HIV Prevention at Scale: Prevention of Mother-to-Child Transmission of HIV and Child Mortality in Zambia*

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First Draft: May 2012
Current Version: May 2012

Abstract

Between 1996 and 2008 annual donor expenditure on HIV/AIDS increased from US$300 million to US$7.7 billion. However, HIV incidence has fallen only slightly and there is little evidence of a HIV prevention intervention succeeding at scale. This paper estimates the effect of prevention of mother-to-child transmission (PMTCT) expansion on child mortality in Zambia. My results suggest that the local introduction of PMTCT reduced infant mortality rates by approximately 2 percentage points, or roughly 20 percent. This appears to be the first causal evidence of a HIV prevention intervention succeeding at scale in Sub-Saharan Africa.

JEL classification: I10; J13
Keywords: child mortality; HIV/AIDS; HIV prevention; PMTCT; Zambia

*I would like to thank Marianne Bitler, Alfredo Burlando, Christopher Carpenter, Joseph Cummins, Carlos Dobkin, William Dow, Pascaline Dupas, Frederico Finan, Günther Fink, Andrew Foster, Paul Gertler, Erick Gong, Ethan Ligon, Jeremy Magruder, Zoë McClaren, Sandra McCoy, Edward Miguel, Nancy Padian, Jonathon Robinson, David Sahn, Lucie Schmidt, T. Paul Schultz, Manisha Shah, Lara Shore-Sheppard, Jeffrey Stringer, Anand Swamy, Waly Wane, Tara Watson, David Weil, and seminar participants at the NBER Africa Project Zanzibar Conference, NEUDC 2011 at Yale University, 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, 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 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.

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1 Introduction

Between 1996 and 2008 annual donor expenditure on HIV/AIDS increased from US$300 million (UNAIDS 2006) to more than US$7.7 billion (UNAIDS 2011). Roughly one-fifth of these expenditures appear to have been spent on HIV prevention.[1] HIV prevention policies currently in practice or under consideration range from information campaigns on safe sex practices to paying individuals to remain HIV negative.

The rapid growth in HIV/AIDS spending belies a small body of evidence on what policies are actually effective at preventing new HIV infections at scale. A recent review of HIV prevention research (Padian et al 2011) highlights that there are only a handful of rigorous empirical studies that find a beneficial effect of a HIV prevention intervention. Moreover, there does not appear to be a documented case of a HIV prevention intervention conclusively succeeding at scale in Sub-Saharan Africa.[2,3]

The relationship between HIV/AIDS spending and new HIV infections is consistent with these observations. Figure 1 presents annual HIV/AIDS donor spending and annual new HIV infections for the period 2002-2010. Although annual HIV/AIDS spending increased by more than twenty-fold over this time period, the number of new HIV infections fell by less than 15 percent.[4] Of course much of this money was spent on treatment, not prevention. Nonetheless, HIV/AIDS remains the leading cause of death in Sub-Saharan Africa and one of the main causes of death worldwide (Merson et al 2008).

The discovery of antiretroviral drugs as a HIV prevention strategy may be a major breakthrough in HIV prevention (Padian et al 2008, Padian et al 2011). Clinical trials indicate that antiretroviral prophylaxis for prevention of mother-to-child transmission of HIV (PMTCT) can virtually eliminate vertical transmission (Dabis and Ekpini 2002, Canning 2006). Similarly, recent evidence indicates that initiating antiretroviral therapy for individuals living with HIV dramatically reduces

[1] Arguably the single largest source of global HIV/AIDS funding, the United States President's Emergency Plan for AIDS Relief (PEPFAR), stipulated through 2008 that twenty percent of spending be allocated to HIV prevention (Moss 2008). In 2008, the United States contributed over 51 percent of total donor disbursements on HIV/AIDS spending (Kates et al 2009).

[2] A review of HIV prevention evaluations (Hallet et al 2007) identifies Uganda as the potential success story where a national HIV prevention program in Sub-Saharan Africa may have reduced HIV incidence. However, Hallet et al (2007) notes that there is substantial debate about which of the three ABCs (Abstain, Be Faithful, Consistent and Correct Condom Use) were actually responsible for this decline. Moreover, the evidence in Oster (2012) suggests that declining export (i.e., trucking) activity may explain much of the decline in HIV incidence otherwise attributed to abstinence education programs, condom promotion, and public information campaigns.

[3] In a recent Lancet review of the state of HIV prevention, Piot et al (2008) explicitly calls for additional attention to issues of scale in HIV prevention.

[4] The number of individuals living with HIV/AIDS increased by less than 16 percent over this time (Global Response 2011), suggesting that rising prevalence may not have been a major factor behind the slow decline in HIV incidence.

the likelihood of HIV transmission to their sexual partners (National Institute of Allergy and Infectious Diseases 2011, Smith et al 2011). However, little-to-no evidence exists on the effectiveness of these interventions at scale. Although the use of antiretrovirals (ARVs) for preventing horizontal transmission of HIV is not widespread, prevention of mother-to-child transmission of HIV (PMTCT) offers an opportunity to evaluate ARVs for prevention at scale. Between 2004 and 2010, the proportion of HIV positive pregnant women in Sub-Saharan Africa receiving PMTCT increased from 9 percent to approximately 50 percent (WHO 2010a, WHO 2011).

This paper examines the effects of prevention of mother-to-child transmission of HIV (PMTCT) scale-up on child mortality in Zambia. Nearly 14 percent of pregnant women in Zambia are HIV positive and approximately 8 percent of infants acquire HIV in the absence of PMTCT (Ministry of Health, Zambia 2008). Evidence from elsewhere in Sub-Saharan Africa indicates that as many as 50 percent of HIV positive infants die by age 1 (Spira et al 1999, Taha et al 1999, Dabis et al 2001, Brahmbhatt et al 2001).[5] Between 2000 and the end of 2007, the number of health clinics in Zambia offering PMTCT drugs increased from fewer than 6 to nearly 600.[6] By the end of this period, approximately 40 percent of health clinics offered PMTCT and 75 percent of women lived within 20 kilometers of a PMTCT site.

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. Retrospective birth history modules from repeated nationally representative 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 availability while controlling for time invariant and time varying factors associated with local PMTCT introduction.

