Maternity Ward Crowding, Child Health and Procedure Use*

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Abstract

This paper studies the impact of exogenous shocks to maternity wards—unexpected increases and decreases in the number of daily admissions—on the health of patients. We exploit administrative data from Denmark on the population of hospital births in 2000-2014. Relating the health of mothers and newborns to temporary maternity ward crowding, we find precise and very small effects that do not indicate negative consequences of being admitted on a crowded day. Assessing maternity wards' responses to temporary crowding, we find that they allocate fewer procedures to uncomplicated births on crowded days relative to less crowded days. Our results are not informative on the optimal level of care and focus on the impact of inside-ward changes in crowding for a healthy population of births. For this group, our findings suggest that maternity wards in Denmark are able to accommodate to the observed variation in daily admissions without detectable health risks.

JEL Codes: I11, I12, I14, I18, I21

Keywords: Maternity ward, health care, crowding, health

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1 Introduction

Across developed countries and over the past 30 years, the typical hospital birth has changed: We have witnessed an increase in the use of medical procedures prior to and during labor (such as pain relief, inductions and Caesarean sections). While an existing literature has documented large benefits of additional medical care and specialized medical technologies for at-risk births in the short- and longer-run (Almond et al., 2010; Almond and Doyle, 2011; Bharadwaj et al., 2013; Daysal et al., 2015; Jensen and Wüst, 2015), we lack causal evidence on the impact of the level and variability of medical care around birth that is informative for the majority of relatively *uncomplicated* births. This paper examines the effects of one heavily debated factor that may impact the variability of medical care for a general population of mothers and children: temporary maternity ward crowding. We ask: What is the causal impact on maternal and child health of being admitted for birth on a busy day relative to a less busy day?

To answer this question, we exploit data on all admissions to Danish maternity wards in the years 2000-2014. Maternity wards operate in a similar fashion as emergency rooms–with admissions that are hard to schedule for a majority of uncomplicated patients. Thus, in our data, we observe large day-to-day variation in maternity ward admissions of well above 100 percent of mean admissions, and deviations of above 200 percent are not rare. While wards can anticipate some of this variation in temporary crowding (Macfarlane, 1978; Rehavi and Johnson, 2013; Allin et al., 2015), they cannot perfectly predict it. Our empirical strategy exploits variation in daily admissions conditional on hospital ward, year, season, day of week and hospital×year fixed effects. Taking those factors into account, we can study the impact of residual variation in crowding on the day of admission for otherwise similar patients. Importantly, as we cannot observe the actual patient-staff ratio or the staff assigned to a specific birth, we identify the reduced form impact of being admitted on a busy vs a less busy day. Furthermore, as complicated births are typically performed as scheduled Caesarean sections (CS) and therefore are not likely to "comply" with the treatment that we study, we focus our analyses on the impact of crowding on a general population of births (attempted vaginal births for singleton children).[1]

We start by examining the health consequences of temporary crowding on the day of the mother's admission for birth outcomes child health in the first two years of life. We then proceed to study whether crowding leads to changes in procedures performed at hospitals, such

[1] As detailed in section 2.2, we start by measuring crowding at the ward level including *all* admitted mothers before we focus our analyses on the effects of crowding on a general population of uncomplicated births.

as inductions and epidurals, as well as the timing of those procedures. Our results show that—for the general population of healthy births —temporary crowding has no economically meaningful effects on the health outcomes that we can consider. These outcomes include the probability of having an APGAR score above seven, the probability of experiencing post-birth complications for mothers, and children's hospital readmissions and contacts to GPs during the first two years of their life.

In a second step, we show that maternity wards change medical procedure use due to unexpected fluctuations in the number of daily admissions. Wards use fewer procedures per birth on crowded days than they do on less crowded days. Specifically, we find small but significant decreases in the probability of stimulations of labor and inductions. These findings may indicate that maternity ward staff attempts to reduce "pressure" by not inducing (faster) deliveries. The finding is interesting in the light of steadily increasing induction rates in many developed health care systems and accompanying debates on the benefits of the procedure in marginal cases.

Our results for both health and procedure use are similar across alternative definitions of temporary crowding and in data constrained with respect to the time period that we consider. Furthermore, our analyses do not support threshold effects, i.e. we do not find that our main results based on a continuous crowding measure masks over heterogeneity by the level of crowding. Finally, we find limited evidence for heterogeneity of the effects across characteristics of the birth or hospital. Our findings suggest that the effect of crowding on the probability of experiencing an induction is strongest for first-born children, children born at a gestational age above 41 weeks, and children admitted to smaller wards.

Our results relate to a large literature documenting short- and long-run returns to care at birth. Almond et al. (2010) and Bharadwaj et al. (2013) study returns to specialized care for very low birth weight children and find that additional resources significantly increase survival rates. Bharadwaj et al. (2013) also show that additional specialized treatment around birth has longer-run effects on educational achievement of these high-risk children. Existing studies from Denmark suggest that hospital (and home) care around birth also for a *general population* may impact child health and development (Sievertsen and Wüst, 2017; Kronborg et al., 2016). Sievertsen and Wüst (2017) show that newborns, who are discharged from hospital on the day of birth, have a higher probability of first-month hospital readmission and that at-risk children, who are discharged on the day of birth, have a lower ninth grade GPA. While this literature has been focused on the appropriate level of care and changes in this care/interventions provided, our focus is on the variability of care inside an existing framework. In other words, we study the ways in which the modus operandi in different environments, here defined by the level of crowding, affects patients' health. From a policy perspective, this margin is relevant as "naturally" occurring variation in the number of births is inevitably a central feature of maternity ward care.

Our paper also relates to a large literature that focuses on the returns to marginal health care spending (Skinner, 2012). Estimating those returns is typically complicated by selection of patients into more care based on own and provider unobservables. While a number of papers compare health outcomes of patients across high and low spending regimes,[2] a smaller number of papers have studied the impact of variability in treatment that may be induced by factors like crowding. Crowding has in earlier studies been shown to impact decisions about care allocation and procedure use (Facchini, 2017; Freedman, 2016) and to correlate with worse patient health (Sun et al., 2013; Sprivulis et al., 2006; Fisher et al., 2000). Sun et al. (2013) uses hospital level information about ambulance diversion hours to examine the effect of emergency department crowding and patient outcomes. They find that patients admitted on days with more crowding have higher mortality and longer hospital stays. Freedman (2016) exploits short-term variation in Neonatal Intensive Care Unit capacity and shows that available beds have little to no effect on utilization for the sickest infants but increase utilization for those infants where admission decisions are more discretionary. Silver (2016) takes advantage of allocation of the same physicians to differently paced teams across shifts in the same ER. He examines physicians' use of time- and resource-intensive procedures and, in turn, the effect of those procedures on patient health. He finds that peer group pace matters for procedure use (with higher-paced groups inducing physicians to use less time and resources per patient) and in turn impacts patient mortality risks negatively, especially for patients with unspecific symptoms.

