CAN AT-SCALE DRUG PROVISION IMPROVE THE HEALTH OF THE TARGETED IN SUB-SAHARAN AFRICA?

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ABSTRACT

The single largest item in the US foreign aid health budget is antiretroviral therapy (ART) for the treatment of HIV/AIDS. Many supply- and demand-side factors in sub-Saharan Africa could cause smaller than expected epidemiological effects of this at-scale drug provision. We provide what appears to be the first quasi-experimental evidence on the effect of at-scale drug provision in a poor country, using the phased rollout of ART in Zambia, a setting where approximately one in six adults are HIV positive. Combining anthropometric data from national household surveys and a spatially based triple-difference specification, we find that local ART introduction increased the weight of high HIV likelihood adult women. This finding from a clinically difficult setting suggests that the generalized challenges of scalability of ART for adult health in sub-Saharan Africa are surmountable.

KEYWORDS: foreign aid, health, HIV/AIDS, PEPFAR, targeting, Zambia
JEL CLASSIFICATION: H40, H51, I12, J13, O12

I. Introduction

The single largest item in the US foreign aid health budget is antiretroviral therapy (ART) for the treatment of HIV/AIDS (Moss 2008; Government Accountability Office 2010). The US President's Emergency Plan for AIDS Relief (PEPFAR) has funded the rapid nationwide scale-up of heavily subsidized ART distribution in much of sub-Saharan Africa (UNAIDS 2010), a region of the world where HIV/AIDS causes nearly one-third of mortality among those aged 15–59 (WHO 2011). Despite the central focus of global health policy on drug provision in sub-Saharan Africa, little quasi-experimental evidence exists about the total epidemiological effects of drug provision at scale on the targeted in this setting.[1] In this study we focus on Zambia, a country with one of the highest HIV/AIDS

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1 To the best of our knowledge, Jayachandran, Lleras-Muney, and Smith (2010), which examines the effect of sulfa drugs on health in the United States using a difference-in-differences regression approach, is the only other quasi-experimental evidence on the effects of drug provision at scale in any setting.

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prevalence rates in the world, and estimate the effect of the at-scale provision of ART on the health of likely HIV-positive women.

Even with large expenditures that have financed the rapid scale-up of heavily subsidized nationwide ART distribution in much of sub-Saharan Africa, many challenges remain that could lessen ART's effectiveness. Low overall health spending (WHO 2006a), inadequate infrastructure (WHO 2006a), high patient-health worker caseloads (WHO 2006a), weak incentives (Basinga et al. 2011), health worker absenteeism (Goldstein et al. 2012), and counterfeit drugs (Bate, Jin, and Mathur 2011; Björkman-Nyqvist, Svensson, and Yanagizawa-Drott 2012) have led to weak health systems (De Cock, El-Sadr, and Ghebreyesus 2011) that could inhibit ART effectiveness at scale. Further, demand-side barriers such as incomplete adherence could further impede success (Mills et al. 2014).

We conduct our study in Zambia, a particularly interesting context for at least two reasons. First, Zambia has one of the highest HIV prevalence rates in the world with roughly one in six adults in the country being HIV positive (Central Statistical Office et al. 2009). Second, Zambia was one of the 15 original PEPFAR focus countries and under PEPFAR I received substantial external support for ART provision and little support for the broader health sector.[2]

To identify the effects of at-scale ART provision on health, we use a difference-in-difference-in-differences (i.e., triple-difference) strategy. We combine typical spatial and temporal variation from the geographic location of all health facilities and the date when these facilities first distributed ART with a third difference, an individual's likely HIV status. This triple-difference specification allows us to identify the effect of the availability of ART net of any time-invariant or time-varying differences across regions.

Our data provide compelling evidence for a highly relevant question, but our HIV data are unfortunately not ideal. National surveys at the height of the epidemic, our pre-ART availability period, that include HIV testing are rare. Given the sensitivity of the question prior to the availability of ART and the desire to respect the confidentiality of respondents, the HIV test results cannot be linked to individual respondents of the first round of our household survey that was completed in 2001. Instead individual test results were anonymized at the age group, gender, urban or rural, province cell. Data anonymized using this method are the only data from this era that can be spatially linked to ART proximity in a high HIV prevalence country. We create a binary HIV approximation based on the cell-level averages. Additional information on our HIV measure appears in Section IV. Our empirical strategy appears to be the best feasible strategy for estimating the effect of ART expansion on the health of the targeted during the height of the epidemic.

2 Among the original 15 PEPFAR I focus countries with a high HIV prevalence, Zambia is unique in having national household surveys with an HIV testing module conducted before and after substantial ART expansion. Two countries that were not PEPFAR I focus countries—Lesotho and Zimbabwe—have high HIV prevalence and national household surveys with an HIV testing module conducted before and after (at least limited) ART expansion. In addition to not being among the original PEPFAR focus countries, Lesotho was unsuitable for our study because of limited ART expansion, and Zimbabwe was unsuitable because of other turmoil within the country that would have led to low external validity.

In order to address concerns related to our measurement of HIV status, we conduct two checks of our main estimates. One check relaxes the binary HIV specification of the main analysis to use the full, continuous measure as a likelihood of being HIV positive. A second check calibrates our estimates using results from efficacy studies of ART and body mass from other low-income settings.

We use respondent weight as a proxy for overall health status and respondent height as a placebo outcome. HIV-positive women clinically eligible for ART experience substantial weight loss because of the development of HIV into AIDS. Evidence from efficacy studies conducted in various developing countries found weight gains of 2.6 to 10.3 kilograms after 6 to 12 months of treatment (Médecins sans Frontières South Africa et al. 2003; Koenig, Le Andre, and Farmer 2004; Severe et al. 2005; Saghayam et al. 2007; Koethe et al. 2010; Thirumurthy and Graff Zivin 2012). Because of data availability, our analysis is limited to women aged 15–49.

Our empirical framework allows us to compare the changes in anthropometrics associated with the timing of local ART introduction for high HIV likelihood and low HIV likelihood individuals residing near and far from health facilities where ART was introduced. Our overall effect will include both direct and indirect effects of local ART introduction on high HIV likelihood women.

Our results indicate that local ART introduction improved the health of the targeted. We find that ART introduction within 10 kilometers of the respondent increased the weight of high HIV likelihood women by approximately 1.6 kilograms, or approximately one-sixth of a standard deviation. While this point estimate is smaller than some clinic-based studies that focused only on HIV-positive women, we approximate the effect on directly treated women of over 10 kilograms. Consistent with a causal interpretation of this main result, semiparametric triple-difference evidence indicates that our findings are not the result of a differential preintroduction trend. We also find evidence that the increase in weight was concentrated among women living within 10 kilometers of health facilities that distributed ART, and that local ART introduction did not affect height, a health outcome that should not be affected by receiving ART, further reinforcing a causal interpretation of our main result.

