https://doi.org/10.1016/j.healthpol.2020.10.001

Birth models of care and intervention rates: the impact of birth centres

Abstract

Birth centres offer a midwifery-led model of care which supports a non-medicalised approach to childbirth. They are often reported as having low rates of birth intervention, however the precise impact is obscured because less disadvantaged mothers with less complex pregnancies, and who prefer and often select little intervention, are more likely to choose a birth centre. In this paper, we use a methodology that purges the impact of these selection effects and provides a causal interpretation of the impact of birth centres on intervention outcomes. Using administrative birth data on over 364,000 births in Australia's most populous state between 2001 and 2012, we implement an instrumental variables framework to address confounding factors influencing choice of birth setting. We find that giving birth in a birth centre results in significantly lower probabilities of intervention, and that critically, this impact has been increasing over time. Our estimates are larger than those in existing studies, reflecting our newer data, diverging intervention rates across birth settings, and our accounting for important selection effects. The results emphasise the greater role of birth centres in delivering on policy priorities which include greater maternal autonomy, lower intervention rates, and lower health system costs.

Keywords: maternity care, birth interventions, instrumental variables, administrative data

1. Introduction

Recent policy initiatives have drawn attention to variation in birth intervention rates, particularly in high-income countries, and prioritised reducing interventions in the absence of clinical indications (AHMAC 2011; World Health Organization 2018). Studies have found that the complexity of a woman's pregnancy does not explain the substantial variation, and there is significant concern that birth care is tending towards 'too much, too soon' without corresponding benefit in outcomes for mother or baby (Lee et al. 2013; Miller et al. 2016; Saini et al. 2017). Not only does such variation raise concern about appropriate care, but it also contributes to an inappropriate use of health resources. Studies have found that birth interventions increase the cost of childbirth by between 10 and 67 percent (Allen et al. 2005; Bernitz, Aas, and Øian 2012; Schroeder et al. 2011). These proportionate costs are not trivial and add significantly to the national health budget in public health systems. In Australia, spontaneous birth and caesarean section of a singleton infant are the two most common reasons for an overnight public hospital admission, with labour and childbirth care comprising 19.5 percent of total public hospital expenditures (Australian Institute of Health and Welfare 2017a).

In this study, we focus on the impact of birth setting on intervention outcomes, specifically the impact of giving birth in a birth centre. Birth centres are midwifery-led, separate spaces (in Australia they are typically within a hospital) designed to provide a home-like setting for low-risk women. Birth centres are characterised by a commitment to the 'normality of pregnancy and birth', and have arisen as a response to both the 'medicalisation' of the birth process and homebirth safety concerns (Laws et al. 2009). Globally, there is substantial variation in where women choose to give birth. In high income countries, between 0.5 percent (in the United States) and 10 percent (in The Netherlands and New Zealand) of women choose birth centres (Scarf et al. 2018). These differences are attributable to variation in the status, scope and regulation of the role of the midwife, as well as other institutional factors such as funding and the level of integration across maternity care options (Benoit et al. 2005; Scarf et al. 2018; Vedam et al. 2018). In Australia, while the vast majority of women labour and give birth in a obstetric unit based within a hospital (97% in 2015) (Australian Institute of Health and

Welfare 2017b), within our sample of low-risk women for whom birth centres represent a feasible choice, around 7.5 percent chose a birth centre.

The choice of birth setting for pregnant women is a complex one. Studies have shown that not only is the complexity of the pregnancy a factor, but the woman's previous experience, knowledge of available services, her attitudes towards childbirth and risk, the opinions of her peers, the culture of the health service as well as provider factors contribute to her decision (Cunningham 1993; Dahlen et al. 2011; Hollowell 2011). These factors contribute to observed and unobserved differences between the women giving birth in birth centres and in obstetric units, and make it empirically challenging to measure the impact of giving birth in a birth centre. Two systematic reviews (Hodnett et al. 2012; Scarf et al. 2018) of studies examining care in midwifery-led settings versus standard maternity care found significantly lower odds of intervention in birth centres, and women were nearly three times as likely to have a normal vaginal birth. The studies in these reviews are challenged in two main ways. First, the randomised control trial (RCT) studies (including two Australian studies, Byrne et al., 2000; Rowley et al., 1995) are now quite dated making them problematic given the trends revealed below in Figure 2. They are also based on small samples, with estimated effects which vary substantially, and may lack precision and generalisability (Deaton and Cartwright 2017). Importantly, it is doubtful that the women who choose to be randomised to their birth care are a random sample of pregnant women – indeed over three-quarters of invitees refused to participate in the only Australian RCT with this information available (Byrne, Crowther, and Moss 2008). Second, existing observational cohort studies control only for a limited set of observed maternal attributes (Homer et al. 2014; Laws, Tracy, and Sullivan 2010), and are unable to account for selection effects. The aim of this study is to provide high-quality estimates of the impact of birth centres on intervention outcomes. We use a large, population-based dataset to implement an instrumental variables framework, which overcomes the selection effects affecting both randomisation (of participation) in RCT studies, and those associated with the observed and unobserved traits of women choosing birth centres in cohort studies.

1.1 The Australian context

Australia has a mixed public-private system of healthcare. All women receive universal maternity care provided in public hospitals, and giving birth in a traditional obstetric unit in a public hospital remains the default option for women after confirming their pregnancy with their GP. However, after this initial visit with a GP or with their hospital, some women choose a birth centre model of care, or alternatively pay for private maternity care. All birth centres in NSW are publicly funded and exist within a health service both organisationally and financially. Women in these centres who require higher level care are transferred to an obstetric hospital birth unit following the initial management of the emergency.

This study focuses on births in New South Wales (NSW). NSW is Australia's most populous state, with a population of around 7.9 million people and a geographically vast area of over 800,000 square kilometres (over 310,000 square miles). Births in NSW account for over a third of all births in Australia. All birth centres are public facilities, and most are co-located with their public hospital counterparts; two facilities in our study are stand-alone facilities (i.e. geographically separated from an obstetric unit but part of a general hospital).

2. Materials and Methods

2.1 Study design

We present a retrospective cohort study using a population-based administrative dataset. We implement an instrumental variables framework to address the issue of selection effects, using a distance-to-facility-based instrument. Our analytical sample comprises all births to women with low-risk pregnancies in the years 2001 to 2012.

