Why is Aging Associated with Lower Adoption of New Technologies? Evidence from Voluntary Medical Male Circumcision and a Structural Model

Current draft: January 2, 2020

Abstract

A popular conception is that older people are less likely to adopt new technologies than are younger people. The mechanism underlying this relationship is less well-known. I provide evidence on this question using data from the introduction of voluntary medical male circumcision (VMMC), a new medical technology with substantial health benefits in high HIV prevalence settings. I find limited support for several leading potential mechanisms such as previous investment in older substitute technologies, cohort differences in educational attainment, or various life-cycle changes (i.e. marriage, having ever had sex, coital frequency). I provide a model demonstrating that shorter time horizons and lower consumption values of life mechanically associated with aging may cause lower VMMC adoption among older males and simulate the adoption-age profile under various parameter assumptions. I discuss implications for policymaking and future research.

Keywords: aging; health; technology
JEL codes: I12, I15, O33

1 Introduction

A popular conception is that older people are less likely to adopt new technologies than are younger people. For example, the New York Times, the Pew Research Center, and the AARP all have recent commentary on the hypothesis that older people are less likely to adopt internet technology (Anderson 2016, Gustke 2016, Anderson and Perrin 2017). This perspective is not new, with historical references dating back to at least 1721 (Bailey 1917) and includes a wide range of technologies such as automobiles, telephones, the worldwide web. Yet the mechanism underlying this relationship is less well-known. Why is aging associated with lower adoption of new technologies?

I provide evidence on this question using data from a new medical technology with substantial health benefits, far from universal take-up, and lower take-up among older people. Voluntary medical male circumcision (VMMC) reduces female-to-male HIV transmission by approximately 50-75% (Auvert et al. 2006, Bailey et al. 2007, Gray et al. 2007). Projections suggest that achieving 80% coverage among males age 15-49 in 14 priority countries in sub-Saharan Africa may help avert 3.4 million HIV infections and generate US$16.5 billion in net savings due to averted treatment and care costs (WHO 2012).[1,2] As of 2016, only 14.5 million (WHO 2017) of the target number of 27 million VMMCs in Eastern and Southern Africa had been performed (UNAIDS 2015). Coverage among age 30 and above has lagged behind VMMC coverage at younger ages (Plotkin et al. 2013, Hankins et al. 2016, Grund et al. 2018), yet promoting take-up in this older population is required to achieve the greatest reduction in HIV incidence (Thirumurthy et al. 2016).

The literature on the microeconomics of household (or individual) technology adoption largely has focused on adoption determinants other than age (see Foster and Rosenzweig (2010) for a review), yet economic intuition yields several key insights about potential mechanisms. As individuals age they may be less likely to adopt new technologies for several key reasons. First, older individuals have shorter time

[1] In sub-Saharan Africa, a region of nearly 1 billion people, HIV/AIDS is the leading cause of adult mortality and causes approximately 10% of under age-5 mortality (WHO 2011).
[2] A reduction in new infections will slow the future spread of HIV/AIDS and reductions in HIV/AIDS mortality and morbidity have been shown to improve community mental health (Baranov et al. 2015).

horizons over which to accrue benefits from investing in new technologies. Second, older individuals may have invested in earlier technologies that are substitutes for new technologies. Third, other cohort differences, particularly in educational attainment, may affect the likelihood of adoption and in turn affect the cross-sectional adoption-age profile. Fourth, other life-cycle changes (e.g., in the case of VMMC, marriage, having ever had sex, coital frequency) could underlie low technology adoption.[3]

Previous investment in older technologies may be particularly important in settings where the technology is long-lasting, or even irreversible as in the case of traditional circumcision and VMMC. Although the time horizon hypothesis may seem appealing, the ability of this mechanism to generate declining adoption-age profiles may be sensitive to assumptions about the individual discount factor. In the case of VMMC, all of the aforementioned hypotheses appear plausible. Understanding why VMMC adoption declines with age will yield behavioral insights for policymakers to increase VMMC take-up among this critical, older group (Thirumurthy et al. 2016). More broadly, it will help researchers understand the empirical relevance of mechanisms possibly underlying low technology adoption among older people in other settings. Despite its plausibility, there appears to be little economic evidence on the role of time horizons in explaining declining technology adoption with age.

I examine health technology adoption decisions from over 14,000 males ages 15-59 in Zambia. Starting in 2008, Zambia began performing VMMCs as part of the World Health Organization (WHO) mass VMMC campaign for HIV prevention. By 2014, nearly 1 million VMMCs had been performed, equivalent to approximately 11% of the male population. The Zambia 2013 Demographic and Health Survey (DHS) includes information from male respondents on circumcision status, age at circumcision, place of circumcision (e.g., health facility, home), who performed the circumcision (e.g., health provider, traditional healer), and reason for circumcision (e.g., disease prevention, disease treatment, traditional). I use this information to provide large-scale evidence on who adopts VMMC and to unpack the mechanisms linking age to adoption. Although at first glance VMMC may seem to be an unusual setting, the

[3] In the case of VMMC, HIV status and knowledge about HIV prevention methods are two additional factors possibly affecting VMMC adoption that may manifest as cohort differences or life-cycle differences.

circumcision adoption decision is a part of everyday life in Zambia and, as I discuss later in the analysis, the immediate benefits of VMMC are not confined to a particular demographic group (e.g., young individuals or unmarried individuals).[4]

I find limited support for several leading potential mechanisms such as previous older substitute technologies, cohort differences in educational attainment, various life-cycle changes (e.g., marriage, having ever had sex, coital frequency), or other factors hypothesized to affect adoption that may vary across cohorts or across the life-cycle (e.g., HIV status and knowledge about HIV prevention methods). These results are robust to including additional controls and to restricting the regression samples to males outside of the age range targeted in VMMC campaigns, suggesting that supply-side factors do not fully explain the adoption-age gradient.

I provide a model demonstrating that shorter time horizons and lower consumption values of life mechanically associated with aging may cause lower VMMC adoption among older people. I use this model to simulate adoption-age profiles and find that the model readily generates the observed adoption age profile. Ideally, it would be possible to exploit quasi-experimental variation in life expectancy to further test this mechanism. In lieu of such variation, I rely on the structural model, simulations, and ruling out alternative mechanisms. I review the limitations of this strategy in the Discussion section.

A key insight from the structural model is that limited time horizons inhibit individual investments in new health technologies. Simulation result indicate that one policy commonly used to improve health behaviors and outcomes – raising incomes (e.g., through unconditional cash transfers) – is unlikely to substantially increase take-up unless the income transfers are substantial in magnitude. Instead, conditional cash transfers targeted toward older males or interventions designed to reframe the adoption decision away from a cost-benefit decision and toward a conceptual framework that does not emphasize shorter time

[4] VMMC shares key similarities with several other elective surgeries. Cardiovascular surgery (e.g., angioplasties), reproductive health surgery (e.g., hysterectomies, prophylactic mastectomies, tubal ligation, vasectomies), and orthopedic surgery (e.g., hip replacements) all share similarities with VMMC. Many of these surgeries convey substantial benefits, some include risks of sexual side effects, and most have less than universal take-up among eligible/targeted groups.

horizons may be required. I conclude by discussing this insight and several additional implications for policymaking and future research.

These findings contribute to several bodies of literature. First, I expand the literature on the microeconomics of technology adoption (e.g., Bandiera and Rasul 2006, Gine and Yang 2009, Conley and Udry 2010, Duflo et al. 2011, Adhvaryu 2014, Tarrozzi et al. 2014, Bensch and Peters 2015, Carter et al. 2016; see Foster and Rosenzweig 2010 for a review) by examining the role of age, a factor that this literature appears not to have examined. Second, I expand the economics literature on time horizons and VMMC (Wilson et al. 2014) by demonstrating that time horizons may affect adoption. Third, I add to the broader economic literature on circumcision, which includes studies of how to increase VMMC take-up (Thirumurthy et al. 2014, Kim et al. 2015, Thirumurthy et al. 2016, Wilson et al. 2016, Friedman and Wilson 2017), how beliefs and information about circumcision affects risky sexual behavior (Wilson et al. 2014, Godlonton et al. 2016), and how circumcision affects marriage markets (Wilson and Janicki 2016).

The rest of the analysis is organized as follows. Section 2 describes the study context. Section 3 discusses the data and statistical methods. Section 4 presents the regression results. Section 5 provides a structural model, simulates the adoption decision, examines several additional predictions of the structural model, and simulates alternative policy scenarios. Section 6 discusses the main findings and concludes.

2 Context

Mass VMMC scale-up in Eastern and Southern Africa began in 2008. Randomized controlled trials conducted in Kenya, South Africa, and Uganda, indicated that VMMC reduced HIV transmission by upwards of 50% (Auvert et al. 2006, Bailey et al. 2007, Gray et al. 2007). Based on this evidence the WHO identified 14 priority countries in the region of the world with the highest HIV prevalence and has aided scale-up in these countries.