In our setting, we study the ways in which maternity wards adjust staff- and resource-demanding procedures due to crowding. We find that the variability in procedure use due to temporary crowding at maternity wards is not detrimental to the general population of patients that we study. While many existing studies focus on extreme health outcomes, such as mortality, we focus on less severe measures of health (such as contacts to primary care providers). Given that we study a relatively healthy population of mothers and infants, we shed light on the

[2]Using local-area health care spending, Doyle (2011) identifies the returns to additional health care spending in the emergency room (ER). Exploiting information about visitors to Florida, he finds that high-spending areas have lower mortality. Using variation in ambulance referral patterns, Doyle et al. (2015) show that patients who are admitted to higher-spending hospitals have superior health outcomes. These finding suggests that more care is beneficial for patient health in these contexts.

potential health consequences of temporary crowding at an unexplored margin of the patient health distribution.

The paper proceeds as follows: Section 2 provides information on the institutional background and our data. Section 3 presents our empirical strategy and discusses the identifying assumptions. Section 4 presents our main results and examines their robustness. Finally, Section 5 concludes.

2 Background and Data

2.1 Danish health care services during pregnancy and at birth

Danish health care services, including health care around birth, are free of charge for all residents. During the first trimester of their pregnancy, women choose a public hospital of birth. Home births account for around two percent of all births in Denmark. As a default, women give birth at the hospital of their catchment area. If there is excess capacity, pregnant women can choose freely among all other public hospitals. Moreover, high-risk pregnancies can be assigned to specialized hospitals in the same region.[3]

In Denmark, general practitioners (GPs) and midwives provide standard prenatal care.[4] The majority of uncomplicated hospital births are midwife-assisted. Physicians are only involved in case of complications during birth, in anticipated complicated vaginal deliveries (such as vaginal breech deliveries) and in CS deliveries.

After uncomplicated hospital births, mothers and their infants are typically admitted to a separate hospital ward for continued care and observation of the mother and her child. Postnatal hospital care involves guidance and care by hospital-based nurses to help women to establish breastfeeding or other nutrition, as well as health checks and screenings. However, throughout the period that we study, outpatient care after birth for higher parity mothers (and increasingly also first-time mothers) has become increasingly important (Sievertsen and Wüst, 2017). In this case, women, who have experienced an uncomplicated birth, are discharged from hospital 4-8 hours after giving birth (same-day discharge). In our results section we examine whether crowding impacts the probability of a same-day discharge for mothers.

[3]The Danish regions have the primary responsibility for hospital care. Up to the year 2007, there were 16 Danish regions. After a reform in the year 2007, this number was decreased to five.

[4]In the period that we study, this care consists of three prenatal GP consultations, four to seven midwife consultations, and two ultrasound examinations (around week 12 and 20 of the pregnancy).

2.2 Data and Sample

Our point of departure is data on all births during 2000-2014 registered in the Danish Medical Birth Register. The raw data consists of 950,545 life births (including multiple births). We omit the 0.32% of still births and the 2% of births that take place at home, resulting in 935,233 relevant births.[5]

To construct our main treatment variable of crowding on the day of admission for birth, we link the birth records to the Danish Inpatient Register. Not all mothers are admitted to hospital on the day they give birth. To assign the relevant day of admission to each birth, for each mother we identify the hospital admission date that is closest to the date of birth of the relevant child and that is not separated from this date by a hospital discharge date. For 97% of mothers in our sample, the birth admission date to a maternity ward lies during the 3 days up to the birth of the child; for 92%, the relevant admission is on the day before or on the day of their child's birth.

Treatment variable and analysis sample. We use the full sample of hospital births to construct our treatment variables measuring crowding on the day of the birth-related hospital admissions for each mother.[6] Thus we include scheduled CS and multiple births, the latter with the number of children in the birth.[7] We construct three measures of maternity ward crowding: (i) the absolute (leave out) number of admissions to each maternity ward on any admission day, (ii) the percentile rank of any admission day in terms of number of admissions (within hospital and year) and (iii) the number of admissions on any admission day relative to the hospital- and year-specific median day.[8]

Having computed our measure of crowding on our full sample of hospital births, we constrain our estimation data in the following three ways: First, we omit individuals with missing values on outcomes and child characteristics measured at birth (child's birth weight, gestational age and parity; around 3% of the sample). Second, we omit scheduled CS (around 9% of our sample) and multiple births (in our sample, more than half of the multiple births are delivered through a scheduled CS). Hospitals typically plan these births ahead, reschedule them often and typically

[5]We do not find a correlation between our measure of crowding and the extremely rare event of a stillbirth. Furthermore, as mothers have to make the decision to give birth in an assisted home birth already during pregnancy, the selection into this group of births should not be related to our measure of crowding at admission to hospital.

[6]We subtract the focal mother from the number of admissions on her admission day.

[7]We have also generated crowding measures that exclude multiple births and scheduled CS. Results are very similar and available on request.

[8]We have also calculated crowding variables relative to hospital×year×season cells with very similar results.

perform them well-ahead of full term status. Thus those births are less responsive to crowding and are performed under different circumstances than the spontaneous births (with a special focus of medical staff on planning them and on devoting extra resources to them).[9] Third, given that our analysis relies on an extensive set of fixed effects (i.e. compare outcomes in cells defined by maternity war×year, season, and day of the week cells), we drop births in small year×ward cells of less than 700 births (another 3% of the sample). These constraints result in a final analysis sample of 770,331 mothers and their (singleton) children.

Outcome variables and controls. Our first set of outcomes measures health at birth. We measure mother and infant health with indicators for a range of birth complications,[10] the child's probability of having a low APGAR score at 5 minutes, and an indicator for a set of post-birth complications related to maternal health.[11] To measure longer-run health effects we consider health care usage in the first years of the child's life: the length of hospital stay after birth, readmissions to hospital, and contacts with a general practitioner (henceforth GP) within the first month and the first and second year of the child's life.

To assess both potential channels for health effects and hospital wards' adjustments to crowding, we exploit unique data on procedure use and the timing of events during and after labor. We exploit administrative data that allows us to assess in more detail the extent to which the birth was staff- and resource-intensive. First, based on information from the medical birth register, we study mothers' probability of experiencing a (medical) stimulation during labor, their probability of experiencing an induction of birth, and the probability of experiencing an acute CS. All these procedures require more and more continuous support and monitoring of the birth by staff (midwives and, in the case of a CS, also physicians). Inductions may lead to a higher risk of experiencing an acute CS—although this relationship is debated in the medical literature. Acute CS in our data are classified as such either because they are performed subsequent to an attempted vaginal birth or performed with short notice, i.e. the decision for a CS is taken upon admission to hospital.

Besides these procedural measures, which are indicative of the course of birth, we also have access to detailed information on other staff- and resource-demanding factors for a shorter sample period, namely the timing between admission to hospital and the birth and the waiting time

[9] In our main analyses, we control for the number of scheduled CS on the day of hospital admission.

[10] For a list of the relevant ICD 10 codes, consult Appendix **XX**

[11] This measure combines information on operations and diagnoses from hospitals. For details see Appendix **XXX**.

for an epidural. Finally, we examine a measure reflecting the outcome of the birth, namely the establishment of skin-to-skin contact. All these measures are available for the years 2011-2014. If hospitals attempt to cope with crowding by delaying new admissions, we may expect shorter birth spells on crowded days. Given that the establishment of skin-to-skin contact between infant and parents within two hours after birth was a central quality indicator for Danish hospitals in that period that we study, we create an indicator the ward meeting this target in the given birth.

