The Interdisciplinary Center Herzliya

Tiomkin School of Economics

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Seminar Policy Paper – July 9, 2020

Economic Policy Seminar, Dr. Yael Hadass

What policies should Russia implement to mitigate the growing HIV epidemic?

By:

Alexander Kromkin

Maya Lewis

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Abstract

HIV/AIDS has long been recognized as a global issue. Since first gaining attention in the 1980s, countries around the world have made strides in research to stop the spread of the infection. These efforts have led to a decline in new HIV cases globally, however, cases are still rising in Russia today. This study analyzes the United States effort to combat the spread of HIV/AIDS and identifies their successful strategies in order to recommend policy adaptation for the Russian Federation in dealing with the growing epidemic. We conducted a regression analysis based on panel data collected across the 50 States of America and Washington, DC, over the years 2012-2018. Using this research, we explored the factors that affect the rate at which new HIV cases are diagnosed. Our study concludes that there is a strong negative relationship between higher PrEP medication coverage and the rate of new HIV cases diagnosed, leading us to conclude that this treatment is effective and efficient in decreasing new infection rates. Furthermore, our research reveals that higher funding per HIV-positive individual and a better treatment framework are associated with a lower rate of new HIV cases. In addition, we have performed a cost efficiency analysis which demonstrates that relatively small amounts spent on expanding PrEP coverage and increasing funding for prevention today result in greatly diminished future costs of treatment, thereby saving the government money in the long run. Explicitly, we find that $1 spent on prevention saves up to $8.3 in future medical costs. Based on our research, we propose new policies that Russia should adopt to deal with their HIV crisis. Our recommendation involves a multiple stage policy reform program that starts with improving the national framework for identifying and acknowledging the high-risk populations. The next stage entails creating increased access to testing and treatment. Finally, our strategy recommends using PrEP as the main preventative measure to help high risk individuals and all Russian citizens avoid contracting HIV.

Policy Question and Purpose of the Paper

The HIV/AIDS pandemic is currently one of the major public health threats in the Russian Federation, where 1 to 2 million people (1.2-2.4% of adult population) are living with HIV. Approximately 24,000 people die annually from AIDS complications, and the rate of new infections grows by 10-15% each year (Avert, 2019). These conditions call for immediate and comprehensive public and government efforts to mitigate the growing epidemic.

Since the 90s, scholars have expansively researched HIV/AIDS by assessing, developing and improving cost-efficient prevention and treatment policies. The main body of research has been predominantly conducted in the setting of the Sub-Saharan region, with far less attention paid to other parts of the world. This oversight is understandable given that Sub-Saharan Africa bears the heaviest burden of the pandemic, with more than 25 million HIV-positive individuals living there out of the 38 million people infected across the world (UNAIDS, 2019), and has yet to be bridged by other studies. In our paper, we analyze the HIV response programs enacted in the US in the 2010s in order to estimate and quantify the effectiveness and cost-efficiency of different HIV prevention and treatment measures and provide a set of policy recommendations for Russia to mitigate its growing HIV epidemic.

Background

Theoretical Background

Since the 80s, the world has been suffering from the HIV/AIDS epidemic which has killed more than 30 million people (UNAIDS, 2019), making it one of the leading causes of death in the past few decades (see Graph [1] in the appendix). Thanks to medical and institutional advancements, the global trend has turned downwards since the mid-2000s (UNAIDS, 2019), however, humanity is still vulnerable to this deadly pandemic. Furthermore, there are second order effects of HIV/AIDS, with the higher levels of morbidity and mortality depressing economic output and growth (Dixon, McDonald, Roberts, 2002). One of the key characteristics of the HIV/AIDS epidemic that outlines the motivation for our paper is the geographical discrepancy of its spread. While in most countries the HIV prevalence rate is as low as 0.1-0.3%, there are regions where it is substantially higher. For example, in 2018 in Sub-Saharan Africa and Southern and Eastern Asia, the HIV prevalence rate was as high as 1.1% in Thailand, 3.6% in Central African Republic and 20.3% in Botswana (UNAIDS, 2019). High HIV prevalence in these regions has led to development and advancement of fairly comprehensive sets of policy recommendations aimed to mitigate the HIV/AIDS pandemic.

While the current body of research is extensive, there is plenty of room for advancements. We find that Russia has been left behind by the academic mainstream efforts regarding HIV, despite being a region with an actively growing epidemic which accounts for 64% of all new HIV diagnoses in Europe (Avert, 2019). In particular, our research will focus on the prevention strategies based on PrEP, pre-exposure prophylaxis for HIV. PrEP is a highly effective medicine that prevents HIV seroconversion through sex or injection drug use. HIV-negative individuals at high HIV risk who take PrEP daily are 74%-99% less likely to contract HIV (CDC [3], 2019). In spite of being proven effective, PrEP is not currently covered by any government programs or insurances, nor is it available for private purchase in most regions in Russia (and often, is not available at all, due to occasional shipping and distribution shortages) (Avert, 2019).

We base our analysis on the US experience because of the extensive reporting of the US Statistical Bureau and the Center for Disease Control and Prevention which allows us to collect a sufficient amount of data to perform an econometric analysis. We aim to develop a cost-efficiency analysis framework that will help us gauge the cost of HIV prevention in Russia and estimate its economic benefits. This approach has been utilized in transdisciplinary health economics studies (Floyd, 2002; Kahn, 1996; Cleary, 2008; Nosyk, 2012) but has never been applied to analyze HIV strategies in Russia. We hope to bridge this gap in our work, putting an emphasis on PrEP-based strategies.

Literature Review

While the economic impact of health policies has long been a subject of research, the focus on the effect of HIV/AIDS prevention and treatment programs only began in the 1990s (Forsythe & Rau, 1998).

The work of S. Dixon, S. McDonald and J. Roberts (2002), summarizes findings of 11 studies estimating the economic burden imposed by HIV/AIDS in Africa. They conclude that the infection negatively affects economic growth substantially through reducing the levels of labor supply and labor productivity and increasing the net imports within a country. More recent studies focusing on the populations and economies of Africa (Azomahou, Boucekkine & Diene, 2016; Waziri et al, 2015), Asia (Roy, 2014), Eastern Europe (Fimpel & Stolpe, 2010), Central Europe (Trapero-Bertran & Oliva-Moreno, 2014), and USA (Hutchinson et al, 2006) support these findings by stressing both the threat that HIV/AIDS poses to economic growth and the long-term economic benefits of mitigating the infection. These benefits include decreased future healthcare expenses and avoiding the deterioration of GDP, exemplified in the works of Arndt & Lewis (2000, 2001) who estimated that South Africa's 2010 GDP per capita and consumption per capita was lowered to 8% and 12%, respectively, due to the HIV/AIDS pandemic.

In cross-sectional health economics studies, it is common to estimate the impact of certain health policies using the notion of disability-adjusted life years (DALY) or quality-adjusted life years (QALY) saved. The number of DALYs/QALYs saved equals the total number of years saved, adjusted to reflect the medical disabilities/quality loss that affected people are expected to experience during these years. An analysis of intervention programs implemented in Africa shows that while one DALY can be saved with early selective prevention programs for as little as $1, this cost would grow to several hundred dollars at the stage of providing ARV treatment for HIV-positive individuals, exemplifying the benefit of addressing the growing epidemic as early as possible (Creese et al, 2002).

Addressing HIV/AIDS from the standpoint of a policymaker requires a thorough cost-efficiency analysis of the available prevention and treatment programs. In resource-limited settings, this task is very challenging due to the complex and dynamic nature of the HIV/AIDS epidemic. While the accumulated body of research is fairly rich, some findings were deemed inconsistent by Galárraga et al (2009) in their systematic review, creating a need for further research.

In spite of the aforementioned imperfections, existing literature manages to provide a relatively comprehensive set of guidelines for establishing efficient and effective intervention policies. The framework developed over the last thirty years involves estimating the effects of HIV prevention and treatment intervention programs through assessing the cost of an infection prevented and/or a QALY /DALY saved due to the intervention. While the actual numbers vary across regions, there are relative efficiency patterns unconditional of the geographic and sociocultural factors that highlight desirable courses of action against the epidemic. One of the most important conclusions researchers agree upon is that the least costly ways of mitigating the infection are those aimed to prevent it as early as possible. In their comprehensive analysis of cost-effectiveness of HIV/AIDS interventions in Africa, Creese et al (2002) show that: a) a case of HIV/AIDS can be prevented for $11, and a DALY gained for $1, by selective blood safety measures, and by targeted condom distribution with treatment of sexually transmitted diseases;

b) prevention of mother-to-child transmission, voluntary counselling and testing, and tuberculosis treatment, cost under $75 per DALY gained; and c) other interventions, such as formula feeding for infants, home care programs, and antiretroviral therapy for adults, cost several thousand dollars per infection prevented, or several hundreds of dollars per DALY gained. This study further demonstrates that prevention is much less costly than treatment and care. Another study, conducted by Kahn (1996), quantifies the benefits of recognizing and targeting the high-risk populations by showing that the costs per HIV infection averted may differ by forty to two-hundred-fold depending on the ways the resources are allocated. Another important study on the expenditures of patients entering medical care on different stages of the infection found that the mean medical care expenditures for late presenters were 1.5 to 3.7 times higher than expenditures for early presenters (Fleishman et al, 2010), highlighting the importance of developing and popularizing screening programs. These programs show that there are in fact cheap ways to incentivize and destigmatize HIV, namely, providing symbolic reward and formal reasons for testing (Thornton, 2008).

It is important to note that although some treatment programs are more costly, for example, providing HAART (high-active retroviral therapy) for HIV/AIDS-infected individuals and methadone treatment/syringe exchange programs for those injecting drugs, they are still regarded as cost-efficient and sometimes even cost-saving. This is due partly to the direct effect of the therapy on recipients and partly to their secondary positive effect on the general population. (HAART: Cleary, McIntyre & Boulle, 2008; Nosyk & Montaner, 2012); MT/SEP: Zaric, Barnett & Brandeau, 2000; Laufer, 1999; Bernard et al, 2017).

