Information and the Spread of HIV: A Tale of Sorting

A DISSERTATION
SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL
OF THE UNIVERSITY OF MINNESOTA
BY

Eric McDermott

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
Doctor of Philosophy

Jose Victor Rios Rull, Adviser

June, 2014

Acknowledgements

I am deeply indebted to my adviser Victor Rios-Rull for his support and guidance. Without him this would not be possible. Jonathan Heathcote and Maia Guell have been incredibly helpful and I am equally grateful to them. I would also like to thank Paul Glewwe, Kjetil Storeslettin, Minesh Amin, Ramses Armendariz, Brian Zurowski, Naoki Takayama, and Zach Mahone for helpful suggestions. Many thanks to seminar participants of the Midwest Economics Association Conference in Evanston in 2014 and members of the Labor Economics workshop at The University of Minnesota for their helpful comments and insight.

Dedication

First and foremost, I would like to thank my parents. You have been through more in this past eight years than any two people should ever have to go through and you have handled it with the grace and determination that make me continue to be proud to say that I am your son. I will always be grateful for all of your love and support and could not have had the life that I have without your selflessness. I am also grateful and count myself extremely lucky to have the support and love of two talented brothers and a very beautiful extended family that could not be more fantastic. To my friends here in Minneapolis and all over the world, I say thank you for all of the fond memories past and of those to come and for making me a very lucky individual.

Abstract

This thesis is composed of two separate essays.

In the first essay of this thesis, I examine data from the Voluntary Counseling and Testing Study Group's randomised controlled trial in which individuals learn their HIV status at different points in time. Aspects of sexual behavior were reported in surveys collected at an initial baseline as well as at a six month follow-up for all individuals I consider. These individuals were also tested for Sexually Transmitted Diseases (STDs) to determine if they were newly-infected. The interesting feature of the data that I look at is individuals who believed they were likely HIV negative but were actually HIV positive contracted more new STDs than individuals in a control group with similar beliefs and the same HIV status but who did not learn their status at baseline. This is despite not reporting riskier sexual behavior. Those who believed they were HIV positive but learned they were actually HIV negative contracted fewer new STDs than those in the comparable subgroup.

In the second essay of this thesis, I develop a model which assumes truthful reporting that explains the varied STD contraction rates described in the first essay. The key feature of this model is that it allows for individuals to choose to meet a partner in one of two locations, producing a sorting equilibrium. Since there has been a question as to whether these individuals are truthfully reporting their behavior I also develop models that consider cases where individuals under-report their behavior. I show that even in this case a sorting equilibrium performs better when compared to the data, which implies that subsidizing HIV testing is a policy that reduces prevalence under the assumptions in that model.

Contents

List of Tables

List of Figures

Chapter 1

Data

1.1 Introduction

HIV counseling and testing is recommended by the World Health Organization as a means to slow the spread of HIV and to get better information and healthcare options to those who learn that they are infected. Implicit in their endorsement of HIV testing is the assumption that people who learn they are HIV-positive will not increase their sexual activity with uninfected persons after learning their status. Recent analysis of data from a study initially conducted by Coates et. al (2000) calls this recommendation into question as it suggests that those who receive the bad news that they are HIV positive may increase their risky sexual behaviors. In particular, those who believed they were likely HIV negative but learned they were in fact HIV positive were shown to contract significantly more sexually transmitted diseases (STDs) (STDs will refer to those other than HIV throughout the remainder of this paper) upon learning this status than a comparable control group who did not learn their status over the same period of time. This is despite reporting similar or even less risky sexual behavior than the comparable control subgroup.

The analysis that calls these public health recommendations into question supposes that there must have been an increase in risky behavior to achieve this increase in STDs and, if correct, would suggest public health policymakers may wish to exercise caution when using HIV testing as a tool in the fight against HIV/AIDS. I will offer an explanation using the same data and reach a conclusion that is strongly supportive

of endorsements of voluntary counseling and testing. My paper considers this increase in STDs by those learning their HIV positive status and other facts about the sexual behavior of the individuals in this study and proposes a model with important policy implications which accounts for those facts. I show that individuals sorting themselves and searching for partners whom they believe have an HIV status similar to their own is consistent with the facts observed in the data.

Data from the study done by the Voluntary Counseling and Testing Group is a focus of this paper. I will explain the methods of the study in greater detail in the data section, but provide here a summary of important relevant facts as they pertain to this paper. Individuals from sites in Kenya and Tanzania were randomized into two groups to be tested and surveyed at baseline, as well as come back for further surveying and testing at a six month follow-up. Both groups gave a sample to be tested for chlamydia and gonorrhea. They both were also surveyed on their sexual behavior and prior beliefs about their HIV status at baseline as well as at the six month follow-up. The treatment group was tested for HIV and learned their status, while the control group would not learn theirs until the six month follow-up. The details of how these randomized groups learned their HIV status will be laid out later in the paper. For now, I begin with an explanation of the qualitative changes in behavior and STDs for all individuals, based on their prior beliefs (where high means they believed they were likely HIV positive), actual HIV status, and whether these test results presented them with any new information.

Table 1.1: Displays whether HIV test would give a subgroup new information.

Actual Status	Prior belief	Treatment
HIV+	low	bad news
HIV-	low	old news
HIV+	high	old news
HIV-	high	good news

The focus of the paper will be on the groups who received *good news* and *bad news*. This is because I am interested in how individuals react to new information that does not coincide with their prior belief and any possible behavior changes this triggers. We will see throughout that individuals who receive *old news* do not appear to behave

differently than individuals who have the same prior belief and actual HIV status but do not learn their HIV status.

First, we see what happens with contracted STDs and reported sexual behavior relative to the control group for individuals who receive *bad news*. If telling individuals their HIV status is a universally good policy then we might expect some reduction in risk to themselves for those who learn they are HIV negative and reduction in risk to others upon learning they are HIV positive, relative to control subgroups with similar prior beliefs and actual HIV statuses but does not learn their HIV status. In terms of reported behavior, there does not appear to be any increase in risky behavior by the group learning *bad news* during the study.

Table 1.2: Qualitative comparison of individuals receiving bad news with the control group subset with a low prior belief and HIV+.

Actual Status	Prior belief	Learned	STDs vs Control	Unprotected Sex vs Control
HIV+	low	no	-	-
HIV+	low	yes	higher	similar/safer

At first glance it seems peculiar, or even concerning, that these individuals are reporting similar instances of unprotected sex, yet they are contracting more new STDs. Before I explain the mechanism that accounts for this, I look at the behavior and STDs of those individuals who received *good news*.

Table 1.3: Comparison of individuals receiving good news with the control group subset with a high prior belief and HIV-.

Actual Status	Prior belief	Learned	STDs vs Control	Unprotected Sex vs Control
HIV-	high	no	-	-
HIV-	high	yes	lower	similar

Again, one might think there appears to be an inconsistency in the reported sexual behaviors of individuals who learn they are HIV positive. If these individuals are truly having similar sexual behaviors we would not expect the divergence in STD contraction

if they were meeting their partners in a similar fashion. The model of behavior I propose allows for the possibility that individuals can affect their exposure to HIV infection not only through instances of unprotected sex but also the type of partner they search for. In this sense, I allow them to *aim* for different types of partners with regard to likely HIV status. By allowing them to change their partner search along this dimension I am able to account for the changes that we see in the data, the magnitudes of which we will observe later. Clearly individuals who are less likely to be HIV positive would prefer similar partners. I will propose two possible explanations under which a sorting equilibrium, where individuals who believe they are more likely to be HIV positive, choose to search for a partner who is also more likely to be HIV positive. I include preferences over a partner's willingness to engage in unprotected sex or altruistic concerns over damage done to another's HIV status in order to generate such a sorting equilibrium, and find that a combination of both also generates an equilibrium that is consistent with the reported behavior and changes in STDs contracted in the data.

There are two key facts about the data that will be accounted for by the model proposed here. The first is that those who believed they were likely HIV-negative (had a low prior belief about their HIV status) but were told at baseline that they were in fact HIV-positive had more than a five-fold greater increase in new STDs compared to those in the control group who also had a low prior belief about their status, did not learn their status at baseline, but were in fact HIV-positive. The second fact is that these individuals who learned their status reported sexual behavior similar to those who did not learn their status. In some dimensions those who learned they were HIV positive reduced their risky sexual behavior. A third key fact, which will allow me to observe the sexual behavior of all individuals, whether they learn their status or not, is that individuals with higher beliefs about their HIV status also report having STD symptoms in higher proportions. This is of importance because it allows for the explanation of how individuals can have similar sexual behavior and contract new STDs at different rates if they are sorting into different partner pools.