Zambia is one of the priority countries, with a high HIV prevalence (Central Statistical Office et al. 2015) and low male circumcision prevalence (Central Statistical Office et al. 2015). Figure 1 displays the number of VMMCs performed in Zambia by year using official aggregate statistics from the World

Health Organization (WHO). The number of new VMMCs performed each year increased from around 2,000 in 2008 to around 100,000 by 2011. In total, over 950,000 VMMCs were performed in Zambia through 2014. Although VMMCs disaggregated by age of the recipient only are available for one year, the distribution suggests that around one-half of VMMCs were among males age 15 or older. The Zambia Census Office reports that there were 3,947,139 males age 15 and above in Zambia in 2014 (Central Statistical Office 2013). This suggests VMMC prevalence among males age 15 and above of around 11% by 2015, subject to some uncertainty about the fraction of VMMCs performed on age 15 and above.

Policy documents suggest a high degree of targeting of younger males for VMMC. For example, the United Nations has set a target of circumcising 25 million young males (i.e. age 12-30) by 2020 (UNAIDS 2016). The global VMMC campaign has targeted young males because VMMCs among this population are predicted to generate the greatest reductions in HIV transmission. Targeting in Zambia appears to have focused on this range, with evidence of targeting of males age 15-29 (CIDRZ 2018).

The targeting of younger males, including those of secondary school age, during the introduction of VMMC means that unobserved heterogeneity in supply-side factors may explain differences in VMMC adoption by age. Thus, in the empirical analyses that follow I pay careful attention to this issue and use a variety of strategies to illuminate the relevance of this concern in explaining the adoption-age profile. Ultimately, I find little evidence that this targeting is able to explain the general decline in adoption with age. *Prima facie* evidence against the targeting hypothesis is that adoption declines with age at ages beyond those groups targeted by age.

Despite intentional targeting of younger males, concern remains about low uptake among older males as promoting VMMCs in this population is required to achieve the greatest reduction in HIV incidence (Thirumurthy et al. 2016). Although policymakers targeted younger males for VMMC, older males and married males are at high risk of acquiring HIV. For males, coital frequency does not appear to

decline with age in Zambia.[5] De Walque (2007) presents evidence from five sub-Saharan African countries that in 30-40% of discordant heterosexual partnerships it is the female who is HIV positive and the male who is HIV negative.

3 Data and Statistical Methods

3.1 Data

I use data from the 2013 Zambia Demographic and Health Survey (ZDHS), the first national household survey conducted in Zambia after the introduction of VMMC began in earnest. The ZDHS is a national household survey with standard demographic, health behavior, and health knowledge questions. It also asks male respondents about their circumcision status, age at circumcision, place of circumcision, person who performed circumcision, and reason for circumcision. The survey includes complete data from 14,715 male respondents age 15-59.

On reason for circumcision, the ZDHS asks about circumcision for disease prevention.[6] I define a respondent as having adopted VMMC if they state that they adopted circumcision for disease prevention and they were circumcised within the past 7 years, the period of time over which VMMC became available.[7] The previous ZDHS (i.e. the 2007 survey round) includes virtually no circumcisions reported for prevention reasons. As I discuss in Section 2, Zambia performed only 2,000 VMMCs in 2008. Hewett et al. (2012) presents evidence that some individuals may misreport circumcision status. To the extent that

[5] An analysis of the association between coital frequency and age in the data I use in the current analysis (i.e. the 2013 ZDHS) indicates that coital frequency increases with age among younger males and then remains constant with age at older ages.

[6] The two other complementary circumcision measures – place of circumcision and who performed the circumcision – are highly correlated with reason for circumcision. Over 91% of VMMCs were performed at a health facility, compared to fewer than 25% of traditional circumcisions. In contrast, more than 54% of traditional circumcisions were performed at a ritual site, compared to less than 4% of reported VMMCs. Similarly, doctors or trained nurses/midwifes performed over 93% of VMMCs and fewer than 31% of traditional circumcisions. Circumcisions classified as "other" fall somewhere in between these two ends of the "place of circumcision/who performed circumcision" spectrum.

[7] Other possible reasons for circumcision measured in the ZDHS are: "traditional custom", "treatment for disease", "hygiene", "increase sexual pleasure", and "other".

misreporting is not associated with age, misreporting should attenuate any association between age and circumcision.

Table 1 presents descriptive statistics. Approximately 8% of males had adopted VMMC, roughly consistent with VMMC prevalence as calculated in Section 2 using administrative data. An approximately similar numbers had chosen traditional circumcision and other circumcision.[8] The average age in my sample is approximately 30 years, around ½ of males are married, the majority have ever had sex and are sexually active, over 70% had completed (at least) primary school, and 12% are HIV positive.

As a validation check for circumcision categories, Figure 2 plots the cumulative distribution of age at circumcision by circumcision type. Among individuals choosing traditional circumcision, nearly 100% are circumcised by age 18, broadly consistent with evidence from South Africa that 91% of men who reported receiving a traditional circumcision had received it between the ages of 17 and 22 years (Maughan-Brown et al. 2011). Among individuals choosing VMMC, only around 50% had adopted VMMC by age 18.

3.2 Statistical Methods

I begin by estimating locally smoothed polynomials of indicator variables for circumcision of various types on age. The results of these analyses inform the choice of functional form in the parametric specifications that follow.

Next, I regress an indicator variable for adopting VMMC on a variable measuring age in years, as well as exploring other parameterizations of age. I include DHS cluster fixed effects to address concerns about unobserved place-based supply-side heterogeneity and control for a variety of other covariates. The primary regression specification is:

$$VMMC_{ic} = \gamma + \beta\ age_{ic} + X'_{ic}\ \theta + \gamma_c + \varepsilon_{ic} \qquad (1)$$

[8] "Other" circumcision includes medical circumcision for the (self-reported) treatment of disease and otherwise unclassified circumcision.

where $VMMC_{ic}$ is an indicator variable equal to one if of individual i adopted VMMC, age_{ic} is the age of individual i in years, X'_{ic} is a vector of sociodemographic controls, γ_c are DHS cluster fixed effects, and ε_{ic} is an idiosyncratic error term. I use ordinary least squares (OLS) regression with heteroscedasticity-robust standard errors clustered at the DHS cluster level to estimate the parameters of Equation (1).

This approach does not rely on a typical identification assumption. Instead, I use the fact that if a mechanism is substantively operative, then controlling for that mechanism in a multivariate regression should noticeably attenuate the coefficient estimate on age. Thus, finding that the coefficient estimate on age is not sensitive to including a control (e.g., educational attainment), would indicate that the control is not a key mechanism linking age to adoption.

4 Regression Results

4.1 Non-Parametric Adoption-Age Gradients

Figure 3 displays the fitted locally smoothed polynomial of VMMC by age. Approximately 15% of males age 15-19 have adopted VMMC. Starting around age 20, VMMC prevalence declines rapidly. Around age 30, the decline in VMMC prevalence becomes less dramatic, yet at all ages older males are less likely to have adopted VMMC than are younger males. At the end of the recorded age distribution (i.e. age 55-59), VMMC prevalence is around 1%.

Figures 4-6 display the fitted locally smoothed polynomials of traditional, other, and any circumcision (i.e. VMMC, traditional or other), respectively, by age. The slight increase in traditional circumcision with age in Figure 4 may be due to a secular decline in traditional circumcision, crowding out of traditional circumcision by VMMC, and/or mortality selection (e.g., if traditional circumcision reduces the likelihood of acquiring HIV). The likelihood of other circumcision does not appear to vary systematically by age, as illustrated in Figure 5. Figure 6 reveals that the decline in VMMC adoption with age dominates the increase in traditional circumcision prevalence with age. Overall, there appear to be

some non-linearities – particularly for VMMC and for any circumcision – supporting investigation of sensitivity to functional form in the parametric regression analysis.

4.2 Parametric Adoption-Age Gradients

Table 2 presents OLS regression estimates of the adoption-age profile. The dependent variable in Column (1) is an indicator variable for having adopted VMMC. Specifications with first, second, and third order polynomials in age appear in Panels A, B, and C, respectively. Panel D presents the results of a semi-parametric specification using indicator variables for five-year age group. Throughout, the point estimates reveal a substantially lower likelihood of VMMC adoption for older males. For example, the point estimate in Column (1), Panel A indicates that an additional year in age is associated with an approximately 0.4 percentage point decrease in the likelihood of having adopted VMMC (statistically significant at the 1% level). The higher order polynomial and semi-parametric specifications yield approximately similar results.