We focus on a sample of low-risk mothers to minimise the impact of unobserved pregnancy complications on intervention outcomes. The low-risk sample of women was defined as follows:

- single pregnancy (i.e. no multiples);
- no pregnancy-related complications;

- cephalic (head down) presentation;
- gestational age at least 37 weeks.

This process resulted in the exclusion of women with potential high-risk pregnancies (n=149,812).

We excluded women receiving private maternity care (n=260,305) because private doctors face different incentives – they are remunerated on a fee-for-service basis (compared to salary-based public doctors), and face greater risk of malpractice litigation – which affect their propensity to intervene in childbirth (Allin et al. 2015; Gruber, Kim, and Mayzlin 1999).

Women having a planned caesarean section are also excluded (n=86,240). Planned caesareans are only available to women receiving public care where clinical indications exist, and we exclude these women to reduce the potential impact of unobserved health factors. Homebirths are also excluded from the analysis (n=725).

Rural residents were excluded from the analysis because their geographical remoteness renders access to a birth centre infeasible (n=31,330). These exclusions reduced the final analysis sample to 364,667 births, including 27,696 births in birth centres.

2.2 Data

De-identified maternal and infant data was sourced from the NSW Perinatal Data Collection (PDC). This population-based system collects data on all women who give birth to babies greater than 400 grams birth weight, or 20 weeks gestation. The PDC dataset provides rich information on the birth experience, including the following intrapartum interventions of interest to this study:

- Induction of labour;
- Administration of epidural or spinal analgesia;
- Instrumental birth;
- In-labour caesarean section.

The PDC was linked to the NSW Admitted Patient Data Collection (APDC) using a maternal identifier provided by the Centre for Health Record Linkage. The APDC provides clinical information for each hospital admission according to the International Classification of Diseases (Australian modification ICD-10-AM).

The primary exposure of interest is place of birth. The PDC dataset provides data on place of birth (obstetric unit – also known as the labour ward or delivery suite; birth centre; or homebirth). We define place of birth as the mother's intention at the onset or induction of labour. This captures the instances where the woman planned to give birth in a birth centre, but was transferred to the obstetric unit or operating theatre due to complications. In our sample, 24.6 percent of planned birth centre births resulted after being transferred, but this was only 1.9 percent of total births. Using actual place of birth (instead of intended place of birth at the onset of labour) produced larger treatment effects, because post-transfer interventions were attributed to the obstetric unit, and not to the birth centre where the need for intervention potentially arose. Consequently, our results are conservative, underestimating the rate of interventions which ultimately took place in the obstetric ward.

The PDC dataset also provides a limited set of covariates which control for sociodemographic factors. These covariates include age, marital status, socioeconomic status (using the Australian Bureau of Statistic's Index of Relative Socioeconomic-Disadvantage), private health insurance status, and country of birth (grouped by region).

2.3 Empirical strategy

The main empirical challenge is to account for the endogeneity of choice of birth setting due to selection effects. That is, women choosing a birth centre differ from those in a hospital ward, being more likely to commit to non-pharmacological methods of pain relief and a no-intervention birth, and express desire to exert control over their birth (Cunningham 1993; Dahlen et al. 2011). To estimate the direct impact of birth centres on intervention outcomes would result in biased estimates due to these effects. Following previous studies, we propose an instrumental variables framework to eliminate these confounding effects, using a distance-based instrument to address the endogeneity of hospital choice (Cutler 2007; Doyle et al. 2015; Geweke, Gowrisankaran, and Town 2003;

Gowrisankaran and Town 1999; McClellan, McNeil, and Newhouse 1994; McClellan and Newhouse 1997).

The instrument must be uncorrelated with likely unobserved confounding factors (i.e. valid), yet correlated with choice of birth setting (i.e. relevant). The relevance of our choice of distance-based instrument is motivated by the need to be placed physically close to a birth facility for antenatal care, for the birth of the baby, and for returning home postpartum. In addition, when a woman first confirms her pregnancy in Australia, she is usually referred by her GP to her local public hospital. These considerations strongly suggest that distance-based instruments are likely to be relevant, as we show in the results.

The main concern with the validity of our distance-based instrument is that women with a preference for fewer interventions may choose to be located nearer a birth centre. At face value, this is unlikely, because birth centres are publicly provided services, attached to public hospitals which cater for catchment areas across the state. Nonetheless, following prior studies (Cutler 2007; Doyle et al. 2015; McClellan et al. 1994), in the results section we provide a partial test for the validity of our instrument, presenting how observable demographic factors are related to differential distance.

We now turn to the model specification. Other studies using differential distance measures would typically define the instrument as distance to closest birth centre minus the distance to the closest public obstetric unit. In our study, this approach is problematic, because most birth centres are co-located with their public hospital counterpart; this results in a differential distance of close to zero in many cases. Consequently, we adapt this measure of differential distance, using the distance from the woman's residence to the two nearest public obstetric units, and two nearest birth centres as our instrument Z:

$$Z_i = dBC1_i + dBC2_i - dOU1_i - dOU2_i \tag{1}$$

where $dBC1$ and $dBC2$ are the mother's distance to the closest birth centres, and similarly $dOU1$ and $dOU2$ to the two closest obstetric units. We expect that if a woman is close to at least one public hospital but lives relatively far from her closest birth centre (i.e. Z takes a relatively large, positive value), that she is less likely to attend a birth centre. In the results section, we show that this distance-based measure does indeed predict choice of birth facility.

Using this distance-based instrument for choice of birth setting, our model adopts a standard random utility framework as follows:

$$BC_i^* = \boldsymbol{\beta_1 X_i} + \beta_2 Z_i + \varepsilon_{i1} \tag{2}$$

$$Y_i^* = \boldsymbol{\beta_3 X_i} + \beta_4 BC_i + \varepsilon_{i2} \tag{3}$$

where in equation (2) BC_i^* represents a latent preference for the birth centre model of care. The observed variable BC_i is a binary variable denoting whether or not the woman was admitted to a birth centre for her labour and birth.

