Childhood Health, Marriage Markets, and Young Women's HIV: Evidence from Deworming in Zimbabwe

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Costs of HIV in Sub-Saharan Africa

Untreated HIV: Worker absenteeism, investment in schooling, medical care, GDP growth, tragic early deaths, and more

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Treated HIV: Less devastatingly expensive, but still not cheap!

- \$2 billion spent on antiretroviral therapy (ART) in 34 PEPFAR countries in 2019 (2/3 of funds for HIV-related commodities)
- Donor funding to combat HIV pandemic has plateaued and fallen since 2009 $\rightarrow$ gov'ts of high-HIV prevalence countries will need to bear greater share of costs

Example: Zimbabwe

ART: Costs 1.2% of GDP each year, will likely increase as HIV-related deaths continue to decline while new infections occur

- Delivering ART costs \$175 per patient per year, 1.2 million adults (12.6%) have HIV, 1.1 million of them on ART

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→ **Massive savings:** Avert new HIV infections—or just delay them!

- E.g., 5-year delay with 5% discount rate: 45 years of ART beginning in 5 years is 25% cheaper than 50 years of ART beginning today
- Biggest bang for buck from targeting women 15-24: Comprise 1 in 3 new infections in Zimbabwe and neighboring countries
- At such disproportionate risk because have older and/or more partners

This Paper

HIV status

$\uparrow$

Marriage market matching

This Paper

HIV status

$\uparrow$

Marriage market matching

$\uparrow$

Adult human capital

This Paper

HIV status

$\uparrow$

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Childhood health (very cheap interventions!)

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Childhood health (very cheap interventions!)

Can cheap improvements in girls' health (e.g., deworming) reduce their chances of contracting HIV as young women?

Roadmap

1. **Childhood Health and HIV in Zimbabwe**
   - Theory and evidence: Worms (schistosomiasis) $\rightarrow$ HIV
2. **Deworming Program and Empirical Strategy**
   - Rapid morbidity decline in high-schisto schools $\rightarrow$ diff-in-diff
3. **Diff-in-Diff Results**
   - High-schisto: Young women's HIV $\downarrow$ 44% (2.7 p.p.) more
   - Channels: $\uparrow$ attendance, $\downarrow$ age gap and no. of partners
4. **Toward a Cost-Benefit Analysis**
   - Government finances: PDV HIV benefits 2x more than costs

Contributions

Using economic theory to inform HIV prevention

- Dupas (2011), Robinson and Yeh (2011), Oster (2012), Björkman Nyqvist et al. (2018), Greenwood et al. (2019), Angelucci and Bennett (2021)

Novel and quickly-realized benefit of childhood health . . .

- Case, Fertig, and Paxson (2005), Maccini and Yang (2009), Almond and Currie (2011), Currie and Almond (2011), Gertler et al. (2014), Hoynes, Schanzenbach, and Almond (2016)

. . . And of deworming in particular

- Miguel and Kremer (2004), Bleakley (2007), Baird et al. (2016), Ozier (2018), Hamory et al. (2021) Cochrane review

Marriage markets: Effects of health, non-Western contexts

- Bleakley and Lange (2009), Rocha and Soares (2010), Ashraf et al. (2020), Chiappori (2020), Corno, Hildebrandt, and Voena (2020)

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Nationwide Helminthiasis Prevalence Survey

Source: WHO (2012)

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The mass drug administration is the final phase of a process which started with a national prevalence survey in 2010, and the development of the master plan that began in 2011 and completed in 2012.

The National Prevalence Survey of 2010 showed that Mashonaland East Province, under which Wedza district falls was one of the highly affected. The mass drug administration will therefore target people, mainly under the age of 15, and will be delivered through the country ' s network of schools and health facilities in the high burden districts. The mass drug administration was made possible by WHO which donated to the Ministry of Health and Child Welfare Praziquantel (PZQ) used in the treatment of bilharzia, and Albendazole (ALB) for intestinal worms. A total of 2 583 000 PZQ tablets (600mg) , and 2 450 200 ALB tablets (400mg) were donated. These drugs are expected to cover 3 794 638 people mainly under the age of 15 in the high burden districts.

2010: National prevalence survey

2011-12: Development of master plan for school-based deworming

Schistosomiasis Species Predominated

Prevalence Category	*S. haematobium*	*S. Mansoni*	Hookworm	*A. lumbricoides*	*T. trichiura*
Overall prevalence (95%CI)n	18.0 (17.38–18.71) 13037	7.2 (6.74–7.77) 12249	3.2 (2.91–3.54) 12252	2.5 (2.20–2.76)	0.1 (0.07–2.12)
By gender					
Males	20.8 (19.80–21.80) 6417	7.5 (8.82–8.16) 6040	3.4 (3.00–3.90) 6042	2.4 (2.06–2.85)	0.2 (0.1–0.34)
Females	15.4 (14.52–16.27) 6620	6.9 (6.31–7.59) 6209	3.0 (2.62–3.48) 6210	2.5 (2.12–2.92)	0.01 (0.02–0.16)
Rural based Province					
Manicaland	12.8 (11.33–14.30) 2006	14.3 (12.79–15.93) 1978	2.9 (2.19–3.72) 1978*	1.9 (1.32–2.37) *	0.4 (0.17–0.80)*
Mashonaland East	28.1 (25.72–30.54) 1379	6.4 (5.11–7.88) 1268	1.0 (0.55–1.75) 1269	17.8 (15.74–20.03)	0.2 (0.02–0.57)
Mashonaland Central	26.1 (23.46–28.90) 1034	20.4 (18.00–23.04) 1018	0.6 (0.68–0.22) 1018	1.0 (0.47–1.80)	0.4 (0.11–1.00)
Mashonaland West	22.6 (20.35–20.05) 1259	1.1 (0.56–1.79) 1237	1.6 (0.99–2.48) 1238	1.1 (0.56–1.79)	0.0
Masvingo	27.6 (25.68–29.59) 2054	13.9 (13.40–15.48) 1995	6.0 (5.00–7.10) 1995	0.1 (0.01–0.36)	0.1 (0.01–0.36)
Matabeleland North	3.3 (2.29–4.57) 1032	0.5 (0.17–1.20) 967	14.1 (11.93–16.41) 967	(0.0)*	0.0
Matabeleland South	8.7 (6.95–10.65) 946	0.2 (0.03–0.82) 881	(0.0)** 881	(0.0)*	0.0
Midlands	30.5 (27.76–33.42) 1048	0.3 (0.07–0.97) 896	2.7 (1.72–3.96) 896	0.2 (0.03–0.80)	0.0
Urban Based (metropolitan) Provinces					
Harare	9.6 (7.97–11.46) 1154	0.3 (0.06–0.89) 979	1.5 (0.86–2.51) 980	0.5 (0.17–1.29)	0.0
Bulawayo	3.2 (2.09–4.56) 856	0.6 (0.20–1.43) 815	0.1 (0.00–0.68) 815	0.4 (0.08–1.07)	0.0
Chitungwiza	4.8 (2.60–8.12) 269	0.5 (0.01–2.56) 215	1.4 (0.29–4.02) 215	1.9 (0.51–4.69)	0.0

