Online Appendix

A Detailed ANC and FBD

While Rwanda succeeded in expanding maternal health service accessibility, the impact on NMR reduction may be limited due to the quality of services. In Appendix Figure A.2, Panels (a)-(i) detail factors in ANC.[1] The probability of receiving ANC from a doctor (Panel (a)) or a nurse/midwife (Panel (b)) remained largely unchanged post-reform. Most mothers (over 95%) received ANC from a nurse/midwife, and the probability of doctor-provided ANC stayed constant at 6% before and after the reform.[2] While blood and blood pressure tests and tetanus injections increased, more complex factors like urine tests, malaria care, iron supplements (Panels (e)-(h)), and the probability of having more than three treatments (Panel (j)) showed no significant change.

Panels (j)-(l) in Appendix Figure A.2 illustrate the impact on detailed Facility-Based Delivery (FBD), including location and cesarean sections. The likelihood of FBD at health centers/posts (Panel (j)) and hospitals (Panel (k)) both increased, with a more immediate rise observed in hospital-based FBD. However, the probability of having a cesarean section did not see an increase following the policy change (Panel (l)).

While the figures indicate an overall improvement in the quality of ANC in Rwanda, it may not have been sufficient to significantly reduce NMR (and IMR). Literature reveals persistent shortcomings in maternal health services; Rurangirwa et al. (2018) highlight nurses and midwives in ANC services failing to report critical conditions requiring urgent referral and transfer to a higher-level health facility. Moreover, the lack of formal training is evident, with over 90% of nurses and midwives not receiving in-service training in the past two years, and more than half having never received such training. Similar challenges exist in FBD, where the availability of cesarean sections at district hospitals is hindered by a less-than-smooth referral and transfer process. Factors such as extended travel times and delays from cesarean decision to incision (Harrison and Goldenberg, 2016; Niyitegeka et al., 2017) contribute to potential complications. If complicated deliveries are not successfully transferred in certain areas, this could elucidate why newborn and neonatal mortality rates show relatively less improvement.

[1] These factors are a subset of the WHO (2016)'s recommendation for ANC.

[2] The sum of categories may not equal 1 due to potential receipt from multiple health experts.

B Robustness Check

B.1 Alternative Definitions of Treatment

In Appendix Table A.2, I employ alternative treatment definitions for a robustness check. In Panel A, I use the continuous home delivery rate (1-FBD) instead of a binary treatment variable, resulting in larger estimates due to the magnitude of the treatment variable. The results remain robust when employing continuous treatment or different thresholds.

For further robustness checks in Panels B, C, and D, I define an index that captures the utilization of maternal and general health services, with treatment status defined using various percentiles. In Panel B, I set treatment status using the 25th percentile in the baseline period. In Panels C and D, I construct a composite index summarizing pre-period maternal health service utilization (both FBD and ANC). Principal Component Analysis (PCA) is employed, incorporating district-level FBD rate, frequency of ANC visits, and month of the first ANC, with the first principal component (PC1) serving as the indicator. For general health service use, the index includes health facility visits in the last 12 months, use of modern contraceptive methods, HIV testing, and treatment for diarrhea and fever, in addition to maternal health services.[3] The results, while less precise in Panel C, demonstrate similar magnitudes to the main specification in Panels C and D.

B.2 Applying Rambachan and Roth (2023) Estimator

One may be concerned about potential pre-existing trends in the treatment districts. Specifically, Panel (a) of Figure A.1 compares the trend of FBD rates in treatment and control districts, presenting a light concern on a pre-existing positive trend in FBD rates in treatment districts. This raises the possibility of a secular trend systematically differing based on treatment status. Specifically, because the treatment status is determined by pre-determined FBD rates, confounding factors might influence FBD rates smoothly over time, resulting in a pre-trend.

To address this concern, I employ an alternative estimator recommended by Rambachan and Roth (2023). This method assumes that post-treatment trends cannot significantly differ from pre-trends. By extrapolating pre-existing trends to estimate treatment effects without bias from pre-trends, I use Δ—the set of possible pre- and post-trends—based on Rambachan and Roth (2023)'s recommendation. Given that potential pre-trends are more relevant to long-

[3] See Vyas and Kumaranayake (2006) for further information on PCA.

lasting secular trends evolving slowly, I apply the smoothness restrictions methodology. This method makes the researcher choose M, the amount by which the slope of δ can change between consecutive periods.

Figure A.3 displays the estimate sizes with their 95% confidence intervals, varying the parameter M. These estimates represent the average of post-treatment estimators, roughly aligning with the DiD results in Tables 3 and 4. When M is set to 0, it is akin to incorporating a group-specific linear trend. Introducing positive M allows for deviations from linearity of no more than M between consecutive periods—a relaxation of the assumption (Rambachan and Roth, 2023). Fixed-length confidence intervals (FLCI) in all panels are similar to and encompass the original confidence intervals as the assumption is relaxed with increasing M. The FLCIs widen as more non-linearity is allowed in all panels. Notably, in Panels (a)-(c), the treatment effect remains robust up to $M = 0.002$, which accounts for approximately 20% of the observed trends in FBD during the pre-treatment period. For Panels (d), (f), and (g), where OLS and event study estimators exhibit low or no significance, the estimator suggests that if a differential pre-trend is allowed, the null hypothesis of no treatment effect cannot be rejected. Overall, the alternative estimator indicates that significant estimators from the main specification remain robust even when allowing for differential pre-trends.

B.3 Using New District Boundaries

In Appendix Figure A.4, I exclude 2005 RDHS from the sample and perform the same analysis. Not to lose too many observations in the pre-period, I include birth in 2000-2002 in 2008 RDHS as well. The solid green coefficients in Appendix Figure A.4 become smaller and mostly insignificant in panels (b)-(g). In fact, the point estimates on NMR7 and NMR are mostly positive, confirming that the policy effect on mortality rates is weak.

C Subsample Analysis

In this section, I remove some advantageous households for additional robustness. Control districts have more advantageous households by definition; they have high baseline FBD rates and only better-off households were able to use the service before 2006. In Appendix Table A.3 I remove some of these high SES households to show that the main results are not coming from the comparison between high vs. low SES households. Also, I can show that the effect is not mainly coming from wealthy or educated households in the treatment districts catching

their peers up in control districts. I choose three SES measures: (1) living in the capital, (2) living in an urban area, (3) finishing primary school, and (3) wealth (top 20%).

