FUNDAÇÃO GETULIO VARGAS
ESCOLA DE ECONOMIA DE SÃO PAULO

VICTOR CHAGAS MATOS

LIFE EXPECTANCY AND HUMAN CAPITAL INVESTMENT: THE ARRIVAL OF AIDS TREATMENT IN BRAZIL

SÃO PAULO

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Dissertação apresentada à Escola de Economia de São Paulo da Fundação Getulio Vargas como requisito para obtenção do título de Mestre em Economia de Empresas

Campo de Conhecimento:
Microeconometria – Economia da saúde

Orientador: Prof. Dr. Bruno Ferman

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SÃO PAULO

2016

To those who inspired it

and will not read it

I'm afraid that the following syllogism may be used by some in the future.

"Turing believes machines think
Turing lies with men
Therefore machines do not think"

Yours in distress,

Alan

— Alan Turing

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ABSTRACT

This paper provides microevidence on the relationship between life expectancy and educational investment decisions. Human capital theory predicts an increase in life expectancy should lead to an augmenting in schooling investment. This paper uses an unique data set on AIDS patients among Brazilian inhabitants in an attempt to estimate the impact of the arrival of Antiretroviral therapy (ART) on educational outcomes. The availability of ART offsets the negative relationship between vertical HIV-transmission and schooling, around 68% and 57% for elementary and high school completion, respectively. Robustness tests indicate the results are not driven by convergence effects.

Key-words: Life expectancy, human capital investment, HIV/AIDS, ART.

RESUMO

O presente trabalho apresenta evidências da relação entre expectativa de vida e investimento em capital humano a nível de indivíduo. A teoria de capital humano postula que um aumento da expectativa de vida eleva o investimento em educação. Usando uma base de dados inédita de pacientes com AIDS no Brasil, este estudo se propõe a estimar o impacto da chegada da terapia antiretroviral (ART) sobre resultados educacionais. A disponibilidade da medicação diminui a correlação negativa entre transmissão vertical de HIV e escolaridade em torno de 68% e 57% para a completude do ensino fundamental e médio, respectivamente. Testes de robustez indicam que os resultados não são devido a efeitos de convergência.

Palavras-chaves: Expectativa de vida, investimento em capital humano, HIV/AIDS, ART

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1 Introduction

Life expectancy has risen substantially throughout the 20^{th} century driven by the breakthrough of antibiotics and new medical technologies. However, a large-scale epidemic that started in the early 1980s has already spread to every country in the world. The acquired immune deficiency syndrome (AIDS) was responsible for the death of approximately 39 million individuals worldwide by the end of 2013. Despite significant progress on treatment and prevention, in 2014 alone, 1.2 million persons died of AIDS-related illness (UNAIDS (2014, 2015)).

Antiretroviral therapy (ART) became available around 1994 in developed countries and in 1996 in Brazil. Since then, the medication has been significantly improved and nowadays most HIV-positive individuals can hope to live almost as long as non-infected persons if properly medicated and nutritionally healthy (Samji et al. (2013)). Nevertheless, it is important to state that this scenario is very different from 1996, when life expectancy of HIV-positive patients at age 20 years was about 36 years old in 1996 compared to early 70s in 2013. (Antiretroviral Therapy Cohort Collaboration (2008), Samji et al. (2013)).

The rise in life expectancy that took place since the beginning of the AIDS-epidemic has possibly altered schooling incentives. The relationship between life expectancy and human capital investment has been widely studied because the latter is considered one key channel through which life expectancy impacts growth. Theoretically, the link between life expectancy and education is drawn on Ben-Porath's seminal work asserting that there should be an increase in human capital investment due to improvements in life expectancy, since the time horizon over which the investment pays out has increased (Ben-Porath (1967)). Of particular interest is the model developed by Soares (2005) in which exogenous variations in life expectancy due to medical breakthroughs are the driving forces behind economic development. His model predicts reductions in fertility, increases in human capital accumulation and a higher growth rate as a consequence of a healthcare-related technological innovation.

This paper analyzes how sudden life expectancy gains affected human capital accumulation when the AIDS treatment became available in Brazil. Using a unique data set of AIDS patients, we investigate the case of vertically infected (mother-to-child) individuals who developed AIDS later in life. These individuals have been HIV-positive since birth or, at the latest, since contracting HIV from breastfeeding. Our identification relies on their knowledge of their own HIV status prior to the AIDS diagnosis[1]. Relying on the time of HIV diagnosis as a source of variation in the exposure

[1]The diagnosis of AIDS is based on a threshold of CD4 cell count. Hence, human immunodeficiency virus (HIV)

to the AIDS medication, we employ a difference-in-differences approach using the 2010 Brazilian census respondents as a control group.