Although the cost-efficiency analysis cannot be applied in this area, it has also been shown that political, legal and economic institutions affect the spread of HIV/AIDS substantially. In her work, Anderson, S. (2018) shows a strong causal relationship between the strength of women rights and the spread of the infection. Justesen (2012) demonstrates that states with proportional electoral systems tend to provide significantly better medical care and implement more effective prevention policies than states with plurality electoral systems or autocracies. Finally, DeHovitz, Uuskula & El-Bassel (2014) point out that one of the most significant determinants of the HIV/AIDS growth in Eastern Europe and Russia is associated with stigmatization and neglect over the populations at the highest risk, namely, sex-workers, drug-users, prison inhabitants and homosexual and transgender individuals, These groups are the least protected and lack the option of seeking help from the authorities due to legal or medical reasons.

Research Hypothesis

We hypothesize that nationally introduced HIV prevention strategy based on PrEP is an effective and efficient measure for mitigating the HIV epidemic. We base this hypothesis on prior research that suggests PrEP treatment is highly efficient in preventing HIV seroconversion during medical trials (Spinner et al, 2015), and on the success of locally implemented prevention PrEP programs (Liu et al, 2014). Furthermore, we hypothesize that developing and funding HIV prevention and treatment frameworks is an effective and cost-efficient measure for mitigating the HIV epidemic. Moreover, we hypothesize that funding these intervention frameworks is justified not only morally, but also economically.

Methodology

Building a Model

Our regression will explore the effects of implementing the PrEP strategy, increasing funding, and improving HIV treatment frameworks on the number of new HIV diagnoses. To do so, we analyze the experience of the US, where PrEP has been approved by the FDA and introduced in 2012, with coverage being gradually expanded thereafter. We are working with state-level panel data for the years 2012-2018. Observations for some states-years were omitted from our analysis because no consistent data for them was available. After revisiting the available data and confirming its consistency and reliability, we are left with 241 observations in our panel dataset. The amount of new HIV cases on a state level can be affected by many factors other than PrEP availability, funding and treatment facilities. To account for these factors, we introduce a set of control variables that were suggested to affect the number of new HIV diagnoses by the prior research. The variables used in our regression model are presented in the Table [1].

Dependent Variable

We aim to analyze the determinants of the HIV epidemic growth. Our dependent variable of interest should measure the rate at which new HIV cases are diagnosed, that is, the dynamics of the HIV epidemic. Therefore, the dependent variable of our model is the rate of new HIV cases diagnosed in a given state-year, computed as follows:

$$hiv\_dgns\_rate_t = \frac{\#\ of\ new\ HIV\ cases\ diagnosed\ in\ a\ given\ state - year}{total\ population\ of\ the\ given\ state - year} * 100000$$

Equation [1]

We use the logarithmic form of this variable to account for the large variability across the states and years.

Key Independent Variables

- The first key independent variable used in our model accounts for PrEP coverage provided for HIV-negative individuals at high risk. To construct a variable that reflects the prevalence of PrEP coverage we divide the number of HIV-negative individuals receiving PrEP treatment in a given state-year by the total number of HIV-positive individuals in a given state-year. We combine these two metrics to produce the ratio because providing HIV-negative individuals with prophylactic treatment directly depends on the total number of HIV-positive individuals. The calculation goes as follows:

$$prep\_pct\_hiv = \frac{total\ \#\ of\ HIV - negative\ individuals\ receiving\ PrEP\ in\ a\ given\ state - year}{total\ \#\ of\ HIV - positive\ individuals\ in\ a\ given\ state - year}$$

Equation [2]

- The second key independent variable we include in our model accounts for the funding prevention and treatment facilities received from the government in a given state-year. We emphasize the funding provided relative to the total number of HIV-positive individuals to provide a representative measure that can be compared consistently across the states and years. The calculation goes as follows:

$$hiv\_fnd\_w = \frac{government\ funding\ for\ HIV\ response\ for\ the\ given\ state - year}{total\ \#\ of\ HIV - positive\ individuals\ in\ a\ given\ state - year}$$

Equation [3]

- The third key independent variable is intended to account for the quality of the HIV testing and treatment facilities. The link between the quality of the testing and treatment facilities and the rate of new HIV cases is complex yet persistent. Better testing and treatment framework implies that a) people at high risk of getting the HIV infection will be tested more timely, decreasing the amount of HIV-positive individuals unaware of their status, and that b) people diagnosed with HIV will receive the viral suppression treatment sooner and more effectively, decreasing the chances of further transmitting the virus (CDC [1], 2019). We use a proxy metric to measure the quality of the existing framework. That measures the percentage of individuals diagnosed as HIV-positive in a given state-year that were linked to the treatment facilities within 3 months of the diagnosis, pct_link. The logic here is that the more people receiving treatment soon after their diagnosis with HIV, the better is the existing treatment framework.

Control Independent Variables

- HIV is a contagious disease which can only be transmitted through unprotected direct contact with certain body fluids of an HIV-positive individual (CDC [1], 2019). This implies a strong relationship between the number of new HIV cases and the total number of HIV-positive individuals in the given state-year. We therefore included a variable that measures the total rate of HIV-positive individuals in a given state-year, measured as

$$hiv\_total\_rate = \frac{total\ \#\ of\ HIV - positive\ individuals\ in\ a\ given\ state - year}{total\ population\ of\ the\ given\ state - year} * 100000$$

Equation [4]

- Second, the African-American population is disproportionately affected by HIV in the US (CDC [2], 2019). We therefore include a variable that measures the percentage of African-American population in the given state-year, pct_blck
- Third, we include a variable that measures the percentage of population living in urban areas, pct_urban because it is hypothesized that denser areas can be disproportionately affected by the virus.
- Fourth, we include the percentage of religious people in a given state-year, pct_rel in order to address the ambiguous effect of religion on sexual behavior and associated HIV risk. Affiliation with fundamental Abrahamic religions can postulate less risky sexual behavior, through prohibiting non-heterosexual and extramarital sexual contacts. The conservative nature of religion tends to put stigma on non-heterosexual and extramarital sexual contacts and making it harder for the individuals engaged in them to receive necessary sexual education, protection, HIV testing and treatment. We will see which inclination is stronger.
- Fifth, we include a variable that would account for the level of educational attainment of the population in a given state-year. We hypothesize, based on research from the Sub-Saharan region, that there is a negative correlation between the level of educational attainment and HIV infection risk (Hargreaves et al, 2008). The proxy for the educational attainment used is the university graduation rate in a given state-year.

- Lastly, we include a dummy variable that takes on a value of 1 if the state where the observation is made is in the South, $dSouth$. According to the statistical agencies of the US, Southern states are disproportionately affected by the HIV epidemic (CDC [2], 2019). The reason for this is that the South is associated with larger proportions of African-American populations. It is also the result of the more conservative policies enacted by the officials of the Southern states. Finally, these states are associated with deeply rooted institutional and socio-economic conditions that historically have been formed in the South of the US. While we have accounted for the percentage of African-American population specifically, the rest of the factors named also play an important role. Therefore, we hypothesize that $dSouth$ has significant positive effect on the rate of new HIV cases diagnosed, AEBE.

Table [1]: Description and Sources for the Variables Used

Variable	Explanation	Measure	Source
hiv_dgns_rate	Rate of new annual HIV diagnoses: computed as $\frac{\#\ of\ new\ HIV\ cases\ diagnosed\ in\ a\ given\ state-year}{total\ population\ of\ the\ given\ state-year} * 100000$ Please note that the logarithmic form of this variable is used in the model.	The new HIV diagnoses per 100000 total population per state-year	Numbers of new HIV cases: CDC, HIV surveillance reports Population: US Census Bureau, State Population Totals and Components of Change: 2010-2019
$prep\_pct\_hiv$	Number of HIV-negative individuals receiving PrEP treatment weighted by the total number of HIV-positive individuals in a given state-year. Alternatively stated, it is number of HIV-negative individuals receiving PrEP treatment as a percentage of total number of HIV-positive individuals in the given state-year. Combining these two metrics to produce the percentage is crucial as the need for providing HIV-negative individuals with prophylactic treatment depends directly on the total number of HIV-positive individuals. The calculation goes as follows: $\frac{total\ \#\ of\ HIV-negative\ individuals\ receiving\ PrEP\ in\ a\ given\ state-year}{total\ \#\ of\ HIV-positive\ individuals\ in\ a\ given\ state-year}$	The number of HIV-negative individuals using PrEP per total number of HIV-positive individuals in a given state-year	PrEP coverage: https://aidsvu.org, checked for consistency with CDC data Total numbers of HIV-positive individuals: CDC, HIV surveillance reports
hiv_fnd_w	Government funding for HIV response weighted by the total number of HIV-positive individuals in a given state-year: computed as $\frac{government\ funding\ for\ HIV\ response\ for\ the\ given\ state-year}{total\ \#\ of\ HIV-positive\ individuals\ in\ a\ given\ state-year}$	Government funding for HIV prevention and treatment per number of HIV-positive individuals, in US $	Total funding per state-level: CDC, congressional budget justifications records Total numbers of HIV-positive individuals: CDC, HIV surveillance reports

pct_link	Percentage of individuals who were linked to medical facilities for treatment within 3 months after they are diagnosed as HIV-positive in the given state-year	Percentage	CDC, HIV surveillance supplemental reports
hiv_total_rate	Rate of total HIV diagnoses (i. e., of individuals living with HIV): computed as $\frac{total\ \#\ of\ HIV-positive\ individuals\ in\ a\ given\ state-year}{total\ population\ of\ the\ given\ state-year} * 100000$	The total number of HIV-positive individuals per 100000 total population per state-year	CDC, HIV surveillance reports
pct_blck	Percentage of African-American population	Percentage	US Census Bureau, State Population Totals and Components of Change: 2010-2019
pct_urb	Percentage of population living in urban areas	Percentage	US Census Bureau, Census of 2010
pct_rlgs	Percentage of individuals who said they "believe in God; absolutely certain" in a nation-wide survey conducted in 2014 by Pew Research Center	Percentage	Pew Research Center
$grad\_rate$	Graduation rate is the percentage of population who have obtained a high school diploma	Percentage	US National Center for Education Statistics
$dSouth$	Dummy variable that takes on a value of 1 if the state where the observation is made is a Southern state (defined as such by CDC [2])	Dummy variable	CDC [2]

Model

For our statistical OLS regression analysis, we used *Stata* software. The following is the conclusive OLS regression model we have introduced to test the research hypothesis.