Overall, in columns 1 to 4 of Panel A, the results are very similar to the main effects of this paper. Thus, the effect on maternal service use is not mostly coming from the better-off households in treatment districts. However, the effects on mortality rate are smaller and no longer statistically significant. These results hint that while the increase in service use is observed in all households, the positive effect on mortality rates is limited to high SES households, possibly those who have access to high-quality health facilities.

D Travel Time to Health Centers

In Appendix Figure A.5, I perform a similar analysis with Figure 5 using the linear distance to the closest district hospital. Similar to Figure 5, the policy effect on maternal health service use is slightly stronger in districts where district hospitals are close, but the difference is small and not statistically significant. Impact on mortality rates has also a similar pattern. However, the difference is more distinct in Figure 5 when using the travel time.

E Effect on Use of General Health Services

The health reform may have removed the psychological and financial barriers to health facilities. Mothers may feel more comfortable visiting health facilities more often for different reasons. In Appendix Table A.6, I examine whether mothers' health service use had increased due to the reform. The table shows that the health reform did not increase the health service use of the child but for the mothers. Breastfeeding duration, number of vaccinations, an indicator for fully vaccinated, and treatment of fever or diarrhea did not improve; however, the frequency of facility visits and family plans, testing HIV, and the use of modern contraceptives significantly increased in the treatment districts. Together with the main result, the health reform in Rwanda seems to be effective in improving access to health care, especially for maternal health.

F Effect of the Expansion of Universal Health Insurance

The expansion of universal health insurance or CBHI is an important part of the reform that potentially increased FBD and ANC utilization. This section examines how much expansion

of the CBHI scheme is associated with maternal service use and mortality rates. The strategy I use here is similar to the main strategy. I define the treatment districts as those whose baseline insurance coverage is below the 50th percentile.

Column 1 of Panel B of Appendix Table A.6 shows that the main treatment (low FBD) is not associated with insurance status. Appendix Table A.7 presents the treatment effect of insurance coverage. Unlike Tables 3 and 4, the effect on FBD and prenatal care is small and statistically insignificant. The point estimates are even positive for mortality rates. This result is consistent with Appendix Table A.5, where an increase in insurance coverage is not associated with the treatment effect of free FBD and prenatal care policy.

In columns 4 and 5 of Appendix Table A.5, I compare the treatment effects on outcome variables in districts with larger vs. smaller changes in insurance coverage.[4] Because CBHI is related to improving access to health services, it may reinforce the treatment effect. The treatment effect on FBD is larger in column 4 and statistically significantly different. However, the differences in other dependent variables are mostly not statistically significant, suggesting little evidence that CBHI reinforced the effect of FBD and ANC.

References

Harrison, M. S. and R. L. Goldenberg (2016). Cesarean section in sub-Saharan Africa. *Maternal Health, Neonatology and Perinatology 2*(1), 1–10.

Niyitegeka, J., G. Nshimirimana, A. Silverstein, J. Odhiambo, Y. Lin, T. Nkurunziza, R. Riviello, S. Rulisa, P. Banguti, H. Magge, M. Macharia, R. Habimana, and B. Hedt-Gauthier (2017). Longer travel time to district hospital worsens neonatal outcomes: A retrospective cross-sectional study of the effect of delays in receiving emergency cesarean section in Rwanda. *BMC Pregnancy and Childbirth 17*(1), 1–10.

Rambachan, A. and J. Roth (2023). A More Credible Approach to Parallel Trends. *Review of Economic Studies 90*(5), 2555–2591.

Rurangirwa, A. A., I. Mogren, J. Ntaganira, K. Govender, and G. Krantz (2018). Quality of antenatal care services in Rwanda: Assessing practices of health care providers. *BMC Health Services Research 18*(1), 1–10.

[4] Large increase districts are mostly districts with low baseline insurance coverage. Separating the sample by baseline insurance coverage results in a similar result (Results available upon request).

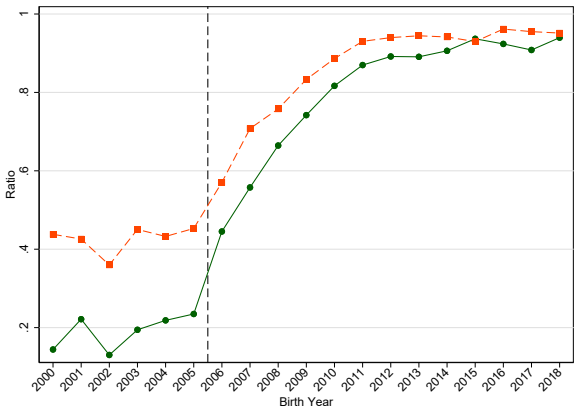
Vyas, S. and L. Kumaranayake (2006). Constructing socio-economic status indices: How to use principal components analysis. *Health Policy and Planning 21*(6), 459–468.

WHO (2016). WHO Recommendations on Antenatal Care for a Positive Pregnancy Experience. Technical report, World Health Organization, Geneva, Switzerland.