Finally, we construct a set of individual level control variables. We add control variables for a range of parental characteristics, including indicators for parental educational status (in education, completed higher education, completed university), parental non-western origin, parental early retirement, parental disposable income (2010 level), and parental age. All characteristics are measured two calendar years prior to the relevant child's birth.[12] Furthermore, we control for an indicator of pregnancy complications.

Descriptive Statistics Table 1 provides summary statistics for the key variables in our analysis dataset. Excluding the focal mother, the average number of maternity ward admissions across all hospitals and years is 8.5. Excluding scheduled any CS, the average number of admissions is 7.7. The lower part of Table 1 describes our central outcome measures. On average, 19% of mothers experience an induction. This figure has, similarly to the CS share, been debated in the Danish medical community in recent years. Given that we use a relatively broad measure of complications at birth, 66% of mothers experience some sort of complication. When moving to more detailed procedural data, our data only covers the years 2010-2014 and thus the number of observations is much smaller. 24% of mothers in our sample are assigned an epidural for pain relief and their average waiting time is around 36 minutes. In our sample, mothers are at the maternity ward for an average of around 10.5 hours before they give birth. With a standard deviation of almost 16 hours, the variation in this measure is large, however.

Figure 1 presents a first look at the data on hospital admissions. To illustrate the variation in maternity ward admissions in our data, the top panel of Figure 1 shows the daily admissions for the year 2010 for a small (Horsens) and a large (Hvidovre) maternity ward. These maternity wards had on average, about five and 15 daily admissions, respectively. However, there is substantial variation in admissions in both the small and the large maternity ward. This point

[12]For missing values, we set the value to zero and include an indicator variable for missing values for each of the covariates.

is underlined by the bottom panel of Figure 1, which shows the relative day-to-day fluctuations in admissions for the same two wards. We observe that days with more than twice as many admissions than the day before are common in both the small and large maternity wards. This point is important as our sample of maternity wards consists of larger units in the end of the sample period compared to the initial years due to hospital mergers and an administrative reform in 2007. Furthermore, we observe day-to-day changes in both the raw measure of number of admissions and a residualized measure that takes out variation across seasons and days of the week in the two wards.

To describe the variable of interest, crowding at the maternity ward, in the entire sample, Figure A.1 illustrates the distribution in the raw number of admissions for all wards for the year 2010. Maternity wards experience between one and 30 admissions per day, and as subfigure (a) illustrates, the distribution in the number of admissions is highly skewed. The median number of admissions in our sample is seven. In subfigure (b) we show a residualized measure of admissions that takes our variation across hospital wards, season and day of the week for the year 2010. The figure illustrates that although we account for those factors–e.g. that there are hospital wards of different size and that certain days of the week are more busy than others–there is remaining variation, namely days with deviations from the average day between -10 and 10 admissions.

3 Empirical methods

To examine formally the impact of crowding on maternal and child health, we exploit residual variation in the number of admissions to Danish hospital wards. Specifically, we estimate

$$Y_{idsyw} = \alpha_0 + \alpha_1 \times Crowd_{idsyw} + \alpha_3 \prime X_{idsyw} + \delta_y + \lambda_s + \theta_d + \gamma_w + \delta_y \times \gamma_w + \epsilon_{idsyw} \qquad (1)$$

Y is an outcomes of interest for mother i admitted to ward w on week dayweekday d in season s of year y, such as the probability of the mother experiencing complications at birth. $Crowd_{idsyw}$ is the level of crowding at the ward on the day of admission measured as (1) the (leave-out) number of admissions on the day of admission, (2) the (leave-out) percentile rank of the admission day (within a given maternity ward in given year) in terms of the number of admitted, or (3) (leave-out) number of admitted births relative to the median number of admitted for a given maternity ward in a given year.

The vector X_{idsyw} includes observable mother, father and pregnancy characteristics. To account for systematic differences across the population of mothers across years and season, we include year of birth and season fixed effects. These cohort effects also capture the impact of shocks such as nation-wide changes in recommendations on procedure use. Furthermore, to capture systematic variation in birth-related admissions over weekdays and weekends, we include weekday indicators (θ_d). γ_w takes out time-invariant differences across the population of mothers admitted to different maternity wards. Finally, by including ward×year fixed effects, $\delta_y \times \gamma_w$, we flexibly account for shocks specific to certain hospitals, such as changes in the population of mothers due to changes in catchment areas of hospitals.[13] The parameter of interest is α_1, which measures the effect crowding on mother and child outcomes. We cluster standard errors at the hospital level to capture arbitrary correlations in unobservable characteristics across mothers within the same hospital.

To ease interpretation of our main results and to give a sense of the variation in the level of crowding that mothers potentially can experience around their own admission for birth, we calculate for each admission day a "potential range of crowding". This measure captures the variation around the actual admission day, which mothers cannot perfectly time. We determine, for each admission day, the difference in absolute admissions between the most and least crowded day considering the admission day, the day before and the day after the admission, see Appendix Table A.5. In our sample, this difference is three on average, i.e. it suggests that on average women can expect the number of admissions to vary with three admitted births, when we consider the days just around the mothers' actual admission day (this variation is slightly smaller when we consider our residualized measure taking out year, ward effects, see Appendix Table A.5). Thus when we present our main results for the absolute measure of crowding, we typically ask what the impact of experiencing the admissions of additional three births is. Similarly, we compute the average of the expectable variation in crowding for our relative treatment measures. For the days around mothers' actual admission day, the average expectable variation is around 30 percentile ranks.

[13]Such changes occur for at least two reasons: First, in 2007 the former 16 Danish counties were merged into five regions. As hospitals were administered by the counties until 2007 and since then by the new regions, both the organization and the catchment areas were potentially changed by this reform. Second, closures of maternity wards during the period that we consider affect nearby wards through the number and composition of patients. Such changes should be absorbed by the year-specific maternity ward fixed effects.

Identifying assumptions To uncover a consistent estimate of α_1, we assume that the residual variation in the number of admissions for childbirth at a given hospital is uncorrelated with unobservable characteristics that also impact outcomes. While this assumption is inherently untestable, Table 2 presents an informal assessment of the credibility of our design. Each row of Table 2 presents a series of estimation results for regressions of maternal, paternal and birth characteristics on our treatment variable, the relative rank of the birth admission day of the mother. Moving from column (1) to (6) we add different sets of fixed effects to this regression. In order for our design to identify the effect of crowding, we expect predetermined characteristics of parents and the birth to be largely uncorrelated with our treatment variable once we account for factors that likely bias our estimation, such as a comparison between large (specialized) wards and small wards.