In Equation (3) Y_i^* represents an unobserved propensity for each of the four intervention outcomes. The observed outcome Y_i for woman *i* takes a value of 1 if an intervention took place, and zero otherwise. Four intervention outcomes are of interest: induction of labour, administration of an epidural analgesia, instrumental delivery by forceps or vacuum, or an in-labour caesarean section.

We assume that both BC_i^* and Y_i^* depend on a vector of observed maternal factors $\boldsymbol{X_i}$ including age, maternal birthplace, smoker status, private health insurance status, metropolitan residence status, primiparous status, and marital status. Private health insurance status is a good proxy for income but insurance coverage has no bearing on the choice of model of care (since both are provided publicly); we have excluded women choosing private maternity care for reasons discussed earlier. We also include a geographic area-level index of socioeconomic disadvantage. The model includes birth weight as a control for the health condition of the infant. We include year dummies interacted with planned place of birth to account for the divergent time trends in each birth setting.

We estimate equations (2) and (3) jointly using a maximum likelihood bivariate probit model. The model assumes a bivariate normal distribution for error terms ε_{i1} and ε_{i2} with a correlation of ρ. Unweighted data was used, and we use clustered standard errors to account for multiple observations on some women. We report the treatment effects (average marginal effects) of each intervention for births taking place in a birth centre.

This study received approval from the NSW Population & Health Services Research Ethics Committee, approval number HREC/14/CIPHS/15.

3. Results

We first present descriptive data on the sociodemographic profile of the women in our sample. Table 1 shows that women choosing a birth centre are on average older, more likely to be married or in a de facto relationship, live in a relatively affluent area, and hold private health insurance. Women with a European, North American, or Australian/Oceania background were more likely to choose a birth centre than women born in Asia or Africa. These characteristics may contribute to selection effects on both observed and unobserved traits, and support the use of an instrumental variables approach.

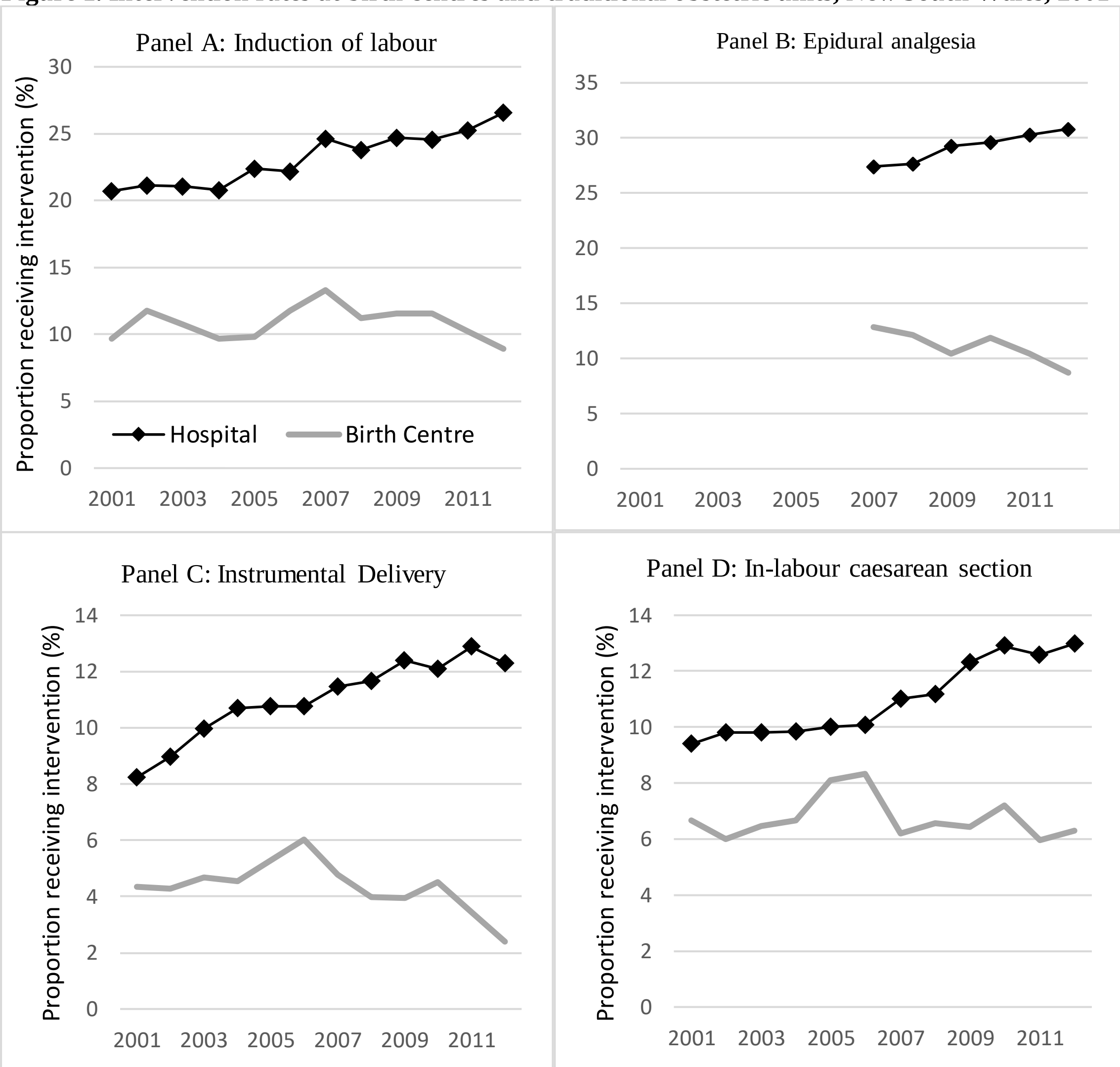
Table 1. Summary data – maternal characteristics