To our knowledge, Baranov e Kohler (2014) are are the first to explore the relationship between ART availability and educational investment. They use spatial variation in ART availability given by the distance that an individual resides from an authorized ART distributor (e.g. hospital, clinics, healthcare centers) to assess the impact of the AIDS medication on savings, children's schooling and expenditures on children's human capital in Malawi. It is important to emphasize the authors evaluate the impact for all children, not taking into account their HIV status. Furthermore, they exclude children whose parents ever tested positive for HIV, eliminating vertically infected children.

Our study, on the other hand, focus on the effect of ART availability on HIV-positive children. Not only are children HIV-positive, but also they are more likely to be aware of their HIV status when completing their years of schooling because they have been infected in their infancy. Hence, our main contribution relies on a direct test on the role of increased life expectancy in raising human capital investment. We find that ART availability significantly reduces the correlation of vertical HIV transmission with lower educational outcomes. Not only do we find evidence that the effect varies between sexual as opposed to vertical transmission but also that the impact on patients who contracted HIV sexually is much smaller.

Our findings are in line with Baranov e Kohler (2014). Their results reveal that a reduction of the distance to the ART distributor by half increases expenditures on children's education by 3% of annual reported earnings spent on each child and increases schooling by 0.3 of a year. Moreover, using HIV-negative respondents Baranov e Kohler (2014) find significant estimates of similar magnitudes compared to the HIV-positive individuals for expenditures on children's education, indicating that their results are not driven by morbidity effects.

Other studies explore the impact of HIV/AIDS on human capital. Fortson (2011) examines the relationship between mortality risk and human capital investment, providing the first estimates of the impact of HIV/AIDS on educational attainment in Sub-Saharan Africa. A high prevalence of HIV in a given region raises the mortality risk perceived by the people living in it, what could in turn lead to a reduction in schooling. Not only does she find that areas with higher HIV prevalence experienced larger declines in schooling - children living in an area with an HIV-rate of 10% complete 0.5 fewer years of schooling, but also she provides evidence that improvements on mortality risk perception are the underlying cause of her results.

Akbulut-Yuksel e Turan (2013) study the intergenerational transmission of human capital in light of the HIV/AIDS epidemic in Sub-Saharan Africa. Their findings support the effects found

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is responsible for the acquired immune deficiency syndrome (AIDS). This will be furthered detailed in chapter 2.

in Fortson (2011): children living in communities where HIV is highly prevalent (around 20%) are less likely to attend school and, if they do, they progress slower than children living in communities without HIV-positive individuals. Furthermore, controlling for maternal education, they provide evidence that having an HIV-positive mother offsets the positive effect of maternal education on the child's progress at school and school attendance.

Wilson (2015) investigates the relationship between child mortality risk and fertility, looking at the expansion of prevention of vertical transmission of HIV in Zambia. His results suggest that the introduction of prevention reduced pregnancy rates by roughly 10%. This, in turn, could lead to distinct educational investments made by the parents through the quantity-quality trade-off[2]. Assuming the existence of prevention reduces the number of children a mother has, she will invest more in the education of her offspring given the fact that with fewer children there are more resources to be spent per child. However, this particular mechanism does not play a role in our estimation because the medication available in 1996 did not reduce mother-to-child transmission of HIV.

Turning to a general body of literature which investigate how changes in life expectancy impact schooling decisions, Soares (2006) presents evidence that higher longevity is systematically related to higher schooling. The author constructs an adult longevity variable using the mortality history of the respondent's family and finds that families with histories of high adult mortality in previous generations exhibit lower educational attainment. Hansen (2013) explores medical breakthroughs in the middle of the 20th century, especially as regards malaria, pneumonia and tuberculosis, to assess the impact of diminished mortality on years of schooling. He finds one additional year of life expectancy leads to an increase in years of schooling by 0.17 of a year and that declining pneumonia mortality is the main cause underpinning the rise of schooling.

In line with the previous findings, Oster, Shoulson e Dorsey (2013) examine the case of Huntington's disease, in which individuals who carry the mutation have a life expectancy of about 60 years. They find that these individuals are 30% less likely to complete post-secondary education. Jayachandran e Lleras-Muney (2009) study a sudden drop in maternal mortality in Sri Lanka in the 1950s, which lead to an increase in girls' life expectancy. Their results show that for each extra year of life expectancy, years of education increase by 0.11 of a year. Additionally, the authors provide a brief discussion of an evaluation of how education responds to longevity using HIV/AIDS data. They raise two important issues: this response might be confounded by (i) HIV morbidity among children and (ii) the effect on the parents' (expected) health.