Model [1]:

$$\log(hiv\_dgns\_rate) = \beta_0 + \beta_1 hiv\_total\_rate + \beta_2 prep\_pct\_hiv + \beta_3 hiv\_fnd\_w + \beta_4 pct\_link + \beta_5 pct\_blck + \beta_6 pct\_urb + \beta_7 pct\_rlgs + \beta_8 grad\_rate + \beta_9 dSouth + e$$

Data Analysis

First, we conducted the preliminary *qualitative analysis* of our data. Table [2] presents the descriptive statistics of the model [1]:

Table [2]: Descriptive Statistics

Variable	# of Observations	Mean	Std. Dev.	Min	Max
hiv_dgns_rate	241	12.49	12.86	1.53	116.35
prep_pct_hiv	241	12.56%	11.01%	0.58%	54.61%
hiv_funding_w	241	$ 208.17	$ 167.71	$ 36.74	$ 969.67
pct_link	241	87.95%	5.77%	71.40%	100.00%
hiv_total_rate	241	320.66	404.87	35.11	2575.75
pct_blck	241	13.42%	12.69%	0.52%	53.86%
pct_urban	241	74.26%	14.25%	38.70%	100.00%
pct_rlgs	241	63.29%	9.40%	40.00%	82.00%
grad_rate	241	83.11%	5.74%	59.00%	91.40%
dSouth	241	0.344	0.476	0	1

This table shows the average rate of new HIV diagnoses in the selected states and years is 12.49 per 100000 population, with relatively high standard deviation of 12.86, minimum value of 1.53 and maximum value of 116.35. This implies high variability across the observations. The average value of *prep_pct_hiv* is 12.56%, with standard deviation of 11.01%, minimum value of 0.58% and maximum value of 54.61%. Such a high discrepancy and variability is explained by the young origins of PrEP-based strategies. States have been gradually increasing the PrEP coverage over the years starting from the scratch at the beginning of the dataset. Further, there is large variability of the funding weighted by the total number of HIV-positive individuals, with mean value of $208.17 per HIV-positive person, a standard deviation of $167.71, minimum value of $36.74 and maximum value of $969.67. The mean value of *pct_link* is 87.95% shows that on average, 87.95% of people who were diagnosed with HIV were transferred to medical facilities within three months. This is a fairly high number. The standard deviation is 5.77%, the minimum value is 71.40% and the maximum value is 100%, which implies low variability of this variable. The average value of *pct_blck* is 13.42% with high variability (min=0.52%, max=53.86%, SD=12.69%). On average, 74.26% of population are living in urban areas with moderate variability (min=38.7%, max=100% and SD=14.25%). On average, 63.29% of population strongly believe in God, with fairly low variability (min=40%, max=82%, SD=9.4%). On average, the graduation rate across the observations is 83.11%, with low variability (but notably extreme outlier(s) at the lower end of the values distribution) (min=59%, max=91.4%, SD=5.74%). Lastly, 34.4% of the observations in our dataset are made in the South, with large variability (min=0, max=1, SD=47.6%).

Regression Diagnostics

We run a preliminary OLS regression to estimate our model. The following Table [3] summarizes results of the regression.

Table [3]: Regression Results of OLS Regression of Model [1]

Variable	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]		Number of observations	=241
prep_pct_hiv	-0.00207	0.000831	-2.49	0.013	-0.00371	-0.00043	F(9, 231)	=226.17
hiv_fnd_w	-0.00053	5.69E-05	-9.32	0	-0.00064	-0.00042	Prob>F	=0
pct_link	-0.00381	0.001669	-2.28	0.023	-0.0071	-0.00052	R-squared	=0.8981
hiv_total_rate	0.000145	3.92E-05	3.7	0	6.77E-05	0.000222	Adj. R-squared	=0.8941
pct_blck	0.010104	0.001426	7.08	0	0.007294	0.012914	Root MSE	=0.11284
pct_urb	0.00695	0.000751	9.26	0	0.005471	0.008428		
pct_rlgs	0.004154	0.00128	3.25	0.001	0.001632	0.006676		
grad_rate	-0.006	0.001655	-3.63	0	-0.00926	-0.00274		
dSouth	0.051669	0.029762	1.74	0.084	-0.00697	0.110308		
_cons	0.943092	0.266823	3.53	0	0.417375	1.468809		

It is important to address the issues that might cause bias and inconsistency in the estimates obtained. According to the Gauss-Markov theorem, the OLS estimators from the panel data analysis are unbiased and consistent when the following assumptions are met:

- *Linear in parameters*: Formal testing of this assumption is beyond the scope of this paper; however, we tried to informally estimated the relationship between the parameters of our model by plotting them against each other. Graph [1] shows the linear relationships between all the variables on scatter plots.
- *Zero conditional mean*: Given the complex nature of the panel dataset, formal testing for endogeneity is beyond the scope of this paper. However, we can informally estimate the distribution of the errors around the conditional zero mean by plotting the residuals against the parameters of our model. Graph [2] depicts residuals from Model [1] plotted against the variables of this model, showing that endogeneity does not appear to be an issue.
- *No perfect collinearity*: A common approach to analyze whether multicollinearity is an issue involves looking at the variance inflation factor (VIF) produced by estimating the given model. As a rule of thumb, a variable whose VIF values are greater than 10 may merit further investigation. We used Stata to estimate the VIF's of our variables. The results are presented in Table [4]:

Table [4]: VIF Estimation

Variable	VIF
pct_blck	6.17
hiv_total_rate	4.76
dSouth	3.79
pct_rlgs	2.73
pct_urb	2.16
pct_link	1.75
hiv_fnd_w	1.72
grad_rate	1.7
prep_pct_hiv	1.58
Mean VIF	**2.93**

Multicollinearity does not appear to be an issue in our analysis.

- *Homoscedasticity*: We used the White Test to check whether heteroscedasticity is an issue in our model. The results are summarized in table [5]:

Table [5]: White's Test

H0: homoskedasticity

against Ha: unrestricted heteroskedasticity

chi^2(53)	prob>chi^2
118.96	0

Indeed, our model appears to be heteroscedastic. We account for this by estimating our model using heteroscedasticity-robust standard errors.

- *No autocorrelation*: Testing for autocorrelation in a panel dataset is beyond the scope of this paper. However, using Newey-West standard errors allow us to estimate the significance of our estimators consistently and in a manner that is robust to heteroscedasticity and serial autocorrelation.
- *Normal distribution of the errors*: To test whether the errors are normally distributed we perform a basic skewness-kurtosis test built in the *Stata* software on the residuals of our model. The results are summarized in Table [6].

Table [6]: Skewness/Kurtosis test for Normality

H0: errors are distributed normally vs. Ha: the distribution of errors is not normal

Variable	Obs.	Pr(Skewness)	Pr(Kurtosis)	Adj. chi^2 (2)	Prob>chi^2
resid1	241	0.1056	0.335	3.58	0.1673

We conclude that errors are distributed normally in our model.

After addressing the Gauss-Markov assumptions according to the results of formal testing, we conclude that multicollinearity is not an issue in our model and errors are distributed normally. Furthermore, we have estimated graphically that endogeneity does not appear to be an issue and that the parameters of our model seem to be linearly related. To account for heteroscedasticity and potential serial autocorrelation in errors, we will estimate our model using robust Newey-West standard errors. The results of the regression are summarized in Table [7].

Table [7]: Regression results of model [1] estimated with OLS using Newey-West standard errors (maximum lag=1)

Variable	Coef.	Std. Err.	t	P>t	[95% Conf. Interval]			
prep_pct_hiv	-0.00207	0.0010585	-1.96	0.052	-0.004157	0.0000139	F(9, 231)	=162.43
hiv_fnd_w	-0.00053	0.0000776	-6.84	0	-0.000684	-0.0003779	Prob>F	=0
pct_link	-0.00381	0.0016585	-2.3	0.023	-0.007076	-0.0005404		
hiv_total_rate	0.000145	0.0000465	3.12	0.002	0.0000535	0.0002366		
pct_blck	0.010104	0.0015244	6.63	0	0.0071002	0.0131071		
pct_urb	0.00695	0.0009978	6.96	0	0.0049837	0.0089156		
pct_rlgs	0.004154	0.0015554	2.67	0.008	0.0010892	0.0072183		
grad_rate	-0.006	0.0021657	-2.77	0.006	-0.01027	-0.0017357		
dSouth	0.051669	0.0289414	1.79	0.076	-0.005354	0.1086915		
_cons	0.943092	0.2975409	3.17	0.002	0.3568507	1.529332		

Number of observations =241

Regression Results and Discussion

The analysis we have performed allows us to estimate the relationship between the independent parameters specified for model [1] and the dependent variable, log (hiv_dgns_rate). First, $\hat{\beta}_1 = -0.0021$, with p-value of 0.052, very close to the critical value. We deem the p-value of 0.052 low enough to conclude that variable $prep\_pct\_hiv$ has significant and positive effect on log (hiv_dgns_rate): AEBE, a 1% increase in the percentage of individuals covered by PrEP is associated with a 0.21% decrease in the rate of new HIV cases diagnosed. This confirms our first research hypothesis and supports the smaller-scale findings of Spinner et al, 2015 and Liu et al, 2014. Additionally, it was shown that better funding is expected to decrease the rate of new HIV diagnoses. Specifically, with $\hat{\beta}_2 = -0.00053$ and p-value of 0, we find that, AEBE, a $1 increase in hiv_fnd_w is associated with a 0.053% decrease in the rate of new HIV cases diagnosed, supporting our second hypothesis. Further, we have demonstrated that better treatment and testing facilities, pct_link, is expected to decrease the rate of new HIV diagnoses. Specifically, as $\hat{\beta}_3 = -0.0038$ with p-value as low as 0.023, we conclude that, AEBE, a 1% increase in the (absolute values of) the percentage of the individuals getting linked to the treatment facilities within three months after the HIV diagnosis in a given state-year, is associated with a 0.38% decrease in the number of new cases, confirming our third hypothesis.