Planned place of birth at onset of labour	Hospital	Birth Centre	Total
n	336,971	27,696	364,667
Maternal age	29.0	30.1	29.0
Married/de facto relationship (%)	78.1	82.4	78.5
Smoker (%)	16.9	10.5	16.4
Holds private health insurance (%)	6.2	8.9	6.4
Region of birth (%)			
Australia/Oceania	67.0	77.6	67.8
North/West Europe	3.7	7.4	3.9
South/East Europe	1.9	2.0	1.9
North Africa/Middle East	7.0	1.7	6.6
SouthEast Asia	6.9	3.3	6.7
North East Asia	5.6	2.3	5.3
South/Central Asia	5.1	2.0	4.8
North America	0.6	1.4	0.6
South/Central America	1.0	1.0	1.0
Sub saharan Africa	1.3	1.2	1.2
Total	100.0	100.0	100.0
SEIFA Index of Socio-economic disadvantage			
Most disadvantaged quintile	20.3	7.8	19.3
2	12.0	4.2	11.4
3	20.5	25.6	20.8
4	23.7	25.6	23.9
Least disadvantaged quintile	23.6	36.7	24.6
Total	100.0	100.0	100.0
Number of previous pregnancies			
0	59.6	56.3	59.4
1-2	37.8	41.5	38.1
3-4	2.5	2.1	2.4
5 or more	0.2	0.1	0.2
Total	100.0	100.0	100.0

Source: NSW Perinatal Data Collection. Each birth contributes a single observation; low-risk women contribute multiple observations where they have had more than one singleton birth. SEIFA quintiles are based on a continuous index score of socioeconomic disadvantage.

It is revealing to consider intervention rates over time by setting. As shown in Figure 1, birth centres in NSW have lower intervention rates compared to traditional obstetric units. Not only are intervention rates systematically lower in birth centres, but there is also a strong time dimension – that is, intervention rates are broadly stable or falling in birth centres (grey line) while rising in traditional obstetric units (dotted line).

Figure 1. Intervention rates at birth centres and traditional obstetric units, New South Wales, 2001-2012



Panels A, C and D present data spanning 2001 to 2012 for low-risk women. Data for Panel B was available for 2007 to 2012 only. Hospital intervention rates are shown in the marked line; birth centre intervention rates in the solid grey line.

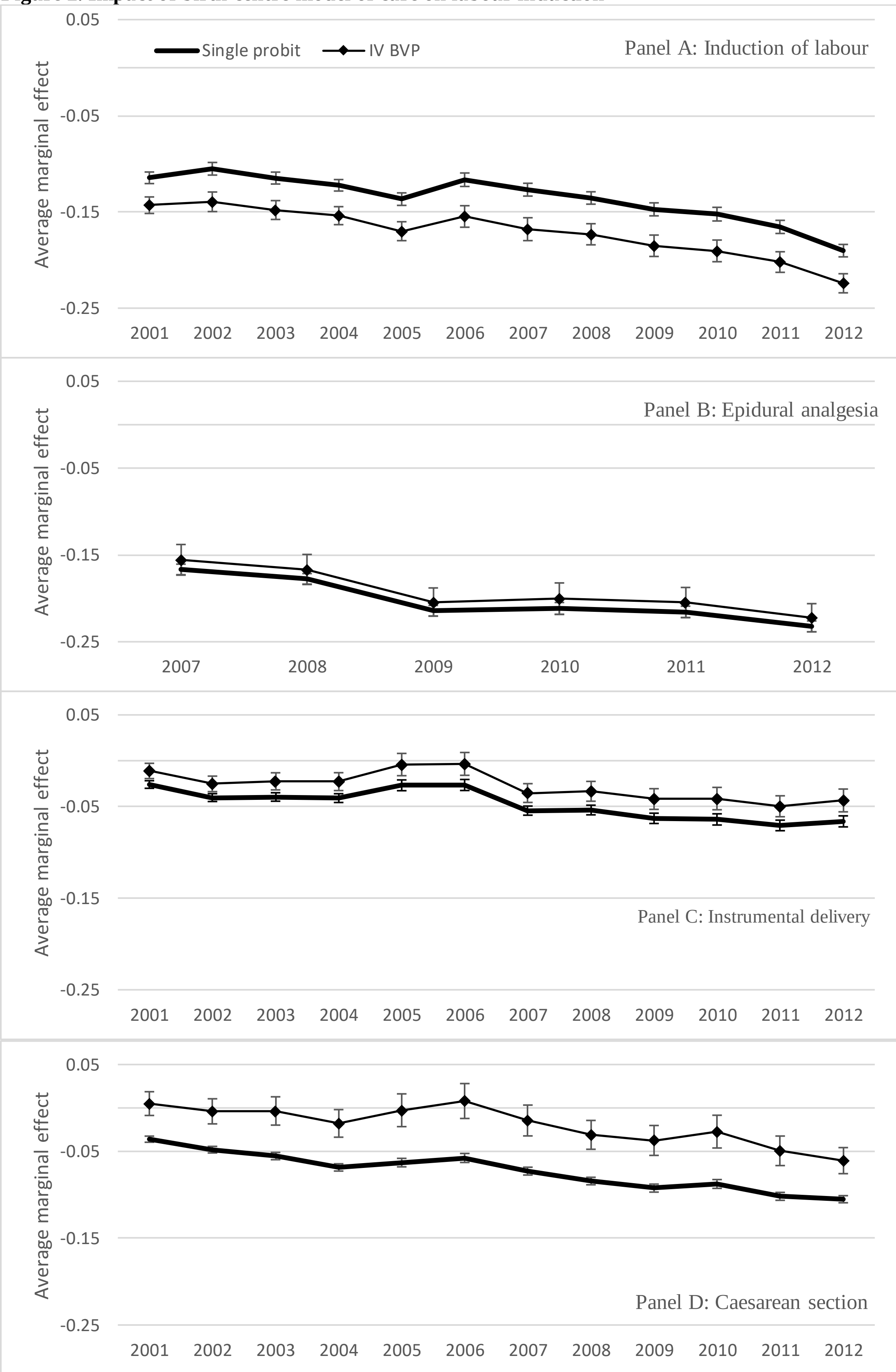
We present results from our instrumental variables modelling graphically first, to illustrate the heterogeneous effects of the birth centre model of care over time. Full results are also provided in tabular form in Table 2. In Figure 2, Panels A to D, we compare two sets of results for each outcome – the first set, ‘single probit’, are based on estimates from equation (2) and controls for observed attributes only (thick black line); the second, ‘IV BVP’, accounts for the endogeneity of choice using our instrumental variables bivariate probit model (thin dotted line). The difference between the two lines indicates the impact of selection effects, with the direction of the associated biases being governed by the sign of ρ, the correlation between the disturbances in equations (1) and (2). While the correlation between interventions and birth centre choice is negative, the estimated ρ reflects the correlation between unobservable factors present in both disturbances after controlling for the direct effect of birth centres on the probability of an intervention and so this correlation can reasonably be positive or negative.