As Table 2 shows, the bivariate regression in column (1) shows small albeit significant correlations for central observable characteristics and our treatment variable. However, most estimates for the correlation between observable characteristics and our treatment variable measure of crowding decrease in size and loose significance when we move towards column (6) with the full set of fixed effects, our preferred specification. This shows that the selection on observables into treatment becomes much smaller when we include our preferred set of fixed effects. Especially accounting for hospital and year fixed effects takes away the predictive power of our treatment variable measure of crowding for the observable characteristics of parents and child birth. The point estimate on mother income remains precisely estimate, but is small in magnitude. One additional admission is associated with a 142 DKK difference in mothers' annual income (about 22 USD). For birth weight, we estimate an (imprecisely estimated) 0.2 gram difference, and we would be able precisely identify a difference of about 1 gram.[14] These findings lend credibility to our identifying assumption that, conditional on the set of fixed effects and controlling for observable characteristics, we identify the impact of temporary crowding on outcomes.

4 Results

Mother and child health. Table 3 presents reduced form results for the effects of temporary crowding on the day of admission for birth on health outcomes. Each cell shows point estimates

[14] All conclusions also hold for our relative measures of crowding, as reported in Appendix Tables A.1 and A.2. Importantly, the nature of potential biases is different when applying the different crowding measures: for the absolute measure, the bivariate regression compares primarily across small and large wards, while the percentile measure abstracts from this comparison being based on a calculation inside a given ward and year.

and standard errors from a different regression. Across columns we present the results for different measures of crowding: the total number of admissions in the same ward and day, the percentile measure, and a measure of the number of admissions relative to the hospital and year-specific median day. All regressions are based on the full set of fixed effects and controls, as presented in equation 1. The bottom row of the table shows the mean range in the level of crowding, i.e. the range of crowding typically observed around a given admission day.

Across the outcomes that we study we find that the effects of temporary crowding are very small, have the same sign across different measures of crowding, and are in general precisely estimated. This combination emphasizes the need for large, population-wide datasets in these types of analyses and the importance of a careful assessment of the economical significance of the effect sizes that we estimate.

Relating the point estimates in panel (A) of Table 3 to the mean range in level of crowding, we observe that an additional three admitted births result in a precisely estimated $3\times0.1=0.3$ percentage points difference in the probability of complications at birth. Similarly, a 30 percentile rank variation in crowding (which is the average variation around admission days in our sample) results in a $0.29\times1=0.29$ percentage points difference in the probability of birth complications. Our estimates for both the probability of the child's APGAR score being above seven and the probability of the mother experiencing post-birth complications are extremely small and do not suggest an impact of temporary crowding on these outcomes.

In panel (B) of Table 3 we extend our analyses to post-birth child health outcomes measured as health care usage at either the GP or at the hospital (admissions). Across specifications we find very small and precise estimates that suggest no longer-run impact of temporary crowding on the health of a general population of children.

Hospital adjustments to crowding. Having studied a set of outcomes that proxy mother and child health at birth and child health in the longer-run, in the following we examine measures of procedure use and timing during birth. While we do not observe information on either the patient-staff ratio and are unable to link staff to patients, our analyses of these outcomes zoom in on potential adjustments and changes inside the maternity ward that may account for the absence of strong health effects.[15]

[15] As highlighted in section 3, we compare admission days within hospitals. Thus the variation in crowding should—given a relative fixed stock of available staff (and ignoring day to day adjustments from e.g temporary work)—be reflected in changes in the patient-staff ratio. However, we cannot explicitly show this change as we do not have data that links hospital and staff on duty.

As Table 4 shows, on crowded days maternity wards are less likely to assign the procedures that we study, albeit the effects are again relatively small. Three additional birth admissions are related to a 3×0.2=0.6 percentage points difference in the probability of an induction. At the sample mean induction rate of 0.186, this corresponds to about 3 percent. Similarly, for the percentile rank measure, a change of 30 percentile ranks in business corresponds to a 0.298×2.3=0.7 percentage points difference in the probability of an induction (or a difference of about four percent, evaluated at the sample mean).

As our findings suggest no or very few health effects on more crowded days, our findings for inductions may indicate that a decreased use of (marginal) inductions is not hurtful in this population of births. Inductions have been shown to be correlated with more complicated progression of labor and (in some studies) with the increased use of acute CS. As we will return to below, we find that the probability of experiencing an induction decreases on crowded days for both pregnancies prior to and after completed week 41 (which is a relevant cut-off in most hospitals for considering an induction for safety reasons). Thus our results suggest that crowding may prevent non-medically indicated inductions.

Finally, Table 5 constrains our analysis sample to the most recent years (2011-2014) and examines outcomes indicative for the access of women to resources in the maternity ward: While estimates again are small in size, we find that women admitted on more crowded days are less likely to have an epidural for pain relief. One reason for this result may be that maternity wards delay the admission of women to the maternity ward. Women are typically in contact with their ward in the hours up to hospital admission. We find that women on more crowded days are less likely to have above-median duration ward stays, i.e. most likely arrive later at the ward and give birth faster. At the same time, in line with wards being able to buffer temporary crowding, we do not find indication for crowding impacting a measure of birth experience quality, namely the timely establishment of skin-to-skin contact between parents and child.

Do the linear effects conceal substantial asymmetric effects? To assess whether the reported parameters for the linear relationship between the temporary crowding and our outcomes appropriately capture the underlying relationship, Figure 2 shows the non-parametric relationships for six main outcomes. The linear specification appears to be appropriate for all considered outcomes. This suggest that there is no "threshold" for the level of crowding, at least for the variation that we observe in our data. The plots for our health care utilization measures are flat and suggest that our main estimates do not cover over the discussed "threshold effects".

Are effects heterogeneous? We assess the heterogeneity in our reported results along a three dimensions using the absolute level of crowding as the treatment.[16] First, in columns (2) and (3) of Table 6 we split the sample by gestational status (below full 41 weeks or not). While most coefficients are similar across these two groups, the effect of crowding on the probability of inductions is significantly higher for births after week 41. In columns (4) and (5) we split the sample by parity. The effect of crowding on the probability of induction is largest for first-born children (marginally significant). There is also some suggestive evidence of significantly different effects of crowding on the APGAR score and on post-birth complications, but also these estimates are very small. Finally, in columns (6) and (7) we split the sample by hospital size (ward size). The effect of crowding on the probability of an induction is significantly larger in smaller wards, but none of the other effects are significantly different.

In sum, the subsample analyses in Table 6 suggest that the effect of temporary crowding on the probability of an induction is larger for births after week 40, for firstborn and for smaller maternity wards.

5 Conclusion

This paper has studied the impact of exogenous shocks to maternity wards—unexpected and frequently large increases and decreases in the number of daily admissions—on the *inside-ward* change in patient health and procedure use. Procedure use is one proxy for quality of care—but as discussed in the literature on "wasteful spending" it is not clear-cut that the marginal procedure has health benefits.

In recent years, cutbacks in Danish hospital budgets for maternity care have led to large debates about the quality of services and potential health consequences for mothers and children. Studying the impact of those budget cuts is complicated in an across-hospital and over-time framework, which may confound the effect of budget changes with other developments. While our paper does not speak to the debate on the optimal level of maternity ward care, we assess the potential impact of its variability due to one heavily debated factor: temporary crowding. If we are willing to think of crowding at the ward level as a good proxy for the resources allocated to each woman at the wards, our findings can inform the current policy debates on the

[16] We only report the results for our main outcomes—additional results are available upon request.

impact of variability of maternity care. Importantly, our analyses only focus on the population of uncomplicated births. Furthermore, wecannot study the impact of crowding on the work environment for hospital staff.