The estimated weight gain suggests a highly successful ART scale-up despite the many logistical and behavioral barriers that are often cited as limiting large public health campaigns in Africa (WHO 2006a; De Cock, El-Sadr, and Ghebreyesus 2011; Fauci and Marsten 2013).

Our paper makes a number of important contributions. First, we provide the first quasi-experimental evidence on the effect of the at-scale provision of adult ART. Second, to the best of our knowledge, this paper provides the first quasi-experimental evidence on the effects of drug provision at scale on adult morbidity in sub-Saharan Africa, complementing quasi-experimental evidence on the effects of sulfa drugs in the United States (Jayachandran, Lleras-Muney, and Smith 2010). Third, we have demonstrated that targeted health campaigns in sub-Saharan Africa can be successful despite health sector barriers.

More broadly, this paper contributes to the quasi-experimental literature in economics on the health effects of large, targeted government-run public health programs in poor countries (e.g., Miller, Pinto, and Vera-Hernández 2013; Gruber, Hendren, and Townsend

2014) and elsewhere (e.g., Finkelstein 2007; Card, Dobkin, and Maestas 2008, 2009; Almond, Hoynes, and Whitmore Schanzenbach 2011; Hoynes and Schanzenbach 2009; Hoynes, Page, and Stevens 2011; Finkelstein et al. 2012). Further, this paper contributes to the quasi-experimental literature on the health effects of HIV/AIDS spending in Africa (e.g., Bendavid et al. 2012), the nonexperimental literature on the direct health effects of ART provision at scale (e.g., Palella et al. 1998; Bor et al. 2013), the quasi-experimental literature on the indirect health effects of ART provision at scale (Lucas and Wilson 2013; Baranov, Bennett, and Kohler 2015), and the quasi-experimental literature on the behavioral effects of ART (e.g., Thirumurthy, Graff Zivin, and Goldstein 2008; Graff Zivin, Goldstein, and Thirumurthy 2009; McLaren 2010; de Walque, Kazianga, and Over 2012; Thirumurthy and Graff Zivin 2012; Friedman 2013; Baranov, Bennett, and Kohler 2015; Lucas and Wilson 2015).

Among existing quasi-experimental literature on HIV/AIDS spending, our paper is most closely related to Bendavid et al. (2012), yet differs in two key ways. First, we isolate the effects of ART availability on the health of the targeted instead of the effect of PEPFAR funding on all-cause adult mortality, the approach of Bendavid et al. (2012). While PEPFAR was not designed to strengthen health sectors broadly, the increase in spending could have increased aggregate demand or had other effects across adults regardless of HIV status.[3] These effects are, by design, included in their estimates, while we focus only on the health of the targeted, those who were HIV positive. Second, our triple-difference specification controls for both time-varying and time-invariant differences between locations that did and did not receive ART. Bendavid et al. (2012) use a difference-in-differences approach that relies on the standard parallel trends assumption and cannot control for time-varying differences between PEPFAR and non-PEPFAR countries or regions within a country with high or low PEPFAR take-up. Therefore, we are answering a different question using a methodology that can better control for potential time-varying heterogeneity.

The paper is organized as follows. Section II briefly describes antiretroviral therapy in sub-Saharan Africa. Section III explains the empirical strategy we use to identify the epidemiological effects of ART scale-up on the targeted. Section IV describes the household survey and health facilities census data. Section V presents the results. Section VI concludes.

II. Antiretroviral Therapy in Sub-Saharan Africa

The development of antiretroviral therapies has been called "one of the greatest . . . breakthroughs" in the fight against HIV/AIDS (Barre-Sinoussi 2011, 1). Antiretroviral drugs reduce the viral load and increase the general health of individuals living in the advanced stages of HIV (WHO 2006b).

Expanding access to antiretroviral therapy (ART) for HIV-positive individuals throughout much of sub-Saharan Africa has been a central component of US foreign

3 In Zambia, the focus of our study, between 2000 and 2008, HIV development assistance increased from US$10 million to US$250 million (Oomman, Bernstein, and Rosenzweig 2007; Resch et al. 2008), an increase from approximately US$1 per capita to US$25 per capita. This represented a substantial fiscal stimulus for a country with GDP per capita in 2007 of US$770 (World Bank 2013).

aid since the mid-2000s, shifting the focus away from cash transfers, investment in economic infrastructure, training, technical expertise, and small grants toward commodities (Tarnoff and Lawson 2011). At the time of our study, ART was the largest item in the US foreign aid health budget, and PEPFAR was the largest source of HIV/AIDS funding worldwide (Schneider and Garrett 2009). PEPFAR's initial funding targeted 15 focus countries, mostly in sub-Saharan Africa, to receive large-scale financial support. More than one-half of PEPFAR I spending was allocated to ART and care for ART patients (Moss 2008). While annual US spending on HIV/AIDS in international health increased from US$204 million in 2001 to US$3.3 billion in 2008, annual US spending on non-HIV international health only increased from US$1.3 billion to US$1.7 billion (Government Accountability Office 2010).

Zambia, the location for the current study, is a PEPFAR focus country having received between US$1 billion and US$1.4 billion for HIV/AIDS through PEPFAR by 2013 (Fan et al. 2013b, PEPFAR 2013). The Global Fund to Fight AIDS, Tuberculosis, and Malaria, the second largest HIV/AIDS donor in Zambia, has disbursed between US$270 million and US$500 million for HIV/AIDS (Fan et al. 2013a; Global Fund to Fight AIDS, Tuberculosis, and Malaria 2012). Other smaller donors are also operating in Zambia, combining to provide the final one-third to one-half of HIV/AIDS donor funding in Zambia (Oomman, Bernstein, and Rosenzweig 2007; Resch et al. 2008).

Prior to the authorization of PEPFAR in 2004, ART was virtually unavailable in Zambia. By 2007, the end of the period that we examine in this analysis, approximately one in five health facilities provided ART and nearly one-half of the Zambian population lived within 10 kilometers of an ART site.[4] In addition to providing ART, these clinics provided nutrition counseling to ART patients (Koethe et al. 2010). Thus, our estimates of the effect of local ART introduction on high HIV likelihood adult female health will be the combined effect of ART provided in conjunction with nutrition counseling.[5]

III. Empirical Strategy

Our primary empirical strategy is a difference-in-difference-in-differences (i.e., triple-difference) specification. We exploit spatial and temporal variation in exposure to ART expansion between two national household surveys (i.e., the 2001 and 2007 Demographic Health Surveys, DHS), as well as variation across individuals in the likelihood of being HIV positive.[6]

Intuitively, our triple-difference strategy creates a treatment group of women with high HIV likelihood who live near a health facility where ART was introduced by 2007 and who are surveyed in 2007. Women who satisfy none or only some of these conditions (e.g., women with high HIV likelihood who live near a health facility where ART was

4 In Section IV, we describe the data we use to make these calculations.

5 While this counseling likely enhanced the efficacy of ART, it was not substantial enough alone to account for our estimates of weight gain due to local ART introduction but could contribute to our relatively large estimates. Nutrition counseling frequently accompanies ART distribution.