* = For each province, the number of participants screened for hookworms, *A. lumbricoides* and *T. trichiura* was the same.
** = The prevalence of parasite species was 0%, 95%CI could therefore not be calculated.
doi:10.1371/journal.pntd.0003014.t002

Source: Midzi et al. (2014)

Schisto: Urogenital (*haematobium*), intestinal (*mansoni*) ▸ Rural

Urogenital Schistosomiasis Species Predominated

Prevalence Category	S. Haematobium infection intensity		S. mansoni infection intensity		
	Light	Heavy	Light	Moderate	Heavy
Overall prevalence	12.4 (13037)*	5.6	3.6 (12062)*	1.4	0.3
By Gender					
Males	13.9 (6417)	6.8	3.6 (5951)	1.4	0.3
Females	11.0 (6620)	4.4	3.6 (6111)	1.4	0.3
Rural Provinces					
Manicaland	8.6 (2006)	4.2	8.8 (1939)	0.4	0.3
Mashonaland East	19.0 (1378)	9.1	3.7 (1257)	0.8	0.3
Mashonaland Central	18.2 (1034)	7.9	8.9 (1016)	4.5	1.3
Mashonaland West	16.1 (1259)	6.4	0.3 (1197)	0.0	0.1
Masvingo	18.4 (2054)	9.2	5.0 (1916)	1.9	0.6
Matabeleland North	2.8 (1032)	0.5	0.2 (965)	0.0	0.3
Matabeleland South	6.1 (946)	2.5	0.2 (871)	0.0	0.1
Midlands	20.8 (1048)	9.7	0.1 (892)	0.0	0.0
Urban Provinces					
Harare	6.8 (1155)	2.9	1.2 (979)	0.0	0.0
Bulawayo	2.8 (856)	0.5	0.6 (815)	0.0	0.0
Chitungwiza¤	3.7 (267)	0.4	0.9 (215)	0.0	0.0

Source: Midzi et al. (2014)

Most morbidity from heavy infection → urogenital matters most

Urogenital Schistosomiasis → HIV?

Disease: Inflammatory response to worm eggs getting trapped in nearby tissues → "anaemia, growth stunting, impaired cognition, ... organ-specific effects such as ... urogenital inflammation and scarring" (Colley et al., 2014, p. 2253)

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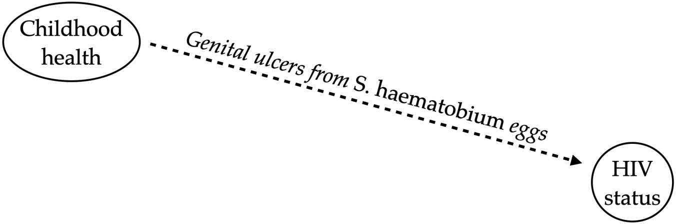

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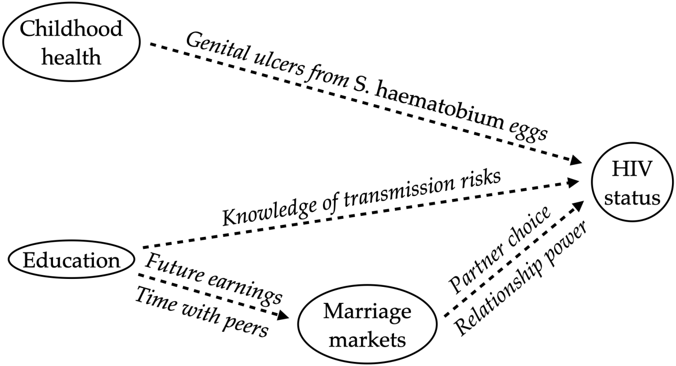

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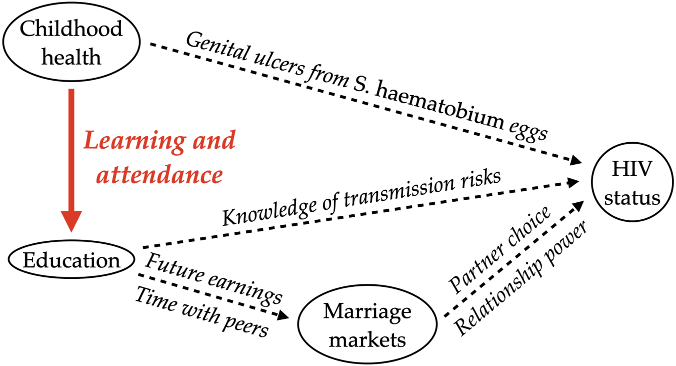
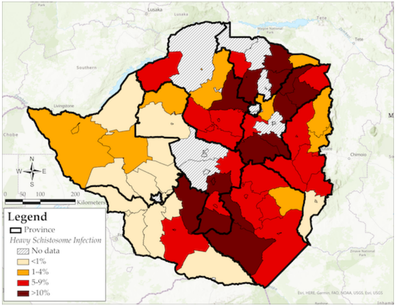
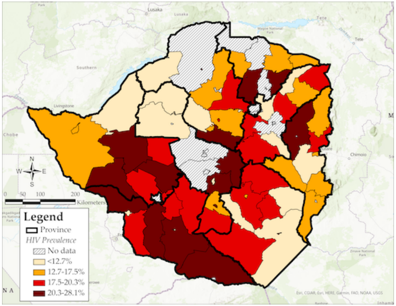


Schistosomiasis and HIV before Deworming



Heavy *S. haematobium* Infection
Students, 2010
(from Midzi et al., 2014)



HIV Prevalence
Ages 15-49, 2005 and 2010
(from DHS data)

