Shock to the System: Prevention of Mother-to-Child Transmission of HIV and Child Mortality *

Nicholas Wilson

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Abstract

This paper examines the effect of introducing a new HIV/AIDS service, prevention of mother-to-child transmission of HIV (PMTCT), on overall quality of prenatal and postnatal care. My results suggest that local PMTCT introduction in Zambia may have actually increased all cause child mortality in the short term. There is some evidence that vaccinations may have declined in the short term in association with local PMTCT introduction, suggesting that the new service may have partly crowded out existing pediatric health services.

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*Nicholas Wilson: Department of Economics, Reed College, nwilson@reed.edu. I would like to thank Eran Bendavid, Marianne Bitler, Alfredo Burlando, Raluca Buzdugan, Christopher Carpenter, Joseph Cummins, Carlos Dobkin, William Dow, Pascaline Dupas, Frederico Finan, Günther Fink, Emmanuela Gakidou, Paul Gertler, Erick Gong, Laura Guay, Gianmarco León, Ethan Ligon, Jeremy Magruder, Zoë McClaren, Sandra McCoy, Edward Miguel, Christopher Murray, Nancy Padian, Bei Qin, Jonathon Robinson, David Sahn, Lucie Schmidt, T. Paul Schultz, Manisha Shah, Lara Shore-Sheppard, Jeffrey Stringer, Anand Swamy, Harsha Thirumurthy, Waly Wane, Tara Watson, David Weil, and seminar participants at the XIX International AIDS Conference in Washington, DC, the NBER Africa Project Zanzibar Conference, NEUDC 2011 at Yale University, NEUDC 2012 at Dartmouth College, the 1st NOVAFRICA Conference on Economic Development in Africa at Universidade NOVA de Lisboa, the 6th Annual PopPov Conference on Population, Reproductive Health, and Economic Development in Accra, Ghana, the 2012 Population Association of America (PAA) Annual Meeting in San Francisco, California, the University of California, Berkeley, the University of California, Irvine, the University of California, Santa Cruz, the University of Oregon, the University of Washington, and Williams College for many excellent comments. Madeleine Watson and Wentao Xiong provided superb research assistance. The NBER Africa Project provided generous financial and institutional support. This research would not be possible without the assistance of Kunyima Banda and the Network of Zambian People Living with HIV/AIDS (NZP+). All errors are my own. The findings, interpretations, and conclusions expressed in this paper are those of the author and do not necessarily represent the views of the aforementioned individuals or the agencies that employ them.

1 Introduction

There has been a dramatic expansion of HIV/AIDS services in Sub-Saharan Africa over the past decade. Hundreds of millions of people in the region of the world most heavily afflicted with HIV/AIDS have received fully subsidized access to public services such as voluntary counseling and testing (VCT), antiretroviral therapy (ART), and prevention of mother-to-child transmission of HIV (PMTCT). Made largely under the auspices of the United States President's Emergency Plan for AIDS Relief (PEPFAR) and the Global Fund to Fight AIDS, Tuberculosis and Malaria, donor disbursements comprise 88 percent of spending on these services in low income countries (UNAIDS 2010) and currently total approximately US$8 billion per year (Kates et al 2011).

This large increase in mostly disease specific public funding has come in the context of relatively weak health systems (De Cock et al 2011). Low overall health spending, high caseloads for doctors and nurses, and insufficient infrastructure characterize health systems in much of Sub-Saharan Africa.[1,2,3] Health worker absence (Goldstein et al 2012), counterfeit drugs (Bate et al 2011, Bjorkman et al 2012), and weak incentives (Basinga et al 2011) compound these problems. Some argue that the large increase in HIV/AIDS spending may strengthen health systems in recipient countries (e.g., El-Sadr and Abrams 2007, Price et al 2009, Rasschaert et al 2011, Grépin 2012), whereas others argue that the vertical (i.e., disease specific) approach to HIV/AIDS programming may generate negative spillovers for non-HIV care (e.g., England 2007, Garrett 2007, Jaffe 2008, Schiffman 2009, Rabkin et al 2009, Grépin 2011, Grépin 2012).[4]

This paper examines the effects of the expansion of one of the main HIV/AIDS services, prevention of mother-to-child transmission of HIV (PMTCT), on child mortality.[5] Medical trials indicate that PMTCT is highly effective at reducing vertical HIV transmission (Dabis and Ekpini 2002). Based on this evidence, many countries in Sub-Saharan Africa have dramatically expanded public

[1] In 2011, median health expenditure per capita in Sub-Saharan Africa was US$60 (WHO 2013a), approximately 6 percent of median GDP.

[2] The number of physicians and nurses per 1,000 people is 1.9 in the WHO Africa region (i.e., primarily Sub-Saharan Africa, although also including Algeria and Western Sahara, while excluding Somalia and Sudan), compared to 2.9, 3, 4.5, 13, and more than 14 in the WHO South-East Asia, Eastern Mediterranean, Western Pacific, Europe, and Americas regions, respectively (WHO 2006a). An early report on antiretroviral expansion in four Southern African countries (Kober and Van Damme 2004), concluded, "the lack of human resources for health is deplored as the single most serious obstacle for implementing national treatment plans."

[3] In Sub-Saharan Africa, the median country has approximately 1 hospital bed per 1,000 people (World Bank 2013). In contrast, the median countries in the World Bank South Asia, Middle East and North Africa, Latin America and the Caribbean, East Asia and the Pacific, North America, and Europe and Central Asia regions, have approximately 1, 2, 2, 3, 3, and 5 hospital beds per 1,000 people, respectively (World Bank 2013).

[4] Negative spillovers for non-HIV care may occur at the clinic level because of human resource constraints or through changes in donor funding priorities. Although we do not know the counterfactual trajectory of non-HIV health funding, the United States, the single largest source of HIV/AIDS donor funding (Schneider and Garrett 2009), increased annual spending on non-HIV international health from US$1.3 billion to US$1.7 billion between 2001 and 2008 (Government Accountability Office 2010). In contrast, US spending on HIV/AIDS in international health increased from US$204 million to US$3.3 billion over this period (Government Accountability Office 2010).

[5] By measuring effects on child mortality rather than rather than HIV transmission, the current analysis provides evidence on the net effect of PMTCT on a broad measure of child health.

access to this service in the past decade. However, little evidence exists on the effect of PMTCT at scale and the concerns about HIV/AIDS service expansion crowding out non-HIV care in international health suggest that the overall improvements in child health from PMTCT expansion may have been limited.

I constructed a geocoded monthly panel using a census of all health facilities in Zambia that documents the expansion of PMTCT over roughly the first decade of scale-up.[6] Retrospective birth history modules from repeated national cross-sectional household surveys provide information on child mortality. Administrative records from these surveys allow me to identify the location of survey households and calculate their proximity to each health clinic. I use these data to measure the change in child mortality associated with local PMTCT introduction while controlling for time invariant and time varying factors associated with local PMTCT introduction.

My results suggest that local PMTCT introduction may not have reduced all-cause child mortality. In fact, the evidence suggests that PMTCT expansion may have actually increased all-cause child mortality, particularly in the short term. Four main regression results support this view. First, conditional on month and year of birth, the local introduction of PMTCT was associated with approximately a 2 to 3 percentage point increase in under-24 month mortality. Second, a semi-parametric difference-in-differences analysis reveals no clear pre-introduction trend in locations receiving PMTCT. Third, the increase in child mortality appears to have been greater among households residing closer to PMTCT sites. Fourth, the increase in child mortality appears to have been concentrated among women who were less likely to be HIV positive and hence less likely to directly benefit from PMTCT.

I find evidence that local PMTCT introduction may have reduced quality of non-HIV child health services in the short term. Quality of non-HIV pediatric care appears to have rebounded around the event time that the deleterious effect of PMTCT introduction on all cause child mortality dissipated. However, this evidence on a possible mechanism is less strong than the main result.

These results seemingly contrast with existing quasi-experimental evidence on the effects of antiretroviral provision at scale.[7] Bendavid et al (2011), Lucas and Wilson (2013a), and Lucas and Wilson (2013b) report evidence suggesting antiretroviral therapy (ART) expansion for the treatment of HIV positive adults improved mortality and morbidity outcomes for adults and for children at scale. However, the scope for non-HIV service crowd-out due to HIV-specific funding is

[6]Several facts make Zambia an interesting country study. Approximately 14 percent of pregnant women in Zambia are HIV positive (Central Statistical Office et al 2009) and nearly 7 percent of infants are born HIV positive or acquire HIV through breastfeeding (Torpey et al 2010). Zambia is one of the United States President's Emergency Plan for AIDS Relief (PEPFAR) fourteen priority countries and donor aid for HIV in Zambia has increased from US$10 million in 2000 (Ooman et al 2007) to US$250 million in 2008 (Reisch et al 2008), or roughly US$1 per capita to US$25 per capita. In comparison, mean annual total expenditure on health in Zambia over the period 2000-2008 was approximately US$39 per capita (WHO 2013a).