6 We describe how we measure the likelihood of being HIV positive in Section IV.

introduced by 2007 but were surveyed in 2001) act as the control group. This method alleviates concerns about differential trends between HIV-positive and -negative women as well as about differential trends for locations that did and did not have clinics where ART was introduced prior to 2007. Empirically, this process is completed in a single triple-difference specification:

$$\begin{aligned} health_{ijt} = {} & \alpha_0 + \beta ART_j \times Year2007_t \times HIV_{ijt} \\ & + \alpha_1 ART_j + \alpha_2 Year2007_t + \alpha_3 HIV_{ijt} \\ & + \alpha_4 ART_j \times Year2007_t + \alpha_5 ART_j \times HIV_{ijt} + \alpha_6 Year2007_t \times HIV_{ijt} \\ & + Z'_{ijt}\Gamma + \eta_{district} + \delta_m + \varepsilon_{ijt} \qquad (1), \end{aligned}$$

where $health_{ijt}$ denotes the anthropometrics of female respondent i residing in Standard enumeration area (SEA) j and interviewed in month-year combination t, ART_j is an indicator variable equal to one if a health facility located near respondent i offered ART 12 months prior to the 2007 survey (i.e., an "ever ART" measure), $Year2007_t$ is an indicator variable equal to one if the respondent was surveyed in 2007, HIV_{ijt} is a binary measure that captures the respondent's likelihood of being HIV positive, Z'_{ijt} is a vector of individual- and household-level demographic controls (i.e., indicator variables for five-year age group, primary school completion, secondary school completion, urban residence, urban residence interacted with $Year2007_t$, local PMTCT availability, local VCT availability, and district fixed effects interacted with the $Year2007_t$ indicator variable[7]), δ_m are fixed effects for interview month, $\eta_{district}$ are district fixed effects, and ϵ_{ijt} is an idiosyncratic error term, allowed to be correlated within an SEA, the level at which local ART availability varies in our data.[8] We estimate all specifications using ordinary least squares (OLS) regressions. As our specifications control for time-varying differences between locations through the use of a set of district dummy variables interacted with $Year2007_t$ as well as concurrent HIV programs and lower-level interactions of the triple-difference regressor of interest, we interpret β as the causal effect of local ART introduction on the anthropometrics of HIV-positive adult females.[9]

In the baseline specification, we consider respondents within 10 kilometers of a health facility that provided ART as having ART locally available. As a specification check we test for a spatial gradient and find 10 kilometers to be a reasonable catchment approximation.

IV. Data

To undertake our analysis, we use repeated cross-sectional georeferenced national household surveys and a unique georeferenced HIV/AIDS services panel.

7 We include additional controls in the Robustness Section.

8 Because we have more than 300 SEAs in each of the two DHS surveys, standard asymptotic tests are appropriate (Cameron, Gelbach, and Miller, 2008).

9 Our triple-difference strategy identifies the effect of local ART on high HIV likelihood adult females net of any local ART effects shared by high HIV likelihood and low HIV likelihood adult females.

A. INDIVIDUAL-LEVEL DATA

Our individual survey data are the 2001 and 2007 Zambia Demographic Health Surveys (DHS), cross-sectional national household surveys.[10] These data contain adult female anthropometrics, basic demographic and socioeconomic information, geographic location, and HIV testing results. We use respondent weight as a proxy for overall health status and respondent height as a placebo outcome. While in a middle- or high-income country context the weight concern is often obesity, the opposite is true in Zambia. Women are more likely to be below healthy weight than overweight. Mean body mass index (BMI) in our 2001 sample is just over 21, not far from the minimum of the normal range of the BMI guidelines from the US National Institutes of Health. Further, HIV-positive individuals clinically eligible for ART experience substantial weight loss due to the development of HIV into AIDS. As documented in efficacy studies from various developing countries (Médecins sans Frontières South Africa et al. 2003; Koenig, Le Andre, and Farmer 2004; Severe et al. 2005; Saghayam et al. 2007; Koethe et al. 2010; Thirumurthy and Graff Zivin 2012), individuals clinically eligible for ART typically experience noticeable weight gain within 6 to 12 months of treatment, reversing much of the weight loss due to the development of HIV into AIDS.

Only women aged 15 to 49 at the time of the survey were both tested for HIV and weighed and measured. Therefore, we limit our sample to these individuals. For each respondent we calculate the approximate latitude and longitude of their dwelling from details on the location of the primary sampling unit centroids.[11]

Both the 2001 and 2007 Zambia DHS included HIV testing modules. Two issues guided the construction of the HIV measure, the individual's likely HIV status, that we use in the empirical specifications. First, because of privacy concerns, the 2001 HIV data were anonymized and cannot be linked with individuals in the household rosters. Instead for each individual tested, the result is accompanied by the individual's gender, age, urban/rural status, and province of residence. Second, the response rate for the HIV testing

10 Zambia conducted an additional round of the DHS in 2013 and 2014. We do not include these newer data for three reasons. First, when PEPFAR was reauthorized by the US Congress in 2008 and became PEPFAR II, the focus expanded and support was provided to the national health sectors more broadly. This expanded scope of PEPFAR could draw into question whether HIV services or expanded health services more broadly, which were correlated in timing and location with HIV services and could have differentially benefited HIV-positive individuals, increased the health of the HIV-infected population. Second, as PEPFAR's geographic scope increased, it started reaching smaller, more isolated clinics, those that were not in place prior to the start of ART expansion, leaving the potential for endogenous program placement. Third, the nationwide geocoded retrospective monthly panel on ART expansion was undertaken in 2008, documenting ART expansion from its beginnings through the end of 2007. A more recent panel similar in scope and detail is not available.

11 Some geographic imprecision is unavoidable with these data, potentially introducing attenuation bias. For the 2001 DHS, we use a digitized census map provided by the Zambia Central Statistical Office to locate the SEA centroid. Unfortunately, approximately 7 percent of SEAs were missing from the maps used for the 2001 data, resulting in the removal of respondents from these areas in our sample. The 2007 DHS provides approximate GPS locations for each SEA centroid. The exact coordinates are offset by adding a random vector with length drawn from a uniform distribution on 0 to 10 kilometers to maintain respondent privacy.

module was roughly 75 percent in each of the survey rounds. Therefore, we assign each individual a likelihood of being HIV positive measured as the HIV prevalence in the respondent's demographic group defined as the interaction of survey round, gender, five-year age group, urban/rural status, and province of residence.[12] Median HIV prevalence in the 2001 and 2007 Zambia DHS using this measure is 0.14, the 10th percentile is 0.03, and the 90th percentile is 0.35. Our primary regression specifications use an indicator variable to denote likely HIV status, equal to one if the respondent is in a demographic group with HIV prevalence at or above the median. This helps address concerns that HIV prevalence in a demographic group in our sample rarely exceeds 0.5, for example, yet approximately one in six individuals in our sample are HIV positive. As a robustness check, we also use a continuous measure of HIV prevalence in the demographic group.