Columns (2), (3), and (4) turn to traditional, other, and any (i.e. VMMC, traditional, or other) circumcision, respectively. The results indicate that the likelihood of having received a traditional circumcision is higher for older males, unlike the likelihood of having adopted VMMC. For example, the point estimate in Column (2), Panel A indicates that an additional year of age is associated with a 0.1 percentage point increase in the likelihood of having received a traditional circumcision. Although traditional circumcision is more prevalent among older males, the results in Column (3) reveal a gently inverted U-shaped relationship between age and the likelihood of adopting other (i.e. non-VMMC and non-traditional circumcision). The results in Column (4) indicate that the likelihood of having received any circumcision is higher for younger males, with the negative VMMC-age gradient overwhelming the traditional circumcision-age gradient.

Overall, these results indicate a substantial and statistically significant VMMC adoption-age gradient. Older males are less likely to adopt VMMC than are younger males. Moreover, this gradient appears to be larger (in absolute value) than that for traditional circumcision or for other circumcision.

4.3 Mechanisms

Now I turn to examining the mechanisms underlying the adoption-age profile. Table 3 presents estimates while controlling for various factors hypothesized to link age to adoption. These factors include marital status, having ever had sex, coital frequency, previous investment in earlier technologies, educational attainment, knowledge about HIV prevention methods, and HIV status. For each of these factors, if it is a quantitatively important mechanism then controlling for the factor should substantially attenuate or eliminate the negative association between age and adoption.

I begin by examining key potential life-cycle explanations for the negative association between age and VMMC adoption. Columns (1)-(4) of Table 3 control for being married, having ever had sex, sex in the past year, and sex in the past week, respectively. Controlling for marriage reduces the magnitude of the point estimate on age by approximately 25%, yet it remains statistically significant at the 1% level. Similarly, coital frequency does not appear to explain in the adoption age profile, as controlling for measures of coital frequency has little to no effect on the association between age and VMMC adoption. Thus, leading potential lifecycle differences at most can explain one-quarter of the adoption-age profile for VMMC.

Columns (5) and (6) present estimates of the adoption age profile while controlling for investment in substitute technologies. The results indicate that the gradient is robust to controls for traditional circumcision and other circumcision, indicating that this potential mechanism is not the explanation.

I control for educational attainment in Column (7). The point estimate and standard error for age do not change substantially, although higher levels of educational attainment are positively associated with adoption. In Columns (8) and (9), I control for knowledge about HIV prevention methods and for HIV status, respectively.[9] Again the point estimate and standard error on age change very little as compared to the result in Column (1) of Table 2.

[9] The DHS does not ask about knowledge of circumcision for HIV prevention. It does ask about knowledge of abstinence for HIV prevention, condom use for HIV prevention, and being faithful to one partner for HIV prevention.

Thus, neither marriage, having ever had sex, coital frequency, traditional circumcision, other circumcision, educational attainment, knowledge about HIV prevention methods, nor HIV status appear to fully link age to the likelihood of VMMC adoption. If life-cycle differences, previous investments in earlier technologies, or cohort differences are driving the main results, them they are not the factors I am able to examine in Table 3. The remainder of this section presents the results of various robustness checks. Then I provide a model highlighting the role of time horizon and technology adoption.

4.3 Robustness Checks

Table 4 presents the results of robustness tests. Column (1) includes the full set of controls in Table 3 and additional controls. These additional controls are indicator variables for urban and for wealth quintile. Columns (2)-(4) restrict the sample to males above various age thresh-holds. The association between age and VMMC adoption persists in all of these specifications. The fact that restricting the sample to older males does not change the main result indicates that it is not targeting of younger males (e.g., age 15-29) that is driving my main result. To illuminate the puzzle of what explains lower technology adoption among older individuals, I provide a structural model and use the model to simulate adoption-age profiles under various parameter assumptions.

5 Model and Simulations

In this section I provide a model demonstrating that shorter time horizons and the lower consumption value of life mechanically associated with aging may cause lower technology adoption among older individuals. Then I use the model to simulate the adoption-age profile, generate additional comparative statics, and simulate the adoption-age profile under alternative policy scenarios.

5.1 Setup

An individual receives utility *b* each period that he is alive, where $\infty > b > 0$. Let δ denote the individual's total discount factor, including time preference and the likelihood of survival, where $1 > \delta > 0$. Let T denote the final period in which the individual might survive.

Expected utility at time *t=0* is given by:

$$E[U] = \sum_{t=0}^{T} b\delta^t \qquad (2)$$

which may be rewritten as:

$$E[U] = b\left[\frac{1-\delta^{T+1}}{1-\delta}\right] \qquad (3)$$

5.2 Demand for VMMC

It is straightforward to incorporate VMMC into the model by allowing δ to depend on VMMC adoption. Recall that δ is the total discount factor, including time preference and likelihood of survival. Let $1 > \delta_V > \delta_{NV} > 0$, where δ_V denotes the discount factor under VMMC adoption and δ_{NV} denotes the discount factor without VMMC adoption. The assumption that $\delta_V > \delta_{NV}$ reflects the prophylactic effect of VMMC documented in the medical literature.

An individual chooses to adopt VMMC if and only if the expected utility from adopting VMMC exceeds the expected utility from not adopting VMMC. Let *c* denote the utility cost of adopting VMMC.

Then:

$$E[U_V] = b\left[\frac{1-\delta_V^{T+1}}{1-\delta_V}\right] - c \qquad (4)$$

and

$$E[U_{NV}] = b\left[\frac{1-\delta_{NV}^{T+1}}{1-\delta_{NV}}\right] \qquad (5)$$

Thus, the individual adopts VMMC if and only if:

$$b\left[\frac{1-\delta_V^{T+1}}{1-\delta_V}\right] - c - b\left[\frac{1-\delta_{NV}^{T+1}}{1-\delta_{NV}}\right] > 0 \qquad (6)$$

Rearranging yields:

$$b\left[\frac{1-\delta_V^{T+1}}{1-\delta_V} - \frac{1-\delta_{NV}^{T+1}}{1-\delta_{NV}}\right] - c > 0 \qquad (7)$$

5.3 Comparative Statics

Prediction 1: The probability of take-up declines with age.

Proof: In period *t=1*, the adoption decision from Equation (7) becomes:

$$b\left[\frac{1-\delta_V^{T}}{1-\delta_V} - \frac{1-\delta_{NV}^{T}}{1-\delta_{NV}}\right] - c > 0 \qquad (8)$$

Thus, the difference in the change in expected utility from adopting VMMC for 1 year of aging is:

$$b\left[\frac{1-\delta_V^{T}}{1-\delta_V} - \frac{1-\delta_{NV}^{T}}{1-\delta_{NV}}\right] - b\left[\frac{1-\delta_V^{T+1}}{1-\delta_V} - \frac{1-\delta_{NV}^{T+1}}{1-\delta_{NV}}\right] \qquad (9)$$

Rearranging yields:

$$b\left[\frac{\delta_V^{T+1}-\delta_V^T}{1-\delta_V}+\frac{\delta_{NV}^{T+1}-\delta_{NV}^T}{1-\delta_{NV}}\right] \qquad (10)$$

Note that $\delta_V^{T+1} < \delta_V^T$ and $\delta_{NV}^{T+1} < \delta_{NV}^T$. Also note that $1-\delta_V > 0$, $1-\delta_{NV} > 0$, and $b > 0$. Thus, the expression in Equation (10) is negative.

Prediction 2: The age gradient in take-up should be steeper for individuals with higher consumption.

Proof: Equation (10) is continuous and differentiable in *b*. Taking the derivative of Equation (10) with respect to *b* yields:

$$\left[\frac{\delta_V^{T+1}-\delta_V^T}{1-\delta_V}+\frac{\delta_{NV}^{T+1}-\delta_{NV}^T}{1-\delta_{NV}}\right] \qquad (11)$$

which is negative by the previous proof and the fact that $b > 0$.

Prediction 3: The age gradient should be steeper in higher HIV prevalence areas.