We are able to rule out the morbidity effect as a confounding factor because individuals present

[2]For a detailed discussion on quantity-quality trade-off, see Hanushek (1992).

in our sample have nonexistent or recent symptoms[3]. However, the potential effect of parents' health can play a role in our estimations. Hence, our coefficients do not represent exclusively the impact of an increase in the child's life expectancy. Instead, they are a combination of the child's own life expectancy, parents' morbidity alleviation and life expectancy. It is relevant to stress that at least each respondent's mother is HIV-positive, since the individuals in our sample are all cases of mother-to-child transmission. Therefore, the availability of treatment affects the mother through two channels: increasing life expectancy and alleviating morbidity.

Unfortunately, we do not possess information about parents' education, which is considered one of the most important determinants of the offspring's schooling[4]. On this issue, the findings of Akbulut-Yuksel e Turan (2013), despite being for an African country facing a different reality, points to a minor role of maternal educational on the child's human capital in cases of HIV-positive mothers. Nevertheless, epidemiological research shows that vertical transmission of HIV was more prevalent among less educated mothers in the beginning of the epidemics and this pattern only became worse throughout the 1990s (Vermelho, Silva e Costa (1999)). Therefore, maternal education evolves in the opposite direction of children's education, indicating our estimates are likely a lower bound.

In addition, we perform several robustness tests narrowing our census sample in an attempt to overcome a convergence effect on our results. We look at four different census groups: (i) blacks, (ii) mixed, (iii) reside in the North and Northeast regions, and (iv) live in municipalities whose human development index (HDI) falls at the 20^{th} percentile. The robustness tests indicate our results are not driven by convergence effects, providing evidence that ART availability is correlated with improvements in educational outcomes.

This paper is divided into 6 chapters, including this introduction. In the next chapter, we explain briefly the state-of-the-art pathophysiology of HIV/AIDS and detail the Brazilian reality throughout the epidemic. The third chapter describes our data sets and presents some descriptive statistics. The fourth chapter explains our empirical methodology, outlining the possible channels through which ART availability might affect educational outcomes. The fifth chapter presents our results and robustness tests. Lastly, the sixth chapter concludes.

[3] More details in chapter 3.

[4] For a profound discussion on the intergenerational transmission of human capital, see Black, Devereux et al. (2011), Carneiro, Meghir e Parey (2013).

2 AIDS and the Brazilian context

The acquired immune deficiency syndrome (AIDS) is caused by the human immunodeficiency virus (HIV) and its diagnosis is given when the immune system of an HIV-positive person stops functioning properly (Gaffeo (2003)). The mechanisms through which HIV infection causes AIDS are not fully understood, nor is it understood why some individuals develop the syndrome and others do not. Accumulating evidence shows that the connection between the HIV infection and AIDS arises from the growth of the virus in CD4 T cells (Murphy et al. (2012)).

Figure 1 displays the average course of untreated HIV infection, with the y-axis representing the number of CD4 T cells in the peripheral blood lymphocytes (PBL) and the x-axis duration of each stage of the infection[1]. As can be seen, there is a long period of latency (asymptomatic phase) before symptoms start. The symptomatic phase duration depends on whether the patients take antiretrovirals or not. If not, once the patients develop opportunist infections (e.g. pneumonia, candidiasis), they live on average 2 years[2]. They are considered as having progressed to AIDS when their CD4 T cell counts drop below 200 per microliter of blood. At this point, the patients contract acute opportunistic infections, develop renal failure and degeneration of the central nervous system. Without treatment, they live less than a year, on average (Murphy et al. (2012)).