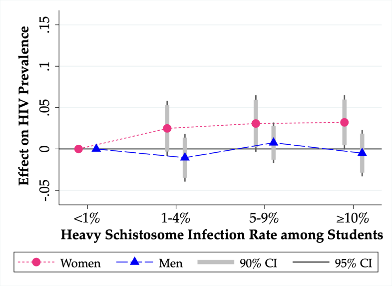
Measuring Correlations

Pre-deworming relationship: Estimate effect on HIV of increasing category of schistosomiasis morbidity in 2005 and 2010 data

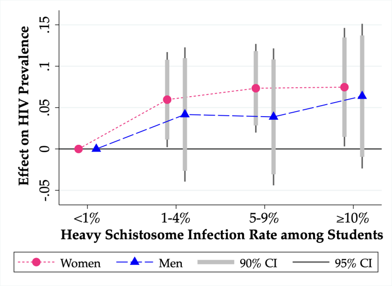
$$HIV_{i,c,t} = \alpha_{p(c)} + \gamma_t + \sum_{k=2}^{4} \tau_k \times Category_{d(c)} + \mathbf{X}_i \beta + f(Lat_c, Lon_c) + \epsilon_{i,c,t}$$

- $\alpha_{p(c)}$, γ_t: FEs for cluster's province, year of observation
- $Category_{d(c)}$: District's category of heavy schistosome infection rate (1 lowest and omitted, 4 highest)
- Controls: Quadratics in individual's age, cluster's lat./lon.
- Standard errors: Cluster by 67 districts in data from pre-deworming years

Pre-Deworming Correlations by Age Group and Sex



Ages 15-34



Ages 35-54

Notes: Regressions use 7,625 observations for females and 5,656 for males ages 15 to 34, and 2,673 for females and 2,134 for males ages 35 to 54. Mean pre-treatment HIV prevalence in lowest-category districts was 16.0 percent for females and 8.7 percent for males ages 15 to 34, and 23.3 percent for females and 25.3 percent for males ages 35 to 54.

✓ Consistent with schisto contributing to cycle of transmission driven by age-disparate relationships ▸ Explanation

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Nationwide School-Based Deworming Program

Source: WHO (2012)

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End of 2012 school year: Mass deworming began in schools

→ Targeted high-burden districts, "mainly under the age of 15"

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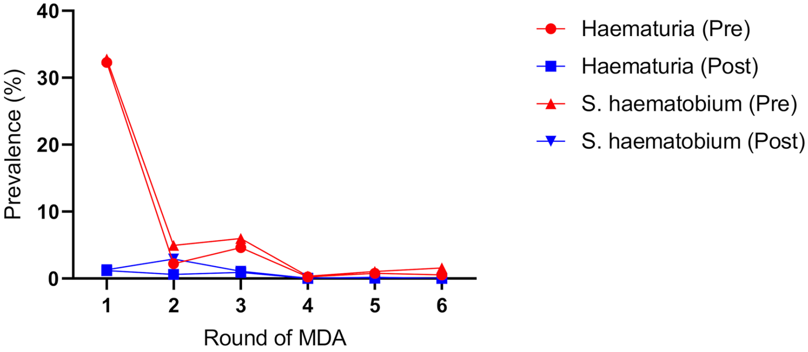
→ Planned to treat 3.8 million students (est. 5.2 million under age 15)

Deworming Program Quickly Reduced Morbidity



Source: Mduluza et al. (2020)

2012-17: 6 years of mass drug administration (MDA) in schools

Tracked prevalence in sentinel sites (mostly high-schisto areas)

Defining Groups for Comparison

Prevalence category	Districts (IUs)	Comments and intervention strategies
≥10%	Murehwa, Shamva, Mwenezi, Shurugwi, Chikomba, Mutoko, UMP, Hwedza, Mazowe, Mt. Darwin, Zvimba, Chivi, Insiza, Mberengwa (n = 14)	Morbidity is highest, highest transmitting districts. Highest priority requiring uninterrupted intensified PCT with annual geographic coverage of 100% per district. Complementary strategies urgently required. The goal is to control morbidity (reduce prevalence of heavy infection by any schistosome to <5%) in the first 5 years and prevent transmission.
≥5% but <10%	Buhera, Chimanimani, Makoni, Mutare, Mudzi, Seke, Guruve, Muzarabani, Chegutu, Kariba, Kadoma, Chiredzi, Gutu, Masvingo, Zaka, Gwanda, Chirumhanzu, Zvishavane (n = 18)	Morbidity is high. High transmitting districts requiring MDA regularly according to WHO strategies with geographic coverage of 75–100% per district. Complementary strategies are required. The goal is to control morbidity by reducing the prevalence of heavy infection by any schistosome species in the first 5 years to <5% and prevent transmission.
≥1% but <5%	Mutasa, Nyanga, Goromonzi, Marondera, Rushinga, Makonde, Karoyi, Bikita, Hwange, Lupane, Gokwe North, Glenview/Mufakose, Highfields/Glen Norah, Marlbereign/Warren Park, Mabvuku/Tafara, Chitungwiza-Zengeza, Mbare/Hatfield, Khami (n = 17)	Morbidity is moderate though unjustifiable. Moderate transmitting districts. Regular MDA according to WHO guidelines based on prevalence. In addition, identification of transmission foci for intensified PCT is recommended. Complementary strategies are required. The goal is to eliminate schistosomiasis as a public health problem.
<1%	Chipinge, Binga, Beitbridge, Chitungwiza-Seke (n = 4)	Morbidity is low. Low transmitting districts. PCT to be implemented according to WHO guidelines. In addition, monitoring and surveillance of schistosomaisis transmitting foci for intensified PCT is recommended. Complementary strategies are required. The goal is to interrupt transmission.
0%	Bubi, Nkayi, Tsholotsho, Umguza, Bulilima, Matobo, Magwe, Umzingwane, Gokwe South, Reigate, Imbizo, Mzilikazi, Sizinda, North Central (n = 15)	Detailed surveillance should be done to identify any transmitting foci for intensified PCT. Complementary strategies are required. The goal is to interrupt schistosomiasis.