The model considers sexually active individuals who will differ only in their prior belief about their own HIV status. They will choose between two locations where they will look for a partner. The distribution of beliefs in each of those markets will be known by all and these markets will be labeled $safe$ and $unsafe$ to denote locations where I

find people with lower HIV prior beliefs (safe) and higher beliefs (unsafe) sort to (in equilibrium). Upon deciding the location in which to look for a partner, each agent will decide how much effort to use to protect him or herself from contracting HIV.

One key concept in this paper is the definition of the word *risky* as it pertains to sexual behavior. Often this is used as a general term, referring to behaviors such as having multiple partners, having unprotected sex, etc. Although this paper will use specifics such as instances of unprotected sex rather than risky, the spirit of this paper proposes considering the riskiness of an act as a relative term. An individual who knows he or she is HIV-positive faces no risk of contracting HIV from another individual. Similarly, two individuals who are both certain the other is HIV-negative are not placing themselves at risk for HIV infection by having unprotected sex (it is true that it is possible to contract a different HIV subtype but in this paper I assume individuals have preferences over being HIV positive or negative, and not over how many subtypes they have been infected with). It is extremely unlikely for an individual to be fully certain of their own status as well as the status of their partner at any given point in time, but this paper makes the assumption that they have some belief about both their own status as well as the status of others as they consider their optimal sexual behavior. Individuals who match in an assortative manner, in that they are partnering with those who they believe have an HIV status similar to their own, allow for those with low prior beliefs about their own status to have unprotected sex in a less risky manner than if they were to search randomly and risk partnering and having unprotected sex with those who have high prior beliefs. Using the model proposed by this paper, I will show that assortative matching by HIV status is consistent with the facts mentioned above.

1.2 History of Human Immunodeficiency Virus

Prior to introducing the data set which is the basis for the model this paper proposes, I will briefly discuss the history of the Human Immunodeficiency Virus. The precursor for HIV was SIV, the Simian Immunodeficiency Virus, which affects chimpanzees. In order to determine the earliest case of HIV in the current epidemic, scientists had to analyze actual samples of blood and/or tissue from individuals infected with HIV and

backdate it to a common ancestor using the approximate rate of genetic change that is observed in HIV. There were samples available from the current Democratic Republic of the Congo (DRC) from around 1960 as well as from Thailand in 1987 which had been identified and tested positive for HIV and which had fortunately been preserved. This analysis allowed them to concluded that the human 'patient zero' must have contracted HIV at around the year 1921 (this of course is not with perfect precision, but is likely to have occurred within a decade or so of this time). The type of SIV positive chimpanzee it was likely contracted from was *Pan Troglodytes Troglodytes*. Further analysis reveals that SIV can be traced back to its first chimpanzee host within a few centuries prior to passing over to humans. It is possible that the virus could have passed over prior to the previously mentioned human 'patient zero' but dying out rather than being sustained through to epidemic status. In addition to the length of time HIV can remain in a person's body before causing their premature death, there was another major factor at play in the mid-20th century that set the table for this to become an epidemic of devastating proportions. Colonial leaders in places like the Belgian Congo (now the DRC) were using lots of human labor in large camps to mine and perform other tasks like building railroads. In some cases, they very much restricted the number of women who were allowed to live in these camps. This set up a situation where women were in short supply and prostitution flourished. These were perhaps ideal conditions for HIV to flourish and spread. (Pepin 2011)

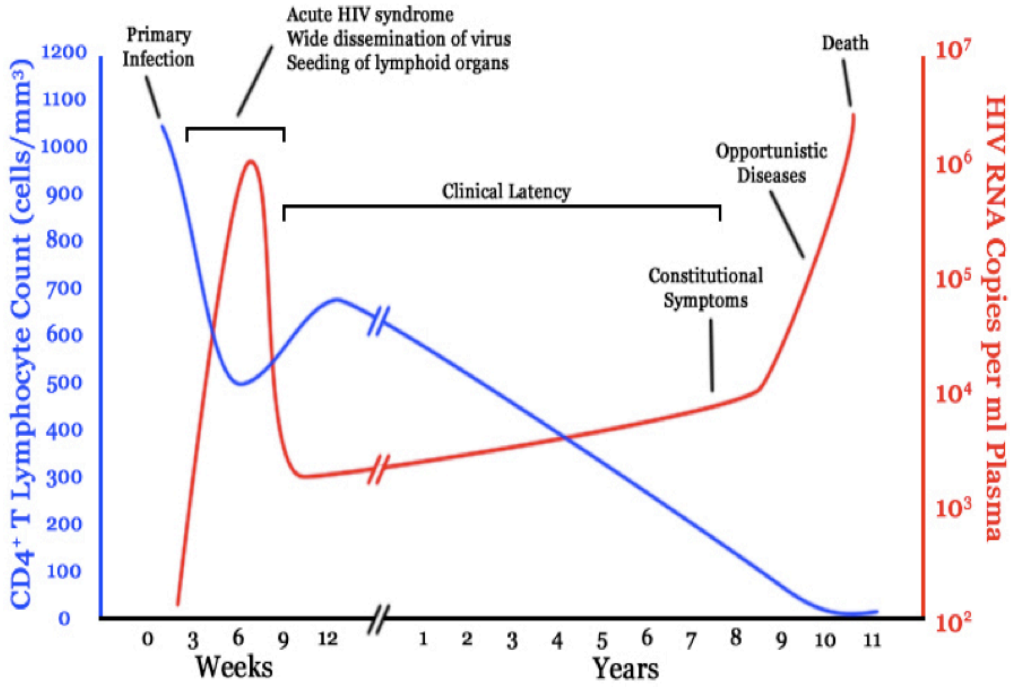
It would be several decades later before the virus was identified to the point where it could be treated. Since then, it is estimated that 36 million people have died from illnesses related to HIV and another 35 million are currently living with HIV. Nine sub-Saharan African countries have double-digit HIV prevalence among adults aged 15-49, with Swaziland leading the way with an estimated prevalence of 26%. The study under discussion here took place in Tanzania and Kenya beginning in 1995 when the HIV rates there were both in the teens and the HIV rate of the sample in the study was 19%.

There are a number of reasons why it is important to understand how behavior changes in the face of new information about HIV status. With changes in the cost of of testing and treatment it appears this importance is only increasing. Access to treatment is one area that is likely to be changing. In June 2013, the WHO changed its recommendation of when countries should provide free access to anti-retroviral (ARV)

therapy drugs. The previous recommendation, issued in 2010, was to offer universal access to individuals when their CD4 cell counts dropped below 350 cells per mm^3. The more recent recommendation increased this level to 500 cells per mm^3. CD4 counts tend to decrease over time after seroconversion so this simply corresponds with earlier treatment for HIV positive individuals. This weakly improves the incentive for individuals to seek out their HIV status in countries that follow this recommendation as the negative consequences of learning an HIV positive status are reduced. There may be other possible behavioral effects associated with increased access to ARVs but I do not consider them in this paper.

Another important level to consider with HIV is its viral load within the body. This typically increases and has an early peak within the first two to three months after seroconversion, reduces as the body begins to fight it, and then slowly increases thereafter. The viral load is important because individuals with a higher viral load are more likely to transmit the disease to someone else. As we consider the possibility of improved incentives for individuals to learn their HIV status through increased access to ARVs and the incentive for a society to learn if individuals have a high viral load and are more likely to infect others, it is crucial for policymakers to know how these individuals respond to learning their HIV status. If, for example, it is determined that an individual has a very high viral load and is significantly more likely to infect a partner during unprotected sex, that individual's response is an extremely valuable thing to know or predict. If he or she reduces the amount of unprotected sex they have with individuals who are likely HIV negative, then there are good reasons to seek and share this information. We see in Figure 1 a typical timeline of both the CD4 cell count levels and the HIV viral load from infection to death.

Figure 1.1: Typical life cycle of CD4 cell counts and HIV viral load, dated from initial HIV infection.



1.3 Voluntary Counseling and Testing Study Group

The data set this paper uses comes from the Voluntary Counseling and Testing Study Group's study in the mid-1990's. The study was conducted in the countries of Kenya, Tanzania, and Trinidad and Tobago. Since the primary focus of this paper is related to how people who are at risk for HIV infection react to learning new information about their HIV status, I will focus on Kenya and Tanzania, as the adult prevalence in Trinidad and Tobago was not estimated to be above 1% in this time period. beginning in 1995, The Voluntary Counseling and Study Group, let by Dr. Kenneth Coates, accepted 2,942 volunteers from Kenya and Tanzania who were willing to be surveyed on their background information and sexual behavior, as well as be tested for HIV, chlamydia,

and gonorrhea.