Proof: The protective effect of VMMC against acquiring HIV is only beneficial in the presence of HIV in the population of sexual partners. As the likelihood a sexual partner is HIV positive decreases, the likelihood of survival in the absence of VMMC adoption (i.e. δ_{NV}) increases. Taking the derivative of Equation (10) with respect to δ_{NV} yields:

$$\frac{(T+1)\delta_{NV}^{T} - T\delta_{NV}^{T-1}}{1-\delta_{NV}} + (\delta_{NV}^{T} - \delta_{NV}^{T+1}) \qquad (12)$$

Rearranging yields:

$$\frac{(T+1)\delta_{NV}^{T} - T\delta_{NV}^{T-1} + (1-\delta_{NV})\delta_{NV}^{T} + (1-\delta_{NV})\delta_{NV}^{T+1}}{1-\delta_{NV}} \qquad (13)$$

And again:

$$\frac{T(\delta_{NV}^{T} - \delta_{NV}^{T-1}) + 2(\delta_{NV}^{T} - \delta_{NV}^{T+1}) - \delta_{NV}^{T+2}}{1-\delta_{NV}} \qquad (14)$$

Note that $(\delta_{NV}^{T} - \delta_{NV}^{T-1}) < 0$, $(\delta_{NV}^{T} - \delta_{NV}^{T+1}) > 0$, and the denominator is positive. Thus, the whole expression is negative (i.e. an increase in δ_{NV} reduces the adoption-age gradient) if and only if:

$$2(\delta_{NV}^{T} - \delta_{NV}^{T+1}) > \delta_{NV}^{T+2} + T(\delta_{NV}^{T-1} - \delta_{NV}^{T}) \qquad (15)$$

Divide by δ_{NV}^{T-1} (note: $\delta_{NV}^{T-1} > 0$) to simplify and yield:

$$(2+T)\delta_{NV} - 2\delta_{NV}^{2} - \delta_{NV}^{3} - T > 0 \qquad (16)$$

Numerical exploration indicates that Equation (16) is negative over wide ranges of T (i.e. 1 to 100) and δ_{NV} (i.e. 0.1 to 1.0). Thus, Equation (12) – the derivative of Equation (10) with respect to δ_{NV} – is positive. Hence, the age gradient is steeper in higher HIV prevalence areas.

5.4 Baseline Simulations

Next, I simulate VMMC adoption using the model described above. As demonstrated in Section 5.2, an individual adopts VMMC if and only if:

$$b\left[\frac{1-\delta_V^{T+1}}{1-\delta_V}-\frac{1-\delta_{NV}^{T+1}}{1-\delta_{NV}}\right]-c>0 \qquad (17)$$

The proportion of individuals predicted to adopt is given by:

$$P(VMMC)={}^{1}\!/_{[1+e^{-(E(U_V)-E(U_{NV}))}]} \qquad (18)$$

I set values of T, δ_V, and δ_{NV}.[10] I normalize *b* to be 1 and calibrate *c* to fit smoothed VMMC prevalence at age 30 (i.e. 5.1%), an age threshold after which few individuals in my data would have been exposed to VMMC campaigns targeting younger males. Then I simulate the prevalence-age profile from age 30-59. I repeat this process with alternative values of T, δ_V, and δ_{NV}.

The existing literature provides a basis for values for δ_V, δ_{NV}, and *T*. In developed country settings with relatively low, stable mortality rates, economists typically assume that δ is approximately 0.95. In lower income settings, where life expectancy is lower and uncertainty about life expectancy may be greater, more reasonable assumptions may be 0.9 or even 0.8. VMMC reduces HIV transmission by 51 to 76% (Auvert et al. 2006, Bailey et al. 2007, Gray et al. 2007), approximately 14% of adults in Zambia are HIV positive (Central Statistical Office et al. 2015), and HIV appears to be the leading cause of adult mortality (WHO 2011), suggesting that receiving VMMC may generate approximately a 0.05 unit increase in the

[10] The discount factor, δ_V or δ_{NV}, may be expressed as $\delta=\frac{1}{1+r}$, where *r* is the subjective discount rate. Setting the subjective discount rate to an average real interest rate of 5% would yield a discount factor of 0.952. A subjective discount rate of 10% yields a discount factor of 0.909. A subjective discount rate of 20% yields a discount factor of 0.833.

discount factor (e.g., an increase from 0.85 to 0.90). Therefore, I begin by assuming $\delta_{NV} = 0.85$ and $\delta_V = 0.90$. I examine sensitivity to alternative choices of δ_{NV} and δ_V. Unlike in high income settings (e.g., Hurd and McGarry 1996), evidence from low-income settings indicates that individuals are more pessimistic about their life expectancies than are official state-specific life tables (Delavande et al. 2017). Thus, although the WHO life table for Zambia indicates that males age 30-35 should expect to live an additional 38.4 years (WHO 2018), I examine sensitivity to shorter and longer time horizon assumptions.

Figure 7 reports the results of several simulations. The simulated VMMC prevalence-age profile associated with a life expectancy of 65 or 70 years approximately matches the actual VMMC prevalence-age profile. More extreme time horizons (e.g., life expectancies of 60 or 80 years) worsen the fit somewhat, yet it remains fairly close. Alternative values for the discount rates yield qualitatively similar adoption-age profiles. Table 5 reports goodness-of-fit measures – Chi-squared tests and root mean squared errors (RMSE) – for each of the simulations. The results of the Chi-squared tests indicate a high degree of model fit across all of the specifications. The RMSEs are larger than a common threshold criteria (i.e. 0.06 (Hu and Bentler 1999)), suggesting that time horizon alone may not fully explain the age-adoption profile.

As displayed in Table 5, the calibrated value of c ranges from between approximately 6 and 8. Relative to the normalized per period (i.e. annual) consumption (i.e. b) of 1, this suggests that the instant disutility of circumcision of the representative individual is roughly 6-8 times annual consumption.[11] Although this may seem large, it is consistent with the observed low take-up of this potentially life-saving health input. A back-of-the-envelope calculation may help place this estimate in context. Approximately 12% of the study sample is HIV positive and VMMC reduces HIV transmission by approximately 50-75% (Auvert et al. 2006, Bailey et al. 2007, Gray et al. 2007). Suppose the average age an adult male acquires HIV is age 30.[12] In the absence of initiating and adhering to antiretroviral therapy, then someone who acquires HIV at age 30 is highly likely to die at or around age 40. If he had not acquired HIV, then he

[11] GNI per capita (PPP) in Zambia in 2012 was $3,530 (World Bank 2018).
[12] HIV incidence by age group in Zambia is not readily available. In the 2013 ZDHS, the median HIV prevalence age group among males is between age 30-34 and age 35-39.

should expect that he would survive to around age seventy.[13] Then a prime-age HIV negative male should expect to increase his life expectancy by approximately 2 years by receiving VMMC. The fact that many men in this setting do not adopt VMMC supports the hypothesis that the disutility of VMMC exceeds the consumption value of 2 years of life.

5.5 Additional Predictions

The structural model generated two additional testable predictions about VMMC adoption. Prediction 2 stated that the age gradient in take-up should be steeper for individuals with higher consumption. Prediction 3 stated that the age gradient should be steeper in higher HIV prevalence areas. Table 6 explores these predictions. In Columns (1)-(4), I allow the age gradient to vary by wealth quintile indicators, wealth quintile, HIV prevalence median or above, and by (continuous) HIV prevalence. The wealth results suggest that the age gradient is steeper for wealthier (i.e. higher consumption) individuals. Likewise, the HIV prevalence results suggest that the age gradient is steeper in higher HIV prevalence areas.

5.6 Policy Scenarios

This section uses the structural model to simulate and evaluate several alternative policy scenarios. The take-up condition in Equation (7) highlighted four main determinants of take-up: (1) the protective effect of VMMC (i.e. δ_V relative to δ_{NV}), (2) per period consumption (i.e. b), (3) the cost of VMMC (i.e. c), and (4) the discount factor (i.e. δ_{NV}). An obvious policy lever is subsidizing VMMC. Conditional cash transfers for VMMC would move an already zero sticker price to a payment for being circumcised.[14] I simulate the effects of CCTs for VMMC (i.e. reducing c) on take-up and benchmark these effects against scenarios with higher per period consumption, b, (e.g., unconditional cash transfers in the form of lifetime

[13] The World Health Organization life table for Zambia indicates that males age 30-35 should expect to survive approximately another 38 years (World Health Organization 2019).

[14] One concern with this policy is the donor community's hesitancy to pay an individual to get circumcised. Friedman and Wilson (2017) provides evidence from a RCT in South Africa that cash transfers disbursed conditional on completing a counseling session for VMMC increase take-up of the VMMC procedure. A CCT such as this presumably would conform with the donor community's wishes not to pay individuals to get circumcised.

basic income guarantees) and alternative discount factors, δ_{NV} and δ_V, (e.g., due to reductions in competing health risks).

Table 7 presents the policy simulation results. In each scenario, the baseline parameters are set to $b = 1, c = 6.120, \delta_V = 0.90, \delta_{NV} = 0.85$, and $T = 70$, and then one (set of) parameter value(s) is varied. Panel A presents the fraction of males predicted to adopt VMMC. Panel B presents HIV infections averted under each of these scenarios.[15] Column (1) displays the results of the baseline simulation. Columns (2)-(4) display simulation results for scenarios with conditional cash transfers for VMMC of various sizes. Columns (5)-(7) repeat this for annual unconditional cash transfers. Column (8) present simulation results for a policy scenario with higher discount factors (i.e. lower discount rates).