[7]Brugha et al (2010a) provides a largely descriptive analysis of service quality in 39 health facilities in 3 districts in Zambia in the context of HIV/AIDS service scale-up and finds mixed evidence of a link between HIV/AIDS service introduction and non-HIV quality of care.

likely much greater for pediatric care than for adult care. In Zambia, HIV/AIDS is responsible for approximately 12 percent of under-5 mortality (WHO 2010b) and other pediatric health conditions endangering life and requiring medical attention are relatively common.[8] In contrast, HIV/AIDS is surely a much greater fraction of adult mortality in Zambia. In Sub-Saharan Africa as whole, where 5 percent of adults are HIV positive (UNAIDS 2010), HIV/AIDS causes 29 percent of mortality among adults age 15-59 and less than 5 percent of mortality among children age 0-4 (WHO 2011a).

The rest of the paper is organized as follows. In Section 2, I discuss PMTCT efforts in Zambia, as well as some simple evidence on associated changes in reproductive health. Section 3 describes the health facilities and individual-level data in more detail. Section 4 explains my empirical strategy for estimating the effect of PMTCT availability on child mortality. Section 5 presents the main results. Section 6 concludes.

2 HIV/AIDS and child health in Zambia

A HIV positive woman may transmit the virus to her fetus or her newborn child through childbirth and breastfeeding. The cumulative transmission probability is as high as 45 percent (Dabis and Ekpini 2002). In Sub-Saharan Africa, mortality rates among HIV positive infants appear to reach 50 percent by 12 months of age (Spira et al 1999, Taha et al 1999, Dabis et al 2001, Brahmbhatt et al 2001, Newell et al 2004b, Brahmbhatt et al 2006)).[9,10] Prevention of mother-to-child transmission of HIV (PMTCT) generally refers to a package of interventions including HIV testing, antiretrovirals for vertical prophylaxis, breastfeeding advice, and family planning. Antiretroviral drugs for vertical prophylaxis appear to be particularly effective.[11]

As part of a broader package of HIV/AIDS service expansion, donors began substantial efforts for facilitating PMTCT scale-up in Sub-Saharan Africa in the early 2000s. Between 1996 and 2008,

[8] The 2006 National Malaria Indicator Survey (MIS) indicates a malaria prevalence of 22 percent among children age 0-59 months (Ministry of Health et al 2009). The 2007 Demographic Health Survey (DHS) indicates 15.5 percent of children age 0-59 months experienced diarrhea in the two weeks preceding the survey and 5.2 percent of children age 0-59 months had symptoms of an acute respiratory infection (ARI) in the two weeks preceding the survey (Central Statistical Office et al 2009). The World Health Organization reports that 15 percent of under-5 mortality in Zambia is due to malaria, another 15 percent is due to diarrhea, and another 15 percent is due to pneumonia (WHO 2010b).

[9] Even in the absence of acquiring HIV/AIDS, child mortality in Zambia is high. Overall, the neonatal mortality rate in Zambia is 36 per 1,000 live births, the under-1 infant mortality rate is 92 per 1,000 live births, and the under-5 child mortality rate is 148 per 1,000 live births. HIV/AIDS accounts for 12% of under-5 mortality in Zambia (WHO 2010b).

[10] Mother-to-child transmission of HIV is not the only way in which having a HIV positive mother increases the probability of child death. Maternal mortality due to HIV/AIDS further reduces the resources available to poor households in poor countries. Consistent with this burden, in a longitudinal study in Rakai, Uganda, Brahmbhatt et al (2006) find under-2 child mortality rates of 166 per 1000 for HIV negative children of HIV positive mothers, compared to 128 per 1000 for HIV negative children of HIV negative mothers. However, mother-to-child transmission appears to be the largest effect, with a under-2 child mortality rate of 547 per 1000 for HIV positive children of HIV positive mothers.

[11] Administering single-dose nevirapine (NVP) at the three stages at which MTCT may occur reduces MTCT by 10-25 percentage points (Guay et al 1999, Jackson et al 2003). Combination therapy (i.e., zidovudine (ZDV) and nevirapine (NVP) may virtually eliminate MTCT (Dabis and Ekpinni 2002).

donor funding for HIV/AIDS in the developing world increased from US$300 million to US$7.6 billion (Kates et al 2012). PMTCT spending appears to have followed a similar trend. Between 2004 and 2010, the proportion of HIV positive pregnant women in Sub-Saharan Africa receiving antiretrovirals for PMTCT increased from 9 percent to approximately 50 percent (WHO 2010a, WHO 2011b).

Throughout this process, there have been major concerns about health worker shortages (e.g., Kober and Van Damme 2004, WHO 2006b, WHO 2007) and other possible spillovers to other services (e.g., England 2007, Garrett 2007, Jaffe 2008, Schiffman 2009, Rabkin et al 2009, Grépin 2011, Grépin 2012). In response to health worker shortages, the World Health Organization began promoting a "task shifting" system as part of its "Treat, Train, Retain" plan (WHO 2007). Under this system, health care workers (including those at antenatal clinics) are asked to take on tasks traditionally assigned to workers further up the delivery hierarchy (e.g., clinical officers conduct the initial consultation/clinical evaluation, a task traditionally assigned to doctors).

These concerns characterize PMTCT expansion in Zambia. Between 2000 and 2008, annual donor funding for HIV/AIDS in Zambia, a country of approximately 10 million people, increased from less than US$10 million (Oomman et al 2007) to roughly US$250 million (Resch et al 2008). These funds appear to have largely financed antiretroviral drugs. For example, of the nearly US$190 million spent on HIV/AIDS in Zambia in 2006, nearly one-half was spent on antiretroviral treatment for adults and care for treatment patients and approximately 38 percent of prevention spending was spent on PMTCT (UNAIDS 2008b). Between 2001 and 2007, the number of health facilities offering PMTCT in Zambia grew from fewer than six to nearly six hundred, or approximately 40 percent of facilities.[12] During this period, few funds appear to have been allocated for health system strengthening (WHO 2009) and there does not seem to have been an expansion in the number of health facilities.

Evidence from a subset of health facilities in Zambia indicates little-to-no-increase in the number of doctors, nurses, and other trained health workers during HIV/AIDS service expansion (Brugha et al 2010b, Walsh et al 2010), suggesting there may not have been a large increase systemwide and that PMTCT introduction may have increased health worker caseload. With approximately 1 physician per 10,000 population (WHO 2008), Zambia has fewer than one-third of the World Health Organization (WHO) recommended physicians per person and a similar shortfall in the number of nurses (Schatz 2008).[13] Salaries for public sector health workers were frozen from 2000 through 2005 (Makasa 2008) despite annual inflation rates ranging from 18 to 27 percent (International Monetary Fund 2006).[14] Many clinics appear to have implemented a task shifting system (Morris

[12] I discuss these data in more detail in Section 3.1

[13] As of 2007 there were approximately fifty doctors in Zambia who had been trained there, despite the fact that approximately six hundred doctors had been trained in Zambia over the preceding forty years (Garrett 2007).

[14] Salaries for health workers in Zambia are relatively low and wages are often in arrears. The average annual salary for a doctor in Zambia is US$17208 and US$4128 for a nurse (McCoy et al 2008). A 2005 health worker survey

et al 2009).[15] This shifting of workers up the delivery hierarchy appears to have been made implicitly towards HIV/AIDS service provision and to have come at the expense of labor previously allocated to non-HIV tasks (Walsh et al 2010).

Data on the PMTCT cascade suggests that the expansion of access to PMTCT translated into increased use of PMTCT.[16] Nonetheless, there appears to have been attrition at every step of the cascade (Stringer et al 2005). National household survey data (i.e., the 2001 and 2007 Demographic Health Surveys and the 2003 and 2005 Zambia Sexual Behavior Surveys) indicate that ANC attendance among pregnant women in Zambia exceeds 90 percent, even prior to local PMTCT availability (see Table 1). Among respondents in the 2003 Zambia Sexual Behavior Survey (ZSBS), conducted toward the beginning of PMTCT scale-up, 15 percent of ANC attendees in all of Zambia were offered a HIV test and 44 percent of these accepted this offer (see Table 1). The likelihood of completing these steps in the PMTCT cascade varied substantially across space, presumably because of variation in the availability of PMTCT services at ANC clinics. Clinical data from the same time period indicate that 82 percent of ANC attendees in Lusaka were offered a HIV test, 71 percent of these accepted the test offer, and 99 percent of those tested received the result (Stringer et al 2005). Since mid-2005, over 90 percent of ANC attendees at Lusaka city ANCs have been tested for HIV (Stringer et al 2008b). In Zambia as a whole, UNAIDS estimates that 47 percent of HIV positive pregnant women in 2007 received antiretrovirals for PMTCT (UNAIDS 2008b).

The time series on PMTCT expansion and infant mortality suggests that this scale-up may have generated a substantial reduction in child mortality. Figure 1 presents the cumulative number of PMTCT sites, the individual-level PMTCT coverage rate, and the age 0-12 month child mortality rate in each year from 1997-2007. The largest reduction in infant mortality appears to precede the period of most rapid PMTCT expansion in terms of cumulative number of PMTCT sites. However, as discussed in Wilson (2013), PMTCT expansion occurred earlier and with greater intensity in urban areas, suggesting that the cumulative number of PMTCT sites understates mother-infant exposure to PMTCT. I calculate the individual-level PMTCT coverage rate as the proportion of adult females residing within 20 kilometers of a PMTCT site. Declining infant mortality tracks rising individual-level PMTCT coverage much more closely than it tracks the cumulative number

indicated that 4 out of 5 respondents received salary late payments, nearly 1 out 6 respondents were not paid what they were owed, and 1 out of 10 respondents paid "expediter's fees" to receive their salaries (McCoy et al 2008).