My results suggest that PMTCT scale-up substantially reduced all-cause infant mortality. I find that the local introduction of PMTCT was associated with approximately a 2 percentage point reduction in infant mortality rates. Larger estimated reductions at ages where infants may be more likely to die of HIV/AIDS and in households residing closer to PMTCT sites support a causal interpretation of this finding. Surprisingly, I do not find strong evidence that the mortality reduction

[5]Evidence on the mortality-age profile for HIV positive infants is relatively limited, with most data coming from relatively small studies or population-based estimates that use assumptions about fertility, transmission rates, and mortality of HIV positive women of childbearing age (Newell et al 2004). The mortality rate for HIV positive infants is between 25 and 50 percent by age 1 (Spira et al 1999, Taha et al 1999, Dabis et al 2001, Brahmbhatt et al 2001, Brahmbhatt et al 2006). By age 2, this increases to between 35 and 60 percent (Spira et al 1999, Taha et al 1999, Dabis et al 2001, Brahmbhatt et al 2001, Brahmbhatt et al 2006). Presumably, HIV positive infants in poor countries do not survive into adolescence.

[6]Single-dose nevirapine (NVP) was the main prophylaxis in the early years of the Zambian PMTCT program and zidovudine (ZDV) (also known as azidothymidine (AZT)) and NVP in the later years of the program (Stringer et al 2003, Stringer et al 2005, Ministry of Health 2007, Ministry of Health 2010).

was greater among children of mothers who were more likely to be HIV positive. However, the point estimates do suggest larger (albeit statistically insignificant) reductions among these groups and my measure of the likelihood of being HIV positive surely includes substantial measurement error.

These estimates are not too far from a back-of-the-envelope calculation of pediatric HIV/AIDS mortality. According to the 2007 Demographic Health Survey (DHS), HIV prevalence among pregnant women is approximately 14 percent. However, the proportion of pregnant women in areas receiving PMTCT who are HIV positive is almost certainly higher because PMTCT expansion occurred with greater intensity in urban areas in Zambia and HIV prevalence is higher in these areas. Suppose 20 percent of pregnant women in areas receiving PMTCT during the period included in the current analysis (i.e., through December 2007) were HIV positive. A mother-to-child transmission rate of 40 percent would imply that 8 percent of infants are born HIV positive or acquire HIV through breastfeeding. If half of HIV positive pregnant women and their newborn children in a given location ultimately receive PMTCT (i.e., single-dose NVP) and single-dose NVP reduces transmission by 10 to 25 percentage points, then we should see a 0.4 to 1 percentage point reduction in child mortality associated with local introduction of PMTCT.[7] If these women and their children received a combination of NVP and zidovudine (ZDV) and this reduces transmission by 30 to 40 percentage points, then we should see a 1.2 to 1.6 percentage point reduction in child mortality associated with the local introduction of PMTCT.[8]

The approach to HIV prevention appears to be shifting toward combination prevention (Merson et al 2008, Piot et al 2008, Padian et al 2011), a combination of behavioral, biomedical, and structural interventions, including basic development programs (Schwartlander et al 2011). Although this approach suggests that focusing on a single prevention intervention is inappropriate, PMTCT offers several key advantages over other interventions in terms of effectiveness at scale. Only a few doses are required which means adherence should be higher and costs lower than antiretroviral prophylaxis against the horizontal transmission of HIV.[9] Moreover, pregnant women arguably are the

[7]Single-dose nevirapine (sd-NVP) reduces the likelihood of mother-to-child transmission of HIV by 10 to 25 percentage points (Guay et al 1999, Jackson et al 2003). Although estimates of the efficacy of NVP plus zidovudine (ZDV) in breastfeeding populations are not available, the available estimates suggest NVP plus ZDV is more effective than single-dose NVP (WHO 2004).

[8]In a sample of mothers receiving antenatal care and delivering at one of the ten public sector delivery centers in Lusaka city in June-August 2003, Stringer et al (2005) finds that 30 percent of mother-infant pairs received both a maternal and an infant dose of NVP. Torpey et al (2010) analyzes the fraction of HIV positive pregnant women reporting to one of the thirty-eight clinics supported by the Zambia Prevention, Care, and Treatment Partnership (ZPCT) who receive antiretroviral prophylaxis and reports that adherence increased each year in the study, from 29 percent in 2005, to 66 percent in 2006, to 97 percent in 2007, and to 100 percent coverage by 2008. However, Stringer et al (2005) reports that only 68 percent of women receiving NVP in the Lusaka city clinics in June-August 2003 actually adhered to the dose. UNAIDS estimates that 47 percent of pregnant women living with HIV in Zambia and approximately 20 percent of infants born to HIV positive mothers received antiretroviral drugs for PMTCT in 2007 (UNAIDS Annex 3).

[9]Padian et al (2011) identifies adherence as one of the major issues involved in using antiretroviral drugs to prevent

population group most likely to access health care which greatly facilitates initiating PMTCT.[10] My effectiveness results support this line of reasoning and provide evidence that the continued expansion of PMTCT services should be an urgent priority among policymakers. Between 2000 and 2007, infant mortality in Zambia roughly halved (see Figure 3) and my estimates suggest that PMTCT expansion explains around one-quarter of this reduction.[11]

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 reproductive health in Zambia

Prevention of mother-to-child transmission of HIV (PMTCT) generally refers to a package of interventions designed to reduce mother-to-child transmission of HIV. In the absence of these interventions (i.e., antiretroviral drugs in particular), approximately 40 percent of infants born to HIV positive women acquire HIV in the womb, during childbirth, or through breastfeeding (Dabis and Ekpini 2002, Canning 2006). In general, these interventions include counseling and testing for HIV, antiretroviral drugs to reduce vertical transmission, breastfeeding advice, and family planning. However, the exact mix of interventions has changed over time with new medical evidence and increased global funding for HIV/AIDS.

Early PMTCT efforts in Zambia appear to have focused on counseling and testing and breastfeeding advice. As early as May 2000 several clinics in Ndola city provided infant feeding guidelines and counseling and testing for prevention of mother-to-child transmission as part of routine antenatal and postnatal care (Kalibala et al 2003). Later, many clinics introduced prophylactic antiretrovirals, primarily single-dose nevirapine (NVP) initially and then combination therapy (i.e., zidovudine (ZDV) and NVP). By 2007, the National Protocol Guidelines stated an opt-out approach to HIV testing for pregnant women at antenatal clinics and codified official breastfeeding advice (Ministry of Health 2007). The 2010 National Protocol Guidelines added family planning

the horizontal transmission of HIV. Abdool et al (2010) and Grant et al (2010) include analyses of adherence in clinical trials evaluating antiretroviral drugs for the horizontal transmission of HIV. Although adherence to antiretroviral drugs is a concern, Pop-Eleches et al (2011) shows that mobile phone short message service (SMS) reminders may substantially increase adherence rates.