These individuals were then randomized into two groups. One group was to learn their HIV status at the beginning of the study and the other was not. I will explain other differences shortly, but first I will lay out the timeline of the study. It was conducted in three waves in which all individuals were tracked over time. It is important to note that each subject had agreed to be tested for HIV and STDs at some point during the study. There was an initial session as well as six month and twelve month follow-up sessions. The first session (which I will refer to as the baseline) was used to gather basic information about personal background, sexual behavior, and beliefs about current HIV status. For personal background, information was gathered on topics such as their religion, their knowledge of HIV, whether they had access to water and electricity in their home. With regards to sexual behavior, they were asked about their number of partners, amount of unprotected sex they had, as well as whether they were suffering any current symptoms of STDs.

With respect to STDs, there is a positive correlation between reporting STD symptoms and prior belief about HIV status. This positive correlation is central to my ability to observe how individuals behave. Since the likelihood of an individual contracting an STD (HIV or otherwise) during unprotected sex depends not only on whether the partner has that virus but also whether that individual already has the virus, contracting a new STD can come from having lots of unprotected sex with any type of partner or it could come from having less unprotected sex with the wrong type of partner (one who is more likely to be STD positive). Likewise, someone who does not contract a new STD during any given time frame could be having less unprotected sex, could already have the STD, or could simply have a partner that does not have it. This much is obvious, but what I propose is that there are different pools of people from which a person may find a partner and that the likelihood that partner is HIV or STD positive is different in each pool. Thus, an individual can have similar (or even fewer) instances of unprotected sex and yet contract more STDs than an otherwise similar peer if they are searching for a partner in a different pool than this particular peer.

Before I describe how prior beliefs about HIV status are generated, I will check the initial randomization process to see whether these groups appear to truly have been randomized. In this first table, we see that for nearly all summary statistics, the groups

appears to have been successfully randomized.

Table 1.4: Summary statistics for treatment and control groups, upon initial randomization.

	Variable	Learned Mean	Control Mean	p value (Diff)
(1)	Male	0.50	0.50	0.97
(2)	Age	28.3	28.3	1.00
(3)	Primary School	0.62	0.63	0.60
(4)	Secondary School	0.26	0.27	0.85
(5)	Muslim	0.28	0.29	0.46
(6)	Catholic	0.33	0.36	0.10
(7)	Protestant	0.35	0.31	0.02
(8)	Tap water in home	0.54	0.54	0.96
(9)	Electricity in home	0.44	0.45	0.49
(10)	Enrolled with partner	0.33	0.32	0.90
(11)	Married	0.39	0.39	0.94
(12)	Cohabiting	0.49	0.49	0.69
(13)	Number living children	1.45	1.48	0.65
(14)	HIV knowledge(of 12)	9.73	9.76	0.75
(15)	HIV/AIDS counseling	0.19	0.22	0.07
(16)	HIV testing	0.01	0.02	0.15

There are a few differences in terms of religion in that the control group is more likely to be Protestant and the treatment group is more likely to be Catholic. This has not affected the likelihood of being married or cohabiting so although this is not ideal, I will assume that these religious views are similar enough to not generate differences that would affect the data at hand. With regards to HIV/AIDS counseling, it is difficult to say what effect this might have on individuals prior to the study. It did not generate a significant difference in knowledge about HIV. Also, at baseline, all individuals were offered some sort of HIV counseling or info session, regardless of whether they were in the treatment or control group (treatment received full counseling and testing, but the control group received an information session).

Since I will be comparing only individuals who were tested twice for STDs (at baseline and the six month follow-up) and took at least one HIV test, I will evaluate the summary statistics for these individuals next.

Table 1.5: Summary statistics for individuals from treatment and control groups who remained in the study (completed follow up STD test as well as initial HIV test).

	Variable	Learned Mean	Control Mean	p value (Diff)
(1)	Male	0.51	0.50	0.64
(2)	Age	28.7	29.0	0.55
(3)	Primary School	0.61	0.63	0.41
(4)	Secondary School	0.27	0.27	0.90
(5)	Muslim	0.25	0.26	0.61
(6)	Catholic	0.34	0.37	0.18
(7)	Protestant	0.36	0.32	0.03
(8)	Tap water in home	0.53	0.51	0.46
(9)	Electricity in home	0.424	0.40	0.39
(10)	Enrolled with partner	0.33	0.32	0.54
(11)	Married	0.40	0.35	0.80
(12)	Cohabiting	0.48	0.49	0.68
(13)	Number living children	1.53	1.68	0.12
(14)	HIV knowledge(of 12)	9.74	9.69	0.65
(15)	HIV/AIDS counseling	0.19	0.20	0.45
(16)	HIV testing	0.01	0.02	0.26

Further, I would like to know whether there were differences between those who remained in the study and those who did not, out of the individuals in the treatment group who learned their HIV status at baseline. Of those who remained in the study, 19.1% of them were HIV positive. Of those who left the study, 22.5% of them were HIV positive. The difference between these has a p-value of 0.14. Although it would be ideal if those leaving had a more similar HIV rate, I find it encouraging that the rate is not lower among those who remained in the study than among those who left, since those who tested positive at baseline were likely encouraged to seek outside medical support in addition to what the study provided.

Lastly, I wish to look at those who either left the study or did not complete enough requirements for me to include them (such as failing to take an HIV test or an STD test). Again, there is a difference in whether they had previously received HIV/AIDS counseling. As I mentioned before, during the course of the study all received some sort of information during baseline so my hope is that any difference there would have been negated at that point. As for the difference in whether there was electricity in the home, one possible explanation may be that those who had more income (as I assume

those with electricity may) could have been more likely to get themselves to a clinic and get an HIV test and no longer be interested in the study if they could access the information elsewhere, rather than remain in the control group of the study. I will leave it to the reader to determine if they feel this difference is problematic for the randomization process of the study.

Table 1.6: Summary statistics for those who left the study, by treatment and control groups.

	Variable	Learned Mean	Control Mean	p value (Diff)
(1)	Male	0.49	0.51	0.46
(2)	Age	27.4	27.1	0.46
(3)	Primary School	0.63	0.62	0.77
(4)	Secondary School	0.25	0.27	0.60
(5)	Muslim	0.34	0.35	0.76
(6)	Catholic	0.29	0.33	0.27
(7)	Protestant	0.31	0.29	0.33
(8)	Tap water in home	0.58	0.60	0.42
(9)	Electricity in home	0.48	0.55	0.03
(10)	Enrolled with partner	0.31	0.33	0.49
(11)	Married	0.37	0.36	0.68
(12)	Cohabiting	0.52	0.47	0.20
(13)	Number living children	1.26	1.10	0.23
(14)	HIV knowledge(of 12)	9.71	9.88	0.23
(15)	HIV/AIDS counseling	0.19	0.24	0.04
(16)	HIV testing	0.01	0.02	0.34

In addition, two thirds of those who initially were in the baseline portion of the study completed the second round interviews, HIV test (for those who were in the control group and did not take one at baseline), and second STD test. The fraction of individuals who remained in the study is comfortingly similar, and this is true for both genders as well.

Figure 1.2: Reuptake rates for all.

Group	Initial Uptake	Re-Uptake (HIV & STD tests)	Fraction Retained
Didn't Learn Status (all)	1,465	966	66%
Learned Status (all)	1,477	1,009	68%

Figure 1.3: Reuptake rates for men.

Group	Initial Uptake	Re-Uptake (HIV & STD tests)	Fraction Retained
Didn't Learn Status (Men)	736	481	65%
Learned Status (Men)	741	513	69%

Figure 1.4: Reuptake rates for women.

Group	Initial Uptake	Re-Uptake (HIV & STD tests)	Fraction Retained
Didn't Learn Status (Women)	729	485	67%
Learned Status (Women)	736	496	67%

With regards to belief about HIV status, I will be following Gong's (2013) measure for generating a prior belief about HIV status. Individuals were asked a series of four questions about their concerns that they have or will have AIDS, for which HIV is a precursor.

The original survey asked individuals to answer four questions related to their beliefs and concerns about their HIV status (since HIV is a precursor for AIDS):

1. What are the chances that you will get the AIDS virus?
2. What are the chances that you already have the AIDS virus?
3. How worried are you that will you will get the AIDS virus?
4. How worried are you that you already have the AIDS virus?

Each person in the study responded to the above questions with the following responses. Those responses were used to generate a value of the person's prior belief of HIV status.