Source: Midzi et al. (2014)

All districts treated simultaneously: "High schisto" vs "low schisto"

→ Treatment guidelines based on heavy infection rates

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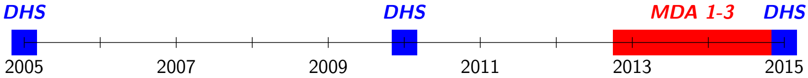
→ "High" ≥ 5% heavy infection (N = 43), "low" < 5% (N = 28)

Empirical Strategy: Diff-in-Diff



Compare: High- vs low-schisto areas, before vs after deworming

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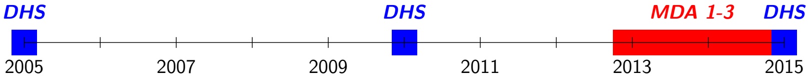

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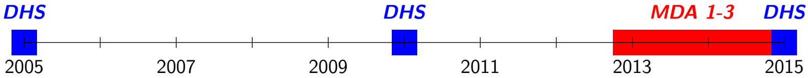
Age-specific focus: Ages 12-17 in 2012 $\rightarrow$ ages 15-20 in 2015

- 17 is last age at which most boys and girls were in school

Empirical Strategy: Diff-in-Diff



Compare: High- vs low-schisto areas, before vs after deworming

Age-specific focus: Ages 12-17 in 2012 → ages 15-20 in 2015

- 17 is last age at which most boys and girls were in school

Robustness and credibility

- Upper end of age range may have migrated, schisto more prevalent in rural areas → check for same effects among rural women ages 15-18
- Ages 18-21 in 2012 (ages 21-24 in 2015) similar but "mostly unexposed" to deworming → use women ages 21-24 as placebo test

Diff-in-Diff Specifications

1. **Dynamic:** Compare each year to 2010 (assess parallel trends)

$$y_{i,c,t} = \alpha_{d(c)} + \gamma_t + \sum_{\substack{k \in \{2005, \\ 2015\}}} \tau_k \times (\mathbf{1}[t = k] \times High_{d(c)}) + \mathbf{X}_i \beta + f(Lat_c, Lon_c) + \epsilon_{i,c,t}$$

- $\alpha_{d(c)}$, γ_t: FEs for cluster's district, year of observation
- $High_{d(c)}$: Indicates whether cluster in high-schisto district
- $\mathbf{1}[t = k]$: Indicates whether observation from year k
- Controls: Quadratics in individual's age, cluster's lat./lon.
- Standard errors: Cluster by 71 districts

Diff-in-Diff Specifications

1. **Dynamic:** Compare each year to 2010 (assess parallel trends)

$$y_{i,c,t} = \alpha_{d(c)} + \gamma_t + \sum_{\substack{k\in\{2005,\\ 2015\}}} \tau_k \times \left(\mathbf{1}[t=k] \times High_{d(c)}\right)$$
$$+ \mathbf{X}_i\beta + f(Lat_c, Lon_c) + \epsilon_{i,c,t}$$

   - $\alpha_{d(c)}$, γ_t: FEs for cluster's district, year of observation
   - $High_{d(c)}$: Indicates whether cluster in high-schisto district
   - $\mathbf{1}[t=k]$: Indicates whether observation from year k
   - Controls: Quadratics in individual's age, cluster's lat./lon.
   - Standard errors: Cluster by 71 districts

2. **Static:** Pool pre-deworming years (improve power)

$$y_{i,c,t} = \alpha_{d(c)} + \gamma_t + \tau \times \left(Post_t \times High_{d(c)}\right)$$
$$+ \mathbf{X}_i\beta + f(Lat_c, Lon_c) + \epsilon_{i,c,t}$$

Roadmap

1. **Childhood Health and HIV in Zimbabwe**
   - Theory and evidence: Worms (schistosomiasis) → HIV
2. **Deworming Program and Empirical Strategy**
   - Rapid morbidity decline in high-schisto schools → diff-in-diff
3. **Diff-in-Diff Results**
   - High-schisto: Young women's HIV ↓ 44% (2.7 p.p.) more
   - Channels: ↑ attendance, ↓ age gap and no. of partners
4. **Toward a Cost-Benefit Analysis**
   - Government finances: PDV HIV benefits 2x more than costs

Effect of Deworming on Young Adults' HIV Prevalence

	Exposed to Deworming				Placebo	
	Ages 15-20		Women 15-18		Ages 21-24	
	Women (1)	Men (2)	All (3)	Rural (4)	Women (5)	Men (6)
Panel A. Dynamic Estimates						
2005 × High	-0.014	0.027	-0.019	-0.013	-0.010	0.027
	(0.018)	(0.016)	(0.018)	(0.019)	(0.028)	(0.041)
2015 × High	-0.034	0.016	-0.041	-0.040	-0.009	-0.007
	(0.016)	(0.018)	(0.020)	(0.021)	(0.029)	(0.030)
Panel B. Static Estimates						
Post × High	-0.027	0.002	-0.031	-0.034	-0.004	-0.020
	(0.016)	(0.012)	(0.019)	(0.017)	(0.029)	(0.024)
Observations	4,309	4,126	3,011	2,499	2,435	1,559
Districts	71	71	71	54	71	70
Pre-Deworming Mean (High=1)	0.062	0.030	0.050	0.044	0.147	0.057

Column 1: Young women's HIV ↓ 44% (2.7 p.p.) more

Effect of Deworming on Young Adults' HIV Prevalence

	Exposed to Deworming				Placebo	
	Ages 15-20		Women 15-18		Ages 21-24	
	Women (1)	Men (2)	All (3)	Rural (4)	Women (5)	Men (6)
Panel A. Dynamic Estimates						
2005 $\times$ High	-0.014	0.027	-0.019	-0.013	-0.010	0.027
	(0.018)	(0.016)	(0.018)	(0.019)	(0.028)	(0.041)
2015 $\times$ High	-0.034	0.016	-0.041	-0.040	-0.009	-0.007
	(0.016)	(0.018)	(0.020)	(0.021)	(0.029)	(0.030)
Panel B. Static Estimates						
Post $\times$ High	-0.027	0.002	-0.031	-0.034	-0.004	-0.020
	(0.016)	(0.012)	(0.019)	(0.017)	(0.029)	(0.024)
Observations	4,309	4,126	3,011	2,499	2,435	1,559
Districts	71	71	71	54	71	70
Pre-Deworming Mean (High=1)	0.062	0.030	0.050	0.044	0.147	0.057