[10] According to the household survey data I use in the current analysis, more than 90 percent of pregnant women in Zambia visit an antenatal clinic at least once during their pregnancy (see Table 2).

[11] The point estimate from the specification with the full set of controls in Table 4 suggests that local PMTCT availability reduced infant mortality by 2.5 percentage points. Supposing that 50 percent of women live within 20 kilometers of a PMTCT site, then local PMTCT availability reduced infant mortality by 1.25 percentage points, or approximately one-quarter of the reduction of roughly 500 deaths per 10,000 births shown in Figure 3.

and condom promotion as part of ongoing postnatal care (Ministry of Health 2010).

The 2007 National Protocol Guidelines (Ministry of Health 2007) appears to have been the first codified national policy on breastfeeding advice for PMTCT. The guidelines recommended that HIV negative mothers and mothers with unknown status practice exclusive breastfeeding for six months and then breastfeed up to twenty-four months. HIV positive mothers were to be "given enough information about advantages and disadvantages of the available options for them to be able to make an informed choice about what might be best for them" and advised to completely avoid breastfeeding when quality replacement feeding was available (Ministry of Health 2007). In the 2010 National Protocol Guidelines breastfeeding advice remained unchanged for HIV negative women and women with unknown status. HIV positive women were advised to practice exclusive breastfeeding for six months and then introduce complementary feeding. For HIV positive mothers with HIV positive infants, breastfeeding to twenty-four months was advised. Prior to 2007, there does not appear to have been a national breastfeeding policy for PMTCT. Evidence from Ndola city (Rutenberg et al 2003) suggests clinics may have offered advice similar to the 2007 National Protocol Guidelines. However, evidence from the same study suggests that breastfeeding advice varied across health workers within a given clinic.[12]

The expansion of antiretrovirals for PMTCT began in the early 2000s. In the capital city, Lusaka, nine antenatal clinics offered PMTCT drugs in 2002 and by January 2004 all twenty-four antenatal clinics in Lusaka city offered PMTCT drugs (Stringer et al 2008). The Center for Infectious Disease Research in Zambia (CIDRZ), in collaboration with the Elizabeth Glaeser Pediatric AIDS Foundation, has supported PMTCT in four of Zambia's nine provinces: Eastern, Lusaka, Southern, and Western (Elizabeth Glaser Pediatric AIDS Foundation 2011). Through the Zambia Prevention, Care, and Treatment Partnership (ZPCT), Family Health International (FHI) has supported PMTCT in the other five provinces: Northern, Luapula, Copperbelt, Central, and Northwestern (Torpey et al 2010). Single-dose nevirapine (NVP) was the main prophylaxis in the early years of the Zambian PMTCT program and zidovudine (ZDV) (also known as azidothymidine (AZT)) and NVP in the later years of the program (Stringer et al 2003, Stringer et al 2005, Ministry of Health 2007, Ministry of Health 2010).[13]

Figure 2 shows the expansion of PMTCT in Zambia by year of introduction.[14] The figure

[12] Goldstein et al (2010) report a similar finding at an antenatal clinic in Western Kenya.

[13] During the period examined in this analysis, single-does NVP was a common prophylaxis: among HIV positive pregnant women receiving PMTCT in low-and-middle-income countries in 2007, 49 percent received single-dose NVP (WHO 2010a).

[14] In Section 3, I describe in more detail the data I use to construct this figure. Official statistics on the number of locations offering PMTCT services are often different. For example, 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 [sic] in 2005, 307 [sic] in 2006, and 678 [sic] 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." In contrast, my data indicate 90 health clinics had

also displays district-level population density and the main transportation routes. Higher HIV prevalence and higher population densities in urban areas mean that the average total cost of preventing mother-to-child transmission should be lower in urban areas. Consistent with this observation, PMTCT expansion was initially concentrated in the main urban areas in Zambia (e.g., Kitwe, Lusaka, and Ndola) and later grew to rural areas along the main transportation network.

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).

Evidence on the PMTCT cascade suggests that the expansion of access to PMTCT translated into increased use. Nationally representative 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 2). 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 2). 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, administrative data indicate that 65 percent of pregnant women in 2007 took a HIV test during an ANC visit (UNAIDS Annex 3).

The time series on PMTCT expansion and infant mortality suggests that this scale-up may have generated a substantial reduction in child mortality. Figure 3 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 reduction in infant mortality appears to precede the period of most rapid PMTCT expansion in terms of cumulative number of PMTCT sites. However, as seen in Figure 2, PMTCT expansion occurred earlier and with greater intensity in urban areas, suggesting

introduced PMTCT by the end of 2003, 372 health clinics had introduced PMTCT by the end of 2005, and 582 clinics had introduced PMTCT by the end of 2007. At the moment, it is not possible to reconcile these differences. However, the official statistics are puzzling because the number of sites offering PMTCT increased tenfold between 2005 and 2007, whereas the number of pregnant women receiving antiretroviral prophylaxis less than tripled.

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 of PMTCT sites.

The results of a simple analysis of child mortality rates in locations receiving PMTCT before and after the local introduction of PMTCT are consistent with the evidence presented in Figure 3. Table 1 provides mortality rates at 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. Locations receiving PMTCT appear to have had slightly lower child mortality rates than places not receiving PMTCT, even prior to local PMTCT introduction. In locations ever receiving PMTCT, the introduction of PMTCT was associated with approximately a 2 percentage point (or 20 percent) reduction in age 0-12 months and age 0-18 months mortality (significant at the 1 and 5 percent levels, respectively). Although age 0-6 month and age 0-24 month mortality rates show some evidence of a reduction associated with local PMTCT introduction, the magnitude of this association is relatively small and statistically insignificant. One explanation for this phenomenon is that HIV may be more likely to kill infants at younger ages (i.e., less than 24 months) and few infants may die of HIV in the first six months of life.

3 Data

3.1 Health facilities data

I collected retrospective data on the month and year each health facility began offering each of the three main HIV/AIDS services: PMTCT, antiretroviral therapy (ART), and voluntary counseling and testing (VCT). The 2006 Japanese International Cooperation Agency (JICA) Health Facility Census (HFC) surveyed each health clinic and hospital in Zambia and recorded the exact latitude and longitude of each health site. To augment these data, I arranged for each clinic to be re-surveyed to provide information on the month and year (if any) it began offering each of the three main HIV/AIDS services. This process effectively began in June of 2008 so this retrospective panel provides comprehensive information on the expansion of HIV/AIDS services in Zambia through the middle of 2008.[15]

[15]Service interruptions (e.g., because of ARV shortages or health worker absence) mean that PMTCT may not have been continuously available at all of these clinics from the local introduction date onward. However, this should only work against the regression analysis yielding any estimate effect of local PMTCT availability on child mortality and related outcomes. The fact that I find a large and statistically significant effect suggests that the behavioral response to any service interruptions was not large enough to outweigh the effect of the documented service availability.