[15] Although the WHO "Treat, Train, Retain" program was not launched until 2006 (WHO 2007), task shifting in Zambia began no later 2004 (Morris et al 2009).

[16] After the introduction of PMTCT drugs at a clinic, there are each of the steps in the PMTCT cascade. The "PMTCT cascade" refers to the sequence of actions required to ensure that mother-infant pairs receive antiretroviral drugs to prevent mother-to-child transmission. Generally speaking, the cascade consists of the following steps: (1) a pregnant woman visits an ANC, (2) the ANC offers voluntary counseling and testing to the woman, (3) the woman accepts the offer, (4) the woman receives the result of the test, (5) the woman agrees to antiretroviral prophylaxis, (6) adherence to the maternal dose, and (7) adherence to subsequent maternal and infant doses (Stringer et al 2005, Stringer et al 2008a).

of PMTCT sites. Notably, aggregate infant mortality appears to have been relatively flat prior to PMTCT expansion.

In contrast, a simple analysis of child mortality rates in locations receiving PMTCT before and after the local introduction of PMTCT yields mixed evidence on the effect of local PMTCT introduction. Table 2 provides mortality rates at 1 month, 6 months, 12 months, 18 months, and 24 months, for individuals in locations: (i) never receiving PMTCT (as of the end of 2007), (ii) receiving PMTCT, prior to local introduction, and (iii) receiving PMTCT, after local introduction. Panel A reports these statistics for the full sample, whereas Panels B-F restricts the analysis to children born in the same year (e.g., 2002). In the full sample, local PMTCT introduction appears to be associated with reductions in child mortality. However, after controlling for year of birth, local PMTCT introduction appears to be weakly associated with increases in child mortality. For example, for children born in 2002, local PMTCT introduction was associated with a 6 percentage point increase the likelihood of under-24 mortality (statistically significant at the 5 percent level). The results in Table 2 suggest that much of the decline in child mortality in Figure 1 may have been due to factors other than PMTCT expansion (e.g., antimalarial efforts).

3 Data

3.1 PMTCT expansion

The Japanese International Cooperation Agency (JICA) 2006 Health Facilities Census (HFC) provides the exact latitude and longitude of each hospital and health clinic in Zambia. I augment these data with information on the month and year each facility introduced PMTCT or whether the facility never introduced PMTCT. This information on timing was collected beginning in June 2008 so the data on PMTCT expansion in Zambia span the period from the first PMTCT introduction in Zambia through the middle of 2008.[17]

3.2 Child mortality

Data on child mortality come from the birth history modules in the 2001 and 2007 Demographic Health Surveys (DHS). I use these data to construct a child level panel and measures of child death

[17]There does not appear to be an authoritative account of aggregate PMTCT expansion in Zambia. The National AIDS Council (2006) reports that by mid-2005 there were 270 PMTCT sites in Zambia. PEPFAR reports supporting PMTCT services in Zambia at 95 clinics in fiscal year 2004 (PEPFAR 2005), 200 clinics in Zambia in fiscal year 2005 (PEPFAR 2006), and 284 clinics in fiscal year 2006 (PEPFAR 2007). The Ministry of Health and the National AIDS Council (2008) state, "Overall, PMTCT services have been rolled out to all the 72 districts of Zambia, representing an increase from 67 in 2005, 307 in 2006, and 678 as of September 2007. This scaling up of PMTCT services resulted in an increase in pregnant women who completed prophylaxis from 14,071 in 2005 to 25,578 in 2006, and by September 2007 this figure had reached 35,314." Bweupe (2006) reports other data from the Ministry of Health suggesting that the number of PMTCT sites in Zambia increased from 6 in 2001, to 64 in 2003, to 265 sites in 2005. Using data from the UNICEF Zambia office, Ngashi et al (2006) reports that in a single year the number of PMTCT sites increased from 80 to 254.

by 6 months, 12 months, 18 months, and 24 months. To help address concerns about possible recall bias, I limit my analysis of child mortality to children born January 1997 or later. Table 1 reports descriptive statistics on child mortality. For example, died by 6 months is an indicator variable equal to one if a child died by 6 months of age and equal to zero if a child survived past 6 months of age. Thus, a sample mean of 0.068 corresponds to a 6 month mortality rate of 68 per 1,000 births.

For the 2001 DHS, administrative records on primary sampling units allow me to identify the Statistical Enumeration Area (SEA) of residence of each respondent. I record the GPS coordinates of the centroid of the SEA of residence as the respondents' location.[18,19] For the 2007 DHS, I use the GPS data points provided as part of the survey. These are the GPS coordinates of the centroid of the SEA of residence with a randomly drawn vector of length 0-10 kilometers added by survey management to ensure respondent confidentiality. In conjunction with the GPS information in the 2006 JICA HFC, these data allow me to calculate the distance from each household to each health facility. Information on the interview date in the 2001 and 2007 DHS allow me to exploit the monthly variation in PMTCT expansion documented in the health facilities data.[20]

3.3 PMTCT cascade

The DHS also include individual-level data on several of the steps in the PMTCT cascade, as do the 2003 and 2005 Zambia Sexual Behavior Surveys (ZSBS). In particular, these surveys provide information on the steps in the cascade leading to and including the respondent receiving the result of a HIV test administered during a ANC visit for her most recent pregnancy. The DHS and ZSBS do not include information on adherence to antiretroviral drugs.

Table 1 reports descriptive statistics on multiple steps in the PMTCT cascade. The vast majority of pregnant women visit an antenatal clinic at least once during their pregnancy, even in 2001 when very few women had access to PMTCT. In contrast, the proportion of women reporting being offered a HIV test at an antenatal clinic nearly tripled between 2001 and 2007 and the proportion accepting this offer increased by nearly 50 percent between 2003 and 2005.[21]

[18] To identify the centroids of the SEA of residence of respondents in the 2001 DHS, I use a digitized census map provided by the Zambia Central Statistical Office. This map is missing approximately seven percent of the more than 15,000 Statistical Enumeration Areas (SEAs) in Zambia. Hence, I am unable to identify the precise location of survey respondents in these missing SEAs and exclude them from the empirical analysis.

[19] For the other household surveys I use in the empirical analysis of the steps in the PMTCT cascade (i.e., the 2003 and 2005 Zambia Sexual Behavior Surveys), administrative records on the primary sampling units allow me to identify the SEA of residence and I follow the same centroid procedure.

[20] The other household surveys I use in the empirical analysis of the steps in the PMTCT cascade, the 2003 and 2005 Zambia Sexual Behavior Surveys (ZSBS), also include information on the interview date for each respondent.

[21] Surprisingly, the proportion of pregnant women offered a HIV test during an ANC visit fell from 22 percent in 2001 to 15 percent in 2003.

3.4 Prenatal and postnatal care

I construct measures of the quality of prenatal and postnatal care using information on maternal and child health in the 2001 and 2007 DHS. These include an indicator variable for whether a blood sample was taken during a visit to an ANC during the most recent birth, as well as a count variable for the number of basic prenatal services received other than the blood sample. They also include indicator variables for a health worker visit in the two months following birth and for receiving a vitamin A dose in the two months following birth. For children I also construct a measure of the number of vaccinations received and and indicator variable for complete vaccinations.[22] Finally, for children under the age of five reporting a cough in the past month, I construct an indicator variable for whether the child received antimalarial drugs at a health clinic.

Descriptive statistics for these variables are in Table 1. For most outcomes there were improvements between 2001 and 2007. Two notable exceptions are the likelihood of receiving no vaccinations and the likelihood of receiving drugs for a fever. The increased likelihood of receiving no vaccinations is consistent with a WHO (2013b) report indicating a general downward trend in the incidence of several vaccinations in Zambia. For example, diptheria tetanus toxiod and pertussis (DTP3) immunization among 1-year olds in Zambia declined from 85 percent in 2001 to 80 percent in 2007 (WHO 2013b). During this period, polio immunization rates also fell from 86 to 77 (WHO 2013b). Similarly, the large reduction in the likelihood of receiving drugs conditional on having a fever is consistent with the trend in the 2006 and 2008 National Malaria Indicator Surveys (MIS) (WHO 2013b).

4 Empirical strategy

I measure the change in child mortality associated with the local introduction of PMTCT. To help address concerns about shocks to child mortality that are temporally or spatially correlated with PMTCT expansion, I control for a host of time and geographic fixed effects. Information on child mortality from multiple periods before the local introduction of PMTCT allow me to control for many time-varying unobservable characteristics affecting child mortality that are associated with the location of PMTCT sites.

In addition, I directly control for two major potential confounding factors: household bednet ownership and piped water access. The evidence in Ashraf et al (2010) suggests that the Zambia national malaria control campaign, initiated in 2003, reduced all-cause under-5 mortality and that household bednet ownership (rather than indoor residual spraying) was the main reason for this decline. Evidence from across the developing world suggests that access to piped water is a major determinant of child health (Fewtrell et al 2005) and access to piped water in Zambia may have

[22]The 2001 and 2007 Zambia DHS record the following vaccinations: BCG, DPT (three doses), polio (three doses, alternatively one dose), and measles (one dose).

increased in parallel to PMTCT expansion as well.