Column 2: No evidence of HIV effect for young men

Effect of Deworming on Young Adults' HIV Prevalence

	Exposed to Deworming				Placebo	
	Ages 15-20		Women 15-18		Ages 21-24	
	Women (1)	Men (2)	All (3)	Rural (4)	Women (5)	Men (6)
Panel A. Dynamic Estimates						
2005 × High	-0.014	0.027	-0.019	-0.013	-0.010	0.027
	(0.018)	(0.016)	(0.018)	(0.019)	(0.028)	(0.041)
2015 × High	-0.034	0.016	-0.041	-0.040	-0.009	-0.007
	(0.016)	(0.018)	(0.020)	(0.021)	(0.029)	(0.030)
Panel B. Static Estimates						
Post × High	-0.027	0.002	-0.031	-0.034	-0.004	-0.020
	(0.016)	(0.012)	(0.019)	(0.017)	(0.029)	(0.024)
Observations	4,309	4,126	3,011	2,499	2,435	1,559
Districts	71	71	71	54	71	70
Pre-Deworming Mean (High=1)	0.062	0.030	0.050	0.044	0.147	0.057

Columns 3-4: Robust to women 15-18, rural restrictions

Effect of Deworming on Young Adults' HIV Prevalence

	Exposed to Deworming				Placebo	
	Ages 15-20		Women 15-18		Ages 21-24	
	Women (1)	Men (2)	All (3)	Rural (4)	Women (5)	Men (6)
Panel A. Dynamic Estimates						
2005 × High	-0.014	0.027	-0.019	-0.013	-0.010	0.027
	(0.018)	(0.016)	(0.018)	(0.019)	(0.028)	(0.041)
2015 × High	-0.034	0.016	-0.041	-0.040	-0.009	-0.007
	(0.016)	(0.018)	(0.020)	(0.021)	(0.029)	(0.030)
Panel B. Static Estimates						
Post × High	-0.027	0.002	-0.031	-0.034	-0.004	-0.020
	(0.016)	(0.012)	(0.019)	(0.017)	(0.029)	(0.024)
Observations	4,309	4,126	3,011	2,499	2,435	1,559
Districts	71	71	71	54	71	70
Pre-Deworming Mean (High=1)	0.062	0.030	0.050	0.044	0.147	0.057

Columns 5-6: No effects detected in placebo tests

Effect of Deworming on Components of Human Capital

	Health: Urogenital		Education: Attending School			
	Women 15-20		Ages 13-18		Rural Women	
	Ulcer	Discharge	Women	Men	13-18	15-18
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Dynamic Estimates						
2005 × High	-0.012	-0.003	-0.005	-0.037	-0.002	-0.030
	(0.012)	(0.019)	(0.037)	(0.034)	(0.041)	(0.062)
2015 × High	-0.010	-0.006	0.057	-0.030	0.069	0.072
	(0.013)	(0.010)	(0.036)	(0.033)	(0.035)	(0.046)
Panel B. Static Estimates						
Post × High	-0.004	-0.004	0.060	-0.010	0.070	0.087
	(0.011)	(0.009)	(0.035)	(0.031)	(0.038)	(0.048)
Observations	4,854	4,850	6,261	6,606	5,310	3,060
Districts	71	71	71	71	54	54
Pre-Deworming Mean (High=1)	0.018	0.024	0.666	0.711	0.674	0.513

Columns 1-2: Absence of evidence on ulcers (data imperfect)

Effect of Deworming on Components of Human Capital

	Health: Urogenital		Education: Attending School			
	Women 15-20		Ages 13-18		Rural Women	
	Ulcer (1)	Discharge (2)	Women (3)	Men (4)	13-18 (5)	15-18 (6)
Panel A. Dynamic Estimates						
2005 × High	-0.012	-0.003	-0.005	-0.037	-0.002	-0.030
	(0.012)	(0.019)	(0.037)	(0.034)	(0.041)	(0.062)
2015 × High	-0.010	-0.006	0.057	-0.030	0.069	0.072
	(0.013)	(0.010)	(0.036)	(0.033)	(0.035)	(0.046)
Panel B. Static Estimates						
Post × High	-0.004	-0.004	0.060	-0.010	0.070	0.087
	(0.011)	(0.009)	(0.035)	(0.031)	(0.038)	(0.048)
Observations	4,854	4,850	6,261	6,606	5,310	3,060
Districts	71	71	71	71	54	54
Pre-Deworming Mean (High=1)	0.018	0.024	0.666	0.711	0.674	0.513

Column 3: Young women's attendance ↑ 9% (6.0 p.p.) more

Effect of Deworming on Components of Human Capital

	Health: Urogenital		Education: Attending School			
	Women 15-20		Ages 13-18		Rural Women	
	Ulcer (1)	Discharge (2)	Women (3)	Men (4)	13-18 (5)	15-18 (6)
Panel A. Dynamic Estimates						
2005 $\times$ High	-0.012	-0.003	-0.005	-0.037	-0.002	-0.030
	(0.012)	(0.019)	(0.037)	(0.034)	(0.041)	(0.062)
2015 $\times$ High	-0.010	-0.006	0.057	-0.030	0.069	0.072
	(0.013)	(0.010)	(0.036)	(0.033)	(0.035)	(0.046)
Panel B. Static Estimates						
Post $\times$ High	-0.004	-0.004	0.060	-0.010	0.070	0.087
	(0.011)	(0.009)	(0.035)	(0.031)	(0.038)	(0.048)
Observations	4,854	4,850	6,261	6,606	5,310	3,060
Districts	71	71	71	71	54	54
Pre-Deworming Mean (High=1)	0.018	0.024	0.666	0.711	0.674	0.513

Column 4: No school effect for young men (as in Baird et al., 2016)

Effect of Deworming on Components of Human Capital

	Health: Urogenital		Education: Attending School			
	Women 15-20		Ages 13-18		Rural Women	
	Ulcer (1)	Discharge (2)	Women (3)	Men (4)	13-18 (5)	15-18 (6)
Panel A. Dynamic Estimates						
2005 × High	-0.012	-0.003	-0.005	-0.037	-0.002	-0.030
	(0.012)	(0.019)	(0.037)	(0.034)	(0.041)	(0.062)
2015 × High	-0.010	-0.006	0.057	-0.030	0.069	0.072
	(0.013)	(0.010)	(0.036)	(0.033)	(0.035)	(0.046)
Panel B. Static Estimates						
Post × High	-0.004	-0.004	0.060	-0.010	0.070	0.087
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Pre-Deworming Mean (High=1)	0.018	0.024	0.666	0.711	0.674	0.513

Columns 5-6: Robust to women 15-18, rural restrictions

Effect of Deworming on HIV Risks (Women 15-20)