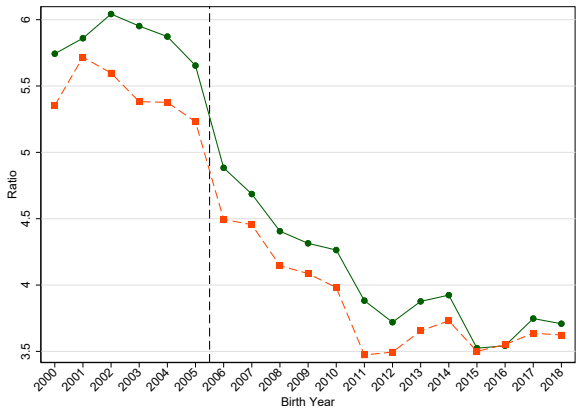
Appendix Figures and Tables

Figure A.1: Trend of FBD, ANC, and Mortality Rates in Rwanda

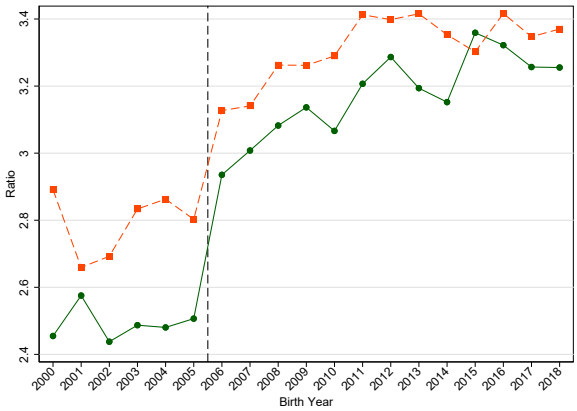
(a) FBD



(b) Month at first ANC



(c) Number of ANC



(d) At least four ANC

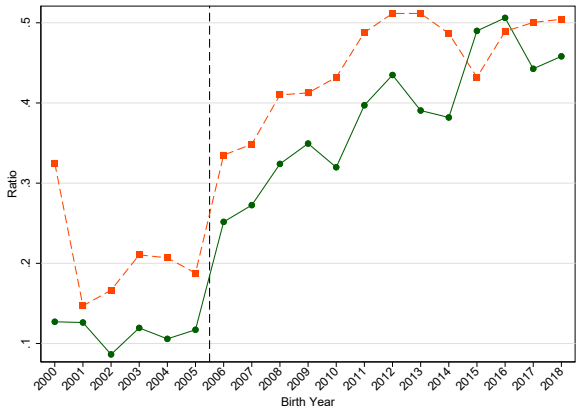
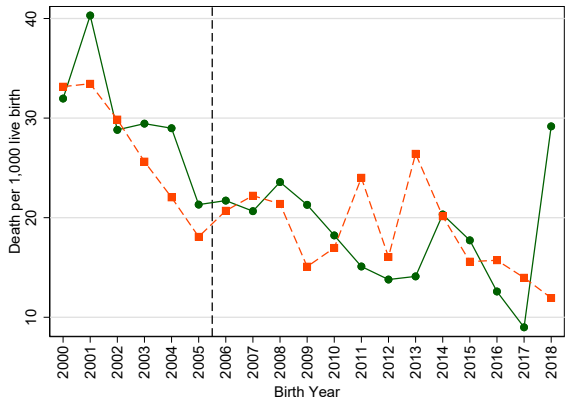
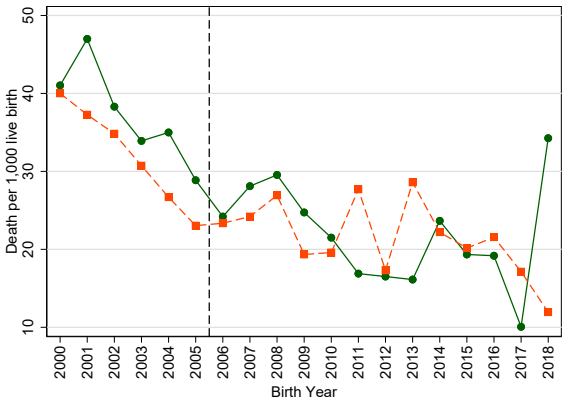


Figure A.1: (Continued) Trend of FBD, ANC, and Mortality Rates in Rwanda

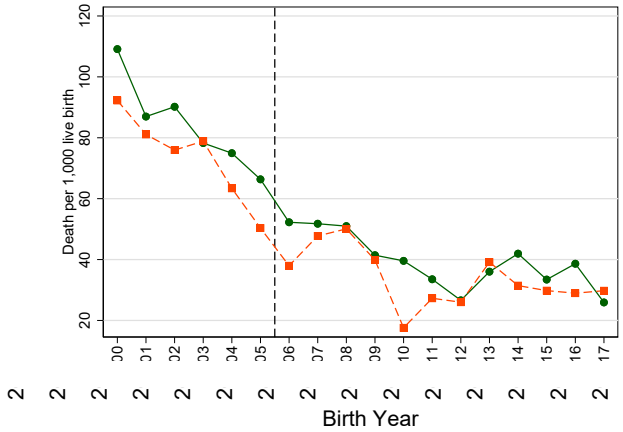
(e) NMR7



(f) NMR



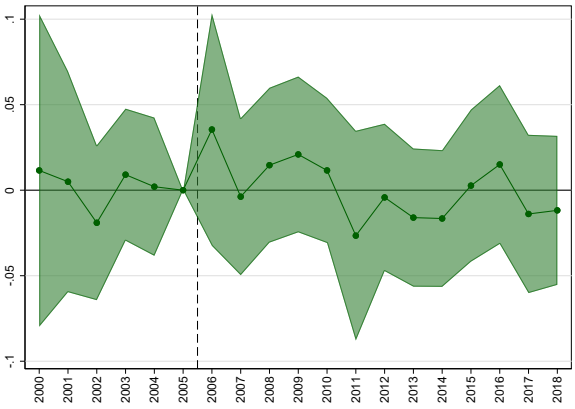
(g) IMR



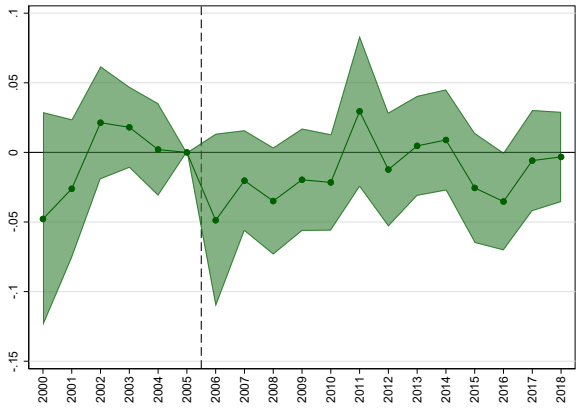
Note: This figure shows the raw mean of variables denoted as the Panel titles in treatment and control districts.