Table 1.7: Values assigned to responses to questions about HIV/AIDS in order to generate value for prior belief about HIV status.

Response for 1 & 2	Response for 3 & 4	Value
Almost certainly will not happen	Not at all or hardly worried	1
It could happen	A little bit worried	2
It probably will happen	Quite a bit worried	3
It almost certainly will happen	Extremely worried	4

As I will be posing a theory that offers an alternative explanation of the data than Gong proposes, I follow his measure of prior belief. I take the average value of these four responses and split the groups into two. Those who have an average response of less than or equal to two are categorized as having a prior belief that they are unlikely to be HIV positive. Those whose average response is greater than two are categorized as having a prior belief that they are likely to be HIV positive. For points of reference, two is the median response of the individuals in this data set. It is important to note that any individual who has an average value strictly greater than two had to answer at least three to at least one of these four questions.

There is a key difference between the two randomized groups that is important to point out. At baseline, the treatment group is tested for and learns their HIV status. From a scientific standpoint, the ideal controlled trial would involve testing the control group as well without revealing to them their status at baseline. This is not possible due to the ethical concerns involved with having knowledge of someone's HIV positive status and not disclosing it to them. Thus, the group who does not initially learn their HIV status gets tested at the six month follow up.

The subgroups I will use for comparison between the treatment (learned HIV status) and control (did not learn) are four:

Table 1.8: Type of information received by test.

Actual HIV Status	Prior Belief	New Information?
HIV +	Unlikely HIV positive	BAD news
HIV -	Unlikely HIV positive	No news
HIV +	Likely HIV positive	No news
HIV-	Likely HIV positive	GOOD news

The groups I will be most interested in are those whose actual status differs from their prior belief. The other groups, who I have put under the category of 'no news,'

have no reason to update their belief since it coincides with their prior. I will focus on those who gain new information with the HIV test and how their behavior may be altered as a result. We see little variation in reported behaviors between the treatment and control in these subgroups.

As for the other two (bad news and good news), the subgroup that may be of greatest concern from a policy standpoint is the people with the low prior who learn they are HIV positive. If we observe these individuals increasing the amount of unprotected sex they have with HIV negative individuals then subsidizing HIV testing may have some undesired effects. If, however, they behave in ways that may reduce the risk they pose to uninfected individuals this strengthens the argument for HIV testing as a policy tool for public health. In general, it is assumed that people practice certain restrained sexual behaviors to avoid contracting HIV, then the question is whether it is damaging to society to reveal an HIV positive status to an individual.

In order to have comparable subgroups from which I can observe behavior changes as a result of information gained, I follow Gong's assumption that those in the control group who learn they are HIV positive at the six month follow-up were also HIV positive at baseline. This assumption relies on the low transmission rates of HIV infection that is estimated to be between 0.0007 and 0.0015 per coital act (Wawer et al., 2005, Cohen and Pilcher, 2005). Given this low transmission rate, and the reported instances of unprotected sex per individual in the two months prior to follow up, I am keeping this assumption and using these as comparable subgroups. In terms of the actual study, of those in the treatment group who were tested HIV negative at baseline and were tested for HIV again at the six month follow up, 12 of 750 or 1.6% seroconverted during the study.

In addition to personal background information and reported behaviors for all individuals, as well as HIV testing for the treatment group, everyone submitted a urine sample at baseline for the purpose of determining whether they contracted chlamydia or gonorrhea during the study. To get around some of the ethical concerns of knowing a subject's STD status and not revealing it to them, the Voluntary Counseling and Testing Study Group did not learn the results of the initial tests during the baseline interviews. Instead, all of these samples were frozen after submission. The only time they were thawed out and tested was when an individual later tested positive for chlamydia

or gonorrhea. At that point the earlier sample which had been collected at baseline and frozen was thawed to determine if this was a newly contracted virus or a previous infection. Thus, I am not able to observe baseline STD rates, but I am able to determine if an individual contracted one of these two viruses during the study. Individuals did report whether they were experiencing any STD symptoms at baseline, however, and I take this as a minimal estimate of the percentage of individuals who have an STD.

Since we want to know how people respond to new information about their HIV status, first I present the percentage of individuals who contracted chlamydia or gonorrhea during the six months between baseline and the six month follow-up visit. We observe no statistically significant difference between control and treatment for whom there was no new information gained (the 'no news' subgroups).

For those who had a low prior belief and were actually HIV positive, those who learned this bad news contracted significantly more new STD's than those with the same prior and same actual status who did not learn their HIV status. This appears to be a bad sign for the use of HIV testing as a tool in the public health fight against HIV. If individuals increase their risky sexual behavior upon learning of a positive HIV status, they may put others at greater risk. The question at this point becomes how did they acquire these new STD's. We will take a look at their reported behaviors next.

Before doing that though, we can also observe the significant difference between individuals who learned of an HIV negative status when they thought they were likely HIV positive as compared to the comparable treatment subgroup. Those who learned this good news contracted significantly fewer new STD's than those who did not. This appears to be a positive argument for HIV testing. We still have to learn how these differences are created and what reported behaviors are, so I move to this next.

Table 1.9: Percentage of individuals with new chlamydia and gonorrhea infections between baseline and six month follow-up.

Actual Status	Prior belief	Learned Status	Control	Sample
HIV+	low	**0.09** (.029)	**0.01** (.011)	94,94
HIV-	low	0.02 (.007)	0.02 (.007)	447,455
HIV+	high	0.08 (.027)	0.13 (.036)	98,86
HIV-	high	**0.02**(.008)	**0.06** (.013)	365,322

The reported instances of unprotected sex per person appears to tell a somewhat different story. None of the differences between the groups are statistically significant and the group who received bad news in fact reporting fewer instances of unprotected sex per person. If this was the only piece of information we would consider it a reason to encourage HIV testing, but it is not clear as of yet how these two pieces of information can be consistent. I will propose that those who learn an HIV status that is different from their prior belief begin to sort and search for partners in a different way than they did previously.

Table 1.10: Reported instances of unprotected sex in two months prior to six month follow-up.

Actual Status	Prior belief	Learned Status	Control	Sample
HIV+	low	4.50 (1.17)	6.33 (1.04)	94,92
HIV-	low	5.68 (0.56)	6.51 (0.56)	440,451
HIV+	high	4.11 (0.88)	5.94 (0.97)	97,86
HIV-	high	5.84 (0.54)	6.26 (0.59)	358,321

Next, I look a bit deeper and see whether there are differences in the fraction of individuals in the various treatment and control subgroups who report having any unprotected sex at all during the six months between baseline testing and the six month follow-up interview. In table 10 we see that, if anything, those who received bad news were less likely to report having unprotected sex and those who received good news were more likely to report having unprotected sex.

Table 1.11: Percentage of all individuals reporting having unprotected sex in two months prior to six month follow-up.

Actual Status	Prior belief	Learned Status	Control	Sample
HIV+	low	**0.38** (0.05)	**0.60** (0.05)	94,94
HIV-	low	0.54 (0.02)	0.58 (0.02)	447,455
HIV+	high	0.36 (0.05)	0.56 (0.05)	98,86
HIV-	high	0.57 (0.03))	0.59 (0.03)	364,322

One possible explanation that was put forth by Gong (2013) was that these individuals who learn they are HIV positive are under-reporting the amount of unprotected sex

they are having to make themselves not appear as bad to their interviewer. I will put forth an alternative explanation but first wish to address this. The follow up interviews were conducted by interviewers who were not permitted to know the HIV status of the interviewee. Any questions where knowledge of HIV status was relevant was conducted in a separate interview by an individual who was allowed to know the interviewee's HIV status (but to keep it private from anyone else of course). (Kamenga et. al. 2000)

To further address the issue of whether any individuals in the study may have under-reported their sexual behavior, I do not refute this possibility. It is also possible that everyone, regardless of status or belief, under-reported instances of unprotected sex. My theory is simply an alternative explanation of the data. I propose that individuals with different prior beliefs search for different types of partners. In the model I propose, individuals have preferences over being HIV negative as well as STD negative, the disutility of unprotected sex as well as utility of having a partner willing to have unprotected sex. I will show that this is sufficient to generate a sorting equilibrium in which individuals match in an assortative manner, in that those with higher likelihoods of having HIV match with each other and those with lower likelihoods match with each other (according to their beliefs).

The gist of how this sorting works is that individuals who believe they are unlikely to be HIV positive are willing to put in a lot of effort to protect themselves from infection. This can be thought of as how frequently they wear a condom or how long they make their partner wait to have unprotected sex (it will be the former in my model). Individuals who know, or believe likely, they have HIV have less to gain for this effort so they may seek out other individuals who they believe are likely HIV positive and who do not wish to put forth so much effort towards protection.