The policy simulation results indicate that offering moderately sized conditional cash transfers for VMMC adoption can yield moderate increases in adoption. Transfers equal to 60%, 300%, and 600% of baseline annual consumption (i.e. "small transfer", "medium transfer", and "large transfer, respectively) can increase adoption among males age 30-59 from 3.3% to 5.9%, 40.4%, and 92.6% respectively. HIAs scale with VMMC adoption, yet the cost per HIA varies substantially with the magnitude of the transfer. Inducing additional increases in VMMC requires increasing larger transfers and these transfers are paid to marginal and inframarginal recipients alike.

Offering an annual unconditional cash transfer can also increase adoption, yet two features make it much less effective (or, equivalently, much more expensive) than conditional cash transfers. First, by definition, unconditional cash transfers are paid to all males age 30-59, invariant of whether they adoption VMMC. Second, the incentive effect of raising per period consumption on the adoption decision declines as an individual approaches their biological maximum age given their environment. In contrast the lump sum utility of a conditional cash transfer is realized in the period in which adoption occurs.

A reduction in competing risks to increase the discount factors in the absence of VMMC (i.e. δ_{NV}) and after VMMC (i.e. δ_V) to 0.90 and 0.95, respectively, yields nearly identical overall effects to medium

[15] A single VMMC generates approximately 1/15–1/5 of an HIV infection averted (UNAIDS et al. 2009). For the purposes of these simulations, I assume that a single VMMC generates 1/10 of an HIV infection averted.

conditional cash transfer. However, reducing competing risks is less effective among the oldest males for the same reason that makes the unconditional cash transfer relatively ineffective: the incentive effect of reducing competing risks declines as an individual approaches their biological maximum age given their environment.

In addition to the aforementioned differences, the policies generate notable differences in the age composition of who is induced to adopt VMMC and in the cost-effectiveness per HIV infection averted. Of the two policies for which it is possible to generate cost-effectiveness estimates, conditional cash transfers are much less expensive per HIA (or per VMMC) – approximately US$21,392 per HIA under the "small" transfer scenario – than is an annual unconditional cash transfer. The unconditional cash transfer must be paid to all men invariant of circumcision status, whereas the conditional cash transfer is only disbursed to men who newly adopt VMMC. Among the three policies under consideration, conditional cash transfers also generate the largest increase for the oldest males (i.e. age 50-59) although it is not clear that these are the "older men" that are required to achieve the full benefits of VMMC scale-up. Males age 30-39 comprise more than 55% of males age 30-59 in Zambia, whereas males age 50-59 comprise 15% of males age 30-59 in Zambia (United Nations 2017).

On the whole, these simulations suggest that it will be very expensive to increase VMMC adoption among older males through interventions that rely solely on reducing the cost or increasing the long-term benefit of adoption. The fact that older males have a shortened time horizon over which to accrue the benefits of adoption severely limits the scope of these types of policies. Instead, alternative interventions aimed at reframing the VMMC decision away from a cost-benefit calculation or aimed at reducing psychological frictions may be required.

6 Discussion and Conclusion

A popular conception is that older people are less likely to adopt new technologies than are younger people. The mechanism underlying this relationship is less well-known. I provide evidence on this question using data from the introduction of voluntary medical male circumcision (VMMC), a new medical technology

with substantial health benefits in high HIV prevalence settings. I find limited support for several leading potential mechanisms such as previous investment in earlier substitute technologies (i.e. traditional circumcision), cohort differences in educational attainment and knowledge about HIV prevention methods, or life-cycle changes (e.g., marriage, having ever had sex, coital frequency). I provide a model showing that shorter time horizons and lower consumption values of life mechanically associated with aging may cause lower VMMC adoption among older males and simulate the adoption-age profile under various parameter assumptions. Although I do not have quasi-experimental variation in life expectancy, I am able to provide evidence ruling out alternative hypotheses and the simulations and additional predictions of the structural model readily fit the data. Reverse causality, in which circumcision affects age and not the other way around, would create an upward sloping VMMC adoption-age profile, not the observed downward sloping profile. An unobserved factor may be simultaneously driving circumcision and age, yet it is not one of the factors for which I directly control (e.g., marriage) and it must vary within respondent cluster, a relatively small geographic unit. Ultimately, the preponderance of evidence supports the interpretation that shorter time horizons are a main mechanism linking aging to lower adoption of this new technology.

My findings help illuminate a heretofore unstudied mechanism in the economic literature underlying a well-known popular belief. Future research may be able to identify and exploit quasi-experimental variation in life expectancy. Furthermore, researchers and policymakers could test methods for increasing VMMC take-up among older males, possibly including targeted cash transfers or reframing the VMMC decision away from a cost-benefit decision and toward a conceptual framework that does not emphasize shorter time horizons.

Compliance with Ethical Standards

This study was not funded by a research grant or other funding source.

This study uses secondary, de-identified data and is deemed as “exempt”.

The author declares that he has no conflict of interest.

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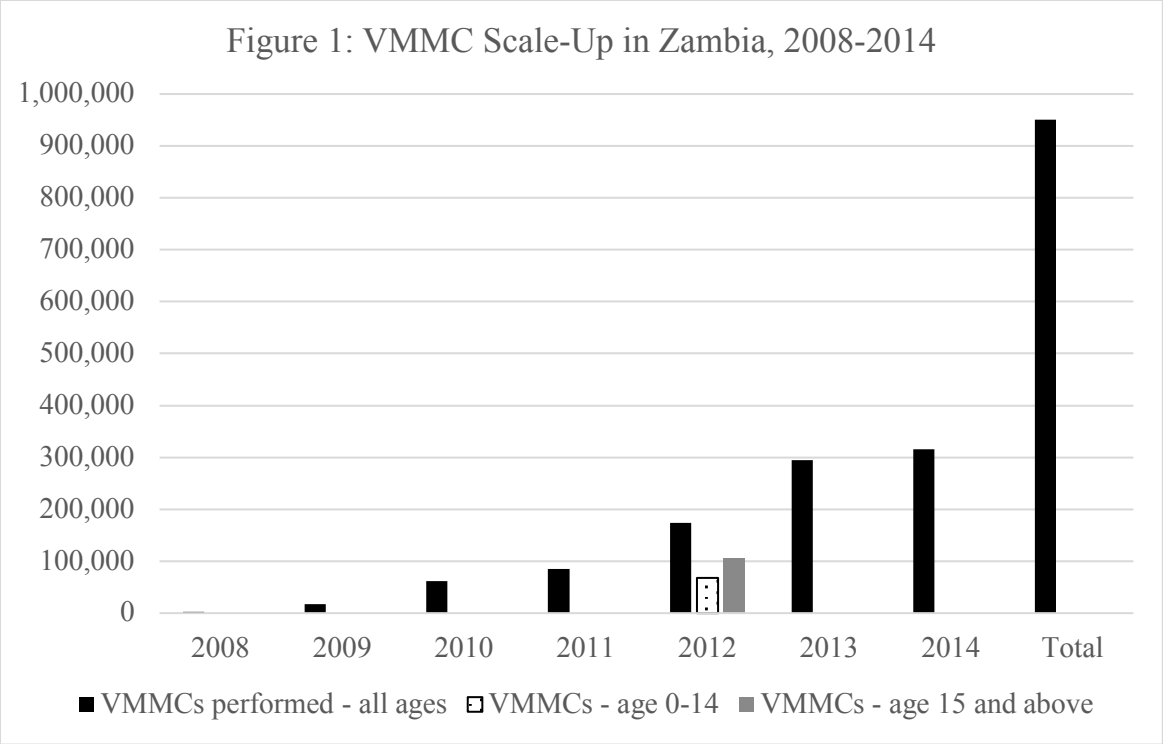

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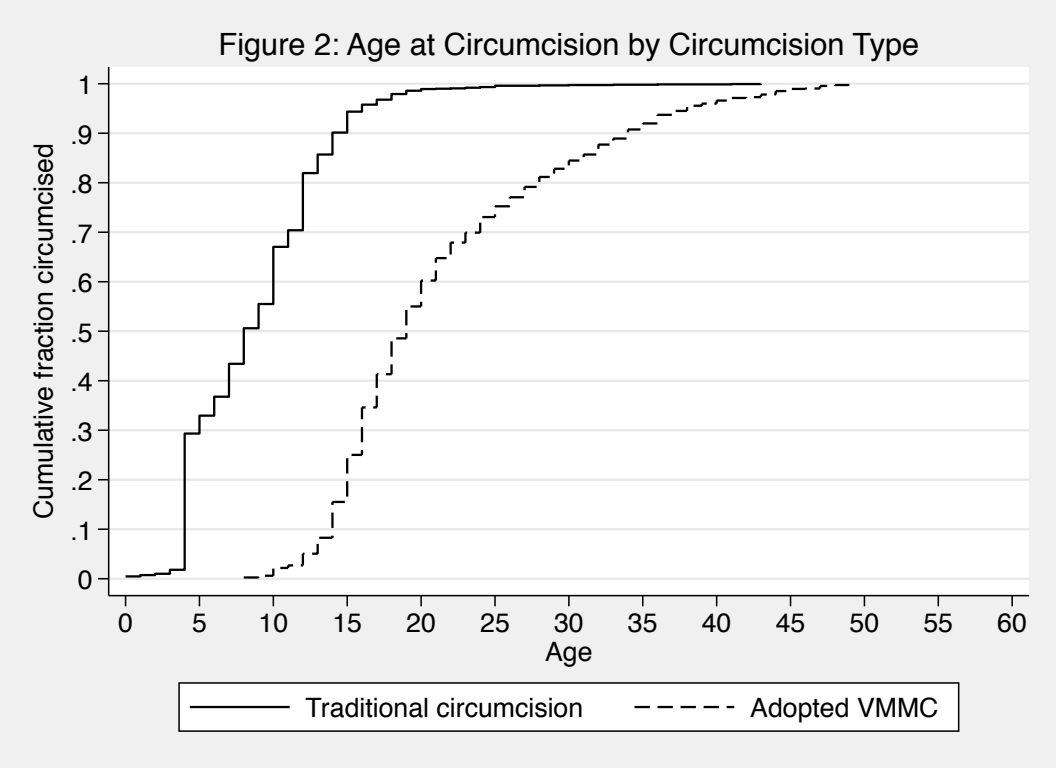