The signs and magnitudes of the estimates for the rest of the parameters in our model are reasonable and consistent with the prior research and intuition. We have shown that, AEBE, a one-unit increase in the rate of total HIV diagnoses is associated with a 0.0145% increase in the rate of new HIV diagnoses. We have also shown that a 1% increase in absolute values in the percentage of African-American population is associated with a 1.01% increase in the rate of new HIV diagnoses, which supports the CDC reports stressing that the African-American community is affected by the HIV disproportionately (CDC [2], 2019). We demonstrated that a 1% increase in absolute values of the percentage of population living in urban areas is associated with a 0.70% increase in the rate of new HIV diagnoses, supporting the hypothesis HIV risks are higher in dense cities. Another conclusion of the analysis is the fact that a 1% increase in the absolute values of pct_rlgs is associated with a 0.42% increase in the rate of new HIV cases, AEBE, indicating that stronger religious prevalence is an HIV risk factor as of today. Consistent with prior research (Hargreaves et al, 2008) and intuition, higher levels of educational attainment are associated with lower rate of new HIV diagnoses, with 1% increase in absolute terms in the graduation rate being associated with a 0.60% decrease in the number of new HIV cases. Finally, we find a positive relationship between $dSouth$ and log (hiv_dgns_rate), but the p-value of 0.076 is close to the critical value. We can confirm this relationship under 10% significance level and conclude that, AEBE, the Southern states are expected to have 5.17% higher rate of new HIV diagnoses.

Cost Efficiency Analysis

The OLS regression results of Model [1] allow us to confirm our hypotheses and conclude that PrEP is an effective strategy against the HIV epidemic, better funding is effective in mitigating the rate of new HIV diagnoses, and better testing and treatment frameworks help stop the spread of the virus efficiently. In the last stage of our analysis, we will address the cost efficiency of increasing PrEP coverage and increasing funding for HIV response. The first assumption is that the estimated effects of the two measures mentioned above, computed using US data, are representative for Russia. In other words, we assume that a 1% increase in $prep\_pct\_hiv$ in absolute values is expected to decrease the rate of new HIV diagnoses by 0.21% (in relative terms) in Russia in the same manner as it would in the US. The same goes for hiv_fnd_w: we assume that the relationship between the HIV response funding and the rate of new HIV diagnoses, computed using the US data, is comparable to Russia. This implies that a $1 increase in the HIV mitigation funding weighted by the total number of HIV-positive individuals, is expected to decrease the rate of new HIV cases by 0.053% in relative values.

To estimate the cost-efficiency of the measures discussed, we estimate and compare between the costs the value generated. Therefore, we start by estimating the cost of investing in hiv_fnd_w. Following the findings from the regression analysis, we recall that a $1 increase in hiv_fnd_w is expected to decrease hiv_dgns_rate by 0.053%. Put it on a larger scale, a $100 increase in hiv_fnd_w is expected to decrease hiv_dgns_rate by 5.3%. Now, to see how much it would cost to increase hiv_fnd_w by $100, we use the marginal form of Equation [3]:

$$\Delta hiv\_fnd\_w = \$100 = \left[\frac{cost(\Delta government\ funding\ for\ HIV\ response)}{total\ \#\ of\ HIV - positive\ individuals}\right]$$

The government spending in the numerator represents the cost of the policy. Rearranging Equation [3], we express the cost of increasing hiv_fnd_w by $100 as follows:

$$cost[\Delta government\ funding\ for\ HIV\ response] = \$100 * total\ \#\ of\ HIV - positive\ individuals$$

Equation [3.1]

According to different estimations and sources, the total number of HIV-positive individuals in Russia is between 1 and 2 million, as of 2017 (Avert, 2017). For the purpose of our analysis, we use average of the two estimates: 1.5 million people with positive HIV-status. Substituting 1.5 million in Equation [3.1], we see that the cost of increasing hiv_fnd_w by $100 for one year in Russia would cost approximately

$$\$100 * 1.5M = \$150M$$

This spending is expected to decrease the hiv_dgns_rate by 5.3% in relative terms for that year. Put differently, a $100M yearly spending for hiv_fnd_w is expected to decrease the hiv_dgns_rate by $5.3\% * \frac{\$100M}{\$150M} \cong 3.53\%$. Later, we will examine the payoff of decreasing the rate of new HIV diagnoses and estimate its cost efficiency.

The next step is estimating the cost of the $prep\_pct\_hiv$, which imposes a more serious challenge. For this step, we use Equation [2]:

$$prep\_pct\_hiv = \frac{total\ \#\ of\ HIV - negative\ individuals\ receiving\ PrEP}{total\ \#\ of\ HIV - positive\ individuals}$$

As we recall from the regression results, a 1% increase in the absolute value of $prep\_pct\_hiv$ in a given year is associated with a 0.21% decrease in hiv_dgns_rate in that year. On a larger scale, a 10% increase in the absolute value of $prep\_pct\_hiv$ is expected to decrease the rate of the new HIV diagnoses by 2.1% in relative terms. By analyzing Equation [2] in marginal terms to reflect the cost of the changes we see how much it would cost to increase $prep\_pct\_hiv$ by 10%:

$$\Delta prep\_pct\_hiv = 10\% = \left[\frac{cost(\Delta total\ \#\ of\ HIV - negative\ individuals\ receiving\ PrEP)}{total\ \#\ of\ HIV - positive\ individuals}\right]$$

And by rearranging we get:

$$\begin{aligned} & cost[\Delta total\ \#\ of\ HIV - negative\ individuals\ receiving\ PrEP] \\ &= cost[covering\ 10\% * total\ \#\ of\ HIV - positive\ individuals\ with\ PrEP] \\ &= cost[covering\ 10\% * 1.5M\ individuals] \\ &= cost[covering\ 150T\ individuals] \end{aligned}$$

That is, increasing the value of $prep\_pct\_hiv$ by 10% in Russia would cost as much as covering 150 thousand persons with PrEP. We must note that while the calculation is based on the number of HIV-positive individuals, PrEP coverage is expanded to the HIV-negative individuals. This approach was elaborated at the stage of defining variables. Given that PrEP was only introduced less than 10 years ago, prices vary substantially across years, producers, and countries. Today, a one-month regimen can cost between $30 and $1500 per month in Russia (Get Prep Online, Russia, 2019). After researching the market for PrEP drugs in Russia, we estimate the price of a monthly regimen of Truvada©, the PrEP medicine that is believed to be the most effective and safe among the alternatives (CDC [3], 2019), to 15500 Russian rubles per month (H-Clinic, PrEP in Moscow, 2019) or 2600 US dollars per year (given the exchange rate of 71.59 RUB/USD as of July 6-th, 2020).

Thus, providing 150 thousand HIV-negative persons with PrEP for a year would cost approximately $150K * \$2600 \cong \$390M$, and is expected to result in the rate of new HIV diagnoses decreasing by 2.1%. Expressed differently, a $100M yearly spending for $prep\_pct\_hiv$ is expected to decrease the hiv_dgns_rate by $2.1\% * \frac{\$100M}{\$390M} \cong 0.54\%$ in relative values.

In the next step, we estimate the payoff from decreasing the rate of new HIV diagnoses. It is important to note that since we were analyzing a log-level model, we previously have established the effect of the measures discussed on the percentage, or relative change in hiv_dgns_rate. In order to proceed, we transform these estimations to absolute terms, for example, quantify in absolute terms the "percentage decrease in hiv_dgns_rate". To do so, consider the following Equation [5]:

$$\Delta hiv\_dgns\_rate_t(\%) \equiv \frac{\Delta hiv\_dgns\_rate_t}{hiv\_dgns\_rate_t}$$

Equation [5]

Rearranging it, we get

$$\Delta hiv\_dgns\_rate_t = \Delta hiv\_dgns\_rate_t(\%) * hiv\_dgns\_rate_t$$

Equation [5.1]

Therefore, to estimate the change in hiv_dgns_rate in absolute terms, we need to know the average/expected value of hiv_dgns_rate in Russia. According to Avert (2017), the rate of new infections (relative to the total number of HIV-positive individuals) is rising by 10% to 15% each year in Russia. Using the average value of 12.5% growth rate and given that the approximate total number of HIV-positive individuals in Russia is 1.5 million (Avert, 2017), we compute the approximate number of new HIV cases that are occurring annually in Russia: $1.5M * 12.5\% \cong 187.5$ thousands new HIV diagnoses annually. Now, we recall how hiv_dgns_rate is computed:

$$hiv\_dgns\_rate = \frac{\#\ of\ new\ HIV\ cases\ diagnosed}{total\ population} * 100000$$

Equation [1]

As of 2017, the total population of Russia was 144.5 million (World Bank, 2019). We can now compute the new diagnoses rate for Russia (relative to the total population):

$$hiv\_dgns\_rate = \frac{187.5K}{144.5M} * 100000 \cong 129.76$$

We can now quantify the ceteris paribus effect of increasing hiv_fnd_w and $prep\_pct\_hiv$ on change in hiv_dgns_rate in absolute terms in a given year. Specifically, it can be shown that a \$100M spending for hiv_fnd_w is expected to decrease hiv_dgns_rate by $3.53\% * 129.76 \cong 4.58$, and that a \$100M spending for $prep\_pct\_hiv$ is expected to decrease hiv_dgns_rate by $0.54\% * 129.76 \cong 0.70$. To put it in terms of the total number of new yearly diagnoses rather than in terms of the rate, following Equation [1], we can specify that an additional \$100M yearly spending for hiv_fnd_w is expected to decrease the yearly number of new HIV cases by $\frac{4.58*144.5M}{100000} \cong 6618$, and an additional \$100M yearly spending for $prep\_pct\_hiv$ is expected to decrease the yearly number of new HIV cases by $\frac{0.70*144.5M}{100000} \cong 1012$. In other words, it would cost $\frac{\$100M}{6618} \cong \$15110$ to prevent one HIV case through spending for hiv_fnd_w and it would cost $\frac{\$100M}{1012} \cong \$98814$ to prevent one HIV cost through spending for $prep\_pct\_hiv$. So far, we can see that it appears that spending for hiv_fnd_w is a much more efficient policy than spending for $prep\_pct\_hiv$. However, it is important to recognize that a) practically, these two approaches must be combined and implemented together for the most efficient outcomes, as they are closely related and are expected to work in synergy , and b) we have chosen a very high bar for the price of PrEP treatment. While Truvada is a good PrEP treatment, there are many other generic prophylactic medicines in the market that are becoming widely recognized and cost up to ten times less, making this treatment much more affordable and decreasing the cost of preventing an HIV case through $prep\_pct\_hiv$ to as low as $10000 (Get PrEP Online, Russia, 2019; H-Clinic, PrEP in Moscow, 2019). Moreover, experiences of other countries show that the government can purchase Truvada for a much less when buying in bulk (The NY Times, 2017).