B. HEALTH FACILITIES DATA

Our health facilities data were originally collected for Wilson (2015). In 2006, the Japanese International Cooperation Agency (JICA) Health Facility Census (HFC) recorded the latitude and longitude of each health facility in Zambia. To augment these data, we surveyed these clinics starting in 2008 to collect information on the month and year (if any) they began offering each of the three main HIV/AIDS services: ART, voluntary counseling and testing (VCT), and preventing mother to child transmission (PMTCT). This augmented HFC contains comprehensive information on the expansion of HIV/AIDS services in Zambia through the middle of 2008.

C. DESCRIPTIVE STATISTICS

Table 1 reports descriptive statistics by DHS survey round, likely HIV status, and location relative to a health facility that distributed ART. Six key facts emerge from this table. The first three are apparent when comparing the full sample in 2001 (column 1) to the full sample in 2007 (column 6). First, although ART was virtually unavailable to the general public in Zambia in 2001, ART availability was relatively widespread by 2007 with 43 percent of the 2007 sample within 10 kilometers of an ART clinic by 2007. Second, although adult female weight increased during this period, adult female height remained virtually unchanged. Third, education levels and urbanization have increased consistent with rapid development and growth in Zambia between 2001 and 2007.

A fourth fact comes from the comparison of high versus low HIV likelihood women (i.e., columns 2 and 3 in 2001 and columns 7 and 8 in 2007). High HIV likelihood women are taller, heavier, more educated, more urban, and more likely to have interacted with the health system as compared to low HIV likelihood women, consistent with existing evidence on the HIV-education gradient (Fortson 2008) and that HIV prevalence is higher among women in the middle of the age distribution who possess greater physical stature than younger or older women. Fifth, a comparison of columns 4 and 5 in 2001 and columns 9 and 10 in 2007 indicates that women who lived closer to locations where ART was introduced were also more likely to have these characteristics, consistent with ART

12 To maintain comparability across survey rounds, we apply this demographic group calculation to each survey round using survey-round-specific data.

TABLE 1. Descriptive statistics for adult female respondents in the 2001 and 2007 Demographic Health Surveys

Survey round:	2001					2007				
Subsample:	Full sample	High likelihood HIV+	Low likelihood HIV+	ART ever within 10 km	ART farther than 10 km	Full sample	High likelihood HIV+	Low likelihood HIV+	ART ever within 10 km	ART farther than 10 km
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
ART within 10 km	0.00	0.00	0.00	0.00	0.00	0.43	0.57	0.29	1.00	0.00
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.50]	[0.50]	[0.45]	[0.00]	[0.00]
Weight, kilograms	53.20	55.20	51.40	55.40	51.60	56.20	59.00	53.20	58.30	53.90
	[9.47]	[10.10]	[8.48]	[10.50]	[8.24]	[11.00]	[12.00]	[8.96]	[12.10]	[9.19]
Height, centimeters	157.50	158.50	156.50	158.30	156.90	157.60	158.70	156.40	158.40	156.80
	[6.38]	[6.24]	[6.38]	[6.27]	[6.40]	[6.82]	[6.62]	[6.83]	[6.77]	[6.79]
BMI	21.40	21.90	20.90	22.10	20.90	22.60	23.40	21.70	23.20	21.90
	[3.32]	[3.63]	[2.90]	[3.73]	[2.87]	[3.98]	[4.41]	[3.25]	[4.36]	[3.40]
BMI z-score	−0.16	−0.02	−0.29	0.02	−0.29	0.15	0.37	−0.08	0.32	−0.03
	[0.89]	[0.98]	[0.78]	[1.00]	[0.77]	[1.07]	[1.19]	[0.87]	[1.17]	[0.91]
Primary school completion	0.45	0.51	0.39	0.62	0.31	0.55	0.63	0.47	0.68	0.42
	[0.50]	[0.50]	[0.49]	[0.48]	[0.46]	[0.50]	[0.48]	[0.50]	[0.47]	[0.49]
Secondary school completion	0.06	0.09	0.04	0.11	0.02	0.11	0.18	0.04	0.17	0.04
	[0.24]	[0.28]	[0.19]	[0.32]	[0.14]	[0.31]	[0.38]	[0.20]	[0.38]	[0.21]
Urban	0.31	0.39	0.23	0.62	0.07	0.45	0.65	0.23	0.74	0.13
	[0.46]	[0.49]	[0.42]	[0.49]	[0.25]	[0.50]	[0.48]	[0.42]	[0.44]	[0.34]
Visited clinic in past 12 months	0.66	0.73	0.59	0.69	0.64	0.45	0.51	0.38	0.48	0.42
	[0.47]	[0.44]	[0.49]	[0.50]	[0.48]	[0.50]	[0.50]	[0.49]	[0.50]	[0.49]