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 measures of child death 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 2 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 0.066 corresponds to a 6 month mortality rate of 66 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.[16] 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 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.[17]

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 2 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.[18]

[16] To identify the centroids of the SEA of residence of respondents in the 2001 DHS, I use a digitized census map provided 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.

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

[18] 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.

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 spatial 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 time-invariant and many time-varying unobservable characteristics affecting child mortality that are associated with the location of PMTCT sites.

The primary regression equation is:

$$\begin{aligned} childdied_{ijt} = \alpha_1 PMTCT_{ij(t-9)} + \alpha_2 PMTCTever_{ij} + X_{ijt}^{'}\Gamma \\ + \eta_j + \delta_t + t\mu_j + tPMTCTever_{ij} + \lambda_{ij} + \epsilon_{ijt} \end{aligned} \quad (1)$$

where $childdied_{ijt}$ is an indicator for child death by a given age (e.g., 12 months) for female respondent i residing in district j in month t (e.g., January 2007). $PMTCT_{ij(t-9)}$ 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. X_{ijt} is a vector of individual-level demographic controls (i.e., five-year age group indicator variables, indicator variables for primary/secondary school completion, and an indicator variable for married). η_j are district fixed effects and δ_t are month times year fixed effects. $t\mu_j$ are district-specific linear time trends and $tPMTCTever_{ij}$ is an additional linear trend for locations ever receiving PMTCT. λ_{ij} are year of local PMTCT introduction fixed effects. As in a standard difference-in-differences empirical strategy, I interpret α_1 as the causal effect of local PMTCT availability on fertility.[19]

My primary regression specification treats a respondent as being near a health clinic if the respondent lives within 20 kilometers of the nearest health clinic. Stekelenburg et al (2004) find that maternal health care usage declines substantially at distances greater than a two-hour walk. Likewise, 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). In alternative specifications, I relax the restrictions that the local introduction of PMTCT has the same effect on behavior 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.

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

There are over 300 SEAs in the 2001 DHS and in the 2007 DHS so standard asymptotic tests are appropriate (Cameron et al 2008).

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 regress an indicator variable for completing the step on the full set of controls indicated in Equation (1). 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.

For each step, the point estimate suggests that local PMTCT availability may have increased the likelihood of completing the step. However, the estimated effect is only statistically significant in the "offered test" regression. Because the first step in the PMTCT cascade is virtually universal in Zambia (even prior to the local introduction of PMTCT), it is reasonable to believe that local PMTCT availability did not increase the likelihood of completing this step. Nonetheless, it is somewhat surprising that local PMTCT availability did not increase the number of ANC visits; presumably being diagnosed as HIV positive at a clinic offering PMTCT would induce additional visits. Similarly, it is surprising that local PMTCT availability did not increase the likelihood that the respondent accepted the test. One explanation for the lack of statistical significance is the very small sample size in this regression.[20] As shown in Column (5), local PMTCT availability may have increased the likelihood that a health worker discussed family planning with the respondent during her ANC visit, suggesting that family planning may have been bundled with antiretroviral drugs for

[20]There are two reasons for the small sample size in this regression. First, the equation 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.

prevention of mother-to-child transmission. However, the coefficient is not statistically significant at conventional levels. It is not clear what to expect because family planning was not formally included in 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 reduced child mortality rates. Estimates of the effect of local PMTCT availability on child mortality rates appear in Table 4. 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. Adding additional controls (e.g., in Column (2), I include five-year age group indicator variables for the mother's age, indicator variables for primary and for secondary school completion, and an indicator variable for married), does not substantially affect the point estimate or the associated standard error. One explanation for the lack of an effect of local PMTCT availability on 0-6 month mortality is that infant HIV/AIDS mortality may be higher at slightly older ages, after HIV has had a chance to progress to AIDS.

In Panel B, I examine the effect on child death by 12 months of age. The point estimate from the regression with no additional controls (i.e., Column (1)) suggests that the local introduction of PMTCT reduced 0-12 month mortality by 2.1 percentage points (significant at the 1 percent level), or roughly twenty percent compared to the mean 12 month mortality rate. In Column (2), I include individual level demographic controls and in Column (3) I also include district and month times year fixed effects. To address concerns about differential linear trends between locations receiving PMTCT and locations never receiving PMTCT, in Column (4) I include district-specific linear trends and a separate linear trend for locations ever receiving PMTCT. Finally, in Column (5) I include indicator variables for the year in which the respondent's location received PMTCT. Throughout the estimated effect of local PMTCT availability on 0-12 month child mortality remains as more than a 2 percentage point reduction and is always statistically significant at the 1 percent level.

Panel C presents the effect on child death by 18 months of age. Throughout the five different

specifications, local PMTCT availability is associated with at least a 1.7 percentage point reduction in 0-18 month child mortality (significant at at least the 10 percent level). However, the estimated effects are slightly smaller in magnitude and less precisely estimated at 18 months than at 12 months. One explanation for this is that peak infant mortality due to HIV/AIDS may occur closer to 12 months than to 18 months.

In Panel D, I examine the effect on child death by 24 months of age. The sign on "PMTCT within 20km" remains negative. However, it is no longer statistically significant and is roughly one-half to two-thirds the magnitude of the point estimates in Panels B and C. Although local PMTCT availability may have reduced mortality among children at risk of acquiring HIV, it does not appear to have significantly reduced 0-24 months mortality. In general, this pattern of declining point estimates on either side of 0-12 month child death is consistent with peak infant mortality due to HIV/AIDS occurring around 12 months of age.

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 respondent residing closer to the clinic where PMTCT is introduced. In Table 5 I allow the effect of local PMTCT introduction 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 that PMTCT availability reduced child mortality rates in a region as far as 20 kilometers from the PMTCT site, but did not affect mortality at a distance greater than 20 kilometers. Although the point estimate on "PMTCT within 30km" is negative in Columns (1)-(3), it is statistically insignificant. Moreover, in Columns (4) and (5) the point estimate becomes an imprecisely estimated zero. This suggests that the introduction of PMTCT a health clinic between 21 and 30 kilometers of the respondent did not affect the likelihood of the death of the respondent's child. In contrast, the point estimate on "PMTCT within 20km" is negative, large, and statistically significant across most of the specifications. These point estimates suggest that the availability of PMTCT within 20 kilometers reduced child death by 12 months by between 2.2 and 2.8 percentage points. However, the estimates for "PMTCT within 20km" in Table 4 are less precise than those in the baseline specification and the point estimate is no longer statistically significant in the regression specification with just the individual level controls and the geographic and time fixed effects.