Figure 2: Age at Circumcision by Circumcision Type
Cumulative fraction circumcised
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
0
5
10
15
20
25
30
35
40
45
50
55
60
Age
Traditional circumcision
Adopted VMMC

Figure 3: VMMC Takeup and Age

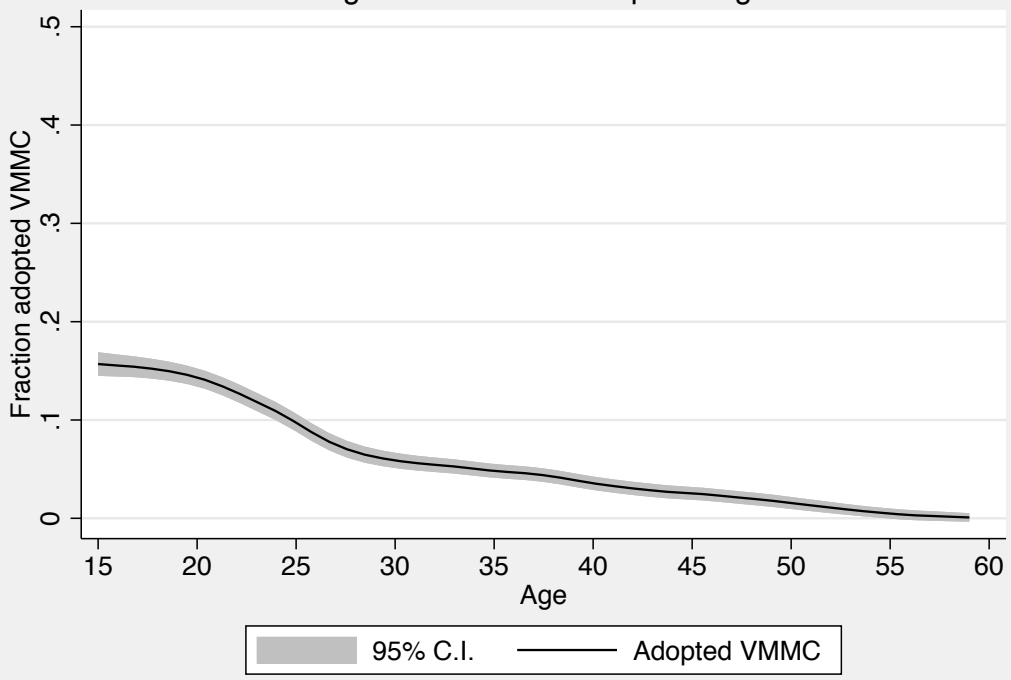


Figure 4: Traditional Circumcision and Age

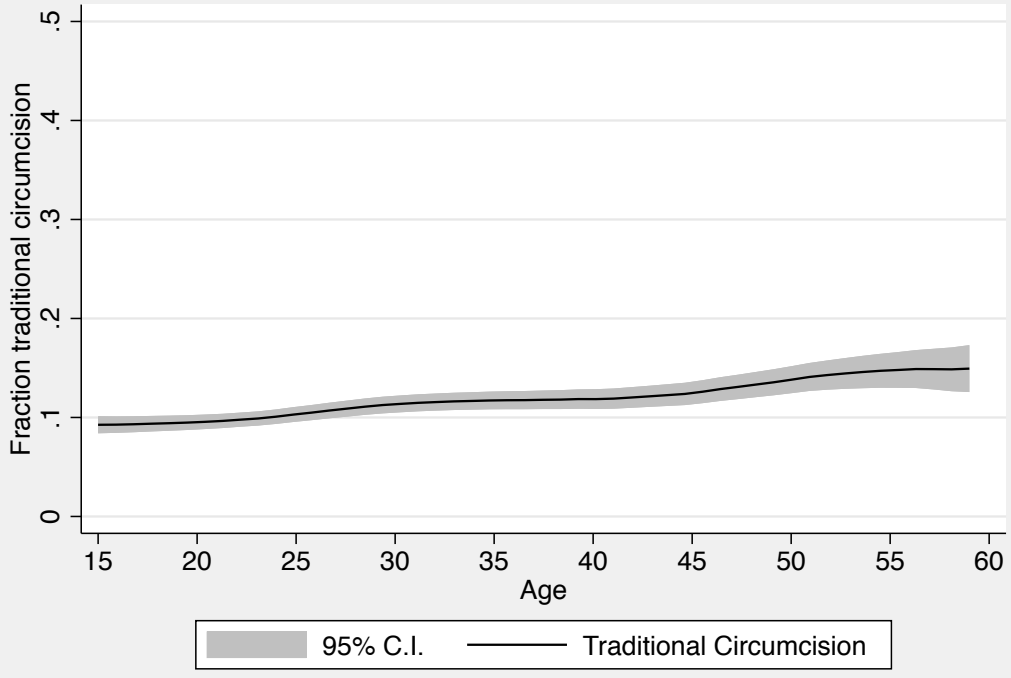


Figure 5: Other Circumcision and Age

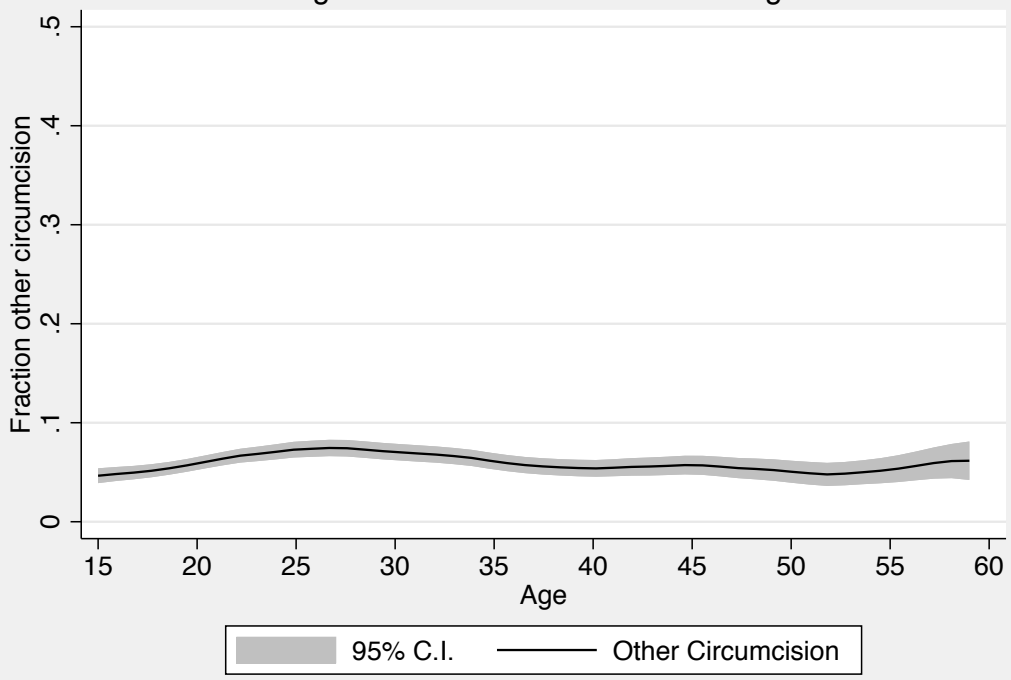


Figure 6: Any Circumcision and Age

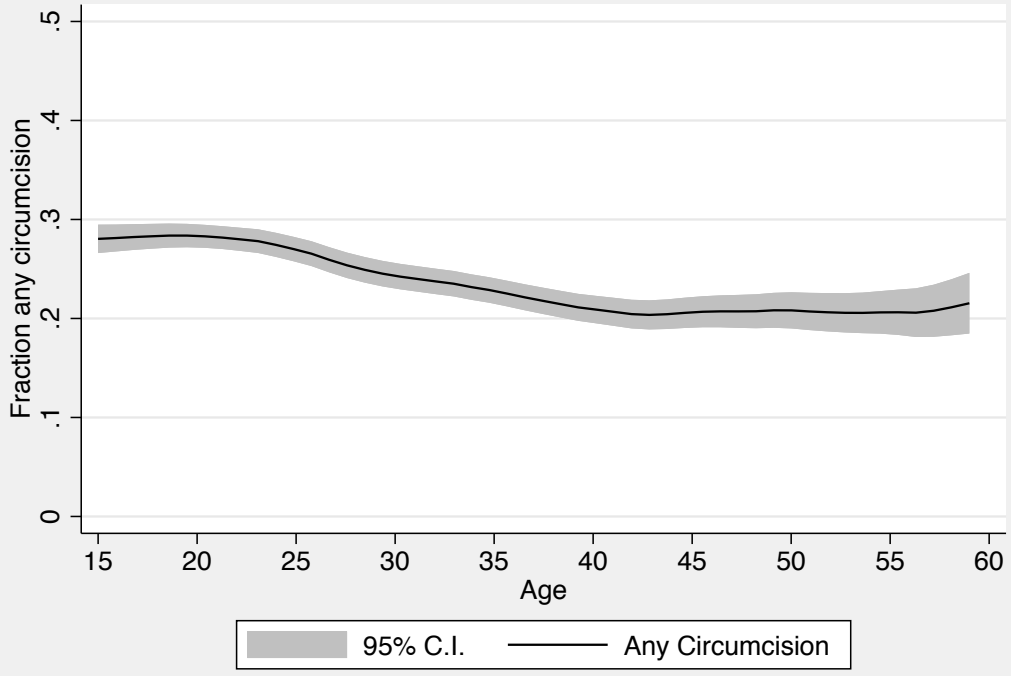
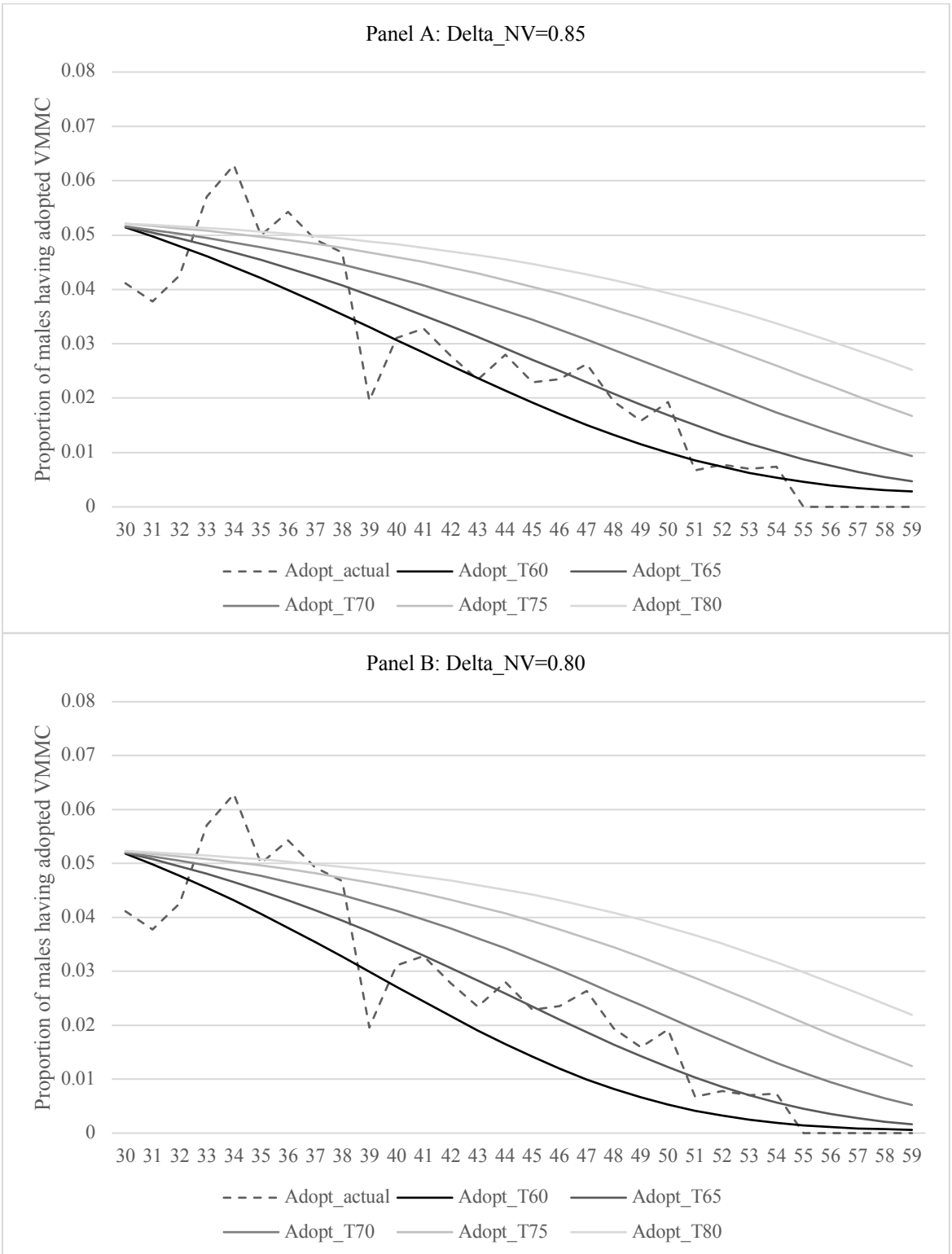


Figure 7: Simulated and Actual Adoption-Age Profiles



Notes: "Adopt_actual" is actual age-adoption profile. "Adopt_T60" is the fitted adoption-age profile with T=60. "Adopt_T65" and so forth are defined similarly. "Delta_NV" is the discount factor in the absence of receiving VMMC.

Table 1: Descriptive Statistics

	Mean	Standard Deviation
	(1)	(2)
Adopted VMMC	0.08	0.27
Traditional circumcision	0.11	0.31
Other circumcision	0.06	0.24
Any circumcision	0.25	0.43
Age	30.67	11.78
Married	0.55	0.50
Ever had sex	0.86	0.34
Sex in past year	0.81	0.40
Sex in past week	0.51	0.50
No education	0.04	0.19
Some primary	0.24	0.42
Completed primary	0.17	0.37
Some secondary	0.35	0.48
Completed secondary	0.13	0.34
Higher education	0.08	0.27
Know abstain	0.91	0.28
Know condom	0.87	0.33
Know faithful	0.97	0.18
HIV positive	0.12	0.32
Wealth index	3.16	1.38
Wealth index - Poorest	0.16	0.36
Wealth index - Poor	0.19	0.40
Wealth index - Middle	0.21	0.41
Wealth index - Richer	0.22	0.41
Wealth index - Richest	0.22	0.41
Observations*	14,197	

Notes: Data come from Zambia 2013 Demographic and Health Survey. All variables except "Age" and "Wealth index" are indicator variables. Education categories are mutually exclusive. *Sample size for HIV positive is 13,061.

Table 2: Age and VMMC Takeup