Our findings suggest that maternity wards allocate fewer procedures to mothers during birth if there are more admissions. We do not find evidence for large health consequences of variation in maternity ward crowding for a general population of mothers and infants—we consider measures of health care utilisation. Future work on the topic should consider other margins (e.g. parental investment behaviors such as breastfeeding decisions).

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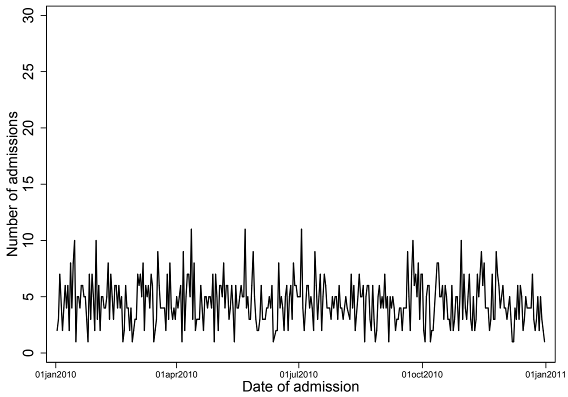
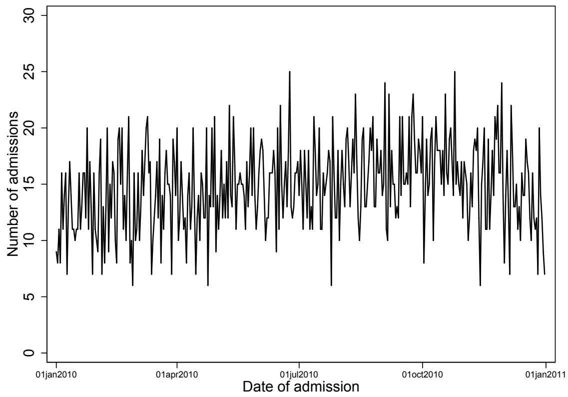
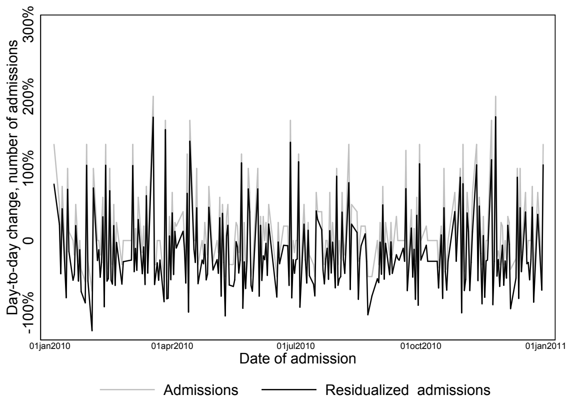
6 Figures and Tables



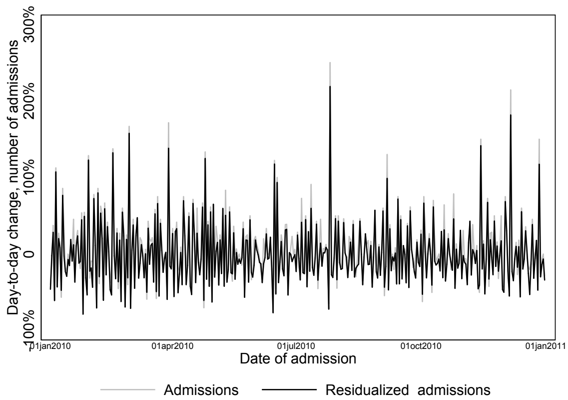
(a) Horsens, admissions



(b) Hvidovre (Copenhagen area), admissions

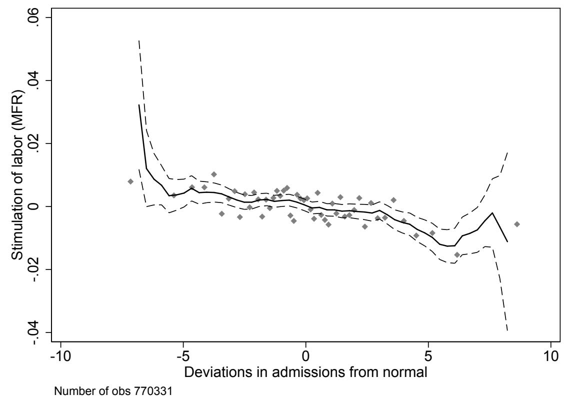


(c) Horsens, day-to-day change

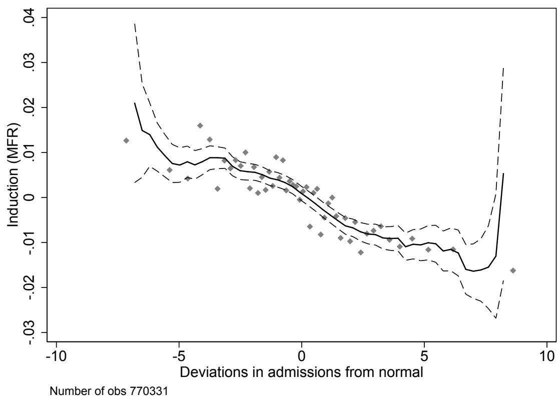


(d) Hvidovre (Copenhagen area), day-to-day change

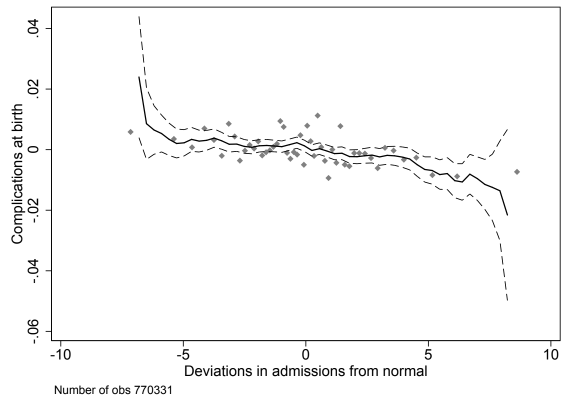
Figure 1: Daily number of admissions and day-to-day variation in the number of daily admissions (residualized), selected maternity wards.