The primary regression equation is:

$$\begin{aligned} childdied_{ijmt} = \alpha_1 PMTCT_{ij(mt-9)} + \alpha_2 PMTCTever_{ij} + X'_{ijmt}\Gamma \\ + \eta_j + \delta_{mt} + mt \times \mu_j + mt \times PMTCTever_{ij} + \epsilon_{ijmt} \end{aligned} \quad (1)$$

where $childdied_{ijmt}$ is an indicator for child death by a given age (e.g., 24 months) for female respondent i residing in province j in month m in year t. $PMTCT_{ij(mt-9)}$ is an indicator variable equal to one if a health clinic offering PMTCT at least 9 months prior to the child's birth date is located near respondent i. $PMTCTever_{ij}$ is an indicator variable equal to one if a health clinic located near respondent i ever offered PMTCT even if it was subsequent to the interview date for respondent i.[23] X_{ijmt} is a vector of individual and household level demographic controls (i.e., five-year age group indicator variables, indicator variables for primary/secondary school completion, an indicator variable for married, an indicator variable for household bednet ownership, and an indicator variable for piped water access). η_j are province of residence fixed effects, δ_{mt} are month of birth times year of birth fixed effects, $mt \times \mu_j$ are province-specific linear time trends, and $mt \times PMTCTever_{ij}$ is an additional linear trend for locations ever receiving PMTCT. As in a standard difference-in-differences empirical strategy, I interpret α_1 as the causal effect of local PMTCT availability on child mortality.[24]

My primary empirical specification treats a respondent as being near a health clinic if the respondent lives within 20 kilometers of the nearest health clinic. Among female respondents in the 2007 DHS, distance is cited as being a primary barrier to seeking health care (Central Statistical Office et al 2009). Stekelenburg et al (2004) find that maternal health care usage declines substantially at distances greater than a two-hour walk. Alternative specifications relax restrictions that the local introduction of PMTCT had the same effect on child mortality invariant of distance conditional on distance being less than or greater than 20 kilometers.

I cluster the standard errors at the Statistical Enumeration Area (SEA) level. This is the geographic unit at which local PMTCT varies according to my spatial measure of PMTCT availability. There are over 300 SEAs in the 2001 DHS and over 300 SEAs in the 2007 DHS so standard asymptotic tests are appropriate (Cameron et al 2008).[25]

[23] I also control semiparametrically for PMTCT expansion date by including indicator variables for year of local PMTCT introduction.

[24] In a difference-in-differences interpretation of this regression specification, $PMTCTever_{ij}$ is the "treatment" indicator variable, the birth month times birth year fixed effects correspond to the standard "post" variable, and $PMTCT_{ij(mt-9)}$ is "treatment" interacted with "post".

[25] The other household surveys I use in the empirical analysis of the steps in the PMTCT cascade (i.e., the 2003 and 2005 Zambia Sexual Behavior Surveys) contain fewer SEAs, but still include over one hundred SEAs.

5 Results

5.1 PMTCT cascade

Before turning to the analysis of the effects of local PMTCT availability on child mortality, I examine the effects of local PMTCT availability on several of the steps in the PMTCT cascade. The 2001 and 2007 DHS and the 2003 and 2005 Zambia Sexual Behavior Surveys (ZSBS) include information from respondents on the following steps in the PMTCT cascade: (i) whether the respondent visited an antenatal clinic (ANC) at least once during her pregnancy, (ii) whether the ANC offered a HIV test, and (iii) whether the respondent accepted the offer. In addition, there is information on whether a health worker discussed family planning during the ANC visit. For each of these steps (and for family planning), I pool the available data and regress an indicator variable for completing the step on the full set of controls indicated in Equation (1).[26] I also construct a measure of the number of ANC visits during a pregnancy in the twelve months leading up to the survey date and examine the effect of local PMTCT availability on this outcome as well.

Table 3 presents the estimates of the effect of local PMTCT availability on the steps in the PMTCT cascade. All specifications include an indicator variable equal to one if the respondent resides with 20 kilometers of a clinic that ever offered PMTCT. In addition, all specifications include the full set of controls as indicated in Equation (1). Standard errors are clustered by Statistical Enumeration Area (SEA) of residence.

The results of this analysis do not provide strong support that local PMTCT introduction increased the likelihood of completing the steps in the PMTCT cascade. None of the estimate effects are statistically significant at conventional levels and the point estimate in the visit ANC regression is actually negative (albeit very close to zero). However, as shown in Table 1, ANC attendance is virtually universal in Zambia, even prior to PMTCT expansion. Many women may not recall being offered a HIV test, possibly attenuating the estimated effect.[27] Finally, family planning was not formally incorporated into PMTCT services in Zambia until the 2010 National Protocol Guidelines (Ministry of Health 2010).

5.2 Infant mortality

5.2.1 Baseline

The main regression results suggest that the local introduction of PMTCT may have increased child mortality in the short term. Estimates of the effect of local PMTCT availability on child mortality

[26] I omit whether the respondent accepted the offer from the regression analysis because of the extremely small sample. There are two reasons for the small sample size in this regression. First, the question is only asked in the 2003 and 2005 ZSBS. Second, it is only defined conditional on being pregnant, visiting an antenatal clinic, and being offered a HIV test.

[27] As we shall see in Table 8, local PMTCT introduction increased the likelihood the respondent received a blood test in general, although not necessarily a HIV test.

rates appear in Table 4. These regressions use the child level panel constructed using the birth history modules from the 2001 and 2007 Demographic Health Surveys (DHS). All specifications include an indicator variable equal to one if the respondent resides with 20 kilometers of a clinic that ever offered PMTCT. Standard errors are clustered by Statistical Enumeration Area (SEA) of residence.

Panel A examines the effect of local PMTCT availability on the likelihood of child death by 6 months of age. Column (1) presents the results of a simple regression that only controls for whether a clinic within 20 kilometers of a respondent ever offered PMTCT. The point estimate is negative (albeit relatively small and statistically insignificant), suggesting local PMTCT introduction may have reduced 0-6 month mortality but that the reduction (if any) was not large. In Column (2), where I control for child birth month times birth year, the estimated effect of local PMTCT availability reverses sign and becomes statistically significant at the 10 percent level. Columns (3)-(6) include additional time, geographic, and individual level controls. Throughout, the point estimate on local PMTCT availability remains positive and statistically significant at (at least) the 10 percent level.

In Panels B-D, I examine the effect of local PMTCT introduction on child death by 12 months, 18 months, and 24 months, respectively. These results follow a pattern similar to that in Panel A. After controlling very flexibly for secular birth time effects, the causal effect of local PMTCT introduction on child mortality appears to be an increase in mortality. Moreover, at older ages (i.e., 18 and 24 months), the point estimate is statistically significant across most of the regression specifications and usually at (at least) the 5 percent level. As a whole, the results in Table 4 suggest that the decline in child mortality in Figure 1 may have been a secular change and that the causal effect of local PMTCT introduction may have actually been an increase in child mortality.

5.2.2 Distance

The spatial nature of these data provides a useful test of whether we should take a causal interpretation of the baseline results. Namely, the effect of local PMTCT introduction should be greater for respondents residing closer to the clinic where PMTCT is introduced. In Table 5, I allow the effect of local PMTCT introduction on under-2 mortality to vary semi-parametrically by the distance at which the respondent resides from the clinic where PMTCT is locally introduced. Notably the three PMTCT availability measures are not mutually exclusive. For example, individuals residing within 10 kilometers of a PMTCT site also reside within 20 kilometers and 30 kilometers of a PMTCT site.

The results presented in Table 5 suggest the effect of local PMTCT introduction on child mortality may have been concentrated among respondents living closest to the health facility where PMTCT was locally introduced. To fix ideas, consider the estimates from the specification with the

full set of controls (i.e., Column (6)). Among individuals residing within 10km of the PMTCT site, under-2 mortality increased by approximately 2 percentage points. In contrast, under-2 mortality increased by only 0.2 percentage points among individuals residing 10-20km from the PMTCT site and the estimated effect is not statistically significant at conventional levels. Likewise, the point estimate for PMTCT within 30km suggests there was neither a large nor a statistically significant effect on under-24 mortality for respondents residing very far from the PMTCT site.

5.2.3 Timing

This section explores the dynamic effects of local PMTCT availability and the possibility of differential pre-PMTCT trends between PMTCT and non-PMTCT locations. In Figure 2, I plot the event study parameters from a semi-parametric difference-in-differences regression analysis of the effect of local PMTCT availability on under-2 mortality.[28] These parameters are β_k from the following regression equation:

$$\begin{aligned} childdeath_{ijmt} = & \sum_{k=-120}^{48} \beta_k 1(\tau_{ijmt} = k) + \gamma_1 PMTCTever_{ij} + X_{ijmt}^{'}\Gamma \\ & + \eta_j + \delta_{mt} + mt \times \mu_j + mt \times PMTCTever_{ij} + \epsilon_{ijmt} \end{aligned} \tag{2}$$

where τ_{ijmt} denotes the twelve (or eleven) month event window and is defined such that $\tau = 0$ for children born 9 to 20 months after the local introduction of PMTCT, $\tau = 1$ for children born 21 to 23 months after the local introduction of PMTCT, $\tau = 2$ for children born 24 to 35 months after the local introduction of PMTCT, and $\tau = 3$ for respondents surveyed 36 to 47 months after the local introduction of PMTCT, and so forth.[29,30] For $\tau < 0$, respondents were surveyed prior to the local introduction of PMTCT. This specification is identical to the specification in Equation (1) except for the addition of these quasi-event study parameters. I estimate the parameters of Equation (2) in a linear probability model (i.e., using ordinary least squares (OLS) regression). In Figure 2, I also plot the results of a semi-parametric difference-in-differences specification that includes a very limited set of controls (i.e., just birth month times birth year fixed effects).