Now that we have seen what the data look like across the entire population of people, let's look at whether there are any interesting differences by gender. First, with women there appears to be a slightly higher rate of HIV contraction. Those who receive bad news also contract significantly more new STD's than the comparable subgroup not learning their HIV status. With respect to the proposed model, there is consistency in that those who would be predicted to sort into an unsafe location tend to contract more new STD's than others.

Table 1.12: Percentage of women with new chlamydia and gonorrhea infections between baseline and six month follow-up.

Actual Status	Prior belief	Learned Status	Control	Sample(L,Didn't)
HIV+	low	**0.10** (.038)	**0.02** (.015)	61,63
HIV-	low	0.03 (.013)	0.03 (.011)	205,219
HIV+	high	0.08 (.033)	0.14 (.044)	71,64
HIV-	high	0.05 (.016)	0.07 (.023)	155,134

As for men, there is a significant difference for those who received good news. As for those who received bad news, the difference is not significant, but they were six percent more likely to pick up an STD, whereas those who had the same prior belief and same status but did not learn did not pick up a single new STD during the first six months of the study. In terms of the prediction of the model, prior to any testing those with a low prior belief would be expected to sort into the safe location and search for a partner there. Due to their HIV positive status, they may be more slightly more likely to contract or have contracted an STD from a partner who had one (although it would be expected that fewer partners would have one). For those receiving bad news, for those learning this HIV positive status, they would be expected to switch to the unsafe location, more likely to be free of STDs than the other individuals there since they were previously in the safe location. Then they would be more likely to contact a new STD due to the partners there who are more likely to be STD positive.

Table 1.13: Percentage of men with new chlamydia and gonorrhea infections between baseline and six month follow-up.

Actual Status	Prior belief	Learned Status	Control	Sample
HIV+	low	0.06 (.042)	0 (0)	33,31
HIV-	low	0.02 (.008)	0.02 (.009)	242,236
HIV+	high	0.07 (.051)	0.09 (.063)	27,22
HIV-	high	**0.01**(.007)	**0.05** (.015)	210,188

With respect to the percentage of individuals who reported having unprotected sex in the months leading up to the six month follow-up survey, there is no significant difference between subgroups when comparing control and treatment groups. This is the case for

both women and men. It's quite possible that these individuals had unprotected sex during the six months after the baseline survey and testing, but this just captures the two months prior to the follow-up so the time frame is consistent.

Table 1.14: Percentage of women reporting having unprotected sex in two months prior to six month follow-up.

Actual Status	Prior belief	Learned Status	Control	Sample
HIV+	low	**0.38** (0.06)	**0.57** (0.06)	61,63
HIV-	low	0.59 (0.03)	0.57 (0.03)	205,219
HIV+	high	0.35 (0.06)	0.58 (0.06)	71,64
HIV-	high	0.62(0.04)	0.64 (0.04)	154,134

Table 1.15: Percentage of men reporting having unprotected sex in two months prior to six month follow-up.

Actual Status	Prior belief	Learned Status	Control	Sample
HIV+	low	**0.40** (0.09)	**0.65** (0.09)	33,31
HIV-	low	**0.50** (0.03)	**0.60** (0.03)	242,236
HIV+	high	0.37 (0.010)	0.50 (0.11)	27,22
HIV-	high	0.54(0.03)	0.55 (0.04)	210,188

As for number of partners, women who receive bad news of an HIV status when they believed they were likely HIV negative actually have significantly fewer instances reported of unprotected sex. This is despite the fact that they were significantly more likely to contract a new STD than their comparable control subgroup counterparts.

Table 1.16: Instances of unprotected sex in two months prior to six month follow-up reported by women.

Actual Status	Prior belief	Learned Status	Control	Sample
HIV+	low	3.30S (0.98)	5.98S (1.23)	61,61
HIV-	low	6.12 (0.73)	6.20 (0.72)	200,215
HIV+	high	4.04 (1.05)	5.51 (1.05)	70,64
HIV-	high	6.55 (0.81)	7.97 (1.03)	153,144

Table 1.17: Instances of unprotected sex in two months prior to six month follow-up reported by men.

Actual Status	Prior belief	Learned Status	Control	Sample
HIV+	low	6.72 (2.78)	7.00 (1.91)	33,31
HIV-	low	5.32 (0.83)	6.79 (0.85)	240,236
HIV+	high	4.29 (1.56)	7.18 (2.34)	27,22
HIV-	high	5.31 (0.71)	5.04 (0.67)	205,187

When considering those who reported having any instances of unprotected sex at the six month follow-up interviews, there is no significant difference between any subgroup. This paper attempts to calibrate a model in which behaviors are similar across subgroups to argue that underreporting of sexual behavior is not the only way to generate increased STDs for those who learn very bad news about their HIV status, but behavior changes can certainly coincide with sorting.

Table 1.18: Average reported instances of unprotected sex with any partner for those who reported having unprotected sex at six month follow-up.

Actual Status	Prior belief (percentile)	Treatment	Control	Sample
HIV+	low	11.75 (2.66)	10.78 (1.49)	36,54
HIV-	low	10.64 (0.94)	11.21(0.86)	235,262
HIV+	high	11.74 (1.95)	10.65 (1.43)	34,48
HIV-	high	10.37 (0.82)	10.69 (0.87)	202,188

There is some variation when this is broken down by gender, although the sample sizes become very small. Men who receive bad news and report having any instances of unprotected sex report an increase in instances of unprotected sex although it is not significant. Again, and increase in unprotected sex for me who receive bad news would not actually be inconsistent with the proposed theory for those who learned they are HIV status. What would be inconsistent is if learning this bad news made them more likely to sleep with individuals who are in the safe location (more likely to be HIV negative). Due to an higher rate of reporting abstinence in the two months prior, there are only 13 men in the treatment group that learned bad news who report having any instances of unprotected sex. Two of these were outliers with a very high number

of instances reported. Certainly this is a concern and something to be aware of, both for myself and for policymakers. At this point though I have no information about who these individuals slept with and if they believed those individuals were likely HIV positive.

Table 1.19: Average reported instances of unprotected sex for men with any partner for those who reported having unprotected sex at six month follow-up.

Actual Status	Prior belief (percentile)	Treatment	Control	Sample
HIV+	low	17.08 (6.15)	10.85 (2.60)	13,20
HIV-	low	10.73 (1.52)	11.37(1.29)	119,141
HIV+	high	11.60 (3.41)	14.36 (3.57)	10,11
HIV-	high	10.09 (1.18)	9.24 (1.06)	108,102

Table 1.20: Average reported instances of unprotected sex for women with any partner for those who reported having unprotected sex at six month follow-up.

Actual Status	Prior belief (percentile)	Treatment	Control	Sample
HIV+	low	8.74 (2.20)	10.74 (1.85)	23,34
HIV-	low	10.55 (1.08)	11.02(1.02)	116,121
HIV+	high	11.79 (2.41)	9.54 (1.50)	24,37
HIV-	high	10.68 (1.14)	12.41 (1.41)	94,86

Another question that has arisen is whether these individuals who are learning a new status, and bad news in particular, are changing the number of partners that they are sleeping with. In terms of risk to others it may be a concern if those receiving bad news are taking on an increased number of sexual partners. If they were quite confident these people are HIV positive it could still be consistent with a theory of sorting, but given that there is likely to be uncertainty about a prospective partner's HIV status, it would still be concerning for a policymaker if this were the case. As it is, both men and women who receive bad news about their HIV status report a reduced number of sexual partners, which are the only significant differences amongst any of the subgroups.

Table 1.21: Number of partners by all in two months prior to six month follow-up.

Actual Status	Prior belief	Learned Status	Control	Sample
HIV+	low	**0.78** (0.07)	**1.11** (0.11)	94,94
HIV-	low	0.98 (0.04)	1.15 (0.13)	447,455
HIV+	high	1.38 (0.61)	1.95 (0.60)	98,86
HIV-	high	1.18 (0.07)	1.18 (0.06)	365,322

Table 1.22: Number of partners by men in two months prior to six month follow-up.

Actual Status	Prior belief	Learned Status	Control	Sample
HIV+	low	**0.76** (0.11)	**1.06** (0.13)	33,31
HIV-	low	1.06 (0.06)	1.11 (0.07)	242,236
HIV+	high	0.74 (0.12)	1.22 (0.27)	27,22
HIV-	high	1.31 (0.09)	1.28 (0.08)	210,188

Table 1.23: Number of partners by women in two months prior to six month follow-up.