	Direct: Knowledge		Indirect: Marriage Market			
	Reduces Risk		Partner Age Gap		Partners	Last Sex
	1 Partner	Condom	$\geq$9 Years	5-8 Years	$\geq$2 in Life	Condom
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Dynamic Estimates						
2005 $\times$ High	-0.043	0.014	-0.063	0.011	0.007	-0.001
	(0.034)	(0.062)	(0.082)	(0.067)	(0.030)	(0.042)
2015 $\times$ High	0.002	0.071	-0.195	0.171	-0.026	-0.025
	(0.031)	(0.039)	(0.087)	(0.102)	(0.021)	(0.039)
Panel B. Static Estimates						
Post $\times$ High	0.024	0.064	-0.164	0.166	-0.030	-0.024
	(0.027)	(0.041)	(0.068)	(0.080)	(0.020)	(0.035)
Observations	4,679	4,677	1,308	1,308	4,861	1,778
Districts	71	71	70	70	71	70
Pre-Deworming Mean (High=1)	0.817	0.724	0.267	0.407	0.075	0.097

Rural women 15-18 Women 21-24

Column 1: Non-parallel trends for knowing monogamy reduces risk

Effect of Deworming on HIV Risks (Women 15-20)

	Direct: Knowledge		Indirect: Marriage Market			
	Reduces Risk		Partner Age Gap		Partners	Last Sex
	1 Partner (1)	Condom (2)	$\geq$9 Years (3)	5-8 Years (4)	$\geq$2 in Life (5)	Condom (6)
Panel A. Dynamic Estimates						
2005 $\times$ High	-0.043	0.014	-0.063	0.011	0.007	-0.001
	(0.034)	(0.062)	(0.082)	(0.067)	(0.030)	(0.042)
2015 $\times$ High	0.002	0.071	-0.195	0.171	-0.026	-0.025
	(0.031)	(0.039)	(0.087)	(0.102)	(0.021)	(0.039)
Panel B. Static Estimates						
Post $\times$ High	0.024	0.064	-0.164	0.166	-0.030	-0.024
	(0.027)	(0.041)	(0.068)	(0.080)	(0.020)	(0.035)
Observations	4,679	4,677	1,308	1,308	4,861	1,778
Districts	71	71	70	70	71	70
Pre-Deworming Mean (High=1)	0.817	0.724	0.267	0.407	0.075	0.097

▸ Rural women 15-18 ▸ Women 21-24

Column 2: Knowing condoms reduce risk ↑ 9% (6.4 p.p.) more

Effect of Deworming on HIV Risks (Women 15-20)

	Direct: Knowledge		Indirect: Marriage Market			
	Reduces Risk		Partner Age Gap		Partners	Last Sex
	1 Partner	Condom	≥9 Years	5-8 Years	≥2 in Life	Condom
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Dynamic Estimates						
2005 × High	-0.043	0.014	-0.063	0.011	0.007	-0.001
	(0.034)	(0.062)	(0.082)	(0.067)	(0.030)	(0.042)
2015 × High	0.002	0.071	-0.195	0.171	-0.026	-0.025
	(0.031)	(0.039)	(0.087)	(0.102)	(0.021)	(0.039)
Panel B. Static Estimates						
Post × High	0.024	0.064	-0.164	0.166	-0.030	-0.024
	(0.027)	(0.041)	(0.068)	(0.080)	(0.020)	(0.035)
Observations	4,679	4,677	1,308	1,308	4,861	1,778
Districts	71	71	70	70	71	70
Pre-Deworming Mean (High=1)	0.817	0.724	0.267	0.407	0.075	0.097

▸ Rural women 15-18 ▸ Women 21-24

Column 3: Age gap above 75 pctile ↓ 16.4 p.p. more ▸ Marriage rates

Effect of Deworming on HIV Risks (Women 15-20)

	Direct: Knowledge		Indirect: Marriage Market			
	Reduces Risk		Partner Age Gap		Partners	Last Sex
	1 Partner	Condom	$\geq$9 Years	5-8 Years	$\geq$2 in Life	Condom
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Dynamic Estimates						
2005 $\times$ High	-0.043	0.014	-0.063	0.011	0.007	-0.001
	(0.034)	(0.062)	(0.082)	(0.067)	(0.030)	(0.042)
2015 $\times$ High	0.002	0.071	-0.195	0.171	-0.026	-0.025
	(0.031)	(0.039)	(0.087)	(0.102)	(0.021)	(0.039)
Panel B. Static Estimates						
Post $\times$ High	0.024	0.064	-0.164	0.166	-0.030	-0.024
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Observations	4,679	4,677	1,308	1,308	4,861	1,778
Districts	71	71	70	70	71	70
Pre-Deworming Mean (High=1)	0.817	0.724	0.267	0.407	0.075	0.097

▸ Rural women 15-18 ▸ Women 21-24

Column 4: Age gap btwn. median and 75 pctile ↑ 16.6 p.p. more

Effect of Deworming on HIV Risks (Women 15-20)

	Direct: Knowledge		Indirect: Marriage Market			
	Reduces Risk		Partner Age Gap		Partners	Last Sex
	1 Partner	Condom	$\geq$9 Years	5-8 Years	$\geq$2 in Life	Condom
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Dynamic Estimates						
2005 $\times$ High	-0.043	0.014	-0.063	0.011	0.007	-0.001
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Panel B. Static Estimates						
Post $\times$ High	0.024	0.064	-0.164	0.166	-0.030	-0.024
	(0.027)	(0.041)	(0.068)	(0.080)	(0.020)	(0.035)
Observations	4,679	4,677	1,308	1,308	4,861	1,778
Districts	71	71	70	70	71	70
Pre-Deworming Mean (High=1)	0.817	0.724	0.267	0.407	0.075	0.097

▸ Rural women 15-18 ▸ Women 21-24

Column 5: Having had 2+ partners in lifetime ↓ 40% (3 p.p.) more

Effect of Deworming on HIV Risks (Women 15-20)