Figure A.2: Event Study Estimates on Detailed ANC and FBD

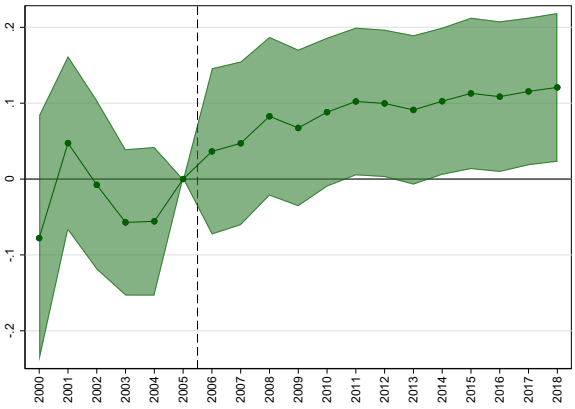
(a) ANC by a doctor



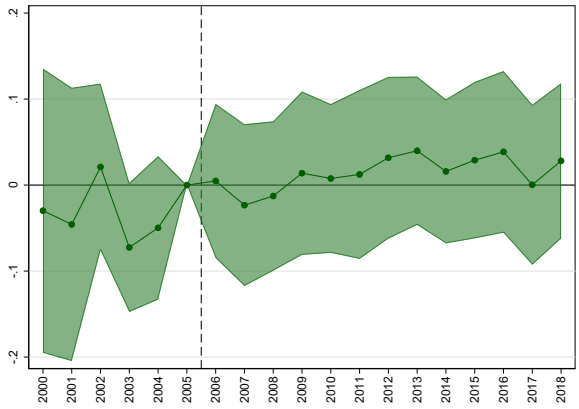
(b) ANC by a nurse/midwife



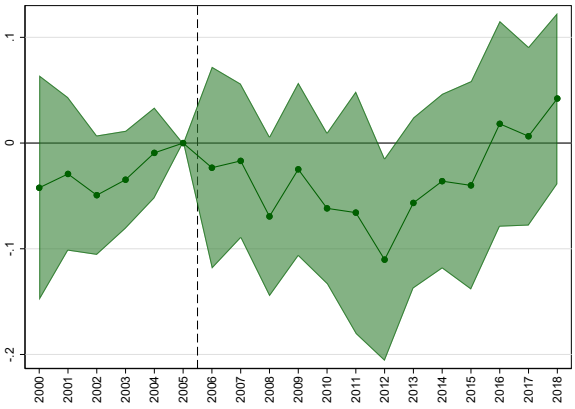
(c) Blood test



(d) Blood pressure



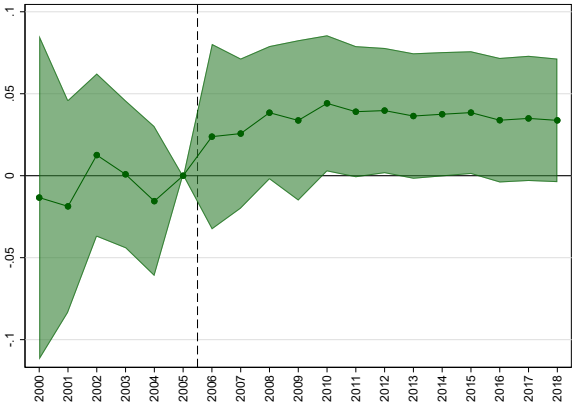
(e) Urine test



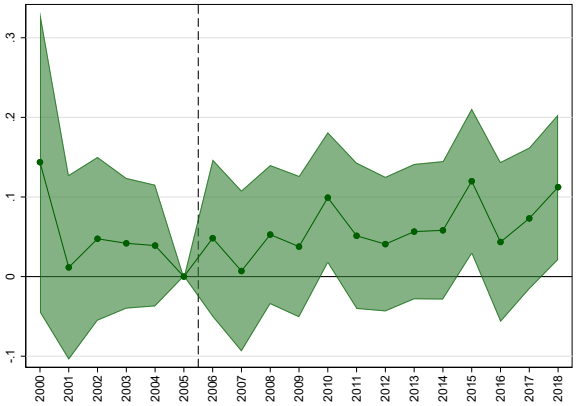
(f) Tetanus injection

Figure A.2: (Continued) Event Study Estimates on Detailed ANC and FBD

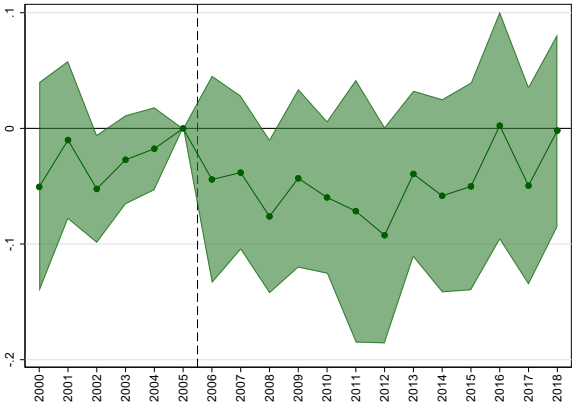
(g) Malaria care



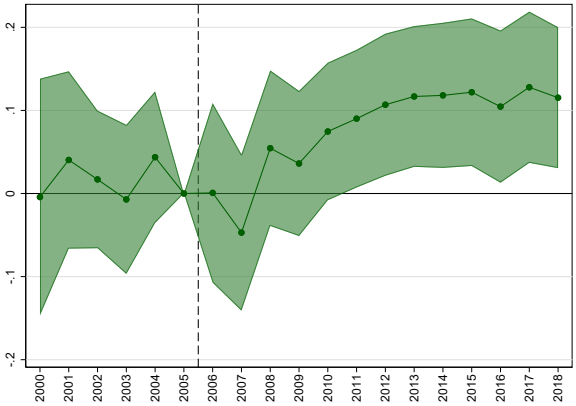
(h) Iron supplement



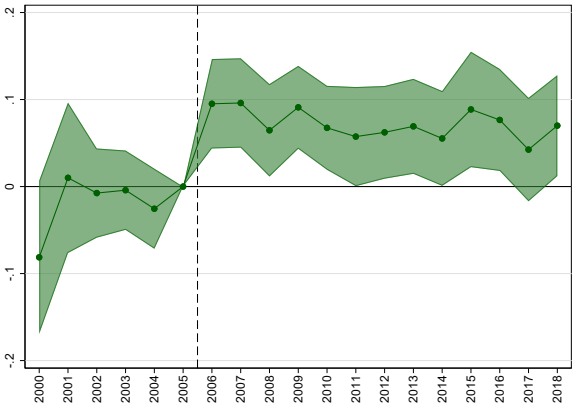
(i) More than 3 treatments at ANC



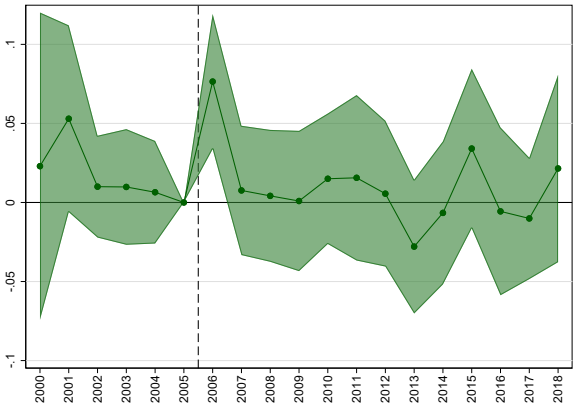
(j) FBD, health center or post



(k) FBD, hospital