Actual Status	Prior belief	Learned Status	Control	Sample
HIV+	low	**0.79** (0.08)	**1.13** (0.15)	61,63
HIV-	low	0.89 (0.04)	1.18 (0.26)	205,219
HIV+	high	1.63 (0.84)	2.20 (0.80)	71,64
HIV-	high	1.01 (0.10)	1.04 (0.08)	180,140

1.4 Conclusion

The purpose of this section is to show and fully describe the features of the data produced by the Voluntary Counseling and Testing Study Group's study which began in 1995. The primary feature of the data that is of interest to this paper is the increased contraction rate of STDs by those who received bad news about their HIV status as well as the decreased rate of contraction of STDs by those who received good news. These STDs were contracted at different rates despite individuals in these subgroups reporting similar behavior to a control subgroup with similar beliefs and actual HIV status. There has

been some question as to whether these individuals are truthfully reporting their sexual behavior. In the next essay I evaluate the possibilities of underreporting as well as truthful reporting and develop a model of truthful reporting which is consistent with the higher rate of STD contraction by those receiving bad news as well as the lower rate of STD contraction by those receiving good news.

Chapter 2

Model of Partner and Effort Choice

2.1 Introduction

In this section propose a model where agents met a sexual partner as well as choose their willingness to have unprotected sex. Agents in all of the models discussed enjoy unprotected sex, but of course the amount of unprotected sex they have will be a determining factor in whether they contract HIV or another STD, both of which they dislike. The phenomenon in the data that has been discussed is that individuals who received bad news about their HIV status (who believed they were likely HIV negative but learned they were HIV positive) contracted significantly more new STDs than those in a control group who also believed they were likely HIV negative and were also HIV positive, but did not learn this. This is despite the fact that those who learned they were HIV positive did not report riskier sexual behavior (and in fact reported less risky in some dimensions).

A previous explanation has been to propose that individuals who learn or believe they are likely HIV positive may under-report their risky sexual behavior. I do not discount this as a possibility but instead offer an alternative explanation. In this section I actually look at three different models. Since a potential point of dispute with respect to interpretation of this data is whether individuals are truthfully reporting their sexual behavior, I will look at models which assume that individuals have under-reported their

instances of unprotected sex. This will be the case of the first two models in fact. In the first model, which is intended to be most similar to that proposed by Gong (2013), individuals will meet a partner at random and choose their willingness to have unprotected sex. We will see in this model that agents who believe they are more likely to be HIV positive have more unprotected sex (as they can no longer contract HIV and can at worst contract a separate, lesser STD). In this model of the world, I observe that giving people more information about their HIV status can in fact increase HIV prevalence.

The next model also does not require truth telling and allows for the possibility that individuals who believe they are more likely to be HIV positive under-report their instances of unprotected sex. The difference between this model and the first is that in this model, individuals can choose to meet a partner from one of two locations instead of meeting them randomly. In this model of the world, individuals enjoy unprotected sex and they also prefer a partner who is willing to have unprotected sex. In this model, those who believe they are likely HIV positive again may choose to have more unprotected sex, consistent with the assumption that individuals have under-reported their sexual behavior (if one assumes so), but there are sorting equilibria in which individuals who believe they are more likely to be HIV positive (whose belief p about their HIV status is above a cutoff value $\bar{p}$ sort into a different location than those who believe they are less likely to be HIV positive. The reason they do so in the model is to meet a partner who is more willing to have unprotected sex. In these cases, even if these individuals are under-reporting their instances of unprotected sex, giving people additional information about their status decreases prevalence because of this sorting behavior.

The final model places a higher value on truth telling as an assumption. This model differs from the previous model only in that individuals have some altruistic concern for any damage they might do to the HIV status of their partner. In this model, agents who know they are HIV positive, or strongly believe that they are, do not necessarily have more unprotected sex because they risk infecting those who are uninfected. Under these preferences, there exists an equilibrium where individuals have similar sexual behavior but with the differing outcomes with respect to STDs that we observe in the data. I show what amount of this altruistic concern is needed to generate a sorting equilibrium

without any preference of a partner's willingness to have unprotected sex, and the sorting behavior is stronger with preferences over both as in this model. With this occurrence of sorting, more information again lowers prevalence.

2.2 Related Literature

The initial study was conducted by Coates, working The Voluntary HIV-1 Counseling and Testing Efficacy Study Group (2000) in Kenya, Tanzania, and Trinidad and Tobago, beginning in 1995. The purpose was to determine the effects of voluntary counseling and HIV testing on sexual behavior. The primary conclusion was that, relative to the control group who were not told their status, individuals who received counseling and testing (and learned their status) reported reduced instances of unprotected sex with primary and non-primary partners. From a public policy standpoint, this conclusion was unambiguously supportive giving individuals increased access to information about their HIV status along with counseling them on the risks of HIV.

More recently, Gong (2013) used the same data from that study, but showed that when controlling for prior belief of HIV status the policy implications are less clear. His analysis included use of the study's data on STD incidence which was obtained from urine samples. The main interpretation of the data in that paper was that individuals who received a HIV test result that was counter to their prior belief (e.g. HIV-positive result when prior belief was low likelihood of HIV), those individuals altered their sexual behavior. My paper is in agreement with the fact that this behavior was altered. Gong's view, however, interpreted those who received *bad news* as increasing their risky behavior and those who received *good news* decreasing their risky sexual behavior relative to those who did not learn their status but had the same prior belief-actual status characteristics. This interpretation was drawn by comparing the STD incidence of those groups to individuals with similar prior beliefs about their HIV status and actual HIV statuses who were in the control group and therefore did not learn their status and observing the significant increase in STDs of those receiving *bad news* and the contraction of significantly fewer new STDs by those receiving *good news* relative to their control subgroup counterpart. While I agree with the conclusion that individuals surprised with an HIV status different from their prior belief alter their behavior, I offer an alternate

explanation as to the behavior change that is generated. My explanation is that those who were surprised by their HIV test results, or who learned an HIV status that was different than their prior belief, sorted themselves into different pools of partners than they were previously searching in. Using a model that allows individuals to choose partners from one of two pools of individuals I am able to generate this variation in new STDs that we observe among those who were surprised by their HIV test results. My model is also consistent with the reported sexual behavior of individuals in the study.

Manuelli and Santaeulalia-Llopis (2012) have a dynamic model of endogenous diffusion of HIV in which all individuals know their status and the status of all others. There is sorting to a degree, in that only those healthy individuals most desiring of sex will accept a partner who is infected. My model provides a mechanism through which agents who do not know their status but believe they are infected will reject partners who are likely to be uninfected. It also allows for the determination of whether giving information about HIV status increases or decreases HIV prevalence.

Kremer (1996) and Kremer and Morcom (1998) have models where individuals have varying degrees of sexual activity. High activity and low activity individuals match with varying degrees of randomness. It is possible in these models for increases in activity by low activity individuals to actually lead to decreased prevalence. By observing subgroups who exhibit similar behaviors in terms of partners and instances of unprotected sex before and after learning new information about their HIV status and showing that a model of sorting behavior is consistent with reported behavior and STDs contracted, this provides evidence that individuals are in fact able to successfully match according to HIV status to some degree.

2.3 Models

Since there has been some question raised as to whether individuals are truthfully reporting their sexual behavior, I explore multiple models which vary in terms of preferences as well as in terms of consistency with truthful reporting of behavior.

2.3.1 Model 1 - Underreporting Without Sorting

The agents in this model have preferences over HIV and other STDs as well effort towards unprotected sex. Agents dislike contracting a new STD but dislike contracting HIV much more. The trade-off in this model is simply that although they would rather have unprotected sex, they will limit their instances of unprotected sex to protect themselves from HIV and other STDs.

Assume a population with a continuum of prior beliefs $p \in [0,1]$ about their HIV status with full support. These individuals have a likelihood of being STD positive with a probability $s = f(p)$ and of being coinfected with both chlamydia and gonorrhea $c = g(p)$. Individuals have preferences that are linear in the value of being HIV negative V^{HIV^-} and HIV positive V^{HIV^+}, as well as in contracting a new STD $V^{STD^{new}}$. They choose a willingness $w \in [0,1]$ to have unprotected sex, over which their preferences are nonlinear. The transmission rates for HIV $\eta_{HIV} = 0.001$ and STDs $\eta_{STD} = 0.2$ are taken from the literature.