The last stage of the cost-efficiency analysis requires estimating the payoff from preventing an HIV case. In their recent research, Schackman et al (2015) estimated that in the US, the average medical cost saved by avoiding one HIV infection is $229800. To account for the price differences between the US and Russia we adjusted the computed cost by price levels of the US and Russia. According to the OECD data (2016), the price level in Russia and the US is 42 and 116, respectively (with average OECD price level serving as a base estimate with value of 100). Thus, we estimate that in Russia, the average medical cost saved by avoiding one HIV infection is $\$229800 * \frac{42}{116} \cong \$83203$.

In conclusion, we have shown that mitigating the HIV infection through spending on expanding PrEP coverage and funding for the HIV prevention and treatment frameworks is justified. This is so from an ethical and epidemiological standpoint, as well as an economic standpoint. Specifically, we have shown that preventing one HIV infection with increasing HIV response funding and expanding PrEP coverage can be achieved for as little as ~$10000, while the estimated cost savings associated with preventing one HIV infection are as high $83203. This indicates that the measures we analyzed are cost-efficient in mitigating the HIV epidemic in Russia.

Limitations of Research

Before using our regression results to recommend policy changes in Russia, it is important to note some possible complications and limitations in our analysis.

The first complication was our inability to acquire certain data that we would have otherwise wanted to incorporate into our analysis. The data we did not acquire was on barrier contraceptive usage, sex education and stigma. Research suggests that consistent barrier contraceptive usage is an effective preventative measure against HIV because it drastically decreases the risks of HIV seroconversion (CDC [3], 2019). Therefore, we believe that the prevalence of barrier contraceptive usage in a given community is an important determinant of the HIV growth rate. We unfortunately did not find statistics on a state-level yearly basis and were unsuccessful in finding other proxies or substitutes for the contraceptive usage variable, thereby forcing us to omit it entirely. The next problematic variable was level of sex education by state in the US. While comprehensive sex and STD/HIV education programs are an important and effective HIV prevention strategy (Kirby, 2008), obtaining estimates for the prevalence of such programs on a state-year basis within the scope of this paper was not possible. Lastly, prior research indicates that the stigma towards HIV and populations that are at high HIV risk, namely, men who have sex with men, sex workers and drug users, imposes a barrier to HIV response activities and increases the HIV risks in the community (Nyblade 2007, Earnshaw & Chaudoir 2009). Obtaining estimates for the level of HIV-related stigma on a state-year basis was also not possible.

Further limitations arise with regards to the differences between the United States and Russia in terms of culture, politics, economics and demographics. We should be careful about extrapolating the results from one to the other. Russia is a conservative society where government and religion are intertwined (Basil, 2009) while the US is liberal with a separation between church and state (US Constitution Amendment I). Therefore, some policies that would work in the US could be rejected by the Russian Federation on the basis of being too progressive. Additionally, some of the tendencies we have explored using the US data might have different magnitudes in Russia. We believe that approximate magnitudes of influence of the HIV growth determinants do not differ substantially between US and Russia. This is supported by the prior research done on the international level.

Another potential limitation of our research stems from the methodological issues we highlighted in our econometric analysis. Specifically, we did not have the means to formally test our regression model for satisfying the *exogeneity* and *linearity* Gauss-Markov assumptions, which are crucial for determining whether OLS estimations are unbiased and consistent. Although we addressed these potential issues informally and concluded that it is not likely that these assumptions were violated in our model, this complication must be kept in mind when interpreting the results of the analysis.

Lastly, an issue we faced when conducting the cost-efficiency analysis was the potential inaccuracies in the HIV-related data for Russia on which we based our framework. Specifically, the precise estimates for the total number of HIV-positive individuals and the rate of HIV growth are hard to obtain due to the following: underdevelopment and underfunding of the HIV prevention and treatment facilities in Russia which may result in limited testing coverage, and possible misreporting from the Russian officials (Clark 2016, Beyrer et al, 2017). The sensitivity analysis we have performed (see the Appendix), shows that even when using the most expensive estimates (instead of the average ones as we used), our conclusion remains that the preventative measures analyzed are cost-efficient.

Conclusion and Policy Recommendations

Our policy recommendations aim to resolve the issue of the growing HIV epidemic in Russia. Keeping the above limitations in mind, we have constructed a set of policy recommendations designed to overcome these obstacles that is both realistic and applicable to Russia.

HIV/AIDS has been a major global public health issue since it was first identified in the early 1980s (CDC [1], 2019). While the rate of new cases is on the decline globally, they continue to rise in Russia where HIV prevalence among the adult population is the highest in the region (Avert, 2019). One of the most successful countries in dealing with the HIV epidemic has been the United States. Over the last 30 years, the US has worked to implement treatment and prevention strategies to combat the spread of the disease, leading to a decline in new cases and increased treatment for infected individuals (UNAIDS, 2019).

In this paper, we focused on analyzing the successful strategies of the US in reducing HIV prevalence and used the findings to recommend policy adaptations to the Russian Federation. Specifically, our econometric research indicates that the use of prevention policies based on PrEP medication has had a significant and persistent effect in reducing the rate of new infections in the US. We have also demonstrated that funding and developing HIV response programs helps to decrease the rate of new infections effectively. Moreover, we developed a cost-efficiency analysis framework and demonstrated that funding HIV response programs and expanding PrEP coverage are cost-efficient policies, meaning that spending relatively small amounts on prevention programs today will lead to substantial government savings on future medical expenses. Currently, HIV response programs are severely underfunded in Russia (Avert, 2019). PrEP is not covered by any government programs or insurances, nor is it available for private purchase in most regions (Avert, 2019). These issues highlight the need to introduce new health policies to mitigate the growing HIV epidemic in the region. So long as insufficient policies allow the upward trend of new infections to continue, the situation will likely continue to worsen, thereby becoming harder to solve given the exponential nature of which new HIV cases are diagnosed over the time.

Based on the research and review conducted above, our recommendation involves a multiple stage policy reform: It starts with drastically improving the national framework for identifying and acknowledging the high-risk populations in Russia. This is crucial for developing comprehensive and effective prevention and treatment policies and programs (Kahn, 1996). Today, the populations in Russia that are at the highest risk are also the most marginalized and vulnerable, with very little access to legal or medical services. These populations are drug users (Heimer, 2017; Lunze, 2016), sex workers (Beyrer et al, 2017), men and transgender women who have sex with men (Wirtz et al, 2016), and people in detention facilities (Avert, 2019). The next stage entails officially acknowledging and raising awareness about the growing HIV epidemic in Russia. This involves initiating contact with the high-risk populations and HIV-positive citizens, thereby dismantling the socio-economic, cultural and legal barriers that currently restrict access to testing and treatment. Finally, our policy recommends using PrEP as the dominant preventative measure to help high risk individuals and all Russian citizens avoid contracting HIV.

Framework

Current HIV/AIDS prevention and treatment programs in Russia are inadequate and fail to address the magnitude of the growing problem. Establishing a framework geared towards identifying key affected populations within Russia is the first step needed in policy reform. It is not enough to merely make testing and treatment available, as people must also be encouraged to be proactive about their health. Since our research shows that more funding per HIV positive individual leads to lowering the rate of new infection, we recommend increasing funding to address the groups with the highest HIV prevalence. This means that Russia must implement policies to reduce the stigma and discrimination facing these populations and acknowledge the severity of the problem. The failure of Russia to shift its current stance on this issue will result in possible insufficient allocation of funding and resources and the exacerbation of the growing infection.

Sex Workers and Drugs Users

We recommend initially focusing on sex workers and people who inject drugs (PWID), for these groups are among the communities with the highest prevalence of HIV in Russia (Beyrer et al., 2017). The proportion of HIV transmission happening through heterosexual contact is continuously rising, resulting in the epidemic becoming more prevalent in the general population and making prevention much harder to achieve today. Sex workers and PWID play a main role in this new trend. It is for this reason that we recommend initially focusing efforts in aiding these two groups of people. One of the major problems facing sex workers and PWID is the illegality of their practices which leaves them susceptible to both social, legal and medical risks. They are often denied proper medical care and even risk detainment upon seeking it. Another barrier for sex workers is fear of being registered as having an STD on their medical records, which might lead to catastrophic outcomes given the lack of access to proper medical care and/or social security programs. While in some instances testing may be available, the lack of anonymity acts as another deterrent for sex workers and PWID to seek treatment because this information can prevent them from finding work in the future and/or lead to detainment (King et al., 2013). Until now, the Russian government has turned a blind eye to these groups of people who are severely in need of immediate attention. In order to reduce HIV prevalence among sex workers, people who inject drugs and consequently their sexual partners and general population, we recommend that the Russian government sponsors community level intervention programs that first encourage sex workers and PWID to seek medical attention and then facilitate testing and treatment. It is crucial for the government to provide these groups of high-risk individuals and their partners with PrEP treatment to stop the spread of HIV. Furthermore, this program should be offered with complete anonymity.