Perhaps surprisingly, the results do not suggest that closer proximity conditional on living with 20 kilometers of a PMTCT site mediates the effect of PMTCT availability on child mortality.

Specifically, the point estimate on "PMTCT within 10km" is an imprecisely estimated zero. Thus, individuals residing within 10 kilometers of a PMTCT site experience the same reduction in infant mortality as individuals residing with 20 kilometers of a PMTCT site. One explanation for this finding is that my measure of local PMTCT availability measures the true spatial availability with error, presumably because I use GPS coordinates of the centroid of the Statistical Enumeration Area (SEA) of residence as the location of the household (or, in the 2007 DHS, the GPS coordinates with the randomly drawn vector of length 0-10 kilometers) rather than the exact GPS coordinates of the household.[21]

5.2.3 Timing

This section explores the dynamic effects of local PMTCT availability. To do so, I allow for an additional effect of local PMTCT availability in locations where PMTCT has been available at least 36 months. Table 6 presents the results of this exercise. Regardless of which controls I include, the results paint a clear picture. Local PMTCT reduced infant mortality by approximately 2 percentage points in the short term and this effect did not differ substantially in the medium term. Although the additional effect of local PMTCT availability in locations where it has been available at least 36 months is negative and (in the specification with the full set of controls) approximately one-half of the magnitude of the short term effect, it is not statistically significant. If the effectiveness of PMTCT programs increases with duration in a local area, then these data are not rich enough to identify this effect.

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. 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 this approach yields a reasonable (albeit noisy) measure of the likelihood a respondent was HIV positive.

Panel A in 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 district fixed effects requires substantial caution because the measure of HIV prevalence is highly correlated by construction with five year age group and district of residence. Thus, although the point estimate on the PMTCT availability term interacted with HIV prevalence is positive in Columns (1) and (2), this is likely

[21] Data on the exact GPS coordinates of DHS respondents are unavailable.

a spurious correlation driven by the method used to construct the measure of HIV prevalence. In Columns (3) through (5), where I control for these important omitted variables, the point estimates suggest that the effect of local PMTCT availability on child mortality was greater among respondents in higher HIV prevalence groups. Although the interaction term is never statistically significant, the point estimate on the interaction term ranges from roughly the same magnitude as the main effect (i.e., "PMTCT within 20km") to nearly three times the magnitude of the main effect.

In Panel B of Table 7, I replace the continuous measure of HIV prevalence with an indicator variable equal to one if the respondent is in a demographic group with HIV prevalence at or above the median level. Again, substantial caution should be used in interpreting the regression estimates in Columns (1) and (2) because these specifications do not control for five year age group or province of residence, variables that are correlated by construction with the measure of HIV prevalence. The results in Columns (3), (4), and (5) paint a slightly less clear picture than those in Panel A. Although the interaction term is negative in Columns (4) and (5), it is positive in Column (3) and it is never statistically significant. However, a joint test of the statistical significance of the main effect (i.e., "PMTCT within 20km") and the interaction term indicates that the joint effect for respondent's in demographic groups with HIV prevalence at or above the median level is statistically significant at (at least) the 5 percent level.

6 Conclusion

After thirty years of struggling to stem the spread of HIV/AIDS, the discovery of antiretroviral drugs for HIV prevention appears to be a major breakthrough (Padian et al 2008, Padian et al 2011). Clinical studies indicate antiretroviral drugs given to mothers and their newborn infants may virtually eliminate HIV transmission (Dabis and Ekpini 2002, Canning 2006). However, little-to-no evidence exists on the effectiveness of these interventions at scale.

I examine the effect of prevention of mother-to-child transmission of HIV (PMTCT) expansion on all-cause child mortality in Zambia. To do so, I used a geocoded census of all health facilities in Zambia to construct a monthly panel documenting the nationwide expansion of PMTCT. Data on child mortality in areas receiving PMTCT before and after they received PMTCT, as well as in areas never receiving PMTCT, come from the birth history modules in the 2001 and 2007 DHS.

A variety of empirical specifications point toward the same conclusion: the local availability of PMTCT appears to have reduced all-cause infant mortality by approximately 2 percentage points (or roughly 20 percent). These estimates suggest that PMTCT expansion accounted for roughly one-quarter of the decline in infant mortality in Zambia between 2000 and 2007. More generally, these results suggest that PMTCT may be the first HIV prevention intervention that has succeeded at scale in Sub-Saharan Africa. However, further research on the epidemiological and

behavioral effects of PMTCT is required. Moreover, several recent innovations in HIV prevention (e.g., antiretroviral therapy to prevent the horizontal transmission of HIV or male circumcision for HIV prevention) may prove to be successful at reducing HIV transmission at scale.