Thus the expected utility for an individual with prior belief p is given as:

$$\begin{aligned} u(p;P) = \{ & \max_e \{u_{sex}(w) + (p'(p,e,\eta^{HIV});P)V^{HIV^+} \\ & + (1-(p'(p,e,\eta^{HIV});P)V^{HIV^-} \\ & + (s'(s,e,\eta^{STD});P)V^{STD^{new}}\} \end{aligned}$$

An equilibrium for this economy is defined as a set of functions $\hat{e}(p) \ \ \forall \ p \ \in [0,1]$.

Table 2.1: Model 1 compared to data in terms of new STDs contracted.

New Info	STDs if Learned (model)	STDs if Didn't (model)
Bad News	0.09 (0.12)	0.01 (0.07)
Good News	0.02 (0.06)	0.06 (0.07)

In this model of the world, we do see higher increase in new STDs for those receiving bad news and a smaller increase in STD infections for those receiving good news, due to the differences in willingness to have unprotected sex that we will observe next. This model, however, tends to overestimate the amount of new STDs contracted by those

with low prior beliefs who did not learn the bad news of their actual HIV positive status. This is due to the random nature of partner matching. Even if they have less unprotected sex they begin as more likely uninfected with an STD and are equally likely to draw a partner who is infected with an STD in a model without sorting.

Next, I compare how this model performs when comparing the willingness to have unprotected sex with the instances of unprotected sex reported in the data.

Table 2.2: Model 1 compared to data in terms of behavior.

New Info	Unprotected if Learned (model)	Unprotected if Didn't (model)
Bad News	11.75 (0.38)	10.78 (0.07)
Good News	10.37 (0.06)	10.69 (0.12)

Behavior in this model appears to vary greatly when compared to the instances of unprotected sex reported by individuals. This would be consistent with the view that individuals who believe they are likely HIV positive underreport their risky sexual behavior. If one places a higher value on truth telling when viewing the data discussed in this paper, it does not match the data.

The parameters for this model are as follows:

Table 2.3: Parameters for Model 1

Parameter	Value	Comment
V^{HIV^-}	295	utility of being uninfected
V^{HIV^+}	10	utility of being infected
η^{HIV}	0.001	Literature
η^{STD}	0.2	Literature
D_w	0.0095	$D_w(log(w))$, coefficient of utility of unprotected sex
$V^{STD^{new}}$	0.40	Disutility of contracting new STD

The other concern that Gong mentioned was that it may not be optimal to subsidize HIV testing as it may increase the prevalence of HIV if those who learn they are HIV positive increase their risky sexual behavior. In this model of the world, I also find this to occur.

Table 2.4: Cost and number of HIV infections when testing a given percentage of a population of 100,000 people.

% Tested	Cost	Infections
0	-	200
5%	$35,000	210
10%	$70,000	215

The policy experiment that is done here (and in the other two models) is a random sample of individuals across all beliefs. In this case, prevalence increases with testing. While people are certainly legally entitled to know their HIV status, if the true behavior of individuals is to increase their risky sexual behavior upon learning they are HIV positive, it may be suboptimal for governments seeking to decrease prevalence to subsidize HIV testing.

Define the equilibrium. Then discuss the outcomes in terms of STDs (how it's able to match the high end, but not the low). Then discuss the policy implications and how this can be a negative outcome for society.

2.3.2 Model 2 - Underreporting With Sorting

In this model, there are two adjustments from Model 1. The first is that agents can choose from one of two locations. Due to the outcomes in a range of equilibria I will discuss, I am labeling those locations as $safe$ and $unsafe$. The other change is that the agents also prefer partners who are more willing to have unprotected sex. Their preferences over their partner's willingness w^* to have unprotected sex is also nonlinear. From the outcomes of the model, we will see that this does not match the reported behaviors in the data and so it is more consistent with a view of underreporting of sexual behavior by those who believe they are HIV positive. The purpose of investigating this model is to determine if, and when, it may still be optimal to subsidize HIV testing even if individuals under-report their sexual behavior.

The expected utility for an individual with prior belief p choosing w and $i \in$

$[safe, unsafe]$ is:

$$\begin{aligned} u(p;P) = \max_i \{ \max_e \{ & u_{sex}(w, w_i^*(P)) + (p'(p, w, p_i^*(P), \eta^{HIV}))V^{HIV^+} \\ & + (1 - (p'(p, w, p_i^*(P), \eta^{HIV}))V^{HIV^-} \\ & + (s'(s, w, s_i^*(P), \eta^{STD}))V^{STD^{new}} \}\} \end{aligned}$$

The equilibrium for this economy is defined by:

- Functions $\hat{w}_i(p) \quad \forall p \in P,\ i \in \{safe, unsafe\}$
- Functions $\hat{i}(p) \quad \forall p \in P$

First, I compare the outcomes of the model in terms of STDs. This model seems to do pretty well in terms of getting the higher and lower increases in STD infections with the right groups according to prior belief as well as whether the individuals received good or bad news, but in terms of behavior there are a couple inconsistencies with the data. Those who learn or think they are HIV positive are much more willing to have unprotected sex.

Table 2.5: Model 2 compared to data in terms of new STDs contracted.

New Info	STDs if Learned (model)	STDs if Didn't (model)
Bad News	0.09 (0.09)	0.01 (0.05)
Good News	0.02 (0.04)	0.06 (0.07)

Table 2.6: Model 2 compared to data in terms of instances of unprotected sex in the data and willingness to have unprotected sex in the model.

New Info	Unprotected if Learned (model)	Unprotected if Didn't (model)
Bad News	11.75 (0.11)	10.78 (0.05)
Good News	10.37 (0.04)	10.69 (0.09)

As mentioned, this view of the world is more consistent with underreporting of sexual behavior by those who believe they are HIV positive. The biggest difference, however, is the effect of new information when there exists a sorting equilibrium.

A sorting equilibrium is one in which all individuals with a prior belief $p >$ cutoff value $\bar{p}$ choose the unsafe location. ($\hat{i}(p) = unsafe \ \ \forall p > \ \bar{p}$ and $\hat{i}(p) = safe \ \ \forall p < \ \bar{p}$) Under a sorting equilibrium, since the accuracy of beliefs about HIV status reduces the likelihood of new infections.

Table 2.7: Cost and number of HIV infections when testing a given percentage of a population of 100,000 people in Model 2.

% Tested	Cost	Cutoff	Infections	Cost per infection averted
0	-	0.57	220	-
5%	$35,000	0.53	210	$3,500
10%	$70,000	0.41	200	$3,500

The following are the parameters for this equilibrium. Of perhaps greater interest is under what conditions on the weight of the utility of a partner's willingness to have unprotected sex w^* is there a sorting equilibrium, which I state thereafter.

Table 2.8: Parameter Values for Model 2 with sorting.

Parameter	Value	Comment
V^{HIV^-}	201	utility of being uninfected
V^{HIV^+}	1	utility of being infected
η^{HIV}	0.001	Literature
η^{STD}	0.18	Literature
D_w	0.0025	$D_w(log(w))$, coefficient of disutility of effort
D_{w^*}	0.062	$D^*_w(log(w^*))$, coefficient of disutility of partner's effort
$V^{STD^{new}}$	0.5	Disutility of contracting new STD
$\bar{p}$	0.58	cutoff belief

Existence of a sorting equilibrium (D_w) > 0: Holding fixed $V^{HIV^-} - V^{HIV^+} = 200$, $V^{STD^{new}} = 0.5$, and $D_w = 0.0025$, there will exist a sorting equilibrium for all values of $D^*_w \in [0.003, 0.062]$.

The main point of this section is that this model, when matching the directional changes in STD infections, predicts a decrease in prevalence if more individuals are

tested for HIV, even if individuals who learn they are HIV positive underreport their instances of unprotected sex.

2.3.3 Model 3 - Truthful Reporting With Sorting

Although I have shown a mechanism through which individuals who have no concern for others will nonetheless not increase risk to others upon learning an HIV status, one question at the heart of a debate over whether it is wise to give people more information about their HIV status stems from the question of whether individuals have concern over infecting others with HIV. I explore this and show that it is possible to generate both the similar sexual behavior across subgroups as well as the variation in STD contraction that is observed in the data. In this third and final model I add altruistic concern A for damage done to a partner's status $(p'^{*} - p)(V^{HIV^+} - V^{HIV^-})$. The first question I will address with this is under what values for A does this economy generate a sorting equilibrium, as defined above:

Existence of a sorting equilibrium ($A > 0$): Assuming no utility from the partner's willingness to have unprotected sex ($D_{w^*} = 0$, and holding fixed $V^{HIV^-} - V^{HIV^+} = 300$, $V^{STD^{new}} = 0.5$, and $D_w = 0.004$, there will exist a sorting equilibrium for all values of $A \in [0.075, 1.0]$

This holds for larger values of A as well, but I do not consider cases where an individual has more of a concern for the status of another than himself. As for the preferences over a partner's willingness to have unprotected sex, sorting is stronger when this is positive, as it is for this model.