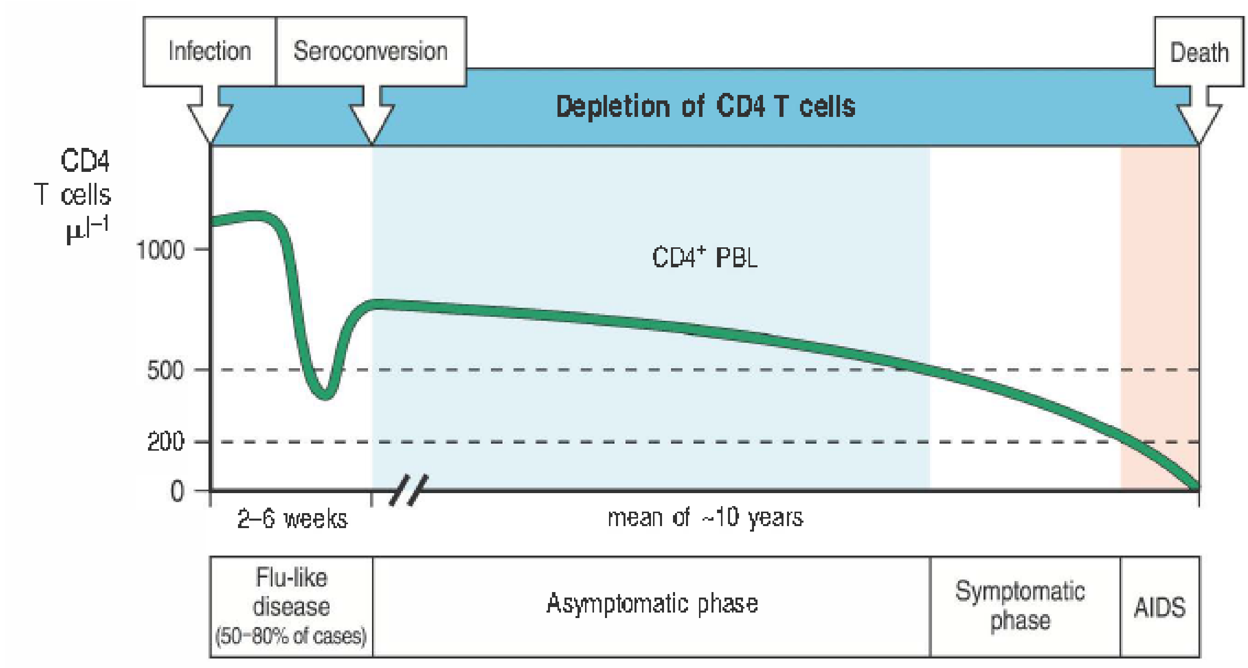
HIV is commonly transmitted through sexual intercourse (vaginal or anal sex), sharing of needles or syringes, of rinsing water or other equipments used to prepare injection drugs, wounds caused by contaminated sharp objects (especially to health care workers), blood transfusion and from mother to child (vertically) during pregnancy, birth or breastfeeding[3]. Focusing on the latter, rates of transmission from an infected mother to her child range from 11% to 60% depending on the severity of the infection and the frequency of breastfeeding (Murphy et al. (2012)). Without treatment, one-third of infected infants die by their first year and half by their second. On the other hand, if they start antiretroviral therapy before their 12^{th} week, the HIV mortality rate is reduced by 75% among children living with HIV (UNAIDS (2014)).

Directing our attention at the Brazilian reality, the first cases of HIV date back to the early 1980s. In the State of São Paulo, the first time a patient was diagnosed with AIDS was in 1983 (Bianco (2015)). However, in the beginning of the epidemic there was no test that could confirm

[1]Further details on Murphy et al. (2012, page 546)

[2]This duration is an average for individuals who contract HIV regardless of transmission type. For details, see An e Winkler (2010), Fauci et al. (1996).

[3]Oral sex is a possible channel of transmission, however very few cases have been documented. See Page-Shafer et al. (2002).