National PrEP Coverage

Finally, PrEP treatment should be accessible to all citizens who need it, especially those at high risk. In the US, and many other Western Countries, there are national programs in place which provide people with access to PrEP at no cost or low cost, including those without medical insurance (Office of Infectious Disease and HIV/AIDS Policy, 2019; UNAIDS, 2019). Moreover, key affected populations should be made aware that their lifestyle puts them at higher risk of contracting HIV. Therefore, these groups must be specifically targeted and encouraged to take PrEP medication on a daily basis.

Bibliography

Anderson S. (2018). Legal origins and female HIV. *American Economic Review, 108(6)*, p. 1407-1439.

Arndt, C., Lewis, J. (2000). The Macro Implications of HIV/AIDS in South Africa: A Preliminary Assessment. *South African Journal of Economics, 68(5)*, p. 380-392.

Arndt, C., Lewis J. (2001). The HIV/AIDS pandemic in South Africa: sectoral impacts and unemployment. *Journal of International Development*, *13(4)*, p. 427-449.

Avert (2019) – HIV and AIDS in Russia, retrieved from https://www.avert.org/professionals/hiv-around-world/eastern-europe-central-asia/russia

Azomahou, T., Boucekkine R., Diene B. (2016). HIV/AIDS and development: a reappraisal of the productivity and factor accumulation effects. *American Economic Review, 106(5)*, p. 472- 477.

Basil, J. (2005). Church-State Relations in Russia: Orthodoxy and Federation Law, 1990–2004. *Religion, State and Society*, *33(2)*, p. 151-164.

Beegle, K., De Weerdt, J. (2008). Methodological issues in the study of the socioeconomic consequences of HIV/AIDS. *AIDS, 1*, p. 79-84.

Bernard, C., Owens, D., Goldhaber-Fiebert, J., Brandeau, M., (2017). Estimation of the cost-effectiveness of HIV prevention portfolios for people who inject drugs in the United States: A model-based analysis. DOI: https://doi.org/10.1371/journal.pmed.1002312.

Beyrer, C., Wirtz, A., O'Hara, G., Léon, N., Kazatchkine, M. (2017). The expanding epidemic of HIV-1 in the Russian Federation. *PLoS Med, 14(11).* DOI: https://doi.org/10.1371/journal.pmed.1002462

CDC [1] (2019) – HIV seroconversion basics, retrieved from https://www.cdc.gov/hiv/basics/transmission.html

CDC [2] (2019) – US HIV statistics overview, retrieved from https://www.cdc.gov/hiv/statistics/overview/ataglance.html

CDC [3] (2019) – PrEP basics, retrieved from https://www.cdc.gov/hiv/basics/prep.html

Clark, F. (2016). Gaps remain in Russia's response to HIV/AIDS. *Lancet, 388(10047)*, p. 857-858.

Cleary, S., McIntyre, Di., Boulle, A. (2008). Assessing efficiency and costs of scaling up HIV treatment. *AIDS, 22*, p. 35-42.

Creese, A., Floyd, K., Alban, K. Guinness, L. (2002). Cost-effectiveness of HIV/AIDS interventions in Africa: a systematic review of the evidence. *The Lancet, 359(9318),* p. 1635- 1642.

DeHovitz, J., Uuskula, A. and El-Bassel, N. (2014). *Current HIV/AIDS Reports, 11*, 168–176. Dixon, S., McDonald, S., Roberts, J. (2002). The impact of HIV and AIDS on Africa's economic development. *British Medical Journal, 324:232*.

Earnshaw, V., Smith, V., Chaudoir, S., Amico, R., Copenhaver, M. (2013). HIV stigma mechanisms and well-being among PLWH: a aest of the HIV stigma framework. *AIDS and Behavior, 17,* p. 1785-1795.

Fimpel, J., Stolpe, M. (2010). The welfare costs of HIV/AIDS in eastern Europe: an empirical assessment using the economic value-of-life approach. *The European Journal of Health Economics, 11(3),* p. 305-322.

Fleishman, J., Yehia, B., Moore, R., Gebo, K. (2010). The Economic Burden of Late Entry Into Medical Care for Patients With HIV Infection. *Med Care, 48(12),* p. 1071–1079.

Forsythe S., Rau, B. (1998). Evolution of socioeconomic impact assessments of HIV/AIDS. *AIDS, 12(2),* p. 47-55.

Galárraga, O., Colchero, A., Wamai, R., Bertozzi, S. (2009). HIV prevention cost-effectiveness: a systematic review. *BMC Public Health, 9(5)*.

Get PrEP Online Organization: how much does it cost to purchase PrEP in Russia? Retrieved from https://getpreponline.com/prep-in-russia/.

H-Clinic: purchase PrEP in Moscow. Retrieved from https://h-clinic.ru/prep/.

Hargreaves, J., Bonell, C., Boler, T., Boccia, D., Birdthistle, I., Fletcher, A., Pronyk, P., Glynn, J. (2008). Systematic review exploring time trends in the association between educational attainment and risk of HIV infection in sub-Saharan Africa. *AIDS, 22(3),* p. 403-414.

Hutchinson, A., Farnham, P., Dean, H., Ekwueme, D., del Rio, C., Kamimoto, L., Kellerman, S. (2006). The economic burden of HIV in the United States in the era of highly active antiretroviral therapy: evidence of continuing racial and ethnic differences. *Journal of Acquired Immune Deficiency Syndromes, 43(4),* p. 451-457.

Heimer, R., Usacheva, N., Barbour, R. Niccolai, L., Uusküla, A., Levina, O. (2017). Engagement in HIV care and its correlates among people who inject drugs in St Petersburg, Russian Federation and Kohtla-Järve, Estonia. *Addiction, 112(8),* p. 1421-1431.

Justesen M. (2012). Democracy, dictatorship, and disease: political regimes and HIV/AIDS. *European Journal of Political Economy, 28(3)*, p. 373-389.

Kahn, J., (1996). The cost-effectiveness of HIV prevention targeting: how much more bang for the buck? *American Journal of Public Health, 86(12)*, p. 1709-1712.

King, E., Maman, S., Bowling, M., Moracco, K., Dudina, V. (2013). The influence of stigma and discrimination on female sex workers' access to HIV services in St. Petersburg, Russia. *AIDS and Behaviour, 17,* p. 2597-2603.

Kirby, D. (2008). The impact of abstinence and comprehensive sex and STD/HIV education programs on adolescent sexual behavior. *Sexuality Research & Social Policy, 5,* article number: 18.

Laufer, F. (1999). Cost-effectiveness of syringe exchange as an HIV prevention strategy. *Journal of Acquired Immune Deficiency Syndromes, 28(3),* p. 273-278.

Liu, A., Cohen, S., Follansbee, S., Cohan, D., Weber, S., Sachdev, D., Buchbinder, S. (2014). Early experiences implementing Pre-exposure Prophylaxis (PrEP) for HIV prevention in San Francisco. *PLoS Med., 11(3):* e1001613.

Lunze, K., Raj, A., Cheng, D., Quinn E., Lunze, F., Liebschutz, J., Bridden, C., Walley, A., Blokhina, E., Krupitsky, E., Samet, J. (2016). Sexual violence from police and HIV risk behaviours among HIV-positive women who inject drugs in St. Petersburg, Russia – a mixed methods study. *Journal of the International AIDS Society, 19(4 Suppl. 3).*

Nosyk, B., Montaner, J., (2012). The Evolving Landscape of the Economics of HIV Treatment and Prevention. *PLoS Med, 9(2)*.

Roy, S. (2014). The effects of HIV/AIDS on economic growth and human capitals: a panel study evidence from Asian countries. *AIDS Care, 26(12)*, p. 1568-1575.

Schackman, B., Fleishman, J., Su, A., Berkowitz, B., Moore, R., Walensky, R., Becker, J., Voss, C., Paltiel, D., Weinstein, M., Freedberg, K., Gebo, K., Losina, E. (2015). The lifetime medical cost savings from preventing HIV in the United States. *Med. Care, 53(4),* p. 293-301.

Smith, J., Ahmed, K., Whiteside, A. (2011). Why HIV/AIDS should be treated as exceptional: arguments from sub-Saharan Africa and Eastern Europe. *African Journal of AIDS Research, 10,* p. 345-356.

Spinner, C., Boesecke, C., Zink, A., Jessen, H., Stellbrink, H., Rockstroh, J., Esser, S. (2015). HIV pre-exposure prophylaxis (PrEP): a review of current knowledge of oral systemic HIV PrEP in humans. *Infection, 44,* p. 151-158.

The NY Times (2017). Brazil Fights H.I.V. Spike in Youths With Free Preventive Drug. Retrieved from https://www.nytimes.com/2017/12/12/world/americas/prep-brazil-hiv-aids.html.

Thornton R. (2008). The demand for, and impact of, learning HIV status. *American Economic Review*, 98(5), p. 1829-1863.

Trapero-Bertran, M., Oliva-Moreno, J. (2014). Economic impact of HIV/AIDS: a systematic review in five European countries. *Health Economics Review, 4(15)*.

Turan, J., Nyblade, L. (2013). HIV-related stigma as a barrier to achievement of global PMTCT and maternal health goals: a review of the evidence. *AIDS and Behavior, 17,* p. 2528-2539.

UNAIDS (2019). Fact Sheet – World AIDS Day 2019.

Waziri, S., Mohamed, N., Raja Abdullah, N., Adamu, P. (2015). Effect of the Prevalence of HIV/AIDS and the Life Expectancy Rate on Economic Growth in SSA Countries: Difference GMM Approach. *Global Journal of Health Science, 8(4)*, p. 212-220.