The expected utility for an individual in this model with prior belief p choosing w

and $i \in [safe, unsafe]$ is:

$$\begin{aligned} u(p;P) = \max_i \{ \max_e \{ & u_{sex}(w, w_i^*(P)) + (p'(p, w, p_i^*(P), \eta^{HIV}))V^{HIV^+} \\ & + (1 - (p'(p, w, p_i^*(P), \eta^{HIV}))V^{HIV^-} \\ & + (s'(s, w, s_i^*(P), \eta^{STD}))V^{STD^{new}} \\ & + A(V^{HIV^+} - V^{HIV^-})(1 - p_i^*(P,T))(p)(1-e)\eta^{HIV} \} \} \end{aligned}$$

The equilibrium for this economy is again defined by:

- Functions $\hat{w}_i(p) \quad \forall p \in P,\ i \in \{safe, unsafe\}$
- Functions $\hat{i}(p) \quad \forall p \in P$

Next, I compare the outcomes of the model in terms of STDs. Those who receive bad news about their HIV status contract more new STDs and those who receive good news contract fewer. Further, those who had low priors with a positive status without learning contracted fewer than those with a high prior but negative status and did not learn. The values in the model are less extreme at either end than that data. One possible explanation for this is that the model restricts individuals to finding partners in one of two locations. If individuals are capable of being more accurate with respect to their belief about a prospective partner's status a model with more, and more precise locations may be a possible solution to this.

Table 2.9: Model 3 compared to data for those learning/not learning bad/good news in terms of new STDs contracted.

New Info	STDs if Learned (model)	STDs if Didn't (model)
Bad News	0.09 (0.062)	0.01 (0.037)
Good News	0.02 (0.031)	0.06 (0.048)

Thus far, this model appears to be a good fit in terms of qualitatively matching the changes in STDs observed. The previous two models fell short in terms of the reported behavior. In this model, I seek to find a solution that is consistent with truth telling

on the part of the individuals in the VCT Study Group study. Here are the results in terms of behaviors.

Table 2.10: Model 3 with sorting and altruism compared to data in terms of instances of unprotected sex in the data and willingness to have unprotected sex in the model.

New Info	Unprotected if Learned (model)	Unprotected if Didn't (model)
Bad News	11.75 (0.06)	10.78 (0.05)
Good News	10.37 (0.05)	10.69 (0.05)

This model produces similar sexual behavior across subgroups, as is observed in the data. The concern for infecting others in the same location (in addition to any concerns about contracting a possible additional STD) causes those who learn they are HIV positive to not drastically increase their risky behavior. Given this, I next look at the policy implications of testing, which are similar to the previous model with sorting.

Table 2.11: Cost and number of HIV infections when testing a given percentage of a population of 100,000 people in Model 3 with sorting and altruism.

% Tested	Cost	Cutoff	Infections	Cost per infection averted
0	-	0.53	220	-
5%	$35,000	0.50	210	$3,500
10%	$70,000	0.50	200	$3,500

The following are the parameters for this equilibrium. Of perhaps greater interest is under what conditions on the weight of the utility of a partner's willingness to have unprotected sex w^* is there a sorting equilibrium, which I state thereafter.

Table 2.12: Parameter Values for Model 2 with sorting.

Parameter	Value	Comment
V^{HIV^-}	295.8	utility of being uninfected
V^{HIV^+}	10	utility of being infected
η^{HIV}	0.001	Literature
η^{STD}	0.2	Literature
D_w	0.0047	$D_w(log(w))$, coefficient of disutility of effort
D_{w^*}	0.005	$D^*_w(log(w^*))$, coefficient of disutility of partner's effort
$V^{STD^{new}}$	0.4	Disutility of contracting new STD
$\bar{p}$	0.53	cutoff belief
A	0.66	Altruistic constant

In my view, this model is the most promising, due to its ability to replicate similar behavior and generate the kinds of STD infections we observe in the data. It assumes truth telling and provides a mechanism through which the changes in STDs could have occurred. Although it is not an argument in favor of this as the true model, if it is there is the added benefit of having the feature that more information is good for society.

2.4 Conclusion

Public Health officials have long been supportive of voluntary counseling and testing programs, wanting more individuals to know their HIV status. Their implicit assumption that more information for individuals yields a better outcome for society was challenged by the fact that some individuals who learned they were HIV positive contracted more new sexually transmitted diseases than those who were HIV positive but did not learn their status. I investigate three possible models of behavior. The models vary in terms of consistency with truthful reporting of behavior as well as whether there exists a possibility of sorting. I show that sorting according to HIV status is consistent with truthful reporting of behavior in date from the VCT Study Group. Further, I show that under two of the three proposed models of behavior, when a sorting equilibrium exists, HIV testing reduces HIV prevalence. Any public health analysis of the benefits of HIV testing which does not include sorting behavior may therefore underestimate its benefits to society in terms of HIV infections averted.

Bibliography

Cohen, M. and Pilcher, C. (2005). "Amplified HIV Transmission and New Approaches to HIV Prevention," Journal of Infectious Diseases, 191, pp.1391-1393.

Coates, T. and VCT Efficacy Study Group (2000). "Efficacy of Voluntary HIV-1 Counseling and Testing in Individuals and Couples in Kenya, Tanzania, and Trinidad: A Randomised Trial," The Lancet, 356, pp.103-112.

Gong, E. (2013). "HIV Testing and Risky Sexual Behavior," Working Papern.

Greenwood, J. and Kircher, P. and Santos, C. and Tertilt, M. (2013). "An Equilibrium Model of the African HIV/AIDS Epidemic," NBER Working Paper.

Kamenga, M. and Sweat, M. and De Zoysa, I. and Dallabeta, G. and Coates, T. and Grinstead, O. and Gregorich, S. and Heilbron, D. and Wolf, W. and Choi, K. and Sangiwa, G. and Hogan, M. and Kilewo, J. and Mwakigile, D. and Furlonge, C. and O'Reilly, K. and Kalibala, S. and Nkowane, B. and Van Praag, E. (2000). "The Voluntary HIV-1 Counseling and Testing Efficacy Study: Design and Methods," AIDS and Behavior, 4 (1), 5-14.

Kremer, M. (1996). "Integrating Behavioral Choice Into Epidemiological Models of AIDS," Quarterly Journal of Economics, 111, pp. 549-574.

Kremer, M. and Morcom, C. (1998). "The Effect of Changing Sexual Activity on HIV Prevalence," Mathematical Biosciences, 151, pp. 99-122.

Magruder, M. (2011). "Marital Shopping and Epidemic AIDS," Demography, 48 (4), pp. 1401-1428.

Manuelli, R. and Santaeulalia-Llopis, R. (2011). "A Quantitative Theory of HIV Diffusion," Working Paper.

Marks, G. and Crepaz, N. and Senterfit, J. and Janssen, R. (2005). "Meta-Analysis of High-Risk Sexual Behavior in Persons Aware and Unaware They are Infected with HIV in the United States," Journal of Acquired Immuno Deficiency Syndromes, 39 (4), pp. 446-453.

Oster, E. (2005). "Sexually Transmitted Infections, Sexual Behavior, and the HIV/AIDS Epidemic," Quarterly Journal of Economics, 120 (2), pp. 467-515.

Pepin, J. (2011). "The Origins of AIDS," Cambridge University Press.

Philipson, T. and Posner, R. (1993). "Private Choices and Public Health - The AIDS Epidemic in an Economic Perspective," Harvard University Press.

Santaeulalia-Llopis, R. (2008). "Aggregate Effects of AIDS on Development," Working Paper.

Santaeulalia-Llopis, R. and Iorio, D. (2011) "Education, HIV Status, and Risky Sexual Behavior: How Much Does the Stage of the HIV Epidemic Matter?," Working Paper.

Thornton, R. (2008). "The Demand For and Impact of Learning HIV Status," American Economic Review, 98 (5), pp. 1829-1863.

Wawer, M. and Gray, R. and Sewankambo, N. and Serwadda, D. and Li, X. and Laeyendecker, O. and Kiwanuka, N. and Kigozi, G. and Kiddugavu, M.

and Lutalo, T. and Nalugoda, F. and Wabwire-Mangen, F. and Maeehan, M. and Quinn, T. (2005). "Rates of HIV-1 Transmission Per Coital Act, by Stage of HIV-1 Infection, In Rakai, Uganda," The Journal of Infectious Diseases, 191 (9), 1403-1409 .