The coefficient estimates plotted in Figure 2 are consistent with a causal interpretation of the baseline child mortality results. Conditional on the birth month times birth year fixed effects there is little evidence of a consistent pre-local introduction trend in pregnancy in locations ultimately receiving PMTCT. Furthermore, there is evidence of an upward trend in the point estimates be-

[28] As in a standard semi-parametric difference-in-differences specification, I include "untreated" respondents (i.e., individuals residing further than 20 kilometers from an eventual PMTCT site) in these regressions.

[29] As in the main regression specification, I also include indicator variables for year of local PMTCT introduction.

[30] Recall that in the main regressions I define the timing of local PMTCT availability as being equal to one if PMTCT was introduced at least 9 months prior to the child's birth date.

ginning immediately with the local introduction of PMTCT.[31]

This figure also reveals that the deleterious effect of PMTCT on child mortality appears to have dissipated around 48 months after local PMTCT introduction. To further investigate this reversal, I estimate a version of Equation (1) allowing for an additional effect of local PMTCT availability in locations where PMTCT had been available at least 48 months. Panel A in Table 6 presents these results. After controlling for birth month times birth year fixed effects, the results suggest that local PMTCT increased under-2 mortality by approximately 3 percentage points in the short term and and had a zero effect on under-2 mortality for children born 48 months or more after local PMTCT introduction.

The results in Panel A could be driven by unobserved heterogeneity between clinics that received PMTCT earlier and those that received PMTCT later. To investigate this possibility, Panel B in Table 6 reports the results of allowing the effect of local PMTCT to vary simultaneously by whether local PMTCT introduction had been available at least 48 months and by whether the location was an early PMTCT recipient.[32] These estimates suggest that the deleterious effect of PMTCT introduction may have been concentrated in locations that were early PMTCT recipients.

5.2.4 Heterogeneity by HIV prevalence

This section tests whether the estimated effect of PMTCT on child mortality varies by the likelihood the respondent is HIV positive. The 2007 DHS includes a HIV testing module with results that are linked to the rest of the individual level information in the survey. Approximately 75 percent of 2007 DHS respondents consented to providing a blood sample for the HIV test and there is evidence from other settings of selection into the DHS HIV testing model by HIV status (Reniers and Eaton 2009). I construct a measure of HIV prevalence in a respondent's demographic group defined by the interaction of five year age group and province of residence. The fact that HIV prevalence has remained relatively constant in Zambia over the period 2001-2007 suggests that, aside from possible downward bias generated by selection into the HIV testing module, this approach may yield a reasonable (albeit noisy) measure of the likelihood a respondent was HIV positive.

Table 7 reports the results of allowing the effect of local PMTCT availability to vary by this continuous measure of HIV prevalence. Interpreting the results of this exercise in the regression specifications that do not include individual level controls or province fixed effects requires substantial caution because the measure of HIV prevalence is highly correlated by construction with five year age group and province of residence. Thus, although the point estimate on the PMTCT availability term interacted with HIV prevalence is positive in Columns (1)-(4), this is likely a spurious correlation driven by underlying heterogeneity across individual characteristics and province of

[31] In Figure 2, "0" on the X-axis denotes 9 to 20 months after local PMTCT introduction and corresponds to the first period I include in the main measure of PMTCT availability in main regression specification (i.e., Equation (1)).

[32] I define a location as an early PMTCT recipient if it received PMTCT prior to January 2003.

residence. In Columns (5) and (6), where I control for these important omitted variables, the point estimates suggest that the increase in child mortality associated with local PMTCT introduction was concentrated among respondents who were relatively unlikely to be HIV positive. In fact, for women who were very likely to be HIV positive, the estimated effect of local PMTCT introduction was a (statistically insignificant) 0.6 to 0.9 percentage point reduction in under-2 mortality.

5.3 Quality of care

Presumably local PMTCT introduction should have decreased mother-to-child transmission of HIV. In a context where roughly 7 percent of infants are born HIV positive or acquire HIV through breastfeeding (Torpey et al 2010), increasing access to PMTCT among a population with ANC attendance rates above 90 percent should have reduced child mortality. Why does the evidence presented thus far largely suggest the opposite?

One possible explanation is that introducing PMTCT at a clinic may have affected the quality of care associated with other critical pediatric health services. As discussed in Section 2, a shortage of health workers may have forced health facilities to support PMTCT activities with labor formerly allocated to non-HIV tasks. Table 8 explores this broad hypothesis by regressing measures of prenatal and postnatal care on the baseline measure of local PMTCT availability. Consistent with increased exposure to PMTCT and the associated HIV blood test, the point estimate in Column (1) suggests that local PMTCT introduction increased the likelihood the respondent received a blood test at an ANC by 5.3 percentage points (statistically significant at the 5 percent level). In contrast, the point estimates in Columns (2)-(7) suggest local PMTC introduction may have reduced the quality of non-HIV prenatal and postnatal care. Although the coefficient on local PMTCT availability is only statistically significant in the vaccination regressions, it is always negative and often large in absolute value.

Panel A of Table 9 examines the dynamic effects of local PMTCT introduction on basic prenatal and postnatal care. The results suggest that the effect on the likelihood of receiving a blood test more than doubled in the medium term compared to the short term.

The dynamic effects on measures of the quality of non-HIV prenatal and postnatal care in Panel A of Table 9 provide additional support for the crowd-out hypothesis. For each of the measures aside from the postnatal health worker visit, the deleterious effects of local PMTCT introduction appear to have been partly to more than fully mitigated after 48 months. This is consistent with a model of service crowd-out in which the adjustment cost to service integration was larger in the short term than the medium term.

Panel B of Table 9 explores whether this seemingly dynamic effect of local PMTCT may have actually been heterogeneity in the effect by the timing of local introduction. On the whole, these results do not provide strong support for the hypothesis that the seemingly short term deleterious

effects of local PMTCT on basic child health service indicators was simply driven by being an early adopter.

An additional piece of evidence that is consistent with the hypothesis of non-HIV service crowd-out is the heterogenous effect of local PMTCT introduction on child mortality by the likelihood the respondent was HIV positive. For women who were relatively unlikely to be HIV positive and hence unlikely to directly benefit from PMTCT, local PMTCT introduction appears to have increased child mortality. For women who were very likely to be HIV positive and hence likely to benefit from PMTCT, local PMTCT introduction appears to have not affected child mortality or even reduced it, consistent with the competing direct and indirect effects of PMTCT. The differential effects by the likelihood the respondent was HIV positive also help rule out an increase in breastfeeding as the mechanism by which PMTCT increased child mortality. This mechanism would increase child mortality among HIV positive women, if among any women, as compared to HIV negative women.

6 Conclusion

This paper examines the effect of prevention of mother-to-child transmission of HIV (PMTCT) expansion on all-cause child mortality in Zambia. I use a geocoded census of all health facilities in Zambia to construct a monthly panel documenting the nationwide expansion of PMTCT. Panel data on child mortality come from the birth history modules in the 2001 and 2007 DHS.

I find that local PMTCT introduction appears to have increased all cause child mortality in the short term. This adverse mortality effect appears to have diminished with event time and non-HIV pediatric health service quality appears to have followed an inverse pattern after local PMTCT introduction. These results suggest that disease specific funding may distort health provider incentives toward the delivery of particular services and away from health outcomes. A high child mortality rate due to competing risks and a shortage of health workers may make this dynamic particularly acute in the context of PMTCT expansion in poor countries. This analysis highlights the value of additional research on alternative funding and performance evaluation mechanisms for health providers in the developing world (e.g., Leonard and Masatu 2010, Basinga et al 2011, Miller et al 2013), with a particular focus on the possibility of heterogeneous effects across pediatric and adult care.