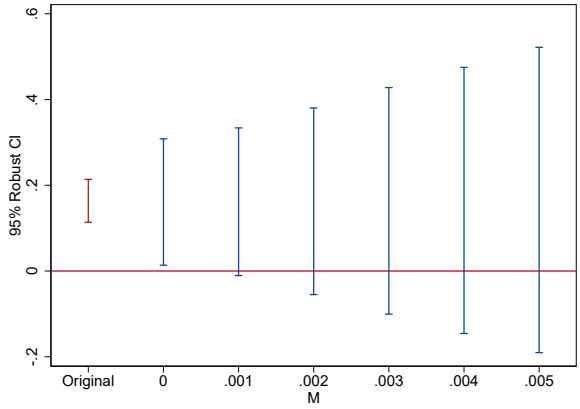
(l) FBD, C-section



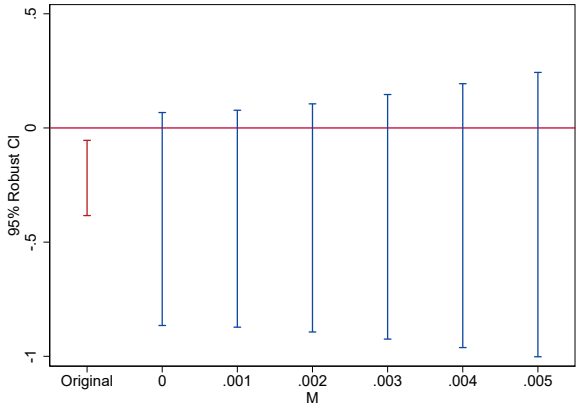
Note: This figure shows the event study estimators of detailed FBD. The specification is the same as column 4 of Table 3. See the notes of Table 3 for the list of control variables. Standard errors are clustered at the proper district level.

Figure A.3: Robustness Check: Applying Rambachan and Roth (2023) Estimator

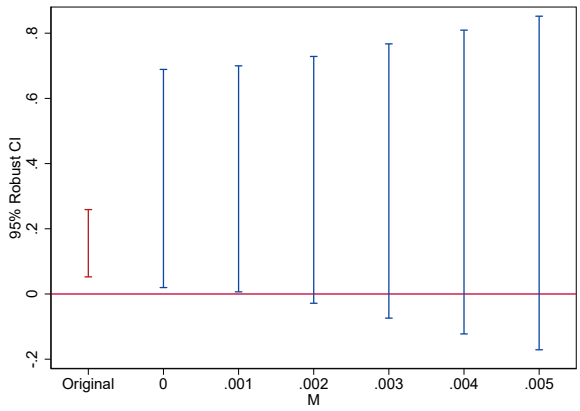
(a) FBD



(b) Month at first ANC



(c) Number of ANC



(d) At least four ANC

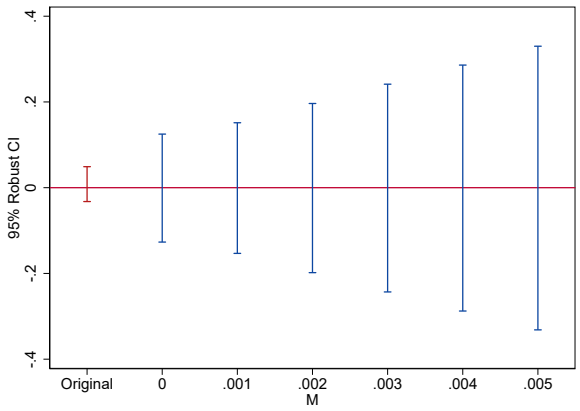
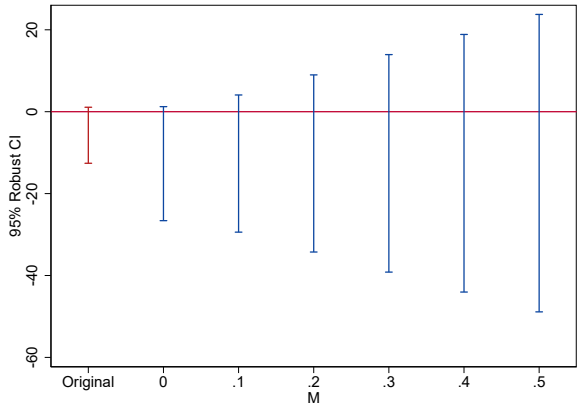
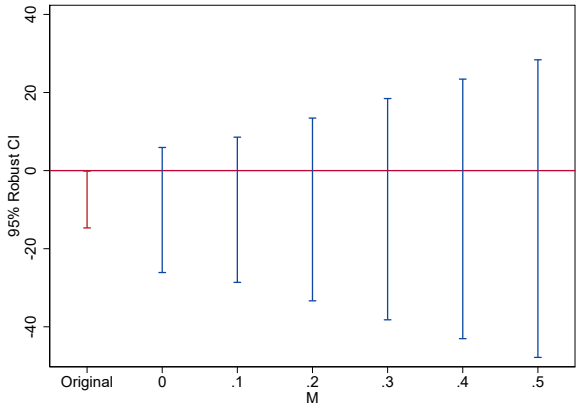


Figure A.3: (Continued) Robustness Check: Applying Rambachan and Roth (2023) Estimator