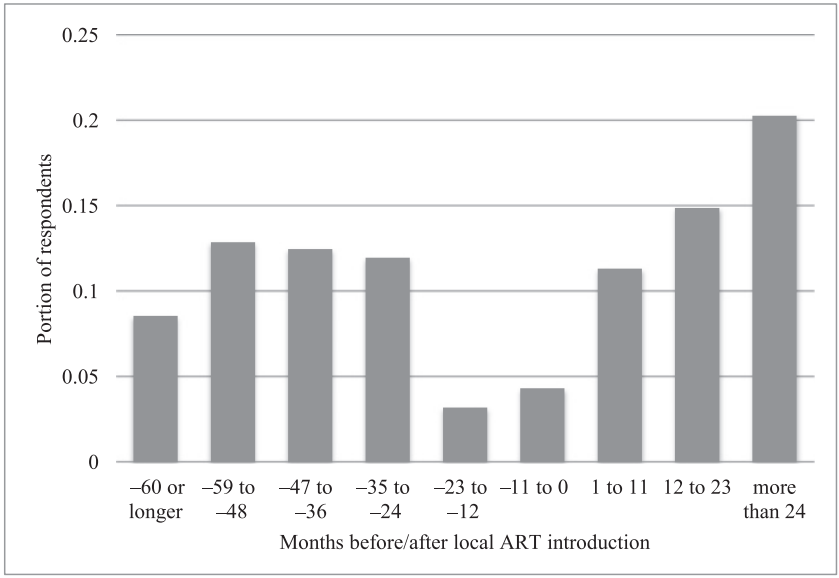
TABLE 1. *Continued*

Survey round:	2001					2007				
Subsample:	Full sample	High likelihood HIV+	Low likelihood HIV+	ART ever within 10 km	ART farther than 10 km	Full sample	High likelihood HIV+	Low likelihood HIV+	ART ever within 10 km	ART farther than 10 km
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Ever took an HIV test	0.09	0.11	0.07	0.13	0.05	0.41	0.52	0.29	0.50	0.31
	[0.28]	[0.31]	[0.26]	[0.34]	[0.23]	[0.49]	[0.50]	[0.45]	[0.50]	[0.46]
Age	26.90	29.40	24.40	26.40	27.20	27.90	30.80	24.80	27.50	28.30
	[8.20]	[6.52]	[8.86]	[7.94]	[8.38]	[9.22]	[7.82]	[9.55]	[9.21]	[9.22]
Likely HIV positive	0.17	0.27	0.07	0.19	0.15	0.17	0.26	0.07	0.21	0.12
	[0.14]	[0.13]	[0.04]	[0.15]	[0.13]	[0.12]	[0.10]	[0.04]	[0.14]	[0.09]
Observations	6,645	3,240	3,405	2,881	3,764	7,039	3,608	3,441	3,635	3,404

Data source: Data come from the 2001 and 2007 Zambia Demographic Health Surveys.

Notes: Entries are sample means. Standard deviations are in brackets. ART within 10 km is an indicator variable equal to one if a clinic located within 10 km of the respondent offered ART at least 12 months prior to the respondent's survey date.

FIGURE 1. Histogram of timing of local ART introduction relative to interview date



being introduced disproportionately in high HIV prevalence locations. Sixth, higher likelihood of being HIV positive and proximity to local ART introduction were associated with greater weight gains between 2001 and 2007, whereas these characteristics were not associated with substantial differences in changes in height.

To help illustrate variation in our data in the timing of local ART introduction relative to respondent interview date, Figure 1 plots a histogram of this variable. While the distribution is not uniform, for the majority of the 12-month event windows, each one contains at least 5 percent of the DHS respondents. Therefore, sufficient variation exists to investigate the pretreatment parallel trends assumption underlying our triple-difference approach, an assumption that we examine in more detail in Section V.D. Further, the distribution to the right of zero suggests that for many respondents ART was locally available long enough to generate epidemiological effects.

V. Results

A. EFFECT OF LOCAL ART ON ART CASCADE

Before turning to the analysis of respondent health, we examine the effects of local ART introduction on the "ART cascade," or the series of behavioral steps required to receive ART. The DHS data do not contain data on whether an individual was receiving ART at the time of the survey. Instead, Table 2 shows the estimated effect of local ART on two steps required to receive ART. First, the DHS asks whether the respondent visited a health

TABLE 2. Effect of local ART on ART cascade

Dependent variable:	Visited clinic	Ever tested
	(1)	(2)
ART ever within 10 km × Year 2007 × HIV+	0.013	0.073[b]
	(0.036)	(0.033)
Observations	13,881	13,797

Data source: Data come from the 2001 and 2007 Zambia Demographic Health Surveys.
Notes: All dependent variables are indicator variables. ART ever within 10 km is an indicator variable equal to one if a health clinic within 10 km of the respondent offered ART at least 12 months prior to the 2007 DHS. HIV+ is an indicator variable equal to one if the respondent is in a demographic group with HIV prevalence above the median. All specifications include the full set of controls, including lower-level triple-difference terms, indicated in equation 1. Parameters estimated using ordinary least squares (OLS) regression. Standard errors are in parentheses and are clustered by standard enumeration area (SEA). [a]significant at the 1 percent level, [b]significant at the 5 percent level, [c]significant at the 10 percent level.

clinic for themselves or their child in the 12 months preceding the survey. Column 1 contains the triple-difference coefficient estimate from equation 1 with an indicator variable for whether the respondent visited a clinic in the last 12 months as the dependent variable. As indicated by the coefficient estimate (and associated standard error) on the triple-interaction term, we do not find statistically significant evidence of an effect of local ART availability on whether the respondent visited a health clinic. The health clinic visit result should be interpreted with caution for at least two reasons. First, as shown in Table 1, there was a 21 percentage point decline between 2001 and 2007 in the proportion of female respondents visiting a health clinic, likely indicating an overall increase in maternal and/or child health that could mask any direct change in visit behavior due to ART receipt. Second, a routine visit to a health clinic for ART medication may not be considered a traditional clinic visit. Column 2 contains an analogous specification with an indicator variable equal to one if the respondent reported having ever been tested for HIV. The point estimate on the triple-interaction term suggests that local ART introduction increased the likelihood of the respondent having ever been tested for HIV by approximately 7 percentage points (statistically significant at the 5 percent level).

B. EFFECT OF LOCAL ART ON ADULT FEMALE ANTHROPOMETRICS

Prior to the estimation of equation 1 with anthropometrics as dependent variables, we present prima facie evidence of effect. Table 3 presents the average weight and average height within the component cells of the triple-difference comparison, effectively estimating equation 1 without covariates. The sample is divided by local ART availability, HIV status, and survey round, the three sources of variation in the triple difference.

As explained in Section IV, respondents with an above median likelihood of being HIV positive based on their demographic group (i.e., defined as the interaction of survey round,

TABLE 3. Adult female anthropometrics in Zambia by proximity to ART, HIV prevalence, and survey year

	Survey round		Differences		
	2001 (1)	2007 (2)	Single (3)	Double (4)	Triple (5)
Panel a: Weight, kilograms					
(1) ART ever within 10 km, high likelihood HIV+	56.78	60.65	3.87		
(2) ART ever within 10 km, low likelihood HIV+	52.90	54.29	1.39		
(3) Double difference				2.48	
(4) ART farther than 10 km, high likelihood HIV+	53.08	56.28	3.20		
(5) ART farther than 10 km, low likelihood HIV+	50.69	52.61	1.92		
(6) Double difference				1.28	
(7) Triple difference					1.20
Panel b: Height, centimeters					
(8) ART ever within 10 km, high likelihood HIV+	158.34	159.20	0.86		
(9) ART ever within 10 km, low likelihood HIV+	157.08	157.14	0.06		
(10) Double difference				0.80	
(11) ART farther than 10 km, high likelihood HIV+	158.30	158.19	−0.11		
(12) ART farther than 10 km, low likelihood HIV+	156.58	156.00	−0.58		
(13) Double difference				0.47	
(14) Triple difference					0.33

Data source: Anthropometric data come from the 2001 and 2007 Zambia Demographic Health Surveys.