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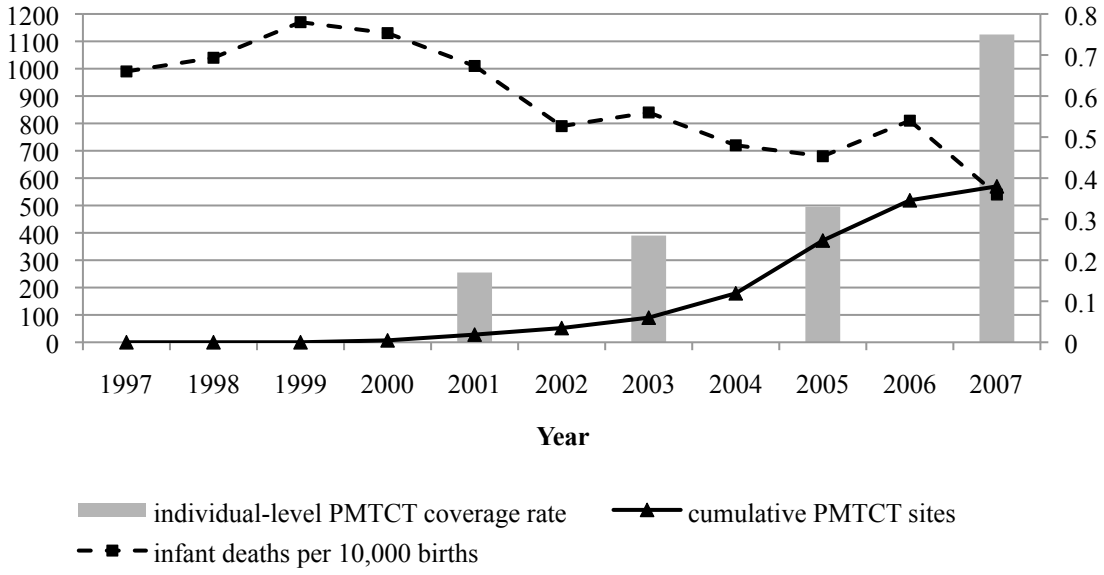
Figure 1: PMTCT Scale-Up and Infant Mortality in Zambia



Notes: Data on the cumulative number of prevention of mother-to-child transmission of HIV (PMTCT) sites come from the augmented 2006 Japanese International Cooperation Agency Health Facilities Census. I calculate the individual-level PMTCT coverage rate as the fraction of adult females in a given household survey round who live within 20 kilometers of a health offering PMTCT at the time of that survey round. The household surveys are the 2001 Demographic Health Survey (DHS), 2003 Zambia Sexual Behavior Survey (ZSBS), 2005 ZSBS, and 2007 DHS. Data on infant deaths come from the birth history modules in the 2001 and 2007 DHS. Infant deaths per 10,000 births is the number of children per 10,000 born not surviving to age 12 months.

Figure 2: Semi-Parametric Difference-in-Differences Analysis of Effect of Local PMTCT on Under-24 Mortality

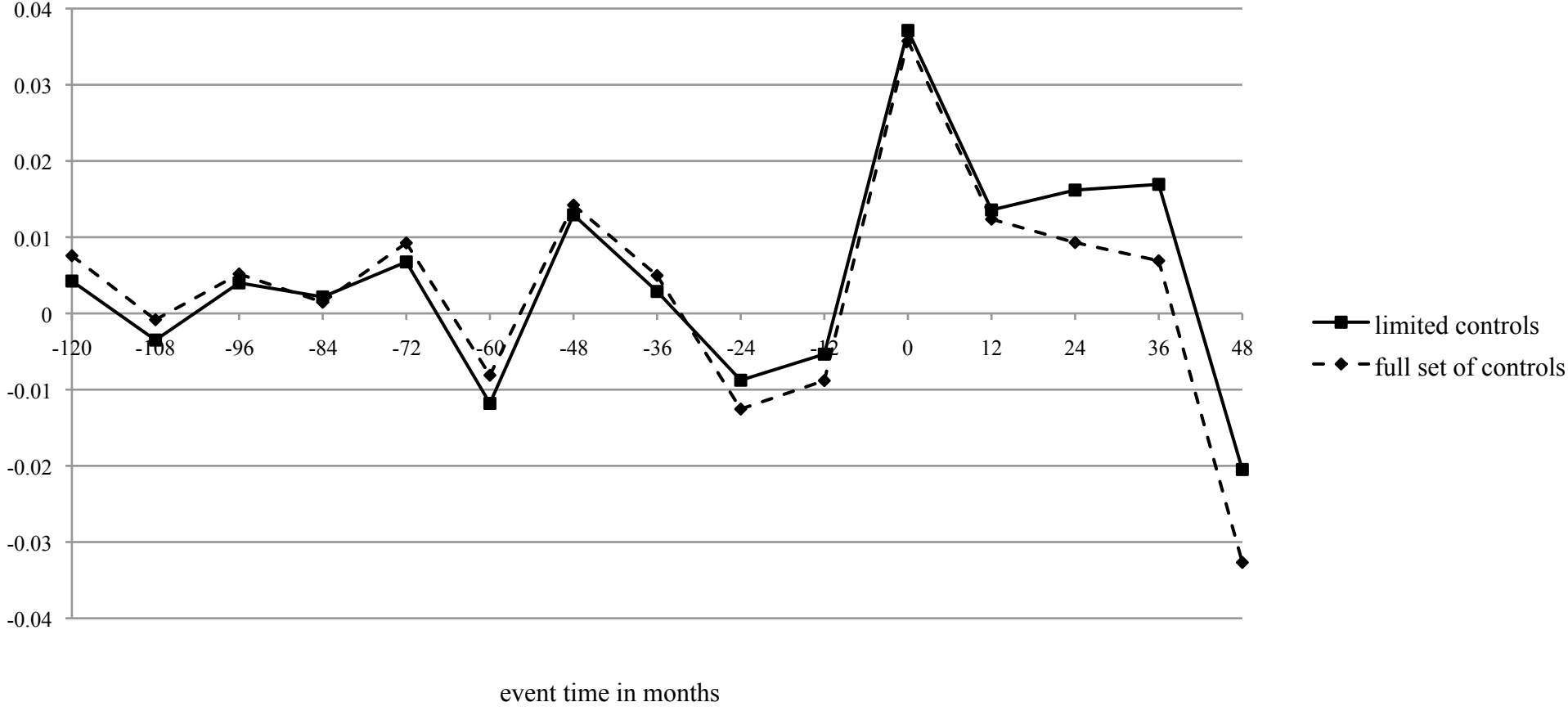


Table 1: Descriptive Statistics on Child Mortality, Basic Prenatal and Postnatal Care, and PMTCT Cascade

	mean	standard deviation	observations
	(1)	(2)	(3)
Child mortality			
Died by 6 months	0.068	0.252	23,152
by 12 months	0.102	0.303	21,796
by 18 months	0.113	0.316	20,458
by 24 months	0.137	0.343	19,133
PMTCT cascade			
Visit ANC in 2001	0.93	0.25	1,879
in 2003	0.95	0.22	599
in 2005	0.94	0.24	564
in 2007	0.93	0.25	2,043
Multiple ANC visits in 2001	0.90	0.30	1,320
in 2007	0.94	0.24	1,446
Offered HIV test in 2001	0.22	0.41	1,754
in 2003	0.15	0.36	569
in 2005	0.25	0.44	529
in 2007	0.58	0.49	1,901
Accepted HIV test in 2003	0.44	0.50	86
in 2005	0.63	0.49	134
Basic prenatal and postnatal services			
Number of basic prenatal services received in 2001	2.03	0.66	4,290
in 2007	2.01	0.76	4,026
Blood sample taken in 2001	0.41	0.49	4,306
in 2007	0.61	0.49	4,024
Postnatal health worker in 2001	0.42	0.49	6,897
in 2007	0.50	0.50	6,348
Postnatal vitamin A in 2001	0.26	0.44	4,511
in 2007	0.46	0.50	4,123
Number of vaccinations in 2001	6.49	2.55	5,976
in 2007	6.69	2.65	5,810
Complete vaccinations in 2001	0.048	0.214	6,031
in 2007	0.058	0.234	5,819
No vaccinations in 2001	0.070	0.255	6,032
in 2007	0.087	0.282	5,819
Received drugs for fever in 2001	0.54	0.50	2,607
in 2007	0.26	0.44	1,769
Other			
Clinic discussed family planning in 2001	0.42	0.49	1,446
in 2007	0.59	0.49	1,152
HIV prevalence	0.163	0.090	14,829

Notes: Data on child mortality come from birth history modules in the 2001 and 2007 DHS survey rounds. Data on the steps in PMTCT cascade come from the 2001 and 2007 DHS survey rounds and the 2003 and 2005 ZSBS survey rounds. Data on HIV prevalence come from the anonymous HIV testing module in the 2007 DHS. HIV prevalence is the proportion of HIV positive women in the respodent's demographic group, where demographic group is defined as the interaction of five-year age group and province of residence, and is reported for the sample of female respondents in the 2001 and 2007 DHS.

Table 2: Local PMTCT Introduction and Child Mortality

Died by:	1 month	6 months	12 months	18 months	24 months
	(1)	(2)	(3)	(4)	(5)
Panel A: Full sample					
Never received	0.044	0.079	0.114	0.125	0.151
Before local introduction	0.040	0.065	0.101	0.110	0.132
After local introduction	0.043	0.058	0.076	0.087	0.116
Change associated with local introduction	0.003	-0.007	-0.025***	-0.023**	-0.016
Observations	24,284	23,152	21,796	20,458	19,133
Panel B: Born in 2006					
Never received	0.039	0.060	0.083	0.000	-
Before local introduction	0.021	0.054	0.111	0.000	-
After local introduction	0.038	0.056	0.068	0.067	-
Change associated with local introduction	0.017	0.002	-0.043	0.067	-
Observations	1,381	1,257	580	36	0
Panel C: Born in 2005					
Never received	0.031	0.051	0.071	0.074	0.156
Before local introduction	0.029	0.041	0.070	0.067	0.067
After local introduction	0.031	0.047	0.063	0.074	0.103
Change associated with local introduction	0.001	0.006	-0.007	0.006	0.036
Observations	1,300	1,300	1,300	1,184	541
Panel D: Born in 2004					
Never received	0.035	0.060	0.076	0.085	0.098
Before local introduction	0.036	0.051	0.073	0.079	0.094
After local introduction	0.034	0.041	0.065	0.072	0.082
Change associated with local introduction	-0.002	-0.010	-0.007	-0.007	-0.011
Observations	1,268	1,268	1,268	1,268	1,268
Panel E: Born in 2003					
Never received	0.023	0.040	0.060	0.060	0.081
Before local introduction	0.037	0.051	0.084	0.087	0.105
After local introduction	0.060	0.081	0.111	0.115	0.150
Change associated with local introduction	0.022	0.030*	0.027	0.028	0.044*
Observations	1,255	1,255	1,255	1,255	1,255
Panel F: Born in 2002					
Never received	0.040	0.053	0.098	0.098	0.114
Before local introduction	0.030	0.048	0.070	0.073	0.086
After local introduction	0.042	0.085	0.092	0.108	0.146
Change associated with local introduction	0.011	0.036*	0.023	0.035	0.060**
Observations	1,141	1,036	1,036	1,036	1,036