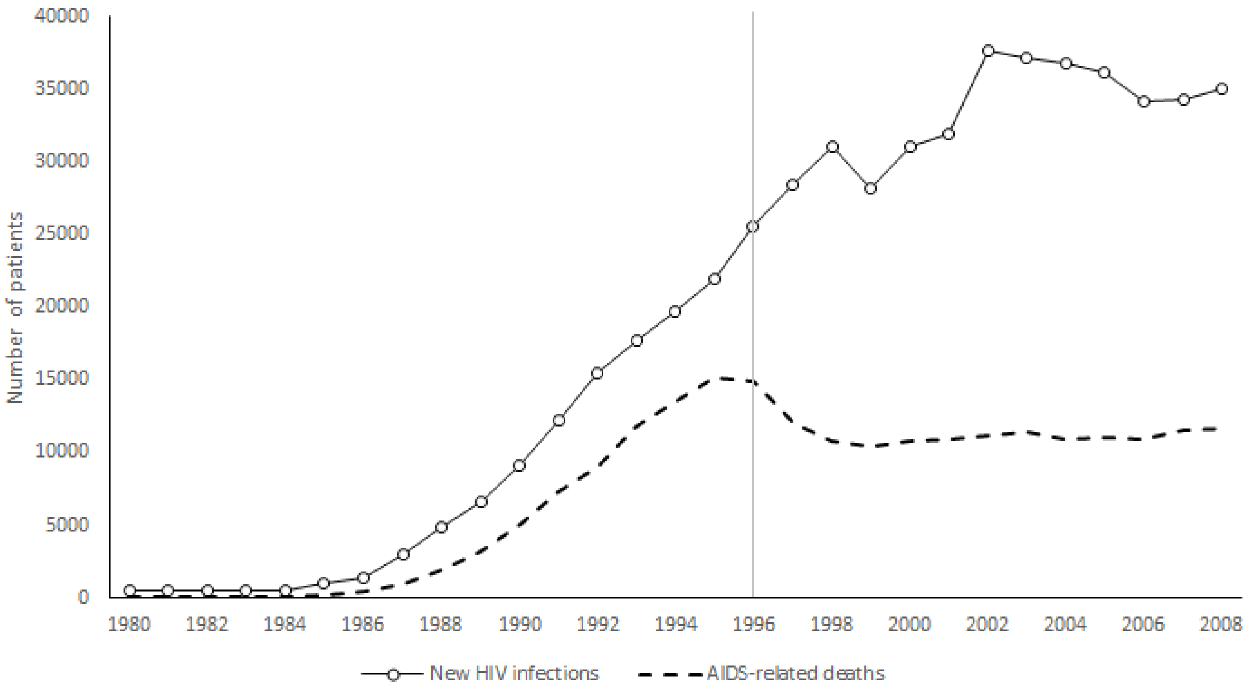
Source: Murphy et al. (2012, page 546)

Figure 1: CD4 cell count according to HIV infection stage

the presence of the virus. AIDS diagnose were given based only on existing symptoms. It was not until 1985 that testing became available in some facilities, particularly in the State of São Paulo. Nonetheless, at the time, there was no treatment; the doctors would only give medication attempting to alleviate symptoms (Loures (2015)).

In 1986, the Brazilian government created the first national program to combat HIV/AIDS. For almost ten years, prevention, awareness-raising about the transmission of HIV and quality assurance in blood banking were the major fronts of the program, due to the nonexistence of treatment (Loures (2015)). In the early 1990s, the first antiretrovirals became available in developed countries. Brazil was the pioneer among developing nations to invest in the availability of treatment to AIDS patients. Under the law 9.313/96 passed in 1996, every patient diagnosed with AIDS had the right to receive free antiretroviral therapy (ART) provided by the Unified Health System (SUS) (Sarney (2015)). It is important to emphasize that until 2015 no HIV-infected individual had free access to the medication before an AIDS diagnosis.

Figure 2 shows the progression of HIV infection and AIDS-related deaths in Brazil since the beginning of the epidemic. The dashed line represents the number of AIDS-related deaths and the dotted line depicts new HIV infections. As can be seen, AIDS-related mortality was extremely high throughout the 1980s and the number of HIV infections rose steeply. The light gray vertical line indicates the arrival of ART drugs in the country. An immediate decline in mortality succeeds the availability of the treatment. However, the number of new infections kept increasing during the rest of the decade. One important benefit of the provision of ART to non-receivers is the reduction in the probability of infection by those who are receiving treatment. The medication, if taken regularly, substantially decreases the viral load of the patient, diminishing the chances of transmission (Baranov e Kohler (2014)). This fact alongside protected sex campaigns can potentially explain the slower increase in the number of infections from 2000 onwards.



Source: Brasil (2008)

Figure 2: HIV infections and AIDS-related deaths per year in Brazil

However, vertical transmission of HIV was difficult to reduce due to (i) reluctance of mothers not to breastfeed, (ii) unawareness of mothers about their own HIV status and (iii) lack of knowledge about HIV transmission. According to anecdotal evidence by Negra (2015), the first cases of HIV-exposed infants in Brazil occurred in 1985 and, for the infected ones, the life span was severely short. In addition, the rate of vertical transmission of HIV was around 25% in the beginning of the 1990s. In other words, one in four infants born to an HIV-positive mother would be infected. It was not until the early 2000s that the incidence rate of HIV-infected infants started to drop (Brasil (2012)).

3 Data

This paper uses data from two data sets: the 2010 Brazilian national socio-demographic census and the information system on diseases of compulsory declaration (Sinan). The first is the commonly used 10% sample microdata, which provides a wide range of information on individual and household characteristics. The latter is a nationwide registry of all the individuals who have at least one of the notifiable diseases, in particular, AIDS[1].