Notes: Entries are sample means. ART ever within 10 km and ART farther than 10 km refer to ART availability at least 12 months prior to the 2007 DHS. High likelihood HIV+ and low likelihood HIV+ refer to whether HIV prevalence in the respondent's demographic group is above or below the median HIV prevalence demographic group, respectively.

gender, five-year age group, urban/rural status, and province of residence) are considered "high likelihood HIV+" in the table. In Table 3, column 1 contains the sample means from 2001 (prior to the availability of ART) and column 2 contains the analogous means from 2007 (after some locations had ART locally available).[13] Column 3 contains the differences

13 Although the sample means in column 1 indicate that individuals residing near locations where ART was subsequently introduced were slightly heavier than individuals residing in other locations, our triple-difference strategy addresses this heterogeneity. In particular, our triple-difference strategy identifies the causal effect of local ART introduction by further comparing high and low HIV likelihood individuals, addressing concerns about systematic differences in health by proximity to ART. In addition, as we demonstrate in Section V.D, our semiparametric triple-difference figure (i.e., Figure 2) reveals no differential pre-treatment trend in our triple-difference estimates.

TABLE 4. Effect of local ART on adult female weight and height

Dependent variable:	Weight (kg)	Height (cm)	BMI	BMI z-score
	(1)	(2)	(3)	(4)
ART ever within	1.619[b]	−0.008	0.624[b]	0.168[b]
10 km × Year 2007 × HIV+	(0.642)	(0.451)	(0.252)	(0.068)
Observations	13,684	13,668	13,662	13,662

Data source: Data come from the 2001 and 2007 Zambia Demographic Health Surveys.
Notes: ART ever within 10 km is an indicator variable equal to one if a health clinic within 10 km of the respondent offered ART at least 12 months prior to the 2007 DHS. HIV+ is an indicator variable equal to one if the respondent is in a demographic group with HIV prevalence above the median. All specifications include the full set of controls, including lower-level triple-difference terms, indicated in equation 1. Parameters estimated using ordinary least squares (OLS) regression. Standard errors are in parentheses and are clustered by standard enumeration area (SEA). [a]significant at the 1 percent level, [b]significant at the 5 percent level, [c]significant at the 10 percent level.

between these two means, a single difference. Column 4 contains the double difference between the single differences in the previous two rows of column 3. Column 5 displays the triple-difference estimate, effectively β from equation 1 without controls. The triple-difference estimate for weight in panel a suggests local ART availability increased the weight of HIV-positive women by approximately 1.2 kilograms or 2.3 percent of average female weight in 2001. The triple-difference estimate for height suggests local ART availability increased height by 0.33 centimeters, or approximately a 0.2 percent change relative to 2001. This substantial increase in weight without a corresponding change in height is consistent with the physiological effects of receiving ART.

Table 4 presents regression estimates of our primary coefficient of interest, the triple-difference parameter in equation 1.[14] Column 1 presents results with weight as the dependent variable and column 2 presents the analogous results with height as the dependent variable. The point estimate on the triple interaction in column 1 suggests that local ART introduction resulted in a weight gain of approximately 1.6 kilograms for women with above median HIV likelihood (statistically significant at the 5 percent level), or an increase of around 2.5 percent relative to mean weight in 2001. In contrast, column 2 shows that local ART availability appears to be associated with a statistically insignificant and small reduction in height of about 0.008 centimeters, or less than 0.1 percent of mean height in

14 Even though lower-level double- and single-difference terms are included in all regressions, the inclusion of a host of temporal and spatial controls (including their interactions) complicates their interpretation. Therefore, in order to avoid confusion, we report only the triple-difference parameter in our main tables. In the Online Appendix (http://www.mitpressjournals.org/doi/suppl/10.1162/ajhe_a_00105), we present results that display the lower-level triple-difference terms (e.g., the $Year2007_t$ times HIV_{ijt}). We discuss these results in the Online Appendix.

2001.[15] These relationships are what one would expect given the timing of ART availability and our focus on adults. Adults would have already reached their full stature prior to treatment, but improvements in health could translate into increased weight.

Columns 3 and 4 present results with body mass index and BMI z-score, respectively, as the dependent variables. The results confirm that local ART introduction was associated with an increase in weight-for-height and not just weight. They also place the effect size in context: local ART introduction was associated with an approximately 0.17 standard deviation increase in the body mass of high HIV likelihood women.

In addition to our wealth of controls, the strong finding for weight without a corresponding change in height bolsters our claim that ART availability has caused this change. First, generally improving health or nutrition over time would likely appear in both height and weight. Second, differential migration by larger HIV-positive individuals, while unlikely, does not appear to be driving the weight results. We provide additional evidence on migration in Section V.E. Third, given the positive correlation between HIV infection and education found in Fortson (2008), one could be concerned that ART has changed the sample selection, keeping people with a higher health endowment alive. The lack of estimated change in height makes this unlikely. Therefore, local ART at scale appears to have increased the health of the targeted.

Our coefficient of interest must be scaled in order to compare it to other studies. To place our estimates in context, studies in various developing countries found weight gains of 2.6 to 10.3 kilograms after 6 to 12 months of treatment, with almost all reporting at least a 5-kilogram increase within 6 months of treatment initiation (Koenig, Le Andre, and Farmer 2004; Severe et al. 2005; Saghayam et al. 2007; Koethe et al. 2010; Thirumurthy and Graff Zivin 2012). Of particular interest to the current study, Médecins sans Frontières South Africa et al. (2003) found in a clinic-based study in a previously untreated area in South Africa that ART initiation led to weight gains averaging 10 kilograms. Our data include some women whose disease had not progressed to the clinical stage. If 20 percent of HIV-positive women in our sample were clinically eligible for ART and one-half of these women accessed and received ART, then local ART availability should directly affect the health of approximately 10 percent of the local adult HIV-positive female population.[16] Therefore, the expected effect of local ART due to treatment alone, averaged across all HIV-positive adult women, those who were and were not eligible for treatment, is a roughly 1-kilogram increase in body mass, approximately two-thirds of our estimate. Recall that our estimate includes both the direct and the indirect effects of treatment. While not all HIV-positive women were clinically eligible for treatment, other studies have found that the availability of ART increased household maize production by increasing mental health even for those not under treatment, potentially accounting for the additional weight

15 The point values in Table 4 differ from the simple triple-difference calculations in Table 3 because the regression used for Table 4 includes the covariates in equation 1.

16 During the period examined in the current analysis, the World Health Organization (WHO) recommended initiating ART for HIV patients in WHO clinical stages "III" or "IV" and for HIV patients with CD4 counts between 200 and 350 cells/milimeter (WHO 2006b). Clinical practice appears to have largely followed these guidelines (Stringer et al. 2006).