Panel A in Figure 2 shows that, based on our bivariate probit model, the impact of birth centres has been to lower the probability of labour induction by between a statistically significant 14 and 22 percentage points, with the impact growing larger over time. This change over time may reflect growing concern about supporting women to labour in a birth centre following induction, resulting in lower rates of induction. The direction of the selection effect – opposite to that observed for the other interventions – occurs because after accounting for the large direct negative effect of birth centres on the probability of being induced, the common unobservables present in the disturbances were positively correlated. While distance to hospital might conceivably have a direct effect on the decision to induce labour (violating the exclusion restriction of our model), following the framework set out in recent studies (Conley, Hansen, and Rossi 2012; van Kippersluis and Rietveld 2018a, 2018b), sensitivity analyses showed our distance-based instrument to be plausibly exogenous and thereby leaving our results qualitatively robust to this concern.

Panel B shows the effects on the use of epidural analgesia between 2007 and 2012 only. The results are statistically significant, and show that birth centres lowered the probability of epidural by between 16 and 22 percentage points. Again, the impact has grown larger over time. There was relatively little difference between the estimates from the single probit and IV BVP models.

By comparison, there were large differences in model results for instrumental birth (Panel C) and caesarean section (Panel D). For both birth outcomes, negative selection effects were found. That is, women choosing birth centres were less likely to have instrumental deliveries or caesarean sections, which led to a downward bias in the single probit estimates. For instrumental delivery, the IV BVP model found effects of around -2 to -5 percentage points lower. For caesarean section, the IV BVP model found statistically significant results from 2009 onwards only, where the impact of a birth centre was to lower the probability of caesarean section by between 4 and 6 percentage points.

Figure 2. Impact of birth centre model of care on labour induction



Panels A, C and D are based on a sample of low-risk women for the period 2001-2012. Panel B is based on a sample of low-risk women for the period 2007-2012. Legend: In each panel, the thick black line illustrates yearly marginal effects from a single probit model; the thin marked line represents yearly marginal effects from the bivariate probit IV model. 95% confidence interval bars are shown for each series.

Table 2. Birth centre treatment effects on intervention rates by year

	Labour induction		Epidural		Instrumental delivery		Caesarean section	
Year[a]	Est.	Std. Err.	Est.	Std. Err.	Est.	Std. Err.	Est.	Std. Err.
2001	-0.143***	(0.0087)			-0.011	(0.0083)	0.005	(0.0149)
2002	-0.139***	(0.0104)			-0.025***	(0.0085)	-0.004	(0.0157)
2003	-0.148***	(0.0099)			-0.023**	(0.0093)	-0.003	(0.0176)
2004	-0.154***	(0.0095)			-0.023**	(0.0097)	-0.018	(0.0175)
2005	-0.170***	(0.0100)			-0.004	(0.0122)	-0.003	(0.0207)
2006	-0.155***	(0.0113)			-0.003	(0.0124)	0.008	(0.0222)
2007	-0.168***	(0.0120)	-0.159***	(0.0164)	-0.035***	(0.0102)	-0.014	(0.0195)
2008	-0.173***	(0.0110)	-0.170***	(0.0161)	-0.033***	(0.0108)	-0.031*	(0.0182)
2009	-0.185***	(0.0112)	-0.208***	(0.0151)	-0.042***	(0.0113)	-0.037**	(0.0187)
2010	-0.190***	(0.0113)	-0.204***	(0.0168)	-0.041***	(0.0122)	-0.027	(0.0205)
2011	-0.202***	(0.0108)	-0.208***	(0.0163)	-0.050***	(0.0114)	-0.049***	(0.0187)
2012	-0.224***	(0.0100)	-0.226***	(0.0152)	-0.043***	(0.0124)	-0.061***	(0.0165)
Average annual effect	-0.171***	(0.0092)	-0.195***	(0.0148)	-0.027***	(0.0089)	-0.019	(0.0169)
Maternal age	0.002***	(0.0001)	0.003***	(0.0002)	0.000***	(0.0001)	0.003***	(0.0001)
Married/defacto relationship[b]	-0.006***	(0.0018)	-0.005*	(0.0028)	0.006***	(0.0013)	-0.008***	(0.0013)
Smoker[c]	0.014***	(0.0021)	-0.001	(0.0032)	-0.015***	(0.0016)	0.007***	(0.0015)
Holds private health insurance[d]	-0.001	(0.0028)	0.014***	(0.0035)	0.010***	(0.0019)	0.002	(0.0020)
Primiparous[e]	0.077***	(0.0015)	0.224***	(0.0021)	0.144***	(0.0013)	0.106***	(0.0012)
Lives in major city[f]	0.011***	(0.0024)	0.047***	(0.0032)	0.005***	(0.0015)	-0.009***	(0.0016)
Region of birth[g]								
North/West Europe	-0.018***	(0.0036)	-0.019***	(0.0051)	0.012***	(0.0026)	-0.012***	(0.0024)
South/East Europe	-0.033***	(0.0049)	-0.008	(0.0072)	0.005	(0.0036)	-0.018***	(0.0032)
North Africa/Middle East	-0.044***	(0.0033)	-0.072***	(0.0046)	-0.015***	(0.0022)	-0.018***	(0.0022)
SouthEast Asia	-0.111***	(0.0027)	-0.050***	(0.0044)	0.013***	(0.0023)	0.020***	(0.0024)
North East Asia	-0.081***	(0.0033)	-0.026***	(0.0047)	0.024***	(0.0026)	-0.001	(0.0025)
South/Central Asia	-0.007*	(0.0039)	0.034***	(0.0051)	0.034***	(0.0028)	0.057***	(0.0032)
North America	-0.036***	(0.0084)	0.029**	(0.0121)	-0.001	(0.0058)	-0.013**	(0.0056)
South/Central America	-0.038***	(0.0067)	0.074***	(0.0106)	0.005	(0.0049)	0.037***	(0.0055)
Sub saharan Africa	-0.017***	(0.0062)	-0.002	(0.0085)	-0.016***	(0.0040)	0.053***	(0.0053)
SEIFA Index of disadvantage[h]								
Quintile 2	-0.005**	(0.0026)	0.013***	(0.0038)	0.006***	(0.0018)	0.004**	(0.0019)
Quintile 3	0.039***	(0.0030)	0.089***	(0.0040)	0.025***	(0.0018)	0.015***	(0.0019)
Quintile 4	0.020***	(0.0026)	0.094***	(0.0036)	0.024***	(0.0017)	0.014***	(0.0018)
Quintile 5 - Least disadvantaged	0.021***	(0.0028)	0.117***	(0.0036)	0.034***	(0.0018)	0.013***	(0.0018)
Birthweight[#]	0.0714***	(0.0015)	0.0883***	(0.0022)	0.0145***	(0.0011)	0.0517***	(0.0011)
No. observations	364,667		185,045		364,667		364,667	