Dependent variable:	Adopted VMMC	Traditional circumcision	Other circumcision	Any circumcision
	(1)	(2)	(3)	(4)
Panel A: Linear specification				
Age	-0.00398***	0.00130***	0.00013	-0.00213***
	(0.00023)	(0.00019)	(0.00016)	(0.00026)
Panel B: Quadratic specification				
Age	-0.01202***	0.00202*	0.00303***	-0.00499***
	(0.00125)	(0.00113)	(0.00103)	(0.00167)
Age squared	0.00012***	-0.00001	-0.00004***	0.00004*
	(0.00002)	(0.00002)	(0.00002)	(0.00002)
Panel C: Cubic specification				
Age	-0.02440***	0.00966**	0.02027***	0.01121
	(0.00580)	(0.00456)	(0.00471)	(0.00758)
Age squared	0.00050***	-0.00025*	-0.00057***	-0.00046**
	(0.00016)	(0.00014)	(0.00014)	(0.00023)
Age cubed	-0.00000**	0.00000*	0.00001***	0.00000**
	0.00000	0.00000	0.00000	0.00000
Panel D: Semi-parametric specification				
Age 20-24	-0.02484**	0.01241*	0.02757***	0.02332**
	(0.010)	(0.006)	(0.007)	(0.012)
Age 25-29	-0.07931***	0.02763***	0.02452***	-0.01464
	(0.010)	(0.007)	(0.008)	(0.012)
Age 30-34	-0.10409***	0.02665***	0.02553***	-0.03717***
	(0.010)	(0.007)	(0.007)	(0.011)
Age 35-39	-0.10362***	0.03691***	0.01219*	-0.03974***
	(0.010)	(0.008)	(0.007)	(0.012)
Age 40-44	-0.11467***	0.02247***	0.01476**	-0.06265***
	(0.009)	(0.009)	(0.007)	(0.012)
Age 45-49	-0.12265***	0.03960***	0.02026**	-0.04800***
	(0.009)	(0.009)	(0.009)	(0.013)
Age 50-54	-0.13646***	0.06162***	0.002	-0.05807***
	(0.010)	(0.012)	(0.009)	(0.014)
Age 55-59	-0.14166***	0.05282***	0.02147*	-0.05165***
	(0.009)	(0.013)	(0.012)	(0.017)
Cluster fixed effects?	YES	YES	YES	YES
Observations	14,197	14,197	14,197	14,197

Notes: Data come from the Zambia 2013 Demographic and Health Survey (DHS). "Adopted VMMC", "Traditional circumcision", "Other circumcision", and "Any circumcision" are indicator variables. Parameters estimated using ordinary least squares (OLS) regression. Robust standard errors in parentheses are clustered at DHS cluster level.