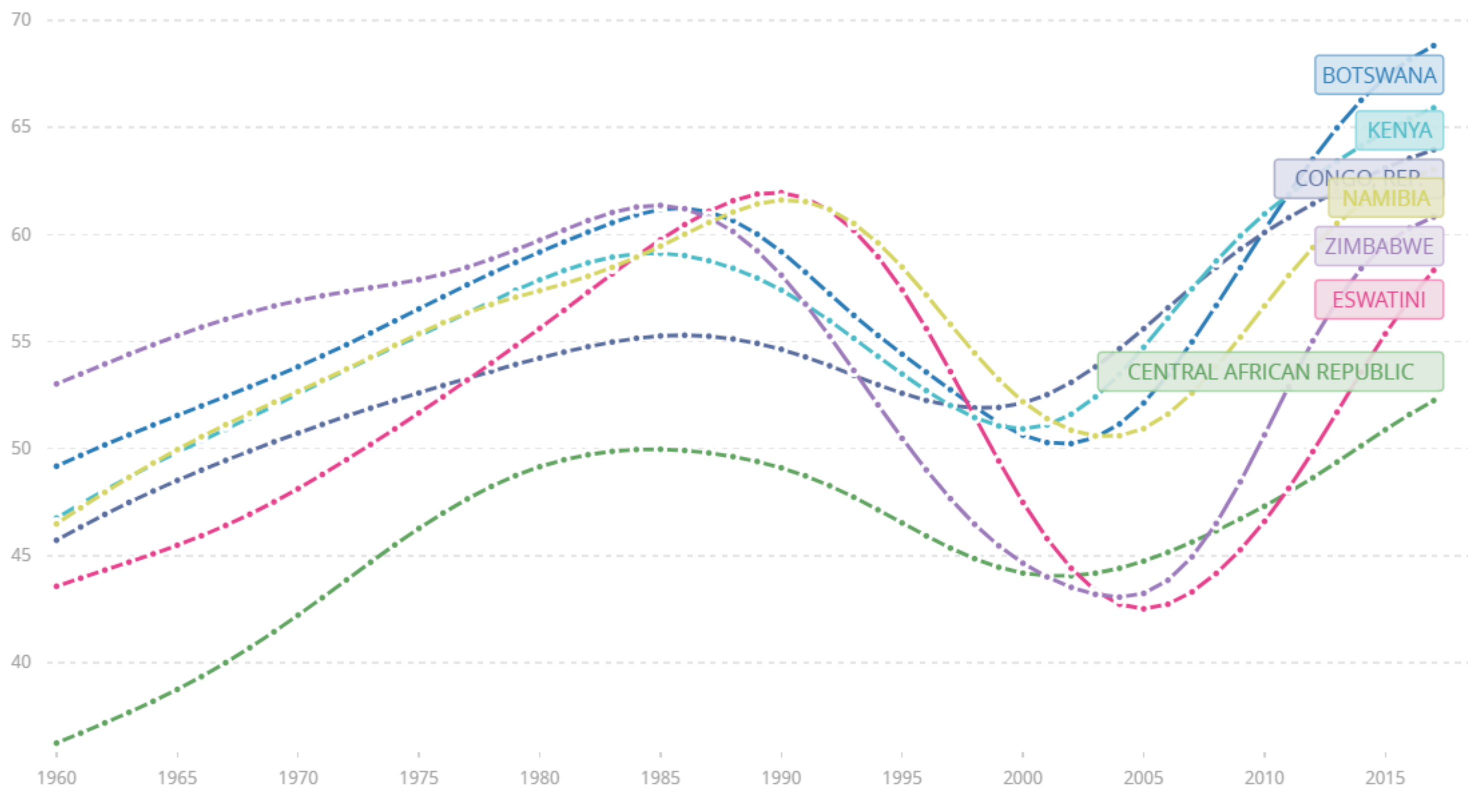
Wirtz, A., Zelaya, C., Latkin, C., Peryshkina, A., Galai, N., Mogilnyi, V., Dzhigun, P., Kostetskaya, I., Mehta, S., Beyrer, C. (2016). The HIV care continuum among men who have sex with men in Moscow, Russia: a cross-sectional study of infection awareness and engagement in care. *Sex Transm. Infect., 92(2),* p. 161–167.

Zaric, G., Barnett, P., Brandeau, M., (2000). HIV transmission and the cost-effectiveness of methadone maintenance. *American Journal of Public Health, 90(7),* p. 1100–1111.

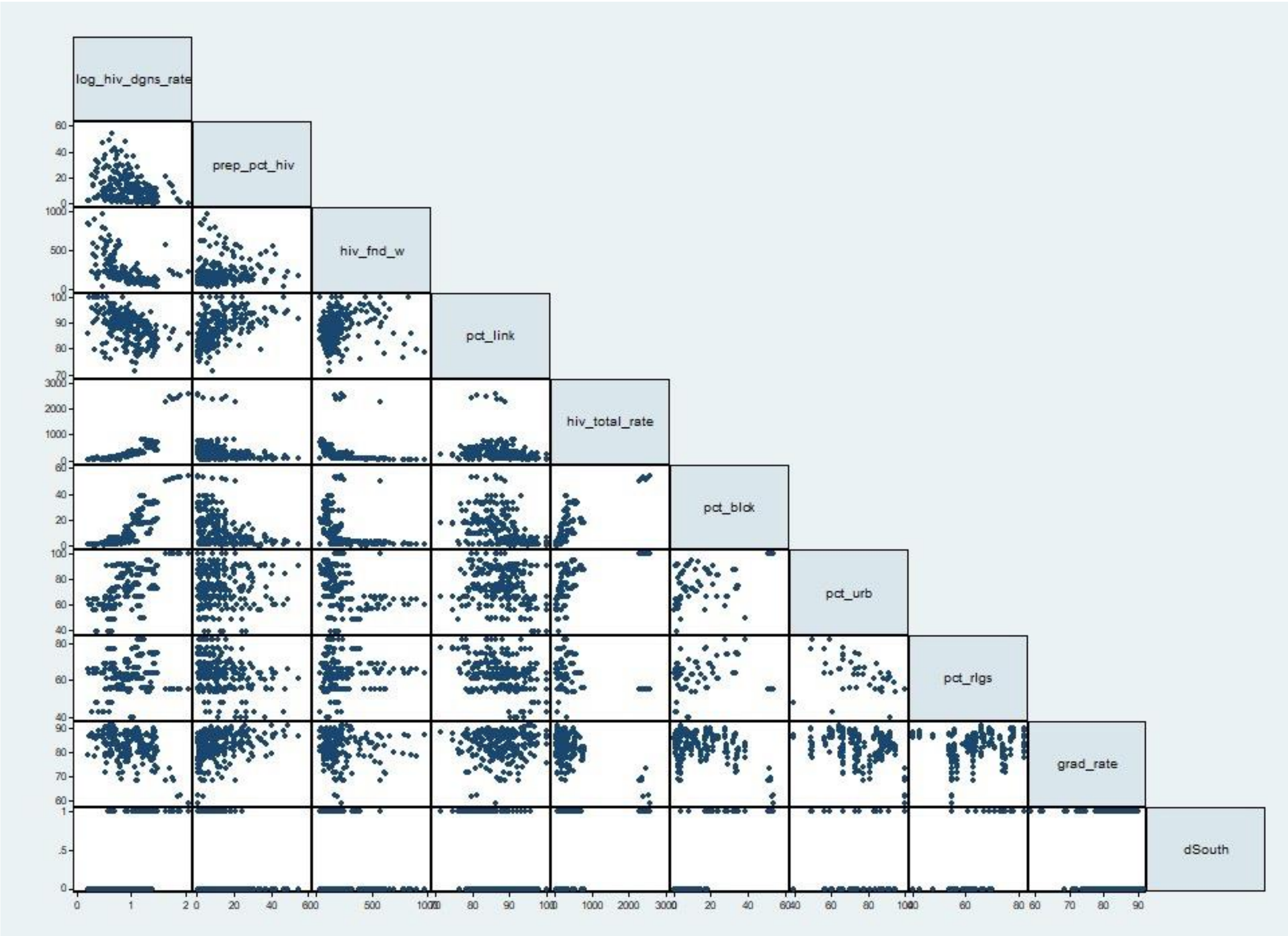
Appendix

Graphs [1]-[3]

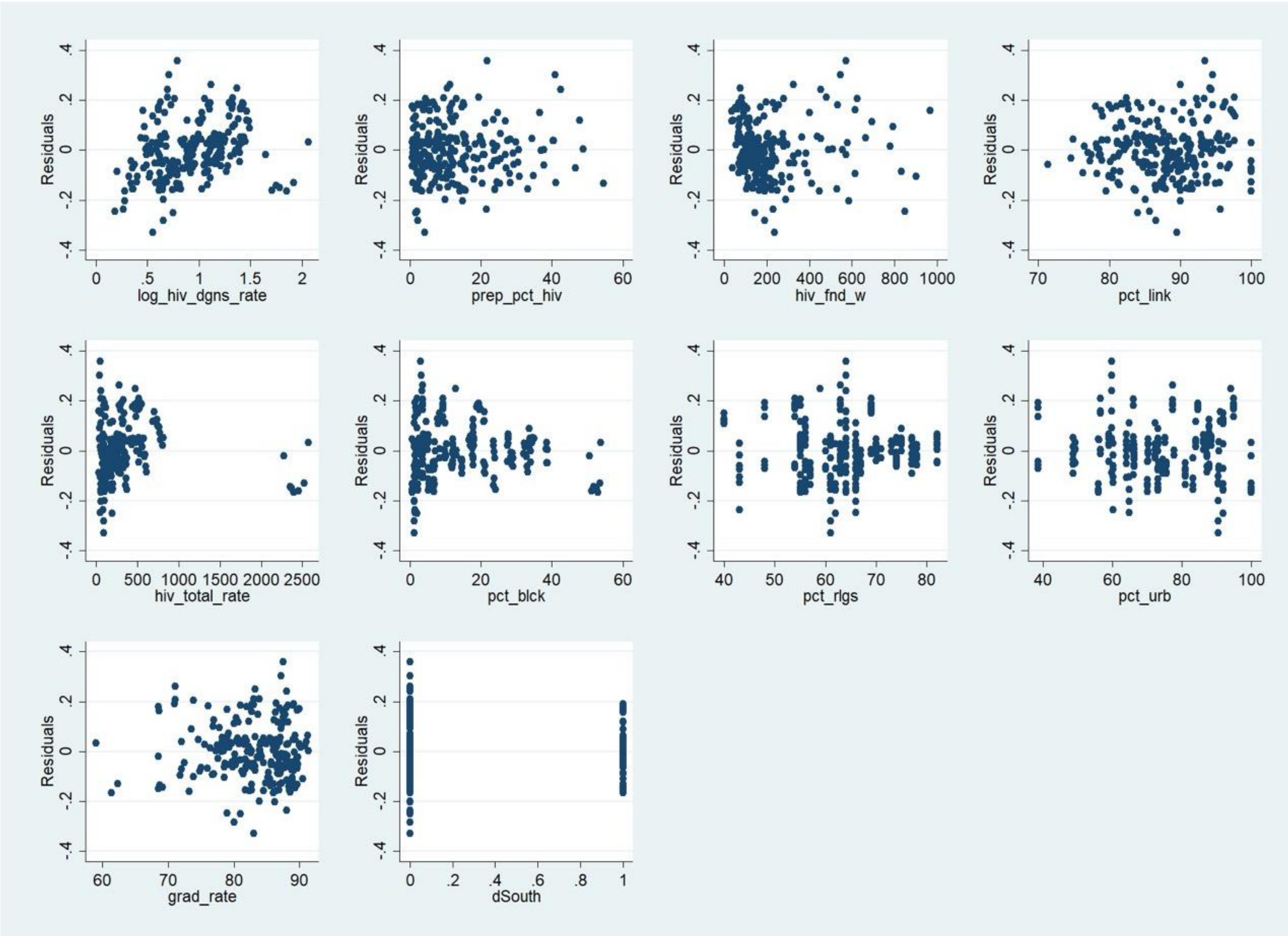
Graph [1]: Life expectancy at birth for selected Sub-Saharan countries, with a sharp fall in the 1990s primarily due to the HIV/AIDS epidemic