Yearly average partial effects from the IV bivariate probit (IV BVP) model are reported for each birth intervention. *** Significant at the 1 percent level. ** Significant at the 5 percent level.* Significant at the 10 percent level. #Birthweight estimates and standard errors are reported x 10^3. Reference categories as follows: a).year 2000, b) Non-partnered, c) Non-smoker, d) Does not hold private health insurance, e) Multiparous, f) Lives outside a major city, g) Australia/Oceania, h) SEIFA Quintile 1

Finally, we present evidence supporting the relevance and validity of our distance-based instrument. Table A1 in the online appendix shows that distance to birth facility is indeed strongly related to a woman's choice of facility. For example, amongst low-risk women planning a birth centre birth, 82.2 percent of women chose their closest birth centre, while 72.0 percent of those choosing a traditional obstetric unit chose their closest facility. Results from a formal statistical test (Table A3 in the online appendix) also demonstrates the strength of the instrument (i.e. its ability to predict choice of birth facility).

As noted earlier, the main concern with the validity of our distance-based instrument is that women with a preference for fewer interventions may choose to be located nearer a birth centre. In Table 3 below, we present a partial test of instrument validity, reporting the sociodemographic profile of women according to differential distance (i.e. distance to birth centre minus distance to hospital), cut off near the median differential distance of 6km . We expect to see that women who live relatively close to a birth centre exhibit similar characteristics to those who live relatively far. In evaluating the significance of any differences, we report normalised difference statistics (Imbens and Wooldridge 2009) rather than p-values, as p-values are sensitive to sample size. As shown in the table, the normalised differences are virtually all below the recommended rule of thumb of an absolute threshold of 0.25, demonstrating balance in the covariates in relation to differential distance to the closest birth centre. That is, the data show that women living relatively close to a birth centre show similar attributes to those relatively close to a traditional obstetric unit. Exceptions are observed in whether the woman resides in a metropolitan area (i.e. a major city), or in different socioeconomically disadvantaged geographic areas. This indicates that many of those with low differential distance to the nearest birth centre live in major cities or areas of relative socioeconomic advantage. To account for this, we include controls for metropolitan location as well as for socioeconomic status (i.e. index of socioeconomic disadvantage, smoker status, and private health insurance status). We argue that any remaining bias due to selection on unobservables is small, but also report results from a further test of validity in Table A2 in the online appendix.

Table 3. Maternal characteristics by differential distance

	Differential distance to BC		Normalised difference
	<6km	>=6km	
n	187,768	176,899	-
Maternal age	29.7	28.4	0.17
Married/de facto relationship (%)	80.6	76.5	0.07
Smoker (%)	13.8	18.9	-0.10
Metropolitan location	83.3	44.4	0.63
Holds private health insurance (%)	8.3	4.6	0.11
Region of birth (%)			
Australia/Oceania	62.9	72.5	-0.15
North/West Europe	5.2	2.7	0.09
South/East Europe	2.3	1.6	0.03
North Africa/Middle East	5.6	7.5	-0.05
South-East Asia	6.4	6.9	-0.01
North East Asia	7.9	2.9	0.16
South/Central Asia	6.4	3.4	0.10
North America	0.8	0.5	0.03
South/Central America	1.1	0.9	0.02
Sub saharan Africa	1.4	1.1	0.02
Total	100.0	100.0	
SEIFA Index of Socio-economic disadvantage			
Most disadvantaged quintile	15.7	19.3	-0.13
2	5.1	11.4	-0.28
3	22.9	20.8	0.07
4	21.4	23.9	-0.08
Least disadvantaged quintile	34.9	24.6	0.34
Total	100.0	100.0	
Number of previous pregnancies			
0	57.4	61.4	
1-2	39.7	36.3	
3-4	2.7	2.1	
5 or more	0.2	0.2	-0.06
Total	100.0	100.0	

Source: NSW Perinatal Data Collection. The sample is divided by the median differential distance to birth centre of 6km. The third data column reports the normalised difference $\Delta = \frac{\bar{X}_1 - \bar{X}_0}{\sqrt{S_0^2 + S_1^2}}$ (Imbens & Wooldridge, 2009).

A range of standard diagnostic tests are performed – these diagnostic checks are reported in Table A3 in the online appendix and support our empirical results.

4. Discussion

We have used a population-based dataset to show that, after accounting for selection effects which include clinical need and maternal preferences, birth centres have a substantial impact on lowering intervention rates (between 2 and 22 percentage points), and that this impact has been growing over time. The reasons for these differences reflect how birth centres are organised and deliver a different model of care from traditional obstetric units. A birth centre is a separate space, often co-located on the grounds of a hospital which provides a maternity service (referred to as an alongside birth centre) and is often within the maternity unit itself. Otherwise, a freestanding birth centre is located on the grounds of a hospital which does not have a maternity service and women who require higher level care are transferred to the nearest maternity referral hospital. Importantly, they are midwife-led, in collaboration with obstetric oversight and referral when necessary, delivering a model of care which embraces the normality, and opposes the medicalisation, of childbirth. For example, birth centres are midwife-led and encourage non-pharmacological pain management options, such as labouring and giving birth in water, which have grown more prevalent over time. The variation may also reflect other changes over time such as the tightening of birth centre eligibility guidelines and growing risk aversion in obstetric units (Dubay, Kaestner, and Waidmann 1999). For example, Laws et al. (2011) found that over time, birth centres have increasingly declined women seeking vaginal births after prior caesarean sections as well as women with obesity, resulting in a lower risk profile of birth centre women.