A registry for an AIDS patient comes along with the type of HIV transmission (sexually, vertically, through injection drug, through blood transfusion or by accidents with biological material), presence of opportunist infections, municipality of residence, color, level of schooling, date of notification, date of birth, whether the patient is deceased and, if deceased, there is cause of death. It is extremely relevant to state that the type of transmission is not self-declared. There is an investigation to determine it conducted by an assigned team of doctors. In addition, once an individual is inserted into the system, there are no follow-up interviews or updates on her record. Hence, all information we possess - paying particular notice to schooling - dates at the time the individual is diagnosed with AIDS.

Sinan was gradually implemented between 1993 and 1998, date at which it became mandatory to regularly feed the system on diseases of compulsory notification. However, Sinan-AIDS experienced adjustments on the collection of data between 2005 and 2006. Prior to 2005, mothers and their children would be linked in the data set, allowing the researcher to identify the family. Since 2006, there are two independent data sets, one for adults (over 13 years) and another for children (under 13 years) (Brasil (2006)). At this point, it is worth to mention that an HIV-positive individual who has not been diagnosed with AIDS will not be registered into the Sinan-AIDS data set and no patient can obtain government-funded medication unless registered.

The information on Sinan-AIDS database from 2007 onwards is better reported and therefore we decided to use the data from 2007 until 2014 (the last year available) for the adults data set only. The year of the data set, also known as the year of notification, is the year when the patient is diagnosed with AIDS. Anecdotal evidence indicates the majority of patients are aware they are HIV-positive before an AIDS diagnosis[2]. Additionally, considering the time when testing became available and suggestions given by the Ministry of Health, we use individuals who are at most 35 years old. In fact, there are individuals who are older than 35 reporting to be HIV-positive vertically

[1] Herein, we will address the data set as Sinan-AIDS so as to be clear that the information is only for AIDS patients.

[2] We will discuss this in further detail on the next chapter.

infected. However, it is difficult to assure the validity of such report due to the nonexistence of testing at the time. Hence, these patients are excluded from our sample.

Turning to the 10% sample of the 2010 Brazilian national census, it is a nationally representative sample of about 20 millions interviewees which is collected by the Brazilian institute of geography and statistics (IBGE). Despite providing several types of information, we only use the variables which are available on both data sets (Census and Sinan-AIDS) because we combine them in order to do our estimation. We also restrict the sample to individuals who are between 13 and 35 years old and live in a municipality where there is at least one patient diagnosed with AIDS through sexual or vertical transmission of HIV. Furthermore, we assume all respondents present in the 2010 census sample are HIV-negative. This hypothesis is based on the fact that the HIV prevalence rate among the Brazilian population between 15 and 49 years is steady at 0.6% since 2004 (Brasil (2012)).

Table 3.1: Descriptive statistics

	Sinan-AIDS		
	Vertical transmission	Sexual transmission	Census
Mean			
Age at notification	19	25	21
Percentage			
Schooling levels			
No education/less than a year	0.83	1.26	3.04
Incomplete elementary	45.11	32.78	35.40
Elementary/incomplete HS	33.33	23.96	26.00
High school/incomplete HE	18.41	33.84	30.12
Higher education	2.32	8.16	5.44
Male	48.59	65.56	50.39
White	46.27	47.19	44.91
Black	12.94	9.83	7.46
Mixed	40.13	42.11	46.04
Other color	0.66	0.87	1.59
Observations	603	45,603	5,106,919

Source: 2010 National census public-use microdata sample, Sinan-AIDS 2007-2014.

Table 3.1 presents all the variables and their respective statistics according to the data set and type of HIV transmission[3]. The age at notification is the respondent's age when she is diagnosed with AIDS (for the Sinan-AIDS data) or in 2010 (for the census data). The schooling levels are used according to the census categorization: (i) *no education/less than a year* means the individual has never been to school or completed less than a year; (ii) *incomplete elementary* indicates the respondent has completed less than eight years of schooling; (iii) *elementary/incomplete HS* means the interviewee has completed elementary school and/or started high school; (iv) *high school/incomplete HE* corresponds to the individual completing high school and/or starting college (higher education); (v) *higher education* indicates the respondent has obtained a higher education degree. All the

[3]In the next chapter, we will discuss the role of sexually transmitted HIV in our empirical exercise.

remaining variables are indicator functions taking the value of one if the respondent is male, white, black, mixed and other color, respectively.