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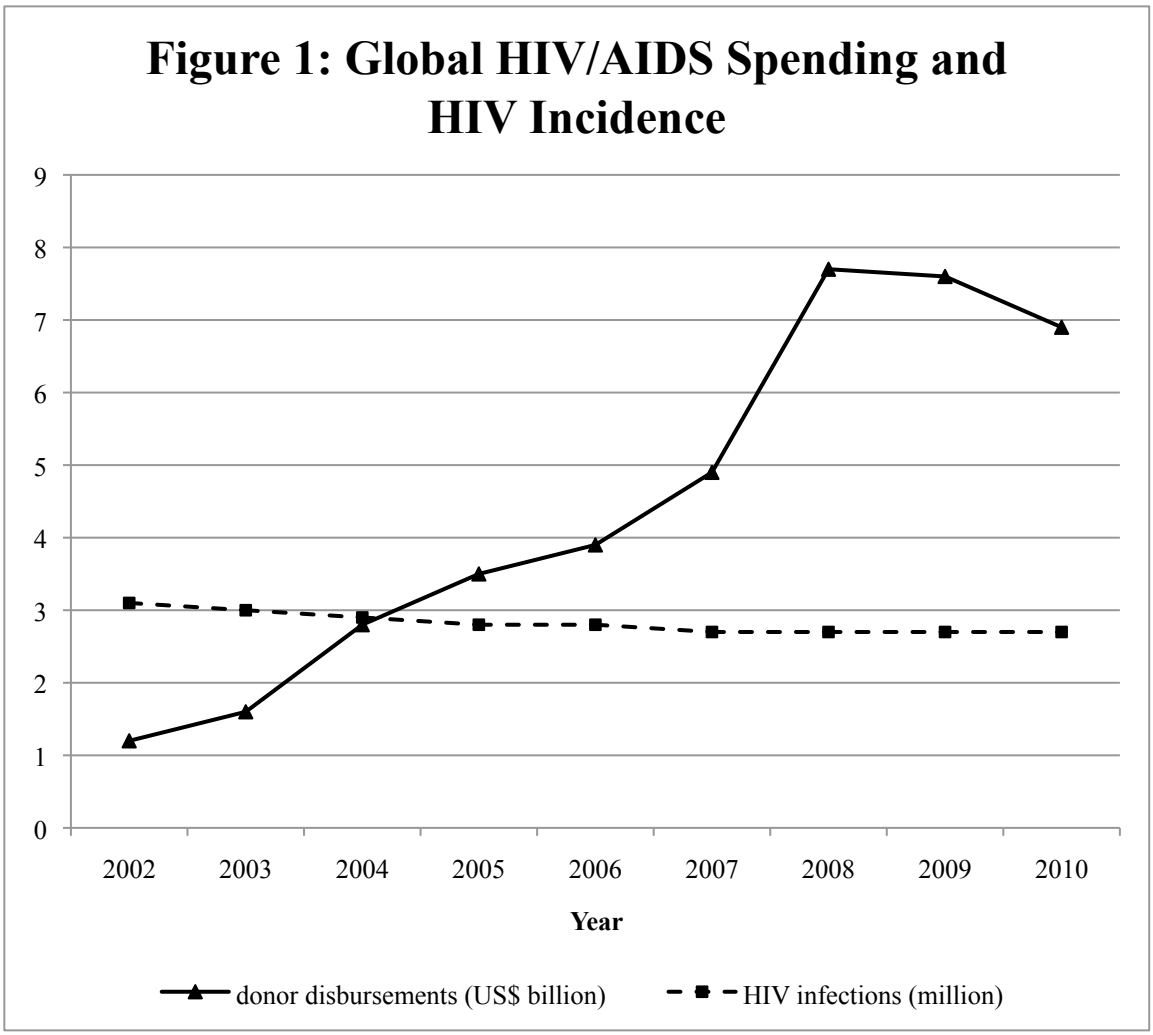
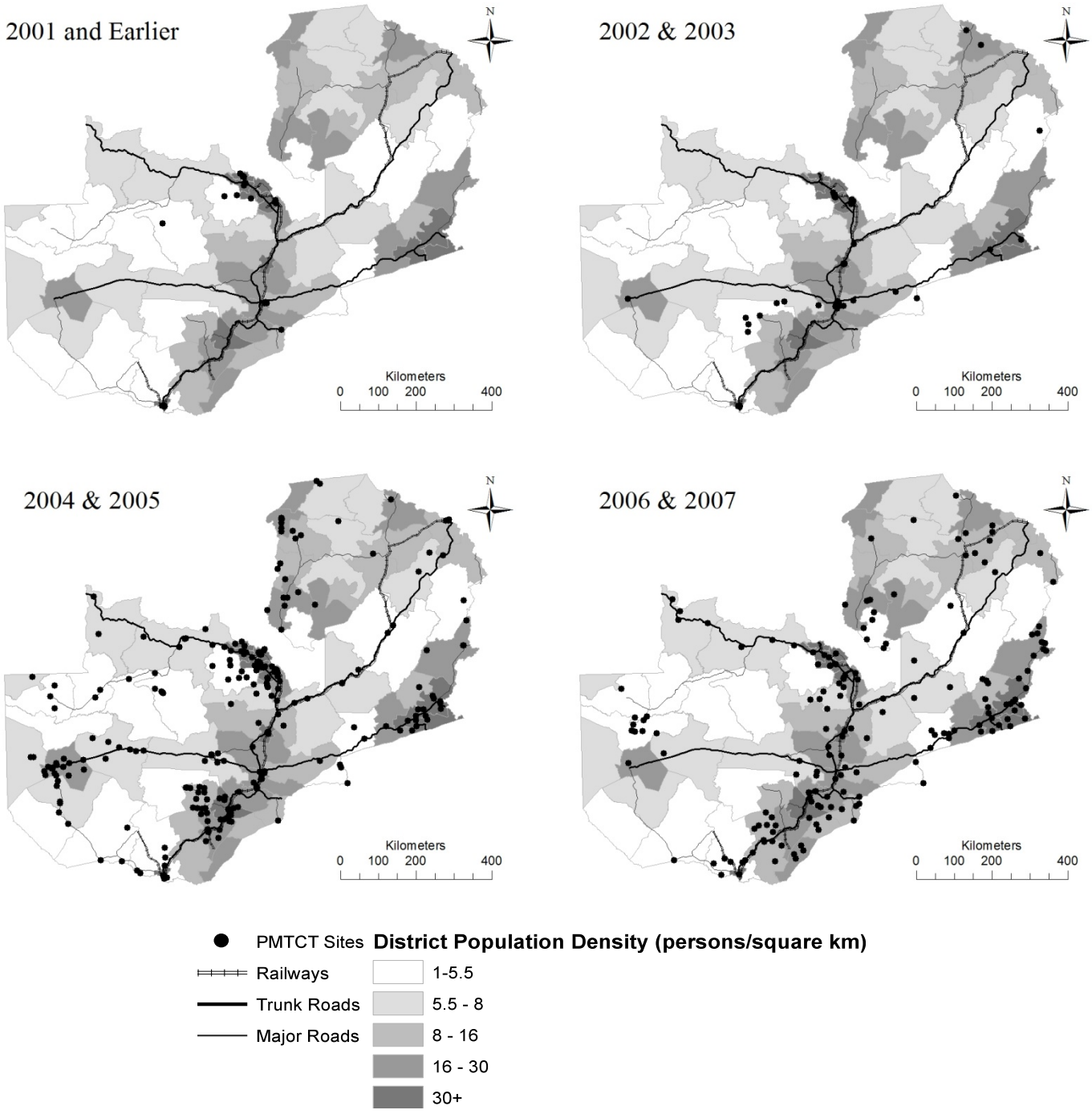