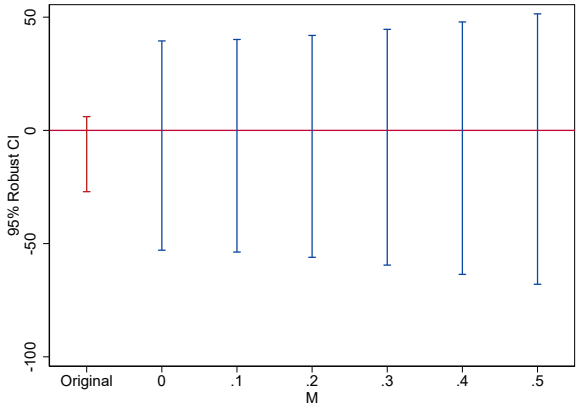
(e) NMR7



(f) NMR

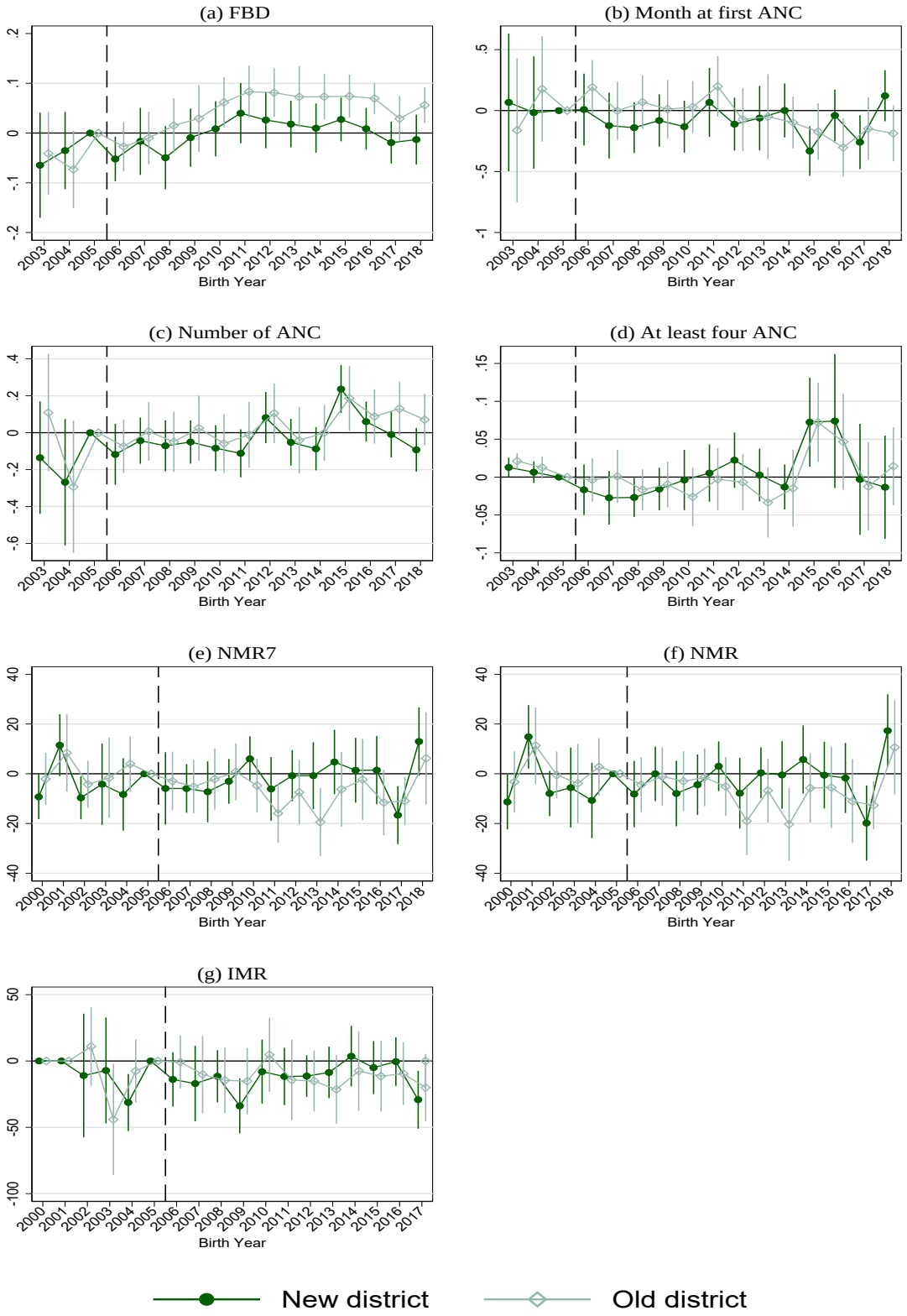


(g) IMR



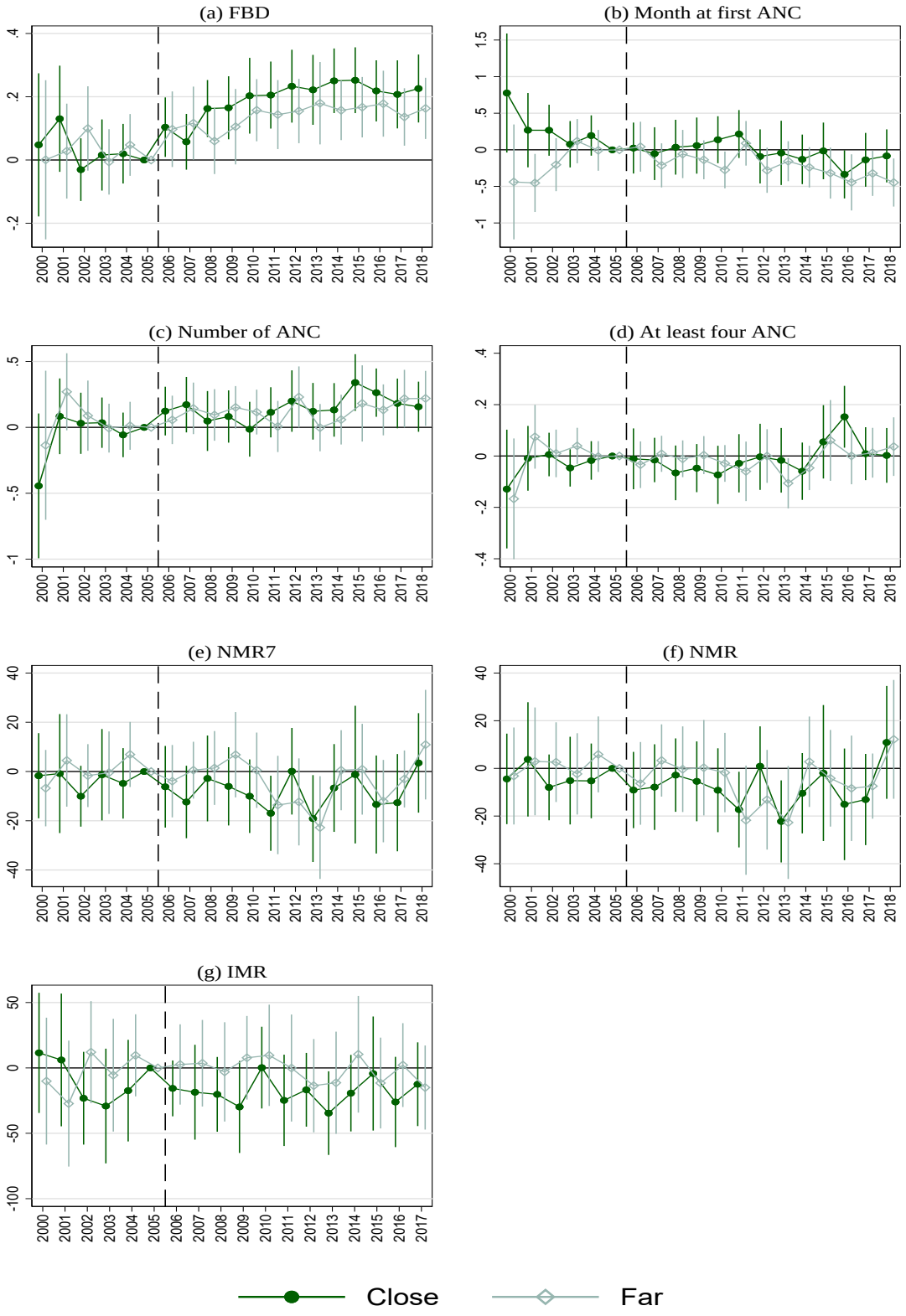
Note: This figure shows the 95% fixed length confidence intervals (FLCI) of the average treatment effect with different choices of M using Rambachan and Roth (2023)'s alternative estimation together with the original estimator. The same weights are assigned to all post-period interaction terms in the event study framework. The smoothness restriction method is chosen.