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

Table 3: Evidence on Mechanisms Linking Age to VMMC Takeup

Dependent variable:	Adopted VMMC								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Age	-0.00294***	-0.00397***	-0.00379***	-0.00363***	-0.00383***	-0.00396***	-0.00395***	-0.00399***	-0.00384***
	(0.00022)	(0.00024)	(0.00023)	(0.00022)	(0.00022)	(0.00022)	(0.00022)	(0.00023)	(0.00024)
Controls for life-cycle differences									
Married	-0.03787***								
	(0.00515)								
Ever had sex		-0.00064							
		(0.00988)							
Sex in past year			-0.01281						
			(0.00841)						
Sex in past week				-0.01876***					
				(0.00494)					
Controls for earlier technologies									
Traditional circumcision					-0.11037***				
					(0.01074)				
Other circumcision						-0.12214***			
						(0.00708)			
Controls for cohort differences									
Some primary							-0.00181		
							(0.00797)		
Completed primary							-0.00323		
							(0.00949)		
Some secondary							0.02021**		
							(0.00887)		
Completed secondary							0.03590***		
							(0.01146)		
Higher education							0.04590***		
							(0.01508)		
Controls for other life-cycle/cohort differences									
Know abstain								0.00897	
								(0.00806)	
Know condom								-0.00416	
								(0.00752)	
Know faithful								0.00884	
								(0.01520)	
HIV positive									-0.01627**
									(0.00735)
Cluster fixed effects?	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	14,197	14,197	14,197	14,197	14,197	14,197	14,197	14,197	13,061

Notes: Data come from the Zambia 2013 Demographic and Health Survey (DHS). "Age" is measured in years; all other variables are indicator variables. "HIV positive" is missing for approximately 8% of the sample, resulting in a smaller sample size in Column (9). Parameters estimated using ordinary least squares (OLS) regression. Robust standard errors in parentheses are clustered at DHS cluster level.

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

Table 4: Robustness Checks

Dependent variable:	Adopted VMMC			
Sample:	Full sample	Age 20-59	Age 25-59	Age 30-59
	(1)	(2)	(3)	(4)
Age	-0.00292***	-0.00249***	-0.00178***	-0.00152***
	(0.00023)	(0.00022)	(0.00023)	(0.00027)
Additional controls?	YES	YES	YES	YES
Other sociodemographic controls?	YES	YES	YES	YES
Cluster fixed effects?	YES	YES	YES	YES
Observations	14,197	11,124	8,888	7,004

Notes: Data come from the Zambia 2013 Demographic and Health Survey (DHS). "Adopted VMMC" is an indicator variable. "Additional controls" are controls reported in Table 3, except for HIV positive. "Other sociodemographic controls" are indicator variables for urban and for wealth quintile. Parameters estimated using ordinary least squares (OLS) regression. Robust standard errors in parentheses are clustered at DHS cluster level.

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

Table 5: Calibration Results

Time horizon:	T=60	T=65	T=70	T=75	T=80
	(1)	(2)	(3)	(4)	(5)
Panel A: Delta_nv=0.85					
Parameters					
c	5.91	6.04	6.12	6.16	6.19
b	1.00	1.00	1.00	1.00	1.00
Goodness-of-fit					
Chi-squared (p-value)	63.35 (0.000)	74.77 (0.000)	84.81 (0.000)	92.64 (0.000)	98.16 (0.000)
RMSE	0.17759	0.17757	0.17757	0.17758	0.17760
Panel B: Delta_nv=0.80					
Parameters					
c	7.53	7.68	7.77	7.82	7.85
b	1.00	1.00	1.00	1.00	1.00
Goodness-of-fit					
Chi-squared (p-value)	58.41 (0.000)	71.76 (0.000)	83.90 (0.000)	93.21 (0.000)	99.38 (0.000)
RMSE	0.17761	0.17757	0.17770	0.17776	0.17760

Notes: Parameters are those used in simulations in Figure 7. "RMSE" is root mean squared error.

Table 6: Evidence on Other Predictions

Dependent variable:	Adopted VMMC			
	(1)	(2)	(3)	(4)
Age	-0.00162***	-0.00010	-0.00196***	-0.00139***
	(0.00044)	(0.00048)	(0.00030)	(0.00035)
Age * Wealth index=poorer	-0.00034			
	(0.00053)			
Age * Wealth index=middle	-0.00026			
	(0.00053)			
Age * Wealth index=richer	-0.00269***			
	(0.00063)			
Age * Wealth index=richest	-0.00327***			
	(0.00068)			
Age * Wealth index		-0.00093***		
		(0.00015)		
Age * HIV prevalence median or above			-0.00196***	
			(0.00044)	
Age * HIV prevalence				-0.01185***
				(0.00216)
Additional controls?	YES	YES	YES	YES
Full set of sociodemographic controls?	YES	YES	YES	YES
Cluster fixed effects?	YES	YES	YES	YES
Observations	14,197	14,197	14,197	14,197

Notes: Data come from the Zambia 2013 Demographic and Health Survey (DHS). "Adopted VMMC" is an indicator variable. "Additional controls" are controls reported in Table 3, except for HIV positive. "Other sociodemographic controls" are indicator variables for urban and for wealth quintile. Parameters estimated using ordinary least squares (OLS) regression. Robust standard errors in parentheses are clustered at DHS cluster level.

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

Table 7: Simulations for Adoption Among Males Age 30+ Under Alternative Policy Scenarios

		Conditional cash transfer for adoption			Annual unconditional cash transfer			Reduction in competing risks
Policy scenario:	Baseline	"Small" transfer	"Medium" transfer	"Large" transfer	"Small" transfer	"Medium" transfer	"Large" transfer	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Fraction adopting VMMC								
All males age 30+	0.033	0.059	0.404	0.926	0.044	0.343	0.780	0.378
Age 30-39	0.048	0.085	0.517	0.958	0.064	0.535	0.963	0.723
Age 40-49	0.035	0.063	0.434	0.942	0.046	0.372	0.898	0.349
Age 50-59	0.016	0.029	0.252	0.872	0.019	0.110	0.446	0.053
Panel B: HIV infections averted (HIAs)								
All males age 30+	5,153	9,203	62,739	143,567	6,763	53,190	121,007	58,620
Age 30-39	4,097	7,260	44,225	81,900	5,506	45,695	82,309	61,836
Age 40-49	1,615	2,892	20,045	43,520	2,115	17,180	41,511	16,145
Age 50-59	372	675	5,904	20,418	454	2,584	10,444	1,230
Panel C: Cost-effectiveness compared to Baseline Scenario								
US$ per HIA	n/a	$21,392	$108,018	$216,036	$2,024,118	$2,573,658	$2,262,563	n/a
Alternative parameter(s):	n/a	reduce c	reduce c	reduce c	increase b	increase b	increase b	increase delta_v and increase delta_nv
Alternative value(s):	n/a	c=5.508 (10% reduction)	c=3.06 (50% reduction)	c=0 (100% reduction)	b=1.1 (10% increase)	b=2 (100% increase)	b=3 (200% increase)	delta_v=0.95, delta_nv=0.90 (~6% increase)

Notes: All scenarios assume b=1, c=6.12, delta_v=0.90, delta_nv=0.85, T=70, unless otherwise stated. "Small transfer", "medium transfer", and "large transfer" are equal to 60%, 300%, and 600% of annual consumption, respectively. Calculations for HIV infections averted assume that one VMMC averts 1/5th of a HIV infection. Population data for Panel B are for Zambia in the year 2012 and come from "United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, custom data acquired via website."