Notes: Data on child mortality come from the birth history modules in the 2001 and 2007 Demographic Health Surveys. Local PMTCT availability defined as PMTCT available within 20 kilometers of respondent.
*** Significant at 1 percent level, ** Significant at 5 percent level, * Significant at 10 percent level

Table 3: Effect of Local PMTCT on PMTCT Cascade

Dependent variable:	visit ANC	multiple ANC visits	offered test	clinic discussed family planning
	(1)	(2)	(3)	(4)
PMTCT within 20km	-0.003	0.019	0.019	0.025
	(0.023)	(0.024)	(0.042)	(0.043)
Month times year fixed effects	YES	YES	YES	YES
Controls for PMTCT expansion stage	YES	YES	YES	YES
Individual level controls	YES	YES	YES	YES
Province fixed effects and linear trends	YES	YES	YES	YES
Controls for piped water and bed net ownership	YES	YES	YES	YES
Observations	4,477	2,764	4,175	2,980

Notes: Data on whether the respondent visited an ANC and whether ANC offered a HIV test comes from 2001 and 2007 DHS survey rounds and 2003 and 2005 ZSBS survey rounds. Data on whether the respondent made multiple ANC visits and whether the clinic discussed family planning come from the 2001 and 2007 DHS survey rounds. All dependent variables are indicator variables and are defined only for respondents reporting being pregnant at some point in the twelve months prior to the survey month. "PMTCT within 20km" is an indicator variable equal to one if a health clinic with 20 kilometers of the respondent offered PMTCT at least nine months prior to the survey date. All specifications include an indicator variable for whether PMTCT was ever introduced within 20 kilometers of the respondent. Parameters estimated using ordinary least squares (OLS) regression. Standard errors are in parentheses and are clustered by Standard Enumeration Area (SEA).

*** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.

Table 4: Effect of Local PMTCT on Child Mortality

Dependent variable:	child death					
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Died by 6 months						
PMTCT within 20km	-0.007	0.011*	0.022***	0.012*	0.015**	0.017**
	(0.006)	(0.006)	(0.008)	(0.007)	(0.008)	(0.008)
Month times year fixed effects	NO	YES	YES	YES	YES	YES
Controls for PMTCT expansion stage	NO	NO	YES	YES	YES	YES
Individual level controls	NO	NO	NO	YES	YES	YES
Province fixed effects and linear trends	NO	NO	NO	NO	YES	YES
Controls for piped water and bed net ownership	NO	NO	NO	NO	NO	YES
Observations	23,152	23,152	23,152	23,152	23,152	23,152
Panel B: Died by 12 months						
PMTCT within 20km	-0.025***	0.003	0.017*	0.017*	0.009	0.009
	(0.007)	(0.008)	(0.009)	(0.009)	(0.010)	(0.010)
Month times year fixed effects	NO	YES	YES	YES	YES	YES
Controls for PMTCT expansion stage	NO	NO	YES	YES	YES	YES
Individual level controls	NO	NO	NO	YES	YES	YES
Province fixed effects and linear trends	NO	NO	NO	NO	YES	YES
Controls for piped water and bed net ownership	NO	NO	NO	NO	NO	YES
Observations	21,796	21,796	21,796	21,796	21,796	21,796
Panel C: Died by 18 months						
PMTCT within 20km	-0.023***	0.013	0.028***	0.028***	0.019	0.020
	(0.008)	(0.010)	(0.011)	(0.011)	(0.012)	(0.012)
Month times year fixed effects	NO	YES	YES	YES	YES	YES
Controls for PMTCT expansion stage	NO	NO	YES	YES	YES	YES
Individual level controls	NO	NO	NO	YES	YES	YES
Province fixed effects and linear trends	NO	NO	NO	NO	YES	YES
Controls for piped water and bed net ownership	NO	NO	NO	NO	NO	YES
Observations	20,458	20,458	20,458	20,458	20,458	20,458
Panel D: Died by 24 months						
PMTCT within 20km	-0.016	0.022*	0.036***	0.036***	0.024*	0.025*
	(0.010)	(0.012)	(0.013)	(0.013)	(0.014)	(0.014)
Month times year fixed effects	NO	YES	YES	YES	YES	YES
Controls for PMTCT expansion stage	NO	NO	YES	YES	YES	YES
Individual level controls	NO	NO	NO	YES	YES	YES
Province fixed effects and linear trends	NO	NO	NO	NO	YES	YES
Controls for piped water and bed net ownership	NO	NO	NO	NO	NO	YES
Observations	19,133	19,133	19,133	19,133	19,133	19,133

Notes: Data come from the 2001 and 2007 DHS survey rounds. Child death is an indicator variable equal to one if the child died by 6 months (Panel A), 12 months (Panel B), 18 months (Panel C), and 24 months (Panel D). "PMTCT within 20km" is an indicator variable equal to one if a health clinic with 20 kilometers of the respondent offered PMTCT at least nine months prior to the survey date. All specifications include an indicator variable for whether PMTCT was ever introduced within 20 kilometers of the respondent. Parameters estimated using ordinary least squares (OLS) regression. Standard errors are in parentheses and are clustered by Standard Enumeration Area (SEA).

*** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.

Table 5: Heterogeneity by Distance in Effect of Local PMTCT on Child Mortality

Dependent variable:	died by 24 months					
	(1)	(2)	(3)	(4)	(5)	(6)
PMTCT within 10km	0.012	0.011	0.012	0.016	0.015	0.019
	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)
PMTCT within 20km	-0.013	0.019	0.024	0.022	0.012	0.010
	(0.016)	(0.017)	(0.019)	(0.019)	(0.020)	(0.020)
PMTCT within 30km	-0.031***	-0.011	-0.013	-0.011	-0.009	-0.008
	(0.008)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Month times year fixed effects	NO	YES	YES	YES	YES	YES
Controls for PMTCT expansion stage	NO	NO	YES	YES	YES	YES
Individual level controls	NO	NO	NO	YES	YES	YES
Province fixed effects and linear trends	NO	NO	NO	NO	YES	YES
Controls for piped water and bed net owne	NO	NO	NO	NO	NO	YES
Observations	19,133	19,133	19,133	19,133	19,133	19,133

Notes: Data come from the 2001 and 2007 DHS survey rounds. Died by 24 months is an indicator variable equal to one if the child died by 24 months of age. "PMTCT within 10km" is an indicator variable equal to one if a health clinic with 10 kilometers of the respondent offered PMTCT at least nine months prior to the survey date. "PMTCT within 20km" is an indicator variable equal to one if a health clinic with 20 kilometers of the respondent offered PMTCT at least nine months prior to the survey date. "PMTCT within 30km" is an indicator variable equal to one if a health clinic with 30 kilometers of the respondent offered PMTCT at least nine months prior to the survey date. All specifications include an indicator variable for whether PMTCT was ever introduced within 20 kilometers of the respondent. Parameters estimated using ordinary least squares (OLS) regression. Standard errors are in parentheses and are clustered by Standard Enumeration Area (SEA).

*** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.

Table 6: Dynamic Effects of Local PMTCT on Child Mortality

Dependent variable:	died by 24 months					
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Simple duration analysis						
PMTCT within 20km	-0.006	0.029**	0.042***	0.042***	0.031**	0.031**
	(0.012)	(0.013)	(0.014)	(0.014)	(0.014)	(0.015)
PMTCT within 20km at least 48 months	-0.049**	-0.042*	-0.039	-0.038	-0.045*	-0.046*
	(0.023)	(0.022)	(0.024)	(0.023)	(0.024)	(0.024)
P > F(PMTCT+PMTCT at least 48 months=0)	0.004	0.506	0.864	0.824	0.545	0.527
Month times year fixed effects	NO	YES	YES	YES	YES	YES
Controls for PMTCT expansion stage	NO	NO	YES	YES	YES	YES
Individual level controls	NO	NO	NO	YES	YES	YES
Province fixed effects and linear trends	NO	NO	NO	NO	YES	YES
Controls for piped water and bed net ownership	NO	NO	NO	NO	NO	YES
Observations	19,133	19,133	19,133	19,133	19,133	19,133
Panel B: Allowing for heterogeneous effects by PMTCT expansion stage						
PMTCT within 20km	-0.036	0.014	0.018	0.016	0.012	0.012
	(0.027)	(0.028)	(0.030)	(0.030)	(0.029)	(0.029)
PMTCT within 20km at least 48 months	-0.054**	-0.045*	-0.044*	-0.043*	-0.049**	-0.050**
	(0.023)	(0.023)	(0.025)	(0.024)	(0.025)	(0.025)
PMTCT within 20km X early PMTCT recipient	0.035	0.018	0.029	0.032	0.023	0.024
	(0.030)	(0.031)	(0.033)	(0.033)	(0.032)	(0.032)
P > F(PMTCT+PMTCT at least 48 months=0)	0.013	0.401	0.515	0.482	0.351	0.328
P > F(PMTCT+PMTCT X early recipient=0)	0.946	0.026	0.002	0.002	0.029	0.027
P > F(PMTCT+PMTCT at least 48 months + early recipient=0)	0.004	0.479	0.878	0.840	0.556	0.539
Month times year fixed effects	NO	YES	YES	YES	YES	YES
Controls for PMTCT expansion stage	NO	NO	YES	YES	YES	YES
Individual level controls	NO	NO	NO	YES	YES	YES
Province fixed effects and linear trends	NO	NO	NO	NO	YES	YES
Controls for piped water and bed net ownership	NO	NO	NO	NO	NO	YES
Observations	19,133	19,133	19,133	19,133	19,133	19,133