Note that the mean age of vertically infected respondents is lower than the other groups. This is of special interest since we want to see effects on education. In addition, the largest share of individuals who are vertically infected have not completed elementary school and very few have higher education diploma. As expected, the gender proportion is close to 50% in vertical transmission cases, illustrating that the chance of a male baby getting infected is the same as a female. As opposed to vertically infected respondents, sexually transmission of HIV is more prevalent among males. Most respondents are white or mixed in all groups, with very few black respondents. It is relevant to mention that the color variable is self-declared. Unfortunately, the number of vertical transmission cases is small, a fact which brings some constrains into the estimation analysis.

4 Empirical strategy

Our empirical exercise explores differential exposure to the AIDS treatment. Using the time of HIV diagnosis as a source of variation in the exposure to the medication, we employ a difference-in-differences approach to estimate the effect of ART availability on three measures of human capital formation along the intensive margin: elementary, high school and higher education completion. We explore specifically the completion of high school because most vertically infected patients become aware of their HIV status on their adolescence. Moreover, the individuals in our sample, as stated in the last chapter, are 13 years or older. Consequently, the vertically infected patients are among the infants who survived throughout childhood infected by the virus and most likely have not developed any symptoms. As seen in chapter 2, this hypothesis seems reasonable considering that once the symptomatic phase starts, the individual survives only for a couple of years without medication. Anecdotal evidence also supports our claim (Negra (2015)).

In addition, sexually HIV-infected individuals can be of substantial assistance in our exercise. Observe in table 3.1 that sexually infected respondents are older in average than vertically infected cases. This difference is expected considering that the exposure to HIV for a sexually infected individual is considerably smaller compared to a vertically one. Furthermore, a sexually infected AIDS patient most likely becomes aware of her HIV status later than a vertically counterpart. As a result, it is likely that ART availability plays a minor role on the educational outcomes of AIDS patients who were sexually infected. At this juncture, it is relevant to mention there is a procedure on STD/AIDS reference medical centers to disclose to vertically infected patients their HIV status, if unknown, at the age of 13, also known as the disclosure year[1]. Therefore, for almost all individuals in our sample, they were certainly aware of their HIV status before receiving the AIDS diagnosis. This is of extreme importance because ART availability will only impact their life expectancies if the patients are aware they are HIV-positive.

According to the year of birth, an individual is more or less exposed to the treatment, a fact of great importance especially during childhood. To capture the time of exposure, we use a linear exposure function that assumes values between 0 and 1, where 0 means the individual was not exposed whatsoever to the medication whereas 1 indicates full exposure. If individual i was born in 1996 onwards, she is completely exposed and the function equals the unit. On the other hand, we assume 1980-born individuals are not exposed to the medication and their function takes the value

[1]This information was obtained at the Coordination of disease control at the Center for reference and training STD/AIDS.

of 0. We must stress that an AIDS patient born in 1980, however unlikely, might benefit from ART availability. Nonetheless, we do not possess any confirmed cases of AIDS prior to 1980; thus, no patient to compare. Put differently, the effect of exposure to be estimated is relative to the effect of the medication on an 1980-born AIDS patient, which we believe is extremely low given the life expectancy of an AIDS patient in the beginning of the epidemics.

In formal terms,

$$f(\text{exposure}) = 1 - \frac{t}{16}$$

where $t = 1996 - \textit{year of birth}$ if the individual is born before 1996 and $t = 0$ if born 1996 onwards. Since the oldest individual in our sample was born in 1980, $t \in [0, 16]$. Figure 3 illustrates our exposure function. Note the function is linear on year of birth and is always between 0 and 1. Let $y_{i,t,m}$ be the educational outcome of individual i notified at year t and municipality m. Then, we estimate the following equation:

$$\begin{aligned} y_{i,t,m} =& \beta_0 + \beta_1 \mathbb{1}\{\text{vertical}\} + \beta_2 \mathbb{1}\{\text{vertical}\} \times f(\text{exposure}) + \beta_3 \mathbb{1}\{\text{sexual}\} \\ &+ \beta_4 \mathbb{1}\{\text{sexual}\} \times f(\text{exposure}) + \beta_5 \mathbb{1}\{\text{male}\} + \beta_6 \mathbb{1}\{\text{black}\} + \beta_7 \mathbb{1}\{\text{mixed}\} \\ &+ \beta_8 \mathbb{1}\{\text{other}\} + \xi_t + \lambda_{m \times \textit{year of birth}} + u_{i,t,m} \end{aligned} \tag{1}$$