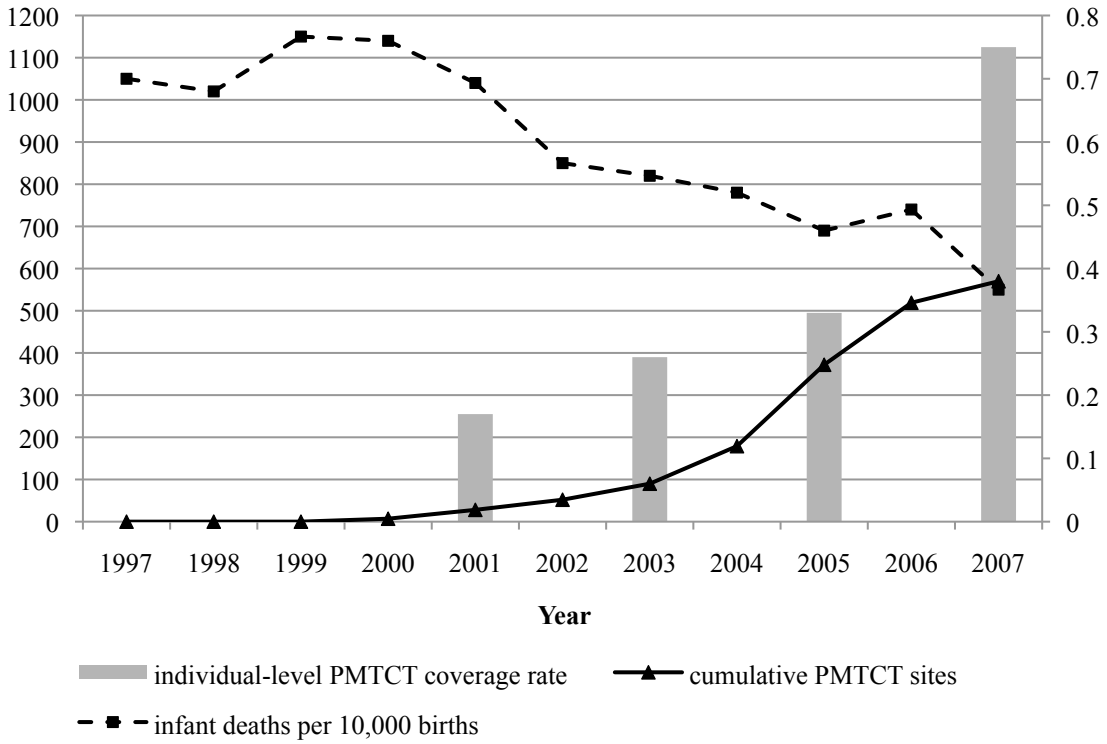
Notes: Data on donor disbursements come from: Kates, Jennifer, Adam Wexler, Eric Lief, Carlos Avila, and Benjamin Gobet. 2011. Financing the Response to AIDS in Low- and Middle- Income Countries: International Assistance from Donor Governments in 2010. The Henry J. Kaiser Family Foundation and UNAIDS, August 2011. Data on HIV infections come from: WHO. 2011. Global HIV/AIDS Response: Epidemic Update and Health Sector Progress Towards Universal Access. World Health Organization.

Figure 2: PMTCT Sites by Year of Service Initiation



Notes: Data on the latitude and longitude of health facilities come from the 2006 Japanese International Cooperation Agency (JICA) Health Facilities Census (HFC). Data on the month and year PMTCT was introduced at a given facility come from the augmented 2006 JICA HFC. Data on transportation routes come from the Zambia Central Statistical Office (CSO). Data on district population levels come from the 2000 Zambia Census of Population and Housing.

Figure 3: 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.

Table 1: Local PMTCT Introduction and Child Mortality

Died by:	6 months	12 months	18 months	24 months
	(1)	(2)	(3)	(4)
Never received	0.076	0.108	0.112	0.138
Before local introduction	0.064	0.097	0.105	0.125
After local introduction	0.058	0.076	0.087	0.117
Change associated with local introduction	-0.006	-0.022***	-0.018**	-0.008
Observations	17,426	16,070	14,730	13,399

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 2: Descriptive Statistics on Child Mortality and PMTCT Cascade

	mean	standard deviation	observations
	(1)	(2)	(3)
Child mortality			
Died by 6 months	0.066	0.249	18,131
by 12 months	0.098	0.298	16,695
by 18 months	0.107	0.309	15,277
by 24 months	0.128	0.334	13,865
PMTCT cascade			
Visit ANC in 2001	0.94	0.25	2,087
in 2003	0.95	0.22	656
in 2005	0.93	0.25	625
in 2007	0.93	0.25	2,053
Multiple ANC visits in 2001	0.90	0.30	1,469
in 2007	0.94	0.24	1,451
Offered HIV test in 2001	0.22	0.42	1,952
in 2003	0.15	0.36	624
in 2005	0.26	0.44	583
in 2007	0.57	0.50	1,911
Accepted HIV test in 2003	0.44	0.50	93
in 2005	0.62	0.49	154
Other			
Clinic discussed family planning in 2001	0.43	0.50	1,606
in 2007	0.59	0.49	1,156
HIV prevalence	0.164	0.091	19,195

Notes: Data on child mortality come from birth history modules in the 2001 and 2007 DHS survey rounds. 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 to 6 months of age. Died by 12 months, 18 months, and 24 months are defined similarly. Data on the steps in PMTCT cascade come from the 2001 and 2007 DHS survey rounds and the 2003 and 2005 ZSBS survey rounds. Visit ANC is an indicator variable equal to one if the respondent visited an antenatal clinic at least once during a pregnancy in the twelve months leading up to the interview date and zero if the respondent did not visit an antenatal clinic during any pregnany in the twelve months leading up to the interview date. Multple ANC visits is an indicator variable equal to one if the respondent visited an antenatal clinic more than once during a pregnancy in the twelve months leading up to the interview date and zero if the respondent did not visit an antenatal clinic more than once during a pregnancy in the twelve months leading up to the interview date. Offered HIV test is an indicator variable equal to one if the respondent reported being offered a HIV test during a visit to an antenatal clinic during a pregnancy in the twelve months leading up to the interview date and equal to zero if the respondent reported not being offered a HIV test during any such visit. Accepted HIV test is an indicator variable equal to one if the respondent reported accepting the result of a HIV test administered during an antenatal clinic visit during a pregnancy in the twelve months leading up to the interview date and equal to zero if the respondent reported not accepting the results of a HIV test administered at an antenatal clinic during a pregnancy in the twelve months leading up to the interview date. Clinic FP is an indicator variable equal to one if the respondent reported having a health worker discuss family planning during a visit to an antenatal clinic for a pregnancy in the twelve months leading up to the interview date and equal to zero if the respondent reported not having a health worker discuss family planning during a visit to an antenatal clinic for a pregnancy in the twelve months leading up to the interview date. 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.