Figure A.4: Robustness Check: Using New District Boundaries



Note: This figure compares the event study coefficients using new and old districts as the unit of variation. The 2005 RDHS is removed from the sample. The specification is the same as column 4 of Table 3. See the notes of Table 3 for the list of control variables. Standard errors are clustered at the proper district level.

Figure A.5: Heterogeneity by Distance to Hospital



Note: This figure compares the event study coefficients in villages where the linear distance to the closest district hospital is short (<8km) and long (≥8km). The specification is the same as column 4 of Table 3. See the notes of Table 3 for the list of control variables. Standard errors are clustered at the proper district level.

Table A.1: Effect on Timing of Deaths

	Timing of the death		
	< 1 week	7-30 days	1-12 months
	(1)	(2)	(3)
Panel A. Without Mother FE			
Low FBD District	-5.617**	-2.463*	-3.976
× Post	(2.285)	(1.451)	(3.550)
Observations	84,117	82,401	76,125
Panel B. With Mother FE			
Low FBD District	-3.763	-3.466*	-1.532
× Post	(3.391)	(1.872)	(4.955)
Observations	78,513	76,707	70,292
Mean before 2006	*28.67*	*11.29*	*43.51*

Note: See the notes of Table 3 for further information. Robust standard errors are in parentheses clustered by the proper district. * significance at 10%; ** significance at 5%; *** significance at 1%.

Table A.2: Alternative Specification

		ANC			Mortality Rates		
	FBD	First Month	Frequency	≥ four visits	NMR7	NMR	IMR
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A. Continuous Home Delivery (1-FBD) Rate							
pre-FBD rate	0.626***	-1.014***	0.707***	-0.0770**	-13.12**	-16.87***	-21.37
× Post	(0.0370)	(0.187)	(0.101)	(0.0348)	(5.755)	(6.327)	(15.70)
Panel B. Home Delivery Rate Above 25th Percentile							
Low FBD District	0.172***	-0.290***	0.191***	-0.0167	-5.458**	-7.473***	-7.828
× Post	(0.0223)	(0.0689)	(0.0445)	(0.0160)	(2.155)	(2.131)	(6.211)
Panel C. Low Maternal Service Use							
Low Service Use	0.116***	-0.379***	0.249***	-0.0343***	-3.479	-4.390	-1.401
District × Post	(0.0163)	(0.0611)	(0.0381)	(0.0127)	(2.548)	(3.028)	(5.944)
Panel D. Low Health Service Use							
Low Service Use	0.128***	-0.250***	0.191***	-0.0334***	-4.363**	-6.596***	-5.425
District × Post	(0.0159)	(0.0606)	(0.0379)	(0.0111)	(2.010)	(2.424)	(5.905)

Note: See the notes of Table 3 for further information. Robust standard errors are in parentheses clustered by the proper district. * significance at 10%; ** significance at 5%; *** significance at 1%.

Table A.3: Subsample Analysis

	Outside Capital (1)	Rural (2)	Education < Primary (3)	Wealth Quintile <4th (4)
Panel A. FBD and ANC				
Facility-based	0.116***	0.0949***	0.102***	0.0779***
delivery	(0.0150)	(0.0154)	(0.0264)	(0.0152)
Number of ANC	0.129***	0.123***	0.177***	0.129***
	(0.0373)	(0.0395)	(0.0533)	(0.0400)
Month at the first ANC	-0.182***	-0.192***	-0.230***	-0.205***
	(0.0636)	(0.0673)	(0.0880)	(0.0658)
Panel B.Mortality Rates				
Newborn mortality (1 weeek)	-2.282	-0.888	3.424	-2.058
	(2.245)	(2.487)	(4.614)	(2.422)
Neonatal mortality (30 days)	-2.643	-1.014	4.885	-2.127
	(2.444)	(2.649)	(4.709)	(2.688)
Infant mortality (1 year)	-3.547	-1.202	-1.540	-2.698
	(4.238)	(4.221)	(8.189)	(4.160)

Note: This table shows the treatment effect with subsamples. The samples are presented at the top of each column: Households living outside of the capital (Kigali), living in rural areas, whose mother's education is less than primary completion, and whose household wealth is under or equal to the 4th quintile. Each cell presents β_1 of Equation 1 with the preferred specification (column 4 in Table 3). See the notes of Table 3 for further information. Robust standard errors are in parentheses clustered by the proper district. * significance at 10%; ** significance at 5%; *** significance at 1%.

