,099
Mean of dependent variable	1.676	1.870	9.663
Non-Dutch	−12.866	−10.986	−0.185
	(12.069)	(12.081)	(0.233)
Observations	61,741	61,741	61,662
Mean of dependent variable	2.268	2.494	9.643
B. Mother's age			
Younger than median (29 years)	−8.210***	−8.619***	−0.001
	(2.837)	(3.003)	(0.080)
Observations	207,598	207,598	207,217
Mean of dependent variable	1.652	1.845	9.668
Older than median (29 years)	−9.618	−12.546	−0.107
	(10.534)	(10.993)	(0.214)
Observations	148,814	148,814	148,544
Mean of dependent variable	1.955	2.164	9.648
C. Gestational age			
Shorter than median (280 days)	−7.267*	−10.214**	−0.069
	(4.365)	(4.730)	(0.092)
Observations	179,213	179,213	178,868
Mean of dependent variable	2.427	2.740	9.677
Longer than median (280 days)	−8.497**	−6.942	0.031
	(4.213)	(4.309)	(0.123)
Observations	177,199	177,199	176,893
Mean of dependent variable	1.123	1.208	9.642
D. Birth weight			
Lighter than median (3,410 grams)	−6.444	−9.291*	−0.012
	(4.689)	(5.063)	(0.097)
Observations	178,346	178,346	178,050
Mean of dependent variable	2.731	3.073	9.653
Heavier than median (3,410 grams)	−9.470**	−8.197**	−0.042
	(3.874)	(3.901)	(0.120)
Observations	178,066	178,066	177,711
Mean of dependent variable	0.826	0.882	9.667
E. Average household income			
Lower than median (1929€)	−12.648***	−15.634***	0.102
	(4.743)	(5.069)	(0.123)
Observations	178,218	178,218	177,863
Mean of dependent variable	1.880	2.037	9.652
Higher than median (1929€)	−1.027	0.122	−0.318*
	(5.493)	(5.956)	(0.174)
Observations	178,194	178,194	177,898
Mean of dependent variable	1.678	1.919	9.668

Notes: Each cell represents the effect of hospital birth on the health outcome listed in the column and in the sample described in the panel, from an IV specification that includes our baseline set of controls. Robust standard errors clustered at the postal code level are shown in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A10: Heterogeneous Results, First Stage

	Mother's Ethnicity		Mother's Age		Avg. HH Income		Gestational Age		Birth Weight	
	Dutch	Non-Dutch	≤ Median	> Median	≤ Median	> Median	≤ Median	> Median	≤ Median	> Median
Distance: < 1 km	0.072***	0.075***	0.096***	0.040***	0.082***	0.043***	0.081***	0.068***	0.082***	0.067***
	(0.009)	(0.016)	(0.011)	(0.008)	(0.012)	(0.014)	(0.010)	(0.009)	(0.010)	(0.009)
Distance: 1–2 km	0.070***	0.075***	0.096***	0.037***	0.073***	0.054***	0.081***	0.066***	0.081***	0.065***
	(0.007)	(0.015)	(0.009)	(0.007)	(0.009)	(0.012)	(0.008)	(0.008)	(0.008)	(0.008)
Distance: 2–4 km	0.057***	0.065***	0.078***	0.031***	0.063***	0.038***	0.065***	0.054***	0.069***	0.051***
	(0.007)	(0.015)	(0.008)	(0.006)	(0.009)	(0.011)	(0.007)	(0.007)	(0.007)	(0.007)
Distance: 4–7 km	0.032***	0.059***	0.048***	0.018***	0.054***	0.016	0.040***	0.033***	0.041***	0.033***
	(0.007)	(0.015)	(0.008)	(0.006)	(0.010)	(0.010)	(0.007)	(0.007)	(0.007)	(0.007)
Distance: 7–11 km	0.028***	0.050***	0.036***	0.019***	0.039***	0.015	0.031***	0.030***	0.031***	0.030***
	(0.007)	(0.017)	(0.009)	(0.007)	(0.011)	(0.011)	(0.008)	(0.008)	(0.008)	(0.008)
Observations	294,671	61,741	207,598	148,814	178,218	178,194	179,213	177,199	178,346	178,066
F-statistic	27.169	5.885	35.299	8.372	16.613	6.792	30.168	21.529	31.162	20.289

Notes: Each column lists estimates from separate regressions. The dependent variable is the probability of a hospital birth. All regressions control for year, month and day-of-week of birth, maternal age, ethnicity, gestational age, a third degree polynomial in birth weight, newborn gender, multiple birth, obstetrician supervision, breech birth, and average income in the postal code of mother's residence (see section 4). The F-statistic comes from a test of joint significance of the distance indicators. Robust standard errors clustered at the postal code level are shown in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A11: Complier Characteristics by Distance

	Distance to the nearest hospital					Obs.
	< 1km (1)	1–2 km (2)	2–4 km (3)	4–7 km (4)	7–11 km (5)	(6)
Mother's Ethnicity: Dutch	1.12	1.05	1.26	1.04	0.93	294,671
Mother's Age $\leq$ median (29 years)	1.25	1.34	1.36	1.13	1.40	207,598
37 wk $\leq$ Gestational Age $\leq$ 42 wk	1.02	1.04	1.05	1.03	1.05	337,830
Birth weight $\leq$ median (3410 grams)	1.05	1.08	1.26	1.15	1.29	178,346
Share of compliers	0.027	0.030	0.013	0.015	0.021	356,412

Notes: Each cell in columns 1–5 gives the relative likelihood that the compliers corresponding to the distance indicator in the column have the characteristic described in the row, calculated as the ratio of the first stage coefficient of the instrument in the sample of individuals who have that characteristic to the first stage coefficient in the full analysis sample. The last row shows the fraction of compliers corresponding to the distance indicator in the column in the analysis sample, calculated as the first stage coefficient of the instrument in the analysis sample.