This study's limitations include being limited to births in one Australian state, New South Wales, and being focused on a select number of birth interventions. Future directions of research may include expanding the analysis to a national database, as well as considering factors influencing demand for the birth centre model of care.

Our results differ from prior studies in two key ways – we account explicitly for selection effects, and our data sample is newer. A comparison of our estimates to previous studies, reported in Table A4 in the online appendix, suggest that 1) selection effects for method of birth (instrumental or caesarean section) reduce the estimated effects of birth centres, and 2) our newer estimates are generally larger as intervention rates in obstetric units have increased over time.

This reduction in intervention rates is a policy priority across a number of considerations: A range of evidence has shown that interventions increase birth care costs (Allen et al. 2005; Bernitz et al. 2012), can lead to higher risk by way of a 'cascade' of interventions (Tracy and Tracy 2003), and can impact on long-term child health outcomes (Peters et al. 2018). As well, it is well established that many women seek greater control and autonomy during the birth process (Brown and Lumley 1994; Dahlen et al. 2011), which the birth centre model of care can support.. This research presents further evidence that the birth centre model of care, by lowering the rate of birth interventions, can contribute to a range of policy priorities. Yet across the world, there is high variability in the proportion of women giving birth in birth centres, with different institutional settings (such as occupational regulation) being a driving determinant (Benoit et al. 2005; Scarf et al. 2018; Vedam et al. 2018). In Australia, there has been no expansion of birth centres, with at least two of the centres in this study now closed. Our results show that for low-risk women wishing to pursue a non-medicalised birth, birth centres offer relatively low rates of intervention and correspondingly lower attendant costs.

5. Conclusions

There has been strong international policy interest in variation in intervention rates and the role of birth setting. Australian and international policy initiatives have prioritised ensuring women have greater choice in birth place, and reducing unnecessary interventions. (AHMAC 2011; World Health Organization 2018). While birth centres have long been assumed to reduce intervention rates, their impact has been obscured by selection effects attributable to the women who choose them, who are typically older, more educated and in better health. Our results demonstrate that after accounting for these selection effects, the impact of birth centres is to substantially reduce intervention rates. The implication for policymakers is that there is a stronger role for birth centres in supporting greater choice and autonomy for women, and improved cost outcomes for the health system.

6. References

AHMAC. 2011. “National Maternity Services Plan.” Australian Health Ministers Advisory Council. Canberra: Commonwealth of Australia.

Allen, V. M., C. M. O'Connell, S. A. Farrell, and T. F. Baskett. 2005. “Economic implications of method of delivery.” *American Journal of Obstetrics and Gynecology* 193(1): 192-97.

Allin, S., M. Baker, M. Isabelle, and M. Stabile. 2015. “Physician Incentives and the Rise in C-sections: Evidence from Canada.” *National Bureau of Economic Research Working Paper Series* No. 21022.

Australian Institute of Health and Welfare. 2017a. “Admitted patient care 2015-16: Australian hospital statistics.”. Canberra: AIHW.

Australian Institute of Health and Welfare. 2017b. “Australia's mothers and babies 2015 - in brief.” Canberra: AIHW.

Benoit, C., S. Wrede, I. Bourgeault, J. Sandall, R. D. Vries, and E. R. v. Teijlingen. 2005. “Understanding the social organisation of maternity care systems: midwifery as a touchstone.” *Sociology of Health & Illness* 27(6): 722-37.

Bernitz, S., E. Aas, and P. Øian. 2012. “Economic evaluation of birth care in low-risk women. A comparison between a midwife-led birth unit and a standard obstetric unit within the same hospital in Norway. A randomised controlled trial.” *Midwifery* 28(5): 591-99.

Brown, S. and J. Lumley. 1994. “Satisfaction With Care in Labor and Birth: A Survey of 790 Australian Women.” *Birth* 21(1): 4-13.

Byrne, J. P., C. A. Crowther, and J. R. Moss. 2000. “A randomised controlled trial comparing birthing centre care with delivery suite care in Adelaide, Australia.” *Australian and New Zealand Journal of Obstetrics and Gynaecology* 40(3): 268-74.

Byrne, J. P., C. A. Crowther, and J. R. Moss. 2008. “A randomised controlled trial comparing birthing centre care with delivery suite care in Adelaide, Australia.” *Australian and New Zealand Journal of Obstetrics and Gynaecology* 40(3): 268-74.

Conley, T. G., C. B. Hansen, and P. E. Rossi. 2012. “Plausibly Exogenous.” *The Review of Economics and Statistics* 94(1): 260-72.

Cunningham, J. D. 1993. “Experiences of Australian mothers who gave birth either at home, at a birth centre, or in hospital labour wards.” *Social Science & Medicine* 36(4): 475-83.

Cutler, D. M. 2007. “The lifetime costs and benefits of medical technology.” *Journal of Health Economics* 26(6): 1081-100.

Dahlen, H., V. Jackson M Fau - Schmied, S. Schmied V Fau - Tracy, H. Tracy S Fau - Priddis, and H. Priddis. 2011. “Birth centres and the national maternity services review: response to consumer demand or compromise?” *Women and Birth* 24(4): 165-72.

Deaton, A. and N. Cartwright. 2017. “Understanding and misunderstanding randomized controlled trials.” *Social Science & Medicine* 210: 2-21.

Doyle, J., J. Graves, J. Gruber, and S. Kleiner. 2015. “Measuring Returns to Hospital Care: Evidence from Ambulance Referral Patterns.” *The journal of political economy* 123(1): 170-214.

Dubay, L., R. Kaestner, and T. Waidmann. 1999. “The impact of malpractice fears on cesarean section rates.” *Journal of Health Economics* 18(4): 491-522.