TABLE 5. Spatial Heterogeneity in Effect of Local ART on Adult Female Weight

Dependent variable:	Weight (kg)
	(1)
ART ever within 10 km × Year 2007 × HIV+	1.883[b]
	(0.843)
ART ever within 20 km × Year 2007 × HIV+	−0.415
	(0.765)
Observations	13,684

Data source: Data come from the 2001 and 2007 Zambia Demographic Health Surveys.
Notes: ART ever within 10 km is an indicator variable equal to one if a health clinic within 10 km of the respondent offered ART at least 12 months prior to the 2007 DHS. ART ever within 20 km is defined analogously using a 20-km cutoff. HIV+ is an indicator variable equal to one if the respondent is in a demographic group with HIV prevalence above the median. All specifications include the full set of controls, including lower-level triple-difference terms, indicated in equation 1. Parameters estimated using ordinary least squares (OLS) regression. Standard errors are in parentheses and are clustered by standard enumeration area (SEA). [a]significant at the 1 percent level, [b]significant at the 5 percent level, [c]significant at the 10 percent level.

gain we observe (Baranov, Bennett, and Kohler 2015). Although our estimated effects of local ART introduction are relatively large, they are consistent with a highly successful ART campaign.

C. SPATIAL HETEROGENEITY

Initiating and adhering to ART requires a patient to make regular trips to a clinic for health examinations and to receive medications. Our estimates thus far assumed that individuals more than 10 kilometers from a location where ART was introduced would have been unlikely to initiate and adhere to ART. Table 5 examines spatial heterogeneity in the estimated effect of local ART on weight. We relax the restriction that the local introduction of ART affected all individuals more than 10 kilometers from an ART health facility uniformly. To do this, we include an additional measure of distance in equation 1 that takes a value of one if a household resided within 20 kilometers of a facility with ART availability. We also include the appropriate double and triple interactions using this new distance measure. This distance measure is not mutually exclusive with our existing measure: a household that resides within 10 kilometers of ART also resides within 20 kilometers of ART. Therefore, the estimated effect for individuals within 10 kilometers is the sum of the two triple-interaction coefficients. For those respondents residing between 10 kilometers and 20 kilometers, the estimated effect is simply the coefficient estimate on the new triple-interaction term (i.e., "ART ever within 20 kilometers × Year 2007 × HIV+"). As expected, the results suggest that the statistically measurable effect of local ART introduction on female health was limited to those within 10 kilometers as can be seen by the statistically insignificant coefficient on the 20-kilometer triple-interaction term.

D. PARALLEL TRENDS ASSUMPTION AND TIMING

One concern with our identification strategy is the presence of differential pre-ART trends by HIV status and clinic distance. While we have no reason to believe such trends existed, any such trends would be evident in a semiparametric triple-difference specification in which we allow a more flexible timing of any effect of ART availability.[17] To do this, first we define nine mutually exclusive and completely exhaustive event windows based on when ART was locally available relative to DHS respondent interview date: six windows prior to the introduction and three windows after introduction.[18] Then we estimate the following semiparametric triple-difference regression specification:

$$\begin{aligned} health_{ijt} = & \sum_{k=1}^{9} \alpha_k 1(\tau_t = k) \times ART_j + \sum_{k=1}^{9} \beta_k 1(\tau_t = k) \times ART_j \times HIV_{ijt} \\ & + \gamma_1 Year2007_t + \gamma_2 HIV_{ijt} + \gamma_3 Year2007_t \times HIV_{ijt} \\ & + Z'_{ijt}\Gamma + \eta_{district} + \delta_t + \varepsilon_{ijt} \end{aligned} \quad (2),$$

where τ_t denotes the nine event windows and other notation is the same as in equation 1. In the absence of differential trending, the estimates for β_k for the six windows prior to introduction ($k = 1$ to 6) should show no pattern, while the estimates for β_k for the three windows after local ART introduction ($k = 7$ to 9) should demonstrate treatment effects.

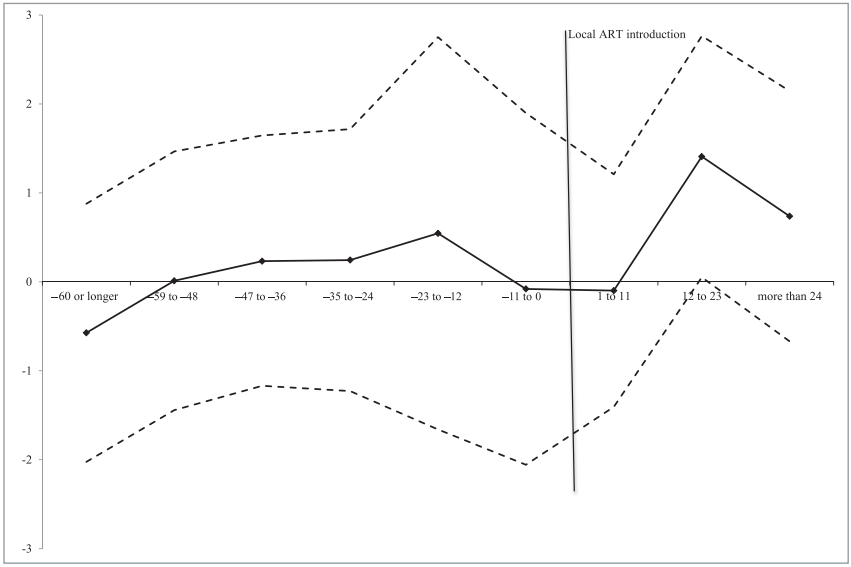
The ordinary least squares regression estimates of the semiparametric triple-difference parameters (i.e., β_k in equation 2) from a regression with respondent weight as the dependent variable are plotted in Figure 2 and support a causal interpretation of the baseline anthropometric results. In the figure, negative numbers on the horizontal axis indicate windows prior to local ART introduction. As all coefficient estimates in this region of the figure are close to zero and statistically insignificant, we do not find a differential prelocal ART introduction trend by HIV status. In addition, the timing of the increase in adult female weight is closely associated with the timing of local ART introduction, with the expected lag.

We also estimate equation 2 using height as the dependent variable, yielding another dynamic placebo test. Figure 3 plots the semiparametric triple-difference parameters from this regression. Again, these estimates fail to suggest any evidence of a differential preintroduction trend and fail to suggest a differential change in sample composition coincident with the timing of local ART introduction.

17 We are able to test for differential pretreatment trends despite only having two rounds of survey data (i.e., the 2001 DHS and 2007 DHS). In particular, we exploit variation in the timing of local ART introduction. For individuals in a given survey round, substantial variation exists in the amount of time between the survey and when ART was locally introduced.

18 The six windows prior to introduction are more than 60 months, 59 to 48 months, 47 to 36 months, 35 to 24 months, 23 to 12 months, and 11 to 0 months prior to introduction. The three windows after introduction are 1 to 11 months, 12 to 23 months, and more than 24 months. Because of the timing of our data collection we cannot extend these windows further.