Notes: Data come from the 2001 and 2007 DHS survey rounds. Died by 24 months is an indicator variable equal to one if the child died by 24 months of age. "PMTCT within 20km" is an indicator variable equal to one if a health clinic with 20 kilometers of the respondent offered PMTCT at least nine months prior to the survey date. All specifications include an indicator variable for whether PMTCT was ever introduced within 20 kilometers of the respondent. Parameters estimated using ordinary least squares (OLS) regression. Standard errors are in parentheses and are clustered by Standard Enumeration Area (SEA).

*** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.

Table 7: Heterogeneity by HIV Prevalence in Effect of Local PMTCT on Child Mortality

Dependent variable:	died by 24 months					
	(1)	(2)	(3)	(4)	(5)	(6)
PMTCT within 20km	-0.015	0.019	0.033	0.025	0.035	0.035
	(0.028)	(0.030)	(0.030)	(0.029)	(0.029)	(0.029)
PMTCT within 20km X HIV prevalence	0.009	0.038	0.008	0.045	-0.044	-0.041
	(0.114)	(0.115)	(0.113)	(0.111)	(0.112)	(0.111)
P > F(PMTCT+PMTCT X HIV prevalence=0)	0.952	0.515	0.636	0.416	0.915	0.936
Month times year fixed effects	NO	YES	YES	YES	YES	YES
Controls for PMTCT expansion stage	NO	NO	YES	YES	YES	YES
Individual level controls	NO	NO	NO	YES	YES	YES
Province fixed effects and linear trends	NO	NO	NO	NO	YES	YES
Controls for piped water and bed net ownership	NO	NO	NO	NO	NO	YES
Observations	19,133	19,133	19,133	19,133	19,133	19,133

Notes: Data come from the 2001 and 2007 DHS survey rounds. Died by 24 months is an indicator variable equal to one if the child died by 24 months of age. "PMTCT within 20km" is an indicator variable equal to one if a health clinic with 20 kilometers of the respondent offered PMTCT at least nine months prior to the survey date. HIV prevalence is the proportion of women in a respodent's demographic group (defined as the interaction of five-year age group and province of residence) who are HIV positive. Data on HIV prevalence come from the anonymous HIV testing module in the 2007 DHS. All specifications include an indicator variable for whether PMTCT was ever introduced within 20 kilometers of the respondent. Parameters estimated using ordinary least squares (OLS) regression. Standard errors are in parentheses and are clustered by Standard Enumeration Area (SEA).

*** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.

Table 8: Effect of Local PMTCT on Quality of Basic Prenatal and Postnatal Care

Dependent variable:	blood sample taken	number of vaccinations	complete vaccinations	no vaccinations	fever drugs	number of basic prenatal services received	postnatal health worker	postnatal vitamin A
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PMTCT within 20km	0.053**	-0.235*	-0.039***	0.019	-0.046	-0.048	-0.004	-0.029
	(0.023)	(0.134)	(0.012)	(0.014)	(0.050)	(0.037)	(0.041)	(0.022)
Month times year fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Controls for PMTCT expansion stage	YES	YES	YES	YES	YES	YES	YES	YES
Individual level controls	YES	YES	YES	YES	YES	YES	YES	YES
Province fixed effects and linear trends	YES	YES	YES	YES	YES	YES	YES	YES
Controls for piped water and bed net ownership	YES	YES	YES	YES	YES	YES	YES	YES
Observations	7,850	11,148	11,203	11,203	3,366	7,839	12,511	8,135

Notes: Data on whether the respondent visited an ANC and whether ANC offered a HIV test comes from 2001 and 2007 DHS survey rounds and 2003 and 2005 ZSBS survey rounds. Data on whether the respondent made multiple ANC visits and whether the clinic discussed family planning come from the 2001 and 2007 DHS survey rounds. All dependent variables are indicator variables and are defined only for respondents reporting being pregnant at some point in the twelve months prior to the survey month. "PMTCT within 20km" is an indicator variable equal to one if a health clinic with 20 kilometers of the respondent offered PMTCT at least nine months prior to the survey date. All specifications include an indicator variable for whether PMTCT was ever introduced within 20 kilometers of the respondent. Parameters estimated using ordinary least squares (OLS) regression. Standard errors are in parentheses and are clustered by Standard Enumeration Area (SEA).

*** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.

Table 9: Dynamic Effects of Local PMTCT on Quality of Basic Prenatal and Postnatal Care

Dependent variable:	blood sample taken	number of vaccinations	complete vaccinations	no vaccinations	fever drugs	number of basic prenatal services received	postnatal health worker	postnatal vitamin A
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Simple duration analysis								
PMTCT within 20km	0.054**	-0.195	-0.033***	0.023*	-0.027	-0.047	-0.018	-0.029
	(0.023)	(0.136)	(0.011)	(0.014)	(0.049)	(0.038)	(0.040)	(0.022)
PMTCT within 20km at least 48 months	0.074**	0.149	0.025*	0.016	0.066	0.063	-0.050	0.015
	(0.033)	(0.164)	(0.015)	(0.016)	(0.064)	(0.052)	(0.054)	(0.038)
P > F(PMTCT+PMTCT at least 48 months=0)	0.003	0.844	0.661	0.080	0.644	0.824	0.332	0.740
Month times year fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Controls for PMTCT expansion stage	YES	YES	YES	YES	YES	YES	YES	YES
Individual level controls	YES	YES	YES	YES	YES	YES	YES	YES
Province fixed effects and linear trends	YES	YES	YES	YES	YES	YES	YES	YES
Controls for piped water and bed net ownership	YES	YES	YES	YES	YES	YES	YES	YES
Observations	7,850	11,148	11,203	11,203	3,366	7,839	12,511	8,135
Panel B: Allowing for heterogeneous effects by PMTCT expansion stage								
PMTCT within 20km	0.082***	-0.211	-0.038**	0.025	-0.073	-0.059	0.061	-0.009
	(0.027)	(0.178)	(0.016)	(0.016)	(0.084)	(0.044)	(0.054)	(0.024)
PMTCT within 20km at least 48 months	0.097***	0.133	0.019	0.017	0.022	0.054	0.030	0.031
	(0.031)	(0.196)	(0.019)	(0.016)	(0.079)	(0.053)	(0.070)	(0.038)
PMTCT within 20km X early PMTCT recipient	-0.092**	0.034	0.012	-0.003	0.079	0.038	-0.169**	-0.065
	(0.041)	(0.292)	(0.025)	(0.029)	(0.104)	(0.061)	(0.081)	(0.043)
P > F(PMTCT+PMTCT at least 48 months=0)	0.001	0.807	0.499	0.105	0.724	0.935	0.398	0.638
P > F(PMTCT+PMTCT X early recipient=0)	0.786	0.425	0.138	0.370	0.930	0.693	0.064	0.058
P > F(PMTCT+PMTCT at least 48 months + early recipient=0)	0.079	0.852	0.694	0.099	0.748	0.645	0.251	0.384
Month times year fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Controls for PMTCT expansion stage	YES	YES	YES	YES	YES	YES	YES	YES
Individual level controls	YES	YES	YES	YES	YES	YES	YES	YES
Province fixed effects and linear trends	YES	YES	YES	YES	YES	YES	YES	YES
Controls for piped water and bed net ownership	YES	YES	YES	YES	YES	YES	YES	YES
Observations	7,850	11,148	11,203	11,203	3,366	7,839	12,511	8,135

Notes: Data on whether the respondent visited an ANC and whether ANC offered a HIV test comes from 2001 and 2007 DHS survey rounds and 2003 and 2005 ZSBS survey rounds. Data on whether the respondent made multiple ANC visits and whether the clinic discussed family planning come from the 2001 and 2007 DHS survey rounds. All dependent variables are indicator variables and are defined only for respondents reporting being pregnant at some point in the twelve months prior to the survey month. "PMTCT within 20km" is an indicator variable equal to one if a health clinic with 20 kilometers of the respondent offered PMTCT at least nine months prior to the survey date. All specifications include an indicator variable for whether PMTCT was ever introduced within 20 kilometers of the respondent. Parameters estimated using ordinary least squares (OLS) regression. Standard errors are in parentheses and are clustered by Standard Enumeration Area (SEA).

*** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.