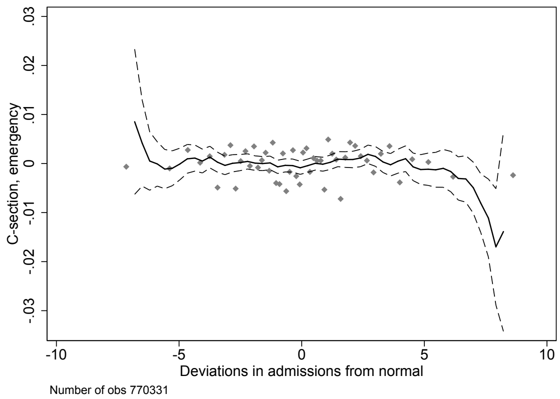
(a) Stimulation of labour



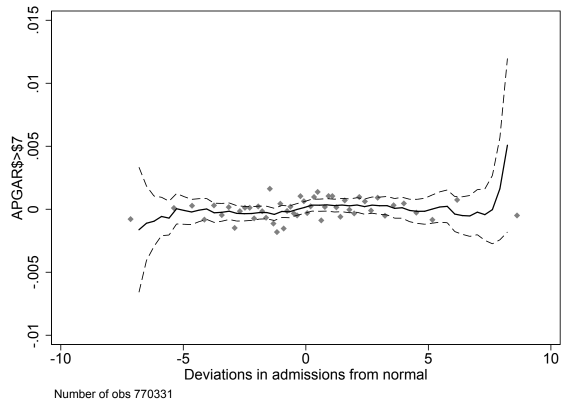
(b) Induction



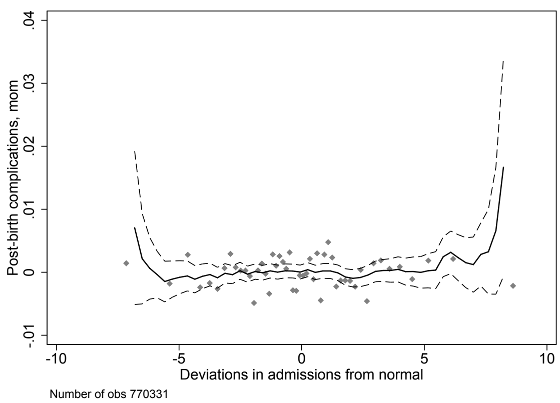
(c) Complications at birth



(d) C-section, emergency



(e) APGAR >7



(f) Post-birth complications

Figure 2: The effect of the number of daily admissions on procedure use and health outcomes, local linear regressions.

Notes: The plots show the relationships between the residualized y-variable and the residualized number of admissions to maternity wards. Each marker contains two percent of observations and plots the mean of the y-variable against the mean of the x-variable. The line represents the local linear regression, with a bandwidth of one.

Table 1: Summary Statistics, means, standard deviations and distribution measures.

	Mean	SD	N	P10	Median	P90
Admitted same day	8.46	5.33	770,331	3.00	7.00	16.00
Admitted same day, no planned CS	7.67	4.75	770,331	2.00	7.00	14.00
Crowding percentile	0.60	0.27	770,331	0.20	0.64	0.95
Crowding relative to median	1.25	0.60	770,331	0.60	1.17	2.00
Female	0.49	0.50	770,331	0.00	0.00	1.00
Gestational age	279.13	12.47	770,331	266.00	281.00	292.00
Birth after week 41 (over term)	0.27	0.45	770,331	0.00	0.00	1.00
First-born child	0.46	0.50	770,331	0.00	0.00	1.00
Birth weight	3523	548	770,331	2875	3540	4190
Mother income (thousands)	178.83	100.55	748,279	65.13	172.39	289.11
Mother western origin	0.89	0.31	748,279	0.00	1.00	1.00
Mother with university degree	0.13	0.34	770,331	0.00	0.00	1.00
Mother with higher education	0.23	0.42	770,331	0.00	0.00	1.00
Mother early retirement	0.00	0.06	770,331	0.00	0.00	0.00
Mother enrolled in edu	0.05	0.22	770,331	0.00	0.00	0.00
Father income (thousands)	249.14	171.40	741,357	88.81	234.37	402.95
Father western origin	0.89	0.31	741,357	0.00	1.00	1.00
Father with university degree	0.14	0.34	761,525	0.00	0.00	1.00
Father with higher education	0.18	0.38	761,525	0.00	0.00	1.00
Father early retirement	0.01	0.08	761,525	0.00	0.00	0.00
Father enrolled in edu	0.02	0.15	761,525	0.00	0.00	0.00
Pregnancy complications, indicator	0.31	0.46	770,331	0.00	0.00	1.00
Scheduled CS on day of adm.	0.80	1.34	770,331	0.00	0.00	3.00
Stimulation of labor	0.28	0.45	770,331	0.00	0.00	1.00
Induction	0.19	0.39	770,331	0.00	0.00	1.00
Complications at birth	0.66	0.47	770,331	0.00	1.00	1.00
C-section, emergency	0.12	0.32	770,331	0.00	0.00	1.00
APGAR>7	0.99	0.11	770,331	1.00	1.00	1.00
Post-birth complications, mom	0.08	0.27	770,331	0.00	0.00	0.00
Hospital nights at birth	3.40	6.45	770,331	1.00	2.00	5.00
Readmitted first 28 days	0.05	0.23	770,331	0.00	0.00	0.00
Readmitted first year	0.22	0.42	770,331	0.00	0.00	1.00
Readmitted second year	0.16	0.37	770,331	0.00	0.00	1.00
Contacts with gp first month	0.70	1.31	770,331	0.00	0.00	2.00
Contacts with gp first year	13.25	13.00	770,331	1.00	10.00	29.00
Contacts with gp second year	7.71	9.88	770,331	0.00	5.00	19.00
Indicator: Epidural	0.24	0.43	186,964	0.00	0.00	1.00
Indicator: Skin-to-skin	0.77	0.42	186,964	0.00	1.00	1.00
Waiting time, epidural (minutes)	36.43	53.63	40,258	0.00	25.00	70.00
Time from adm. to birth (minutes)	631	946	178,245	50	330	1485
Time birth to skin-to-skin (minutes)	42.94	37.06	126,840	7.10	35.23	95.91

Notes: Parental covariates are measured in the calendar year two years prior to child birth.

Table 2: The effect of crowding (absolut measure) on pre-determined characteristics.

	(1)	(2)	(3)	(4)	(5)	(6)
Mother income (thousands)	1.344*	0.531*	0.319*	0.319*	0.341*	0.142*
	(0.391)	(0.191)	(0.114)	(0.115)	(0.124)	(0.046)
Mother with university degree	0.009*	0.002	0.001	0.001	0.001	0.000
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)
Mother age at child birth	0.061*	0.027*	0.017*	0.018*	0.017*	0.004
	(0.018)	(0.008)	(0.004)	(0.004)	(0.004)	(0.002)
Father income (thousands)	1.122	0.410	0.391	0.387	0.419	-0.012
	(0.581)	(0.206)	(0.176)	(0.179)	(0.185)	(0.075)
Father with university degree	0.010*	0.002	0.001	0.001	0.001	0.000
	(0.002)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)
Father age at child birth	0.046*	0.021*	0.012*	0.013*	0.013*	0.002
	(0.016)	(0.007)	(0.004)	(0.004)	(0.004)	(0.002)
Birth weight	-3.154*	-0.247	0.272	0.142	0.299	-0.196
	(0.582)	(0.354)	(0.263)	(0.259)	(0.283)	(0.356)
Hospital FE		Yes	Yes	Yes	Yes	Yes
Year FE			Yes	Yes	Yes	Yes
Quarter of Year FE				Yes	Yes	Yes
Day of week FE					Yes	Yes
Hospital × year FE						Yes

Notes: Each cell presents point estimates from a separate regression. For a description of the main sample, see section 2.2. The outcome variable for all regressions in a given row is denoted in the first column. Standard errors are clustered at the hospital level and presented in parentheses. The table shows estimates for the absolute crowding measure (absolute number of admissions at a given ward and admission date). For equivalent tables based on the percentile rank and the relative to median measure, see Appendix Tables A.1 and A.2, respectively. Point estimates significant at the 1% level are indicated with an an asterisk.