Table A.4: Heterogenity by Distance to District Hospital

	Travel Time		P-value of	Distance		P-value of
	Short (1)	Long (2)	the Difference (3)	Close (4)	Far (5)	the Difference (6)
Panel A. FBD and ANC						
Facility-Based Delivery	0.1247***	0.1110***	0.7053	0.1351***	0.0943***	0.2523
	(0.0322)	(0.0183)		(0.0250)	(0.0238)	
Month at the First ANC	-0.1804	-0.2210**	0.7911	-0.1694*	-0.1430*	0.8332
	(0.1287)	(0.0929)		(0.0983)	(0.0835)	
Number of ANC	0.1350*	0.1604***	0.7732	0.1405***	0.1011**	0.5571
	(0.0747)	(0.0514)		(0.0500)	(0.0467)	
More than four ANC	-0.0401*	0.024	0.0458**	-0.0024	-0.0237	0.4878
	(0.0243)	(0.0222)		(0.0236)	(0.0203)	
Panel B. Mortality Rates						
Newborn Mortality (7 days)	-12.9148***	-1.9645	0.0133**	-5.61	-3.836	0.743
	(3.4025)	(2.8709)		(3.4377)	(3.8895)	
Neonatal Mortality (30 days)	-15.4693***	-2.7154	0.0047***	-5.5957	-5.9031	0.9571
	(3.3565)	(3.0678)		(3.7002)	(4.3156)	
Infant Mortality (1 year)	-37.7084***	0.5177	0.0000***	-14.1731**	-6.391	0.4087
	(7.1541)	(3.8566)		(7.0274)	(6.2336)	

Note: This table shows the DiD estimator in districts with short or long travel times (columns 1-3) and villages with short or long linear distances to the closest district hospitals (columns 4-6). The p-values of the differences are also presented. Each cell presents β_1 of Equation 1 with the preferred specification (column 4 in Table 3). See the notes of Table 3 for further information. Robust standard errors are in parentheses clustered by the proper district. * significance at 10%; ** significance at 5%; *** significance at 1%.

Table A.5: Heterogeneity by PBF and CBMI

	Performance-Based Finance		P-value of	Change in Insurance Coverage		P-value of
	Earlier	Later	the Difference	Large	Small	the Difference
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. FBD and ANC						
Facility-Based Delivery	0.1724***	0.1124***	0.0723*	0.1829***	0.0574***	0.0000***
	(0.0256)	(0.0219)		(0.0233)	(0.0190)	
Month at the First ANC	-0.4031***	-0.1460*	0.0684*	-0.2666***	-0.117	0.263
	(0.1194)	(0.0839)		(0.0945)	(0.0972)	
Number of ANC	0.1705**	0.1917***	0.8085	0.1978***	0.1010**	0.1734
	(0.0775)	(0.0447)		(0.0546)	(0.0470)	
More than four ANC	-0.0075	0.0298	0.2734	0.0212	-0.0252	0.0975*
	(0.0282)	(0.0201)		(0.0223)	(0.0174)	
Panel B. Mortality Rates						
Newborn Mortality (7 days)	-9.2702**	-4.7102*	0.3531	-2.7159	-7.8416**	0.2683
	(4.0989)	(2.7640)		(2.9876)	(3.5678)	
Neonatal Mortality (30 days)	-9.5508**	-6.9603**	0.6479	-3.8172	-8.7886**	0.2963
	(4.7803)	(3.1179)		(3.2626)	(3.4997)	
Infant Mortality (1 year)	-27.9639***	-9.7766*	0.1096	-15.9270**	-7.1845	0.312
	(10.2412)	(5.0975)		(7.1467)	(4.9172)	

Note: This table shows the DiD estimator in districts where PBF was implemented early or late (columns 1-3) and where the insurance coverage change from 2005 to 2014 was large and small (columns 4-6). The p-values of the differences are also presented. Each cell presents β_1 of Equation 1 with the preferred specification (column 4 in Table 3). See the notes of Table 3 for further information. Robust standard errors are in parentheses clustered by the proper district. * significance at 10%; ** significance at 5%; *** significance at 1%.

Table A.6: Effect on Other Facility Utilization

	(1)	(2)	(3)	(4)	(5)
Panel A. Child's Characteristics					
	Breastfeed dur.	Number of Vac.	Fully Vac.	Fever	Diarrhea
Low FBD District	-0.0170	0.00893	0.0134	0.0331	0.0334
× Post	(0.192)	(0.124)	(0.0293)	(0.0225)	(0.0369)
Panel B. Mother's Characteristics					
	Insured	Facility Visit	Family Plan	HIV Test	Contraceptive
Low FBD District	-0.00660	0.0874***	0.0534***	0.129***	0.0499***
× Post	(0.0272)	(0.0212)	(0.0170)	(0.0237)	(0.0139)

Note: This table shows the treatment effect on the mother's other health facility utilization. Dependent variables are presented at the top of each column. Each cell presents β_1 of Equation 1 with the preferred specification (column 4 in Table 3). Treated fever or diarrhea is subject to a sample who had the symptoms in the last two weeks. Visited Facility and Family Plan are one when the mother had visited a facility and family plan within 12 months, respectively. HIV Test is one when women get HIV tested. Contraceptive is one when the mother uses modern contraceptive methods. Controls are as same in Table 3. See the notes of Table 3 for further information. Robust standard errors are in parentheses clustered by the proper district. * significance at 10%; ** significance at 5%; *** significance at 1%.

Table A.7: Effect of Universal Insurance

		ANC		Mortality Rates		
	FBD	Frequency	First Month	NMR7	NMR	IMR
	(1)	(2)	(3)	(4)	(5)	(6)
Low Ins. District	-0.0171	-0.0538	0.0494	3.887	3.531	6.638
× Post	(0.0168)	(0.0346)	(0.0630)	(2.531)	(2.924)	(4.185)

Note: This table shows the DiD estimator of the effect of CBHI on maternal health service use and mortality rates. The treatment status is defined using the baseline insurance coverage of the (old) district, similar to the main specification. Each cell presents β_1 of Equation 1 with the preferred specification (column 4 in Table 3). See the notes of Table 3 for further information. Robust standard errors are in parentheses clustered by the proper district. * significance at 10%; ** significance at 5%; *** significance at 1%.