FIGURE 2. Semiparametric difference-in-difference-in-differences analysis of effect of local ART introduction on adult female weight in kilograms



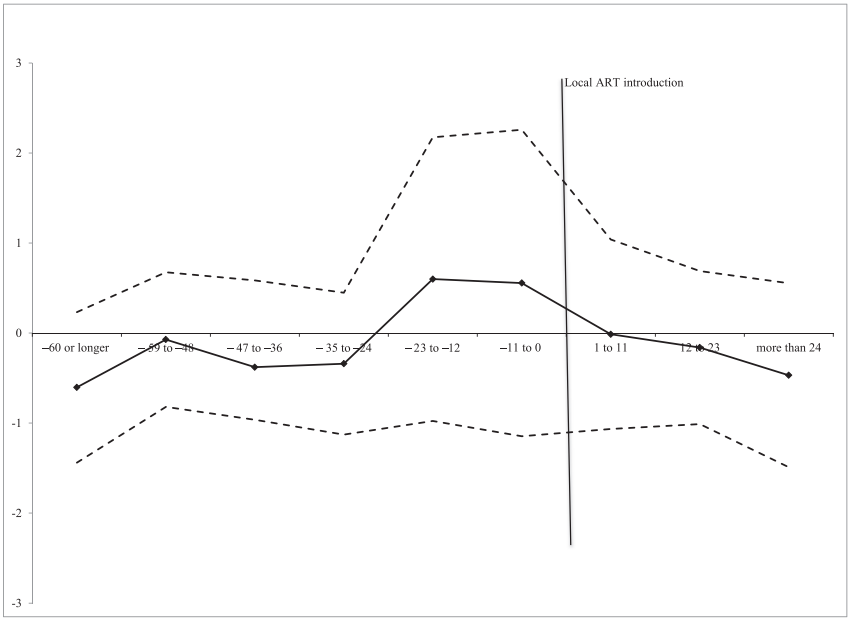
Notes: The solid line plots the estimtates of the β_k's from equation 2, using weight in kilograms as the dependent variable. The dashed lines are the 95% confidence interval associated with that point estimate.

E. ROBUSTNESS CHECKS

While all evidence indicates a causal interpretation of our findings, Table 6 presents estimates of the parameter of interest in versions of equation 1 that include additional covariates or an alternative measure of HIV status. One concern could be that we are measuring other HIV/AIDS services, not ART, but recall that our primary specification of interest included controls for both local PMTCT and VCT availability, therefore our results are the effect of ART, not the two other HIV services. The first five columns of Table 6 contain additional control variables in order to demonstrate that other health or demographic changes are not driving our results.

In columns 1 and 2 we control for two other public health improvements. Column 1 includes a control for household access to piped water and column 2 controls for household bed net ownership. In both cases the results are quite similar to those that appear in column 1 of Table 4. Column 3 controls for marital status of the respondent, again with only small changes to the coefficient of interest. Other potential concerns are that our effect is picking up a differential likelihood in pregnancy or in-migration of heavier individuals. Column 4 controls for whether the respondent was pregnant at the time of the survey, and column 5 controls for whether the individual had resided in her household for less

FIGURE 3. Semiparametric difference-in-difference-in-differences analysis of effect of local ART introduction on adult female height in centimeters



Notes: The solid line plots the estimtates of the β_k's from equation 2, using height in centimeters as the dependent variable. The dashed lines are the 95% confidence interval associated with that point estimate.

than one year. Again, these columns confirm the previous results. We do not include these controls in our primary specification as ART could also affect these outcomes. We include them to demonstrate that their exclusions are not driving the results in Table 4.

Finally, column 6 uses a continuous measure of HIV likelihood, the age group, gender, urban/rural, and province cell-level average, instead of the binary measure in the baseline specifications. In this column the point estimate on the triple-interaction term is larger than in our baseline estimates. Because of the change in our HIV measure, this value is not immediately comparable to the other columns. The point estimate on the triple interaction indicates a weight gain of roughly 5.4 kilograms for someone with a likely HIV status equal to one. However, no observations have this value and the 90th percentile of likely HIV status is 0.333. To scale this coefficient consider the estimated effect for a respondent in the 90th percentile of likely HIV status versus a respondent in the 10th percentile of likely HIV status (i.e., 0.333 versus 0.034). This comparison suggests an expected weight gain of approximately 1.60 kilograms, a large, but not unreasonable, change in weight, and one consistent with the other results in the table. Throughout, the estimates suggest that local ART introduction increased adult female weight.

TABLE 6. Robustness checks for effect of local ART on adult female weight

Dependent variable:	Weight (kg)					
	(1)	(2)	(3)	(4)	(5)	(6)
ART ever within 10 km × Year 2007 × HIV+	1.560[b] (0.645)	1.603[b] (0.643)	1.609[b] (0.634)	1.577[b] (0.636)	1.617[b] (0.642)	5.441[c] (3.001)
Additional controls for	Piped water	Bed net	Married	Pregnant	Migrant	
Alternative HIV measure						Continuous measure of HIV prevalence
Observations	13,681	13,683	13,684	13,684	13,673	13,684

Data source: Data come from the 2001 and 2007 Zambia Demographic Health Surveys.
Notes: ART ever within 10 km is an indicator variable equal to one if a health clinic within 10 km of the respondent offered ART at least 12 months prior to the 2007 DHS. In columns 1–5, HIV+ is an indicator variable equal to one if the respondent is in a demographic group with HIV prevalence above the median. In column 6, HIV+ is a continous measure of HIV prevalence in the respondent's demographic group. All specifications include the full set of controls, including lower-level triple-difference terms, indicated in equation 1. Parameters estimated using ordinary least squares (OLS) regression. Standard errors are in parentheses and are clustered by standard enumeration area (SEA). [a]significant at the 1 percent level, [b]significant at the 5 percent level, [c]significant at the 10 percent level.

VI. Conclusion

A fundamental debate in development and growth is whether foreign aid can be effective at promoting sustained improvements in quality of life (e.g., Boone 1996; Burnside and Dollar 2000; Collier and Dollar 2002, 2004; Easterly 2003, 2007, 2009; Easterly, Levine, and Roodman 2004). We raise a related and more narrowly defined question: can targeted aid for drug provision improve the health of the targeted at scale? We examine this topic in the context of arguably the single largest foreign aid health program in the history of the world, the US President's Emergency Plan for AIDS Relief (PEPFAR), a program directed toward addressing the leading cause of death in the poorest region of the world. Our findings suggest that local ART introduction in Zambia, a PEPFAR focus country, substantially increased the weight of high HIV likelihood adult females, consistent with a reduction in HIV/AIDS morbidity due to local drug provision. These results suggest that despite limited local health sector capacity, a very large foreign health aid program focused on drug provision improved the health of the targeted.

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DISCLAIMER

All errors are our own. The findings, interpretations, and conclusions expressed in this paper are those of the authors and do not necessarily represent the views of the aforementioned individuals or agencies.

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