Geweke, J., G. Gowrisankaran, and R. J. Town. 2003. “Bayesian Inference for Hospital Quality in a Selection Model.” *Econometrica* 71(4): 1215-38.

Gowrisankaran, G. and R. J. Town. 1999. “Estimating the quality of care in hospitals using instrumental variables.” *Journal of Health Economics* 18(6): 747-67.

Gruber, J., J. Kim, and D. Mayzlin. 1999. “Physician fees and procedure intensity: the case of cesarean delivery.” *Journal of Health Economics* 18(4): 473-90.

Hodnett, E. D., D. Downe S Fau - Walsh, J. Walsh D Fau - Weston, and J. Weston. 2012. “Alternative versus conventional institutional settings for birth.” *Cochrane Database of Systematic Reviews*(8).

Hollowell, J. 2011. “Birthplace programme overview: background, component studies and summary of findings. Birthplace in England Research programme. Final report part 1.” NIHR Service Delivery and ORganisation programme.

Homer, C. S. E., C. Thornton, V. L. Scarf, D. A. Ellwood, J. J. N. Oats, M. J. Foureur, D. Sibbritt, H. L. McLachlan, D. A. Forster, and H. G. Dahlen. 2014. “Birthplace in New South Wales, Australia: an

analysis of perinatal outcomes using routinely collected data." *BMC Pregnancy and Childbirth* 14(1): 206.
Imbens, G. W. and J. M. Wooldridge. 2009. "Recent Developments in the Econometrics of Program Evaluation." *Journal of Economic Literature* 47(1): 5-86.
Laws, P. J., C. Lim, S. Tracy, and E. A. Sullivan. 2009. "Characteristics and practices of birth centres in Australia." *Australian and New Zealand Journal of Obstetrics and Gynaecology* 49(3): 290-95.
Laws, P. J., C. Lim, S. K. Tracy, H. Dahlen, and E. A. Sullivan. 2011. "Changes to booking, transfer criteria and procedures in birth centres in Australia from 1997 – 2007: a national survey." *Journal of Clinical Nursing* 20(19 - 20): 2812-21.
Laws, P. J., S. K. Tracy, and E. A. Sullivan. 2010. "Perinatal Outcomes of Women Intending to Give Birth in Birth Centers in Australia." *Birth* 37(1): 28-36.
Lee, Y. Y., Roberts Cl Fau, J. A. Patterson, J. M. Simpson, M. C. Nicholl, J. M. Morris, and J. B. Ford. 2013. "Unexplained variation in hospital caesarean section rates." *Medical Journal of Australia* 199(5): 348-53.
McClellan, M., B. J. McNeil, and J. P. Newhouse. 1994. "Does More Intensive Treatment of Acute Myocardial Infarction in the Elderly Reduce Mortality?: Analysis Using Instrumental Variables." *JAMA* 272(11): 859-66.
McClellan, M. and J. P. Newhouse. 1997. "The marginal cost-effectiveness of medical technology: A panel instrumental-variables approach." *Journal of Econometrics* 77(1): 39-64.
Miller, S., E. Abalos, M. Chamillard, A. Ciapponi, D. Colaci, D. Comandé, V. Diaz, S. Geller, C. Hanson, A. Langer, V. Manuelli, K. Millar, I. Morhason-Bello, C. P. Castro, V. N. Pileggi, N. Robinson, M. Skaer, J. P. Souza, J. P. Vogel, and F. Althabe. 2016. "Beyond too little, too late and too much, too soon: a pathway towards evidence-based, respectful maternity care worldwide." *The Lancet* 388(10056): 2176-92.
Peters, L. A.-O., C. A.-O. Thornton, A. A.-O. de Jonge, A. Khashan, M. Tracy, S. Downe, E. A.-O. X. Feijen-de Jong, and H. A.-O. Dahlen. 2018. "The effect of medical and operative birth interventions on child health outcomes in the first 28 days and up to 5 years of age: A linked data population-based cohort study." *Birth* 45(4): 347-57.
Rowley, M. J., M. J. Hensley, M. W. Brinsmead, and J. H. Wlodarczyk. 1995. "Continuity of care by a midwife team versus routine care during pregnancy and birth: a randomised trial." *Medical Journal of Australia* 163(6): 289-93.
Saini, V., S. Garcia-Armesto, D. Klemperer, V. Paris, A. G. Elshaug, S. Brownlee, J. P. A. Ioannidis, and E. S. Fisher. 2017. "Drivers of poor medical care." *The Lancet* 390(10090): 178-90.
Scarf, V. L., C. Rossiter, S. Vedam, H. G. Dahlen, D. Ellwood, D. Forster, M. J. Foureur, H. McLachlan, J. Oats, D. Sibbritt, C. Thornton, and C. S. E. Homer. 2018. "Maternal and perinatal outcomes by planned place of birth among women with low-risk pregnancies in high-income countries: A systematic review and meta-analysis." *Midwifery* 62: 240-55.
Schroeder, L., S. Petrou, N. Patel, J. Hollowell, D. Puddicombe, M. Redshaw, and P. Brocklehurst. 2011. "Birthplace cost-effectiveness analysis of planned place of birth: individual level analysis. Birthplace in England research programme. Final report part 5." NIHR Service Delivery and Organisation programme.
Tracy, S. K. and M. B. Tracy. 2003. "Costing the cascade: estimating the cost of increased obstetric intervention in childbirth using population data." *BJOG: An International Journal of Obstetrics & Gynaecology* 110(8): 717-24.
van Kippersluis, H. and C. A. Rietveld. 2018a. "Beyond plausibly exogenous." *The Econometrics Journal* 21(3): 316-31.
van Kippersluis, H. and C. A. Rietveld. 2018b. "Pleiotropy-robust Mendelian randomization." *International Journal of Epidemiology* 47(4): 1279-88.
Vedam, S., K. Stoll, M. MacDorman, E. Declercq, R. Cramer, M. Cheyney, T. Fisher, E. Butt, Y. T. Yang, and H. Powell Kennedy. 2018. "Mapping integration of midwives across the United States: Impact on access, equity, and outcomes." *PLOS ONE* 13(2): e0192523.
World Health Organization. 2018. "WHO recommendations: intrapartum care for a positive childbirth experience." Geneva: WHO.