Table 3: The effect of crowding on birth outcomes and child health; 2000-2014

	Absolute (1)	Percentile (2)	Relative to median day (3)	Mean of dep. var
A. Birth outcomes				
Complications at birth	-0.001*	-0.010*	-0.006*	0.659
	(0.000)	(0.002)	(0.001)	
APGAR>7	0.000	0.001	-0.000	0.987
	(0.000)	(0.001)	(0.000)	
Post-birth complications, mom	0.000	0.001	0.001	0.076
	(0.000)	(0.001)	(0.000)	
B. Child health outcomes				
Hospital nights at birth	-0.001	-0.020	-0.022	3.398
	(0.003)	(0.036)	(0.014)	
Readmitted first 28 days	-0.000	-0.001	-0.000	0.054
	(0.000)	(0.001)	(0.000)	
Readmitted first year	-0.000	-0.002	-0.000	0.224
	(0.000)	(0.002)	(0.001)	
Readmitted second year	-0.000	-0.003	-0.001	0.162
	(0.000)	(0.002)	(0.001)	
Contacts with gp first month	0.000	0.003	0.002	0.701
	(0.001)	(0.006)	(0.002)	
Contacts with gp first year	-0.009	-0.113	-0.046	13.248
	(0.006)	(0.072)	(0.032)	
Contacts with gp second year	-0.008	-0.070	-0.035	7.711
	(0.003)	(0.051)	(0.020)	
Mean of "expected" variation in crowding	3.067	0.298	0.546	

Notes: Each cell presents estimates from a separate regression for our analysis sample of mothers with singleton children. The first column presents the estimate for the impact of the absolute number of admissions, column (2) presents the estimate for the impact of the percentile rank of the admission day in the distribution of days in the hospital and year, and column (3) presents the estimate for the impact of the number of admissions relative to the median day in the hospital and year cell. All coefficients come from regressions accounting for fixed effects for hospital, year, season, day of week, and hospital×year, as well as the following set of control variables: the number of scheduled CS at the hospital and day of admission, an indicator for pregnancy complications, maternal and paternal wage income, maternal and paternal age at child birth, indicators for maternal and paternal education (higher education, university degree), indicators for maternal and paternal early retirement status, maternal and paternal education status (in education vs not in education), indicators for maternal and paternal region non-western origin, and separate indicators that are one for individuals with missing values for the parental control variables. Standard errors are clustered at the hospital level. The mean of the expected variation in crowding is the mean range in crowding across the mother's day of admission, the day before and the day after (for more details, see Table A.5). Point estimates significant at the 1% level are indicated with an an asterisk.

Table 4: The effect of crowding on procedure use; 2000-2014

	Absolute (1)	Percentile (2)	Relative to median day (3)	Mean of dep. var
Stimulation of labor	-0.001*	-0.011*	-0.006*	0.280
	(0.000)	(0.002)	(0.001)	
Induction	-0.002*	-0.023*	-0.010*	0.186
	(0.000)	(0.002)	(0.001)	
Emergency CS	0.000	0.001	0.000	0.119
	(0.000)	(0.001)	(0.001)	
Mean of "expected" variation in crowding	3.067	0.298	0.546	

Notes: See notes for Table 3.

Table 5: The effect of crowding on procedures at birth; constrained sample with timing and procedure data 2011-2014

	Absolute (1)	Percentile (2)	Relative to median day (3)	Mean of dep. var
Time admission to birth>p50	-0.002*	-0.022*	-0.010*	0.508
	(0.000)	(0.004)	(0.003)	
Indicator: Epidural	-0.001*	-0.015*	-0.006	0.242
	(0.000)	(0.004)	(0.002)	
Indicator: Skin-to-skin	0.000	0.000	-0.000	0.769
	(0.000)	(0.004)	(0.002)	
Waiting time for epidural>p50	0.001	-0.001	0.007	0.481
	(0.001)	(0.009)	(0.006)	
Mean of "expected" variation in crowding	3.067	0.298	0.546	

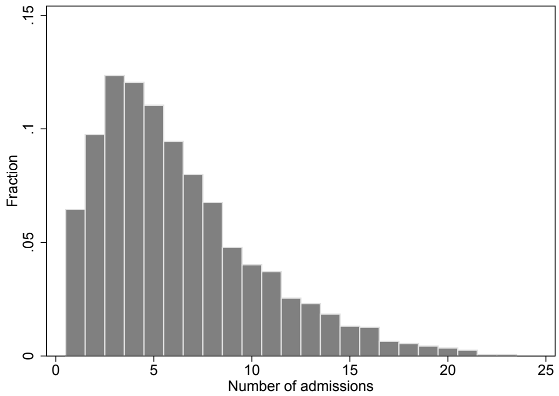
Notes: See notes for Table 3.

Table 6: Heterogeneity: The effect of crowding on selected health outcomes and use of procedures, 2000-2014

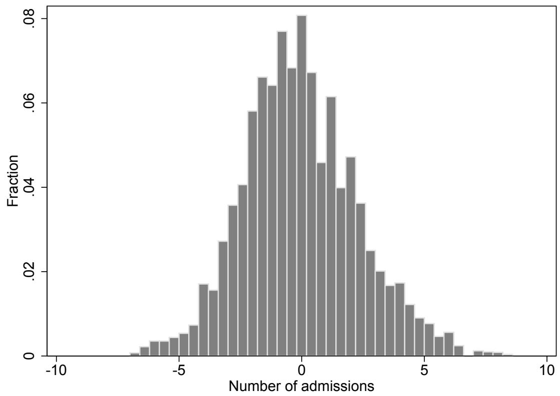
	Main	Gest. age		Parity		Hospital size	
		< 41w	≥ 41w	=1	> 1	<p50	>p50
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Stimulation of labor	-0.001*	-0.001*	-0.001	-0.002	-0.001*	-0.001	-0.001*
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
		[0.971]		[0.337]		[0.188]	
Induction	-0.002*	-0.002*	-0.003*	-0.003*	-0.002*	-0.002*	-0.003*
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
		[0.005]		[0.058]		[0.005]	
Complications at birth	-0.001*	-0.001*	-0.001	-0.001	-0.001*	-0.001*	-0.001*
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
		[0.950]		[0.225]		[0.330]	
Emergency CS	0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
		[0.864]		[0.250]		[0.441]	
APGAR>7	0.000	0.000	-0.000	-0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
		[0.511]		[0.034]		[0.736]	
Post-birth complications	0.000	0.000	-0.000	0.001	-0.000	-0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
		[0.117]		[0.051]		[0.444]	
Observations	770,331	560,247	210,084	187,155	583,176	356,153	414,178

Notes: Each cell presents estimates from a separate regression for the impact of the number of admission. Column (1) is based on the full sample, columns (2) and (3) are for children born below and above 41 completed weeks of gestation, columns (4) and (5) are for first-born and higher parity samples, columns (6) and (7) are for small and large hospitals, respectively (split at the median). P-values for the test of equal coefficient across subgroups are in square brackets. Standard errors are clustered at the hospital level an presented in parenthesis. For further notes see notes for Table 3. Point estimates significant at the 1% level are indicated with an an asterisk.