	Direct: Knowledge		Indirect: Marriage Market			
	Reduces Risk		Partner Age Gap		Partners	Last Sex
	1 Partner	Condom	$\geq$9 Years	5-8 Years	$\geq$2 in Life	Condom
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Dynamic Estimates						
2005 $\times$ High	-0.043	0.014	-0.063	0.011	0.007	-0.001
	(0.034)	(0.062)	(0.082)	(0.067)	(0.030)	(0.042)
2015 $\times$ High	0.002	0.071	-0.195	0.171	-0.026	-0.025
	(0.031)	(0.039)	(0.087)	(0.102)	(0.021)	(0.039)
Panel B. Static Estimates						
Post $\times$ High	0.024	0.064	-0.164	0.166	-0.030	-0.024
	(0.027)	(0.041)	(0.068)	(0.080)	(0.020)	(0.035)
Observations	4,679	4,677	1,308	1,308	4,861	1,778
Districts	71	71	70	70	71	70
Pre-Deworming Mean (High=1)	0.817	0.724	0.267	0.407	0.075	0.097

Rural women 15-18 Women 21-24

Column 6: Surprise! Condom use $\downarrow$ 25% (2.4 p.p.) more, but noisy

Roadmap

1. **Childhood Health and HIV in Zimbabwe**
   - Theory and evidence: Worms (schistosomiasis) $\rightarrow$ HIV
2. **Deworming Program and Empirical Strategy**
   - Rapid morbidity decline in high-schisto schools $\rightarrow$ diff-in-diff
3. **Diff-in-Diff Results**
   - High-schisto: Young women's HIV $\downarrow$ 44% (2.7 p.p.) more
   - Channels: $\uparrow$ attendance, $\downarrow$ age gap and no. of partners
4. **Toward a Cost-Benefit Analysis**
   - Government finances: PDV HIV benefits 2x more than costs

Simplest Approach: Effect on Government Finances

Currency: 2014 $, 3% discount rate (Ndeffo Mbah et al., 2013)

Benefits of averted HIV infections:

- Avoid lifelong costs of antiretroviral therapy: $3,750
- Avoid other health care arising from living with HIV: $868.75
- 4.3-p.p. decrease in HIV prevalence for women 18-20

Simplest Approach: Effect on Government Finances

Currency: 2014 $, 3% discount rate (Ndeffo Mbah et al., 2013)

Benefits of averted HIV infections: Expected PDV of $198.61

- Avoid lifelong costs of antiretroviral therapy: $3,750
- Avoid other health care arising from living with HIV: $868.75
- 4.3-p.p. decrease in HIV prevalence for women 18-20

Simplest Approach: Effect on Government Finances

Currency: 2014 $, 3% discount rate (Ndeffo Mbah et al., 2013)

Benefits of averted HIV infections: Expected PDV of $198.61

- Avoid lifelong costs of antiretroviral therapy: $3,750
- Avoid other health care arising from living with HIV: $868.75
- 4.3-p.p. decrease in HIV prevalence for women 18-20

Costs of averted HIV infections:

- Praziquantel dose per student year: $0.10
- Administering deworming program per student per year: $0.26

Simplest Approach: Effect on Government Finances

Currency: 2014 \$, 3% discount rate (Ndeffo Mbah et al., 2013)

Benefits of averted HIV infections: Expected PDV of \$198.61

- Avoid lifelong costs of antiretroviral therapy: \$3,750
- Avoid other health care arising from living with HIV: \$868.75
- 4.3-p.p. decrease in HIV prevalence for women 18-20

Costs of averted HIV infections: Expected PDV of \$1.05 +

- Praziquantel dose per student year: \$0.10
- Administering deworming program per student per year: \$0.26

Simplest Approach: Effect on Government Finances

Currency: 2014 \$, 3% discount rate (Ndeffo Mbah et al., 2013)

Benefits of averted HIV infections: Expected PDV of \$198.61

- Avoid lifelong costs of antiretroviral therapy: \$3,750
- Avoid other health care arising from living with HIV: \$868.75
- 4.3-p.p. decrease in HIV prevalence for women 18-20

Costs of averted HIV infections: Expected PDV of \$1.05 +

- Praziquantel dose per student year: \$0.10
- Administering deworming program per student per year: \$0.26
- Spending on secondary school per student per year: \$328.20
- 7.1-.p.p. increase in secondary school attendance for women 18-20

Simplest Approach: Effect on Government Finances

Currency: 2014 \$, 3% discount rate (Ndeffo Mbah et al., 2013)

Benefits of averted HIV infections: Expected PDV of \$198.61

- Avoid lifelong costs of antiretroviral therapy: \$3,750
- Avoid other health care arising from living with HIV: \$868.75
- 4.3-p.p. decrease in HIV prevalence for women 18-20

Costs of averted HIV infections: Expected PDV of \$1.05 + 67.89 +

- Praziquantel dose per student year: \$0.10
- Administering deworming program per student per year: \$0.26
- Spending on secondary school per student per year: \$328.20
- 7.1-.p.p. increase in secondary school attendance for women 18-20

Simplest Approach: Effect on Government Finances

Currency: 2014 \$, 3% discount rate (Ndeffo Mbah et al., 2013)

Benefits of averted HIV infections: Expected PDV of \$198.61

- Avoid lifelong costs of antiretroviral therapy: \$3,750
- Avoid other health care arising from living with HIV: \$868.75
- 4.3-p.p. decrease in HIV prevalence for women 18-20

Costs of averted HIV infections: Expected PDV of \$1.05 + 67.89 +

- Praziquantel dose per student year: \$0.10
- Administering deworming program per student per year: \$0.26
- Spending on secondary school per student per year: \$328.20
- 7.1-.p.p. increase in secondary school attendance for women 18-20
- Non-HIV-related health spending per person per year: \$32.50
- 4.3-p.p. decrease in HIV prevalence for women 18-20

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Costs of averted HIV infections: Expected PDV of \$1.05 + 67.89 + 37.04 = \$105.98

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- Spending on secondary school per student per year: \$328.20
- 7.1-.p.p. increase in secondary school attendance for women 18-20
- Non-HIV-related health spending per person per year: \$32.50
- 4.3-p.p. decrease in HIV prevalence for women 18-20

→ Myopic perspective, but HIV-related benefits 2x larger than costs

Conclusion

1. **Childhood health:** Improving it for girls lowers their chances of contracting HIV as young women, most likely by increasing their human capital, which changes their marriage market matches
   - Next step is to assess plausibility: Calculate expected effects on HIV from observed behavioral changes, compare to expected effect from reduction in ulcers

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2. **Cost-effectiveness:** Very cheap to improve childhood health $\rightarrow$ potentially very cheap to avert (very expensive) HIV infections for high-risk group
   - Next steps are to improve current government finances approach, add HIV to Miguel & Kremer (2004) cost-benefit analyses

Conclusion

1. **Childhood health:** Improving it for girls lowers their chances of contracting HIV as young women, most likely by increasing their human capital, which changes their marriage market matches
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   - Next steps are to improve current government finances approach, add HIV to Miguel & Kremer (2004) cost-benefit analyses
3. **Marriage markets:** Helps us understand role of childhood health (as part of human capital), especially in non-Western context

Roadmap

5. **Appendix Slides**

Appendix: Cochrane Review (2019)

Cochrane Library

Cochrane Database of Systematic Reviews

What the research says

In trials that treat only children known to be infected, deworming drugs may increase weight gain (*low quality evidence*), but we do not know if there is an effect on cognitive functioning or physical well-being (*very low quality evidence*).