Graph [2]: Scatter Plots of the Parameters of Model [1] Against Each Other



Graph [3]: Scatter Plots of the Residuals from Model [1] Against the Parameters of Model [1]



Sensitivity Analysis for the Cost-Efficiency Calculations

In conducting the cost-efficiency analysis we lacked precise estimates for HIV-related data in Russia. Specifically, the total number of HIV-positive individuals and the rate of HIV cases growth that are reported with a large variation in estimates by official and unofficial agencies. The estimated number of HIV-positive Russian citizens is 1 to 2 million, and the estimated rate of HIV growth is 10% to 15%. In our cost-efficiency analysis, we used the average values of these estimates and concluded that the measures explored are cost-efficient. Here, we expand our analysis by introducing 4 distinct scenarios that rely on the alternative estimates of the current HIV statistics in Russia. The numbers highlighted in blue are those that were subject to the sensitivity analysis.

1. Assuming 1 million (M) of HIV-positive individuals and 10% growth rate:
    - The annual number of new HIV cases is $1M * 10\% = 100\ thousand\ (K)$. The rate of new cases diagnosed is, therefore, $\frac{100K}{144.5M} * 100000 \cong 69.20$
    - The cost of increasing hiv_fnd_w by \$100 is $\$100 * 1M = \$100M$. The 5.3% decrease in the rate of new HIV cases associated with a \$100M investment in hiv_fnd_w is equivalent to the decrease of $5.3\% * 69.20 \cong 3.67$ in the rate of new cases in absolute terms. Alternatively, it is equivalent to preventing $\frac{3.67*144.5M}{100000} \cong 5300$ new HIV cases. Thus, in this scenario, it would cost approximately $\frac{\$100M}{5300} \cong \$18868$ to prevent one HIV case through spending for hiv_fnd_w.
    - The cost of increasing $prep\_pct\_hiv$ by 10% is the cost of covering 10% of 1M individuals with PrEP, or 100K individuals. This would cost between $\$260 * 100K \cong \$26M$ (assuming generic PrEP medicines are purchased) and $\$2600 * 100K \cong \$260M$ (assuming Truvada is purchased). The 2.1% decrease in the rate of new HIV cases in relative terms associated with this investment is equivalent to the decrease of $2.1\% * 69.20 \cong 1.45$ in the rate of new cases diagnosed in absolute terms. Alternatively, it is equivalent to preventing $\frac{1.45*144.5M}{100000} \cong 2100$ new HIV cases. Thus, in this scenario, it would cost between $\frac{\$26M}{2100} \cong \$12380$ to

$\frac{\$260M}{2100} \cong \$123800$ (depending on the cost of drug chosen) to prevent one HIV case.

- Thus, under this scenario, the policies we have recommended remain cost-efficient.

2. Assuming 1M of HIV-positive individuals and 15% growth rate:
   - The annual number of new HIV cases is $1M * 15\% = 150K$. The rate of new cases diagnosed is, therefore, $\frac{150K}{144.5M} * 100000 \cong 103.80$
   - The cost of increasing hiv_fnd_w by \$100 is $\$100 * 1M = \$100M$. The 5.3% decrease in the rate of new HIV cases associated with a \$100M investment in hiv_fnd_w is equivalent to the decrease of $5.3\% * 103.80 \cong 5.50$ in the rate of new cases in absolute terms. Alternatively, it is equivalent to preventing $\frac{5.50*144.5M}{100000} \cong 7950$ new HIV cases. Thus, it would cost approximately $\frac{\$100M}{7950} \cong \$12579$ to prevent one HIV case through spending for hiv_fnd_w.
   - The cost of increasing $prep\_pct\_hiv$ by 10% is the cost of covering 10% of 1M individuals with PrEP, or 100K individuals. This would cost between $\$260 * 100K \cong \$26M$ (assuming generic PrEP medicines are purchased) and $\$2600 * 100K \cong \$260M$ (assuming Truvada is purchased). The 2.1% decrease in the rate of new HIV cases in relative terms associated with this investment is equivalent to the decrease of $2.1\% * 103.80 \cong 2.18$ in the rate of new cases diagnosed in absolute terms. Alternatively, it is equivalent to preventing $\frac{2.18*144.5M}{100000} \cong 3150$ new HIV cases. Thus, in this scenario, it would cost between $\frac{\$26M}{3150} \cong \$8254$ to $\frac{\$260M}{3150} \cong \$82540$ (depending on the cost of drug chosen) to prevent one HIV case.
   - Thus, under this scenario, the policies we have recommended remain cost-efficient.

3. Assuming 2M of HIV-positive individuals and 10% growth rate:
    - The annual number of new HIV cases is $2M * 10\% = 200K$. The rate of new cases diagnosed is, therefore, $\frac{200K}{144.5M} * 100000 \cong 138.40$
    - The cost of increasing hiv_fnd_w by \$100 is $\$100 * 2M = \$200M$. The 5.3% decrease in the rate of new HIV cases associated with a \$200M investment in hiv_fnd_w is equivalent to the decrease of $5.3\% * 138.40 \cong 7.34$ in the rate of new cases in absolute terms. Alternatively, it is equivalent to preventing $\frac{7.34*144.5M}{100000} \cong 10600$ new HIV cases. Thus, it would cost approximately $\frac{\$200M}{10600} \cong \$18868$ to prevent one HIV case through spending for hiv_fnd_w.
    - The cost of increasing $prep\_pct\_hiv$ by 10% is the cost of covering 10% of 2M individuals with PrEP, or 200K individuals. This would cost between $\$260 * 200K \cong \$52M$ (assuming generic PrEP medicines are purchased) and $\$2600 * 200K \cong \$520M$ (assuming Truvada is purchased). The 2.1% decrease in the rate of new HIV cases in relative terms associated with this investment is equivalent to the decrease of $2.1\% * 138.40 \cong 2.9$ in the rate of new cases diagnosed in absolute terms. Alternatively, it is equivalent to preventing $\frac{2.9*144.5M}{100000} \cong 4200$ new HIV cases. Thus, in this scenario, it would cost between $\frac{\$52M}{4200} \cong \$12380$ to $\frac{\$520M}{4200} \cong \$123800$ (depending on the cost of drug chosen) to prevent one HIV case.
    - Thus, under this scenario, the policies we have recommended remain cost-efficient.

4. Assuming 2M million of HIV-positive individuals and 15% growth rate:
   - The annual number of new HIV cases is $2M * 15\% = 300K$. The rate of new cases diagnosed is, therefore, $\frac{300K}{144.5M} * 100000 \cong 207.60$
   - The cost of increasing hiv_fnd_w by \$100 is $\$100 * 2M = \$200M$. The 5.3% decrease in the rate of new HIV cases associated with a \$200M investment in hiv_fnd_w is equivalent to the decrease of $5.3\% * 207.60 \cong 11$ in the rate of new cases in absolute terms. Alternatively, it is equivalent to preventing $\frac{11*144.5M}{100000} \cong 15900$ new HIV cases. Thus, it would cost approximately $\frac{\$200M}{15900} \cong \$12579$ to prevent one HIV case through spending for hiv_fnd_w.
   - The cost of increasing $prep\_pct\_hiv$ by 10% is the cost of covering 10% of 2M individuals with PrEP, or 200K individuals. This would cost between $\$260 * 200K \cong \$52M$ (assuming generic PrEP medicines are purchased) and $\$2600 * 200K \cong \$520M$ (assuming Truvada is purchased). The 2.1% decrease in the rate of new HIV cases in relative terms associated with this investment is equivalent to the decrease of $2.1\% * 207.60 \cong 4.36$ in the rate of new cases diagnosed in absolute terms. Alternatively, it is equivalent to preventing $\frac{4.36*144.5M}{100000} \cong 6300$ new HIV cases. Thus, in this scenario, it would cost between $\frac{\$52M}{6300} \cong \$8254$ to $\frac{\$520M}{6300} \cong \$82540$ (depending on the cost of drug chosen) to prevent one HIV case.
   - Thus, under this scenario, the policies we have recommended remain cost-efficient.

In conclusion, the sensitivity analysis shows that the cost-efficiency of the policies based on increasing HIV funding and on expanding PrEP coverage does not depend on the rate of HIV cases growth and that these policies remain cost-efficient whichever estimate of the total number of HIV-positive individuals we rely on.