Appendix material



(a) Number of admissions, 2010



(b) Residualized admissions, 2010

Figure A.1: Distribution of the variation in the number of daily admissions to hospital wards, 2010.

Table A.1: The effect of crowding (absolute number of admissions) rank of admission day, including planned CS, in the hospital and year) on pre-determined characteristics.

	(1)	(2)	(3)	(4)	(5)	(6)
Mother income (thousands)	-1.495	0.984	1.242	1.245	1.309	1.395
	(0.885)	(0.566)	(0.599)	(0.600)	(0.524)	(0.547)
Mother with university degree	-0.020*	-0.003	-0.002	-0.002	0.001	0.001
	(0.006)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Mother age at child birth	-0.061	0.048	0.061*	0.061*	0.029	0.037
	(0.046)	(0.021)	(0.021)	(0.020)	(0.020)	(0.021)
Father income (thousands)	-2.854	-0.406	-0.310	-0.301	-0.360	-0.164
	(1.530)	(0.945)	(0.923)	(0.924)	(0.916)	(0.918)
Father with university degree	-0.018*	-0.001	0.000	0.000	0.002	0.003
	(0.005)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Father age at child birth	-0.077	0.008	0.020	0.019	-0.000	0.007
	(0.042)	(0.030)	(0.029)	(0.029)	(0.026)	(0.026)
Birth weight	3.343	-3.169	-3.714	-3.600	-1.941	-1.799
	(4.235)	(3.619)	(3.614)	(3.621)	(3.385)	(3.347)
Hospital FE		Yes	Yes	Yes	Yes	Yes
Year FE			Yes	Yes	Yes	Yes
Quarter of Year FE				Yes	Yes	Yes
Day of week FE					Yes	Yes
Hospital × year FE						Yes

Notes: Each cell presents point estimates from a separate regression. For a description of the main analysis sample, see section 2.2. The outcome variable for all regressions in a given row is denoted in the first column. Standard errors are clustered at the hospital level. Point estimates significant at the 1% level are indicated with an an asterisk.

Table A.2: The effect of crowding (relative to median, including planned CS, in the hospital and year) on pre-determined characteristics.

	(1)	(2)	(3)	(4)	(5)	(6)
Mother income (thousands)	-2.984*	0.306	0.515	0.496	0.505	0.587*
	(1.044)	(0.222)	(0.246)	(0.243)	(0.214)	(0.196)
Mother university degree	-0.022*	-0.001	0.000	0.000	0.001	0.001
	(0.007)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Mother age at child birth	-0.130	0.017	0.029	0.031	0.019	0.020
	(0.049)	(0.012)	(0.011)	(0.011)	(0.012)	(0.011)
Father income (thousands)	-3.629	-0.125	0.020	-0.034	-0.038	0.101
	(1.456)	(0.354)	(0.322)	(0.325)	(0.310)	(0.354)
Father university degree	-0.023*	-0.000	0.001	0.001	0.001	0.001
	(0.007)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Father age at child birth	-0.107	0.005	0.016	0.020	0.014	0.014
	(0.040)	(0.014)	(0.014)	(0.014)	(0.013)	(0.012)
Birth weight	8.476*	-0.820	-1.122	-1.838	-1.198	-0.953
	(2.809)	(1.429)	(1.407)	(1.396)	(1.321)	(1.300)
Hospital FE		Yes	Yes	Yes	Yes	Yes
Year FE			Yes	Yes	Yes	Yes
Quarter of Year FE				Yes	Yes	Yes
Day of week FE					Yes	Yes
Hospital × year FE						Yes

Notes: Each cell presents point estimates from a separate regression. For a description of the main sample, see section 2.2. The outcome variable for all regressions in a given row is denoted in the first column. Standard errors are clustered at the hospital level. Point estimates significant at the 1% level are indicated with an an asterisk.

Table A.3: The effect of crowding on birth outcomes; 2011-2014

	Absolute (1)	Percentile (2)	Relative to median day (3)	Mean of dep. var
Stimulation of labor	-0.002*	-0.021*	-0.010*	0.261
	(0.000)	(0.004)	(0.002)	
Induction	-0.003*	-0.039*	-0.017*	0.266
	(0.000)	(0.005)	(0.005)	
Complications at birth	-0.001	-0.013	-0.007	0.732
	(0.000)	(0.005)	(0.002)	
Emergency CS	-0.000	-0.002	-0.000	0.128
	(0.000)	(0.003)	(0.002)	
APGAR>7	0.000	0.002	0.001	0.987
	(0.000)	(0.001)	(0.001)	
Post-birth complications	0.000	0.002	0.001	0.087
	(0.000)	(0.003)	(0.002)	

Notes: See notes for Table 3. Point estimates significant at the 1% level are indicated with an an asterisk.

Table A.4: The effect of crowding on child health outcomes; 2011-2014

	Absolute (1)	Percentile (2)	Relative to median day (3)	Mean of dep. var
Hospital nights at birth	-0.002	-0.043	-0.020	2.956
	(0.003)	(0.046)	(0.027)	
Readmitted first 28 days	-0.001*	-0.006	-0.003	0.067
	(0.000)	(0.002)	(0.001)	
Readmitted first year	-0.000	-0.007	-0.004	0.254
	(0.000)	(0.004)	(0.002)	
Readmitted second year	-0.000	-0.005	-0.002	0.166
	(0.000)	(0.004)	(0.002)	
Contacts with gp first month	0.001	0.006	0.004	0.888
	(0.002)	(0.018)	(0.009)	
Contacts with gp first year	-0.002	-0.125	-0.021	8.567
	(0.009)	(0.086)	(0.047)	
Contacts with gp second year	-0.009	-0.048	-0.032	3.103
	(0.005)	(0.054)	(0.026)	

Notes: See notes for Table 3. Point estimates significant at the 1% level are indicated with an an asterisk.

Table A.5: Variation in crowding measures in the analysis sample.

	Mean	SD	P25	P50	P75
Range absolute	3.470	2.960	1.000	3.000	5.000
Range absolute (residualized)	3.067	2.520	1.072	2.317	4.177
Range percentile	0.329	0.235	0.141	0.290	0.495
Range percentile (residualized)	0.298	0.214	0.125	0.260	0.440
Range relative to median	0.586	0.549	0.200	0.444	0.800
Range relative to median (residualized)	0.546	0.517	0.189	0.408	0.746

Notes: The range in crowding is calculated as follows: For each actual admission we compute the difference between the most crowded and least crowded day, considering the actual day of admission as well as the day before and the day after the actual admission.