In trials treating all children living in an endemic area, deworming drugs have little or no effect on average weight gain (*moderate quality evidence*), haemoglobin (*low quality evidence*), or cognition (*moderate quality evidence*).

Regular deworming treatment every three to six months may also have little or no effect on average weight gain (*low quality evidence*). The effects were variable across trials: one trial from 1995 in a low prevalence setting found an increase in weight, but nine trials carried out since then from moderate or high prevalence settings showed no effect.

There is good evidence that regular treatment probably has no effect on average height (*moderate quality evidence*), haemoglobin (*low quality evidence*), formal tests of cognition (*moderate quality evidence*), or exam performance (*moderate quality evidence*). We do not know if there is an effect on school attendance (*very low quality evidence*).

Authors conclusions

Treating children known to have worm infection may improve weight gain but there is limited evidence of other benefits. For routine deworming of school children in endemic areas, there is quite substantial evidence that deworming programmes do not show benefit in terms of average nutritional status, haemoglobin, cognition, school performance, or death.

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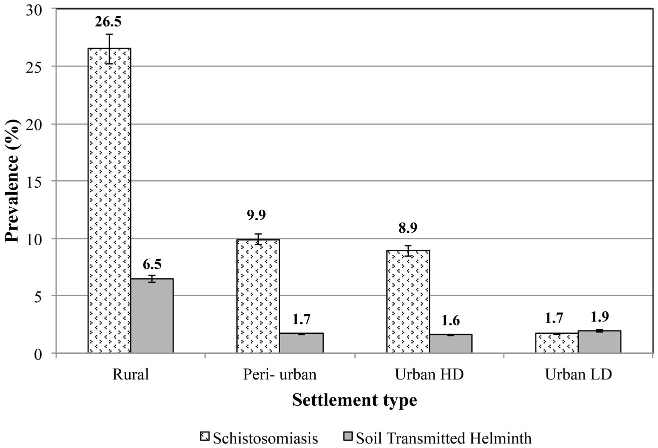
Appendix: Helminths More Common in Rural Areas



Source: Midzi et al. (2014)

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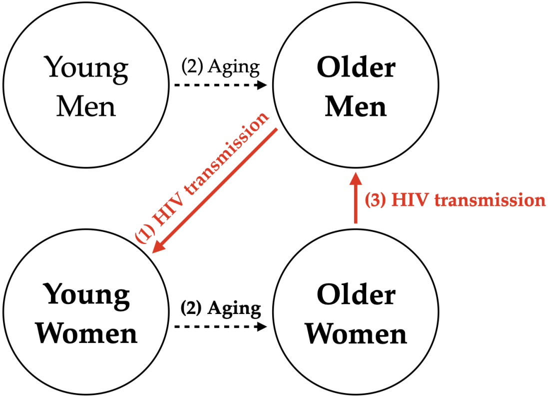
Appendix: Age-Disparate Relationships and HIV



Notes: Based on de Oliveira et al. (2017)

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Appendix: HIV Risks (Rural Women 15-18)

	Direct: Knowledge		Indirect: Marriage Market			
	Reduces Risk		Partner Age Gap		Partners	Last Sex
	1 Partner	Condom	$\geq$9 Years	5-8 Years	$\geq$2 in Life	Condom
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Dynamic Estimates						
2005 × High	-0.027	0.089	-0.098	0.105	0.001	-0.068
	(0.057)	(0.083)	(0.088)	(0.108)	(0.026)	(0.070)
2015 × High	0.033	0.107	-0.124	0.210	-0.038	-0.127
	(0.048)	(0.051)	(0.088)	(0.133)	(0.019)	(0.053)
Panel B. Static Estimates						
Post × High	0.046	0.061	-0.077	0.160	-0.038	-0.095
	(0.038)	(0.053)	(0.079)	(0.119)	(0.020)	(0.056)
Observations	2,616	2,616	494	494	2,751	728
Districts	54	54	54	54	54	54
Pre-Deworming Mean (High=1)	0.797	0.701	0.215	0.465	0.047	0.105

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Appendix: HIV Risks (Women 21-24)

	Direct: Knowledge		Indirect: Marriage Market			
	Reduces Risk		Partner Age Gap		Partners	Last Sex
	1 Partner	Condom	≥9 Years	5-8 Years	≥2 in Life	Condom
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Dynamic Estimates						
2005 × High	-0.073	-0.012	-0.018	0.041	-0.028	-0.002
	(0.051)	(0.040)	(0.055)	(0.069)	(0.047)	(0.031)
2015 × High	-0.047	-0.054	0.020	-0.098	-0.057	-0.030
	(0.034)	(0.044)	(0.048)	(0.045)	(0.047)	(0.041)
Panel B. Static Estimates						
Post × High	-0.010	-0.048	0.029	-0.119	-0.043	-0.029
	(0.033)	(0.046)	(0.052)	(0.045)	(0.053)	(0.034)
Observations	2,640	2,638	1,901	1,901	2,690	2,225
Districts	71	71	71	71	71	71
Pre-Deworming Mean (High=1)	0.893	0.821	0.216	0.357	0.259	0.072

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Appendix: Marriage/Partnership Rates

	Never in Union	
	Women Ages 15-20	Rural Women 15-18
	(1)	(2)
Panel A. Dynamic Estimates		
2005 $\times$ High	-0.037	-0.040
	(0.035)	(0.046)
2015 $\times$ High	-0.046	-0.020
	(0.043)	(0.039)
Panel B. Static Estimates		
Post $\times$ High	-0.027	0.000
	(0.038)	(0.034)
Observations	5,367	3,060
Districts	71	54
Pre-Deworming Mean (High=1)	0.666	0.772

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