Table 3: Effect of Local PMTCT on PMTCT Cascade

Dependent variable:	visit ANC	multiple ANC visits	offered test	accepted test	clinic discussed family planning
	(1)	(2)	(3)	(4)	(5)
PMTCT within 20km	0.022	0.023	0.101**	1.405	0.072
	(0.024)	(0.032)	(0.045)	(4.766)	(0.069)
Individual level controls	YES	YES	YES	YES	YES
District and month times year fixed effects	YES	YES	YES	YES	YES
Linear trends	YES	YES	YES	YES	YES
PMTCT expansion year fixed effects	YES	YES	YES	YES	YES
Observations	5,085	2,764	4,754	220	2,598

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 accepted the HIV test comes from the 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. 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)
Panel A: Died by 6 months					
PMTCT within 20km	-0.006	-0.006	-0.006	-0.007	-0.006
	(0.006)	(0.006)	(0.007)	(0.007)	(0.007)
Individual level controls	NO	YES	YES	YES	YES
District and month times year fixed effects	NO	NO	YES	YES	YES
Linear trends	NO	NO	NO	YES	YES
PMTCT expansion year fixed effects	NO	NO	NO	NO	YES
Observations	17,373	17,373	17,373	17,373	17,373
Panel B: Died by 12 months					
PMTCT within 20km	-0.021***	-0.021***	-0.023***	-0.027***	-0.025***
	(0.007)	(0.007)	(0.008)	(0.008)	(0.008)
Individual level controls	NO	YES	YES	YES	YES
District and month times year fixed effects	NO	NO	YES	YES	YES
Linear trends	NO	NO	NO	YES	YES
PMTCT expansion year fixed effects	NO	NO	NO	NO	YES
Observations	16,017	16,017	16,017	16,017	16,017
Panel C: Died by 18 months					
PMTCT within 20km	-0.017**	-0.017*	-0.017*	-0.023**	-0.021**
	(0.008)	(0.009)	(0.010)	(0.010)	(0.010)
Individual level controls	NO	YES	YES	YES	YES
District and month times year fixed effects	NO	NO	YES	YES	YES
Linear trends	NO	NO	NO	YES	YES
PMTCT expansion year fixed effects	NO	NO	NO	NO	YES
Observations	14,679	14,679	14,679	14,679	14,679
Panel D: Died by 24 months					
PMTCT within 20km	-0.008	-0.006	-0.007	-0.014	-0.015
	(0.010)	(0.010)	(0.012)	(0.012)	(0.012)
Individual level controls	NO	YES	YES	YES	YES
District and month times year fixed effects	NO	NO	YES	YES	YES
Linear trends	NO	NO	NO	YES	YES
PMTCT expansion year fixed effects	NO	NO	NO	NO	YES
Observations	13,354	13,354	13,354	13,354	13,354

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. 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 12 months				
	(1)	(2)	(3)	(4)	(5)
PMTCT within 10km	0.003	0.003	-0.001	0.001	-0.001
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
PMTCT within 20km	-0.022*	-0.022*	-0.022	-0.028*	-0.024*
	(0.013)	(0.013)	(0.014)	(0.014)	(0.015)
PMTCT within 30km	-0.010	-0.010	-0.002	0.000	0.000
	(0.019)	(0.019)	(0.019)	(0.019)	(0.020)
Individual level controls	NO	YES	YES	YES	YES
District and month times year fixed effects	NO	NO	YES	YES	YES
Linear trends	NO	NO	NO	YES	YES
PMTCT expansion year fixed effects	NO	NO	NO	NO	YES
Observations	16,017	16,017	16,017	16,017	16,017

Notes: Data come from the 2001 and 2007 DHS survey rounds. Died by 12 months is an indicator variable equal to one if the child died before turning 13 months old. "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. 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 12 months				
	(1)	(2)	(3)	(4)	(5)
PMTCT within 20km	-0.021**	-0.021**	-0.022**	-0.025***	-0.023**
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
PMTCT within 20km at least 36 months	-0.001	0.000	-0.005	-0.010	-0.011
	(0.014)	(0.014)	(0.016)	(0.016)	(0.016)
P > F(PMTCT+PMTCT at least 36 months=0)	0.058	0.070	0.057	0.016	0.020
Individual level controls	NO	YES	YES	YES	YES
District and month times year fixed effects	NO	NO	YES	YES	YES
Linear trends	NO	NO	NO	YES	YES
PMTCT expansion year fixed effects	NO	NO	NO	NO	YES
Observations	16,017	16,017	16,017	16,017	16,017

Notes: Data come from the 2001 and 2007 DHS survey rounds. Died by 12 months is an indicator variable equal to one if the child died before turning 13 months old. "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. 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 12 months				
	(1)	(2)	(3)	(4)	(5)
Panel A: Continuous measure of HIV prevalence					
PMTCT within 20km	-0.023	-0.030	-0.019	-0.020	-0.015
	(0.022)	(0.021)	(0.023)	(0.023)	(0.023)
PMTCT within 20km * HIV prevalence	0.017	0.040	-0.016	-0.029	-0.043
	(0.091)	(0.091)	(0.095)	(0.095)	(0.096)
Individual level controls	NO	YES	YES	YES	YES
District and month times year fixed effects	NO	NO	YES	YES	YES
Linear trends	NO	NO	NO	YES	YES
PMTCT expansion year fixed effects	NO	NO	NO	NO	YES
Observations	16,017	16,017	16,017	16,017	16,017
Panel B: Binary measure of HIV prevalence					
PMTCT within 20km	-0.022	-0.027*	-0.027	-0.024	-0.020
	(0.016)	(0.016)	(0.017)	(0.017)	(0.018)
PMTCT within 20km * HIV prevalence median above	0.002	0.008	0.005	-0.004	-0.007
	(0.018)	(0.018)	(0.019)	(0.019)	(0.019)
P > F(PMTCT+PMTCT*HIV prevalence median above=0)	0.017	0.029	0.017	0.002	0.004
Individual level controls	NO	YES	YES	YES	YES
District and month times year fixed effects	NO	NO	YES	YES	YES
Linear trends	NO	NO	NO	YES	YES
PMTCT expansion year fixed effects	NO	NO	NO	NO	YES
Observations	16,017	16,017	16,017	16,017	16,017

Notes: Data come from the 2001 and 2007 DHS survey rounds. Died by 12 months is an indicator variable equal to one if the child died by 12 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. 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.