where $\mathbb{1}\{\text{vertical}\}$ is an indicator for whether individual i is HIV-positive vertically infected (from mother to son), $\mathbb{1}\{\text{sexual}\}$ is an indicator for whether individual i is HIV-positive sexually infected, $\mathbb{1}\{\text{male}\}$ is an indicator whether individual i is male, likewise for $\mathbb{1}\{\text{black}\}$, $\mathbb{1}\{\text{mixed}\}$ and $\mathbb{1}\{\text{other}\}$ (*white* is the omitted category), ξ_t is a fixed effect for notification year t, $\lambda_{\textit{year of birth} \times m}$ is a fixed effect for the interaction between year of birth and municipality, and $u_{i,t,m}$ is an idiosyncratic error term. Observe $\lambda_{m \times \textit{year of birth}}$ accounts for underlying differences in educational outcomes across municipalities over time, allowing for a flexible trend in educational outcomes over time across municipalities, and ξ_t captures possible notification year-specific patterns in schooling. The main drawback of this strategy is that we do not have any explicit variable of income or wealth.

Our difference-in-differences amounts to assuming ART availability had no effect on the educational outcomes of 1980-born AIDS patients and a proportional increasing effect according to the year of birth. If our claim that treatment availability impacts in a larger extent vertically infected AIDS patients compared to sexually infected ones holds, then $\beta_2 > \beta_4 \geq 0$. Taking a step backwards, our fundamental hypothesis is that educational outcomes of AIDS patients would have evolved in accordance with the outcomes of the average Brazilian students in the absence of medication, also known as the parallel-trend assumption.

There are two possible channels that link ART availability to increased educational outcomes.

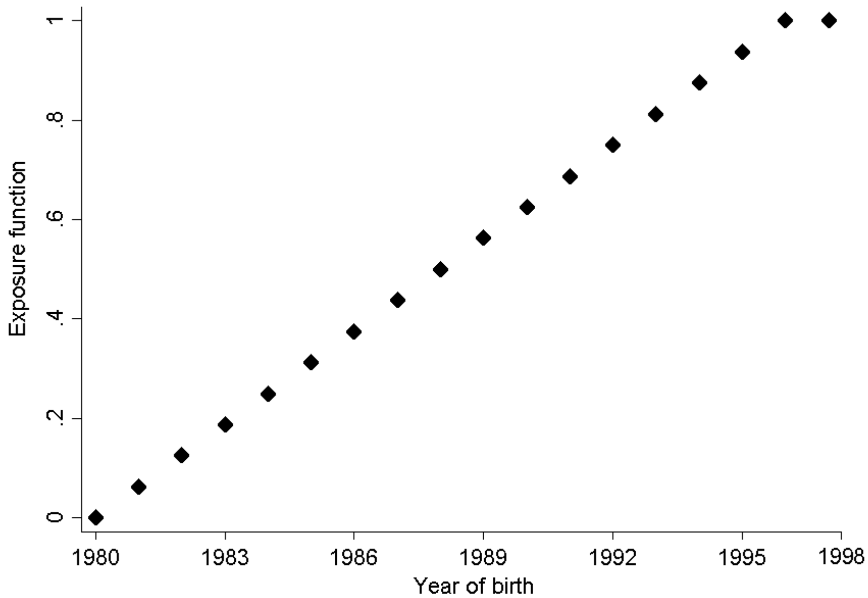


Figure 3: Exposure function

The first is related to life expectancy: the existence of medication amplifies life expectancy, which alters the decision to invest in education. A longer life expands the time horizon over which an educational investment pays out. The second channel is through morbidity alleviation: ART is shown to improve remarkably patients' general condition within a short amount of time. However, as previously explained, the appearance of incapacitating symptoms occurs not long before an AIDS diagnosis. Therefore, the importance of morbidity effects should be limited.

In all the results reported, regressions are weighted by sampling weights and include a municipality-year of birth ($\lambda_{m \times \textit{year of birth}}$) and notification year (ξ_t) fixed effects. For the census observations, we use weights provided by the Brazilian Institute of Geography and Statistics. The Sinan-AIDS respondents are unit weighted. In order to account for correlations between errors terms of individuals living in the same municipality, we cluster standard errors at the municipal level.

5 Results

Table 5.1 presents our main results. The dependent variables are elementary, high school and higher education completion on columns (1), (2) and (3), respectively. All equations are estimated by ordinary least squares (OLS) including municipality-year of birth and notification year fixed effects, and standard errors are clustered at the municipal level. Despite being binary dependent variables, we employ a linear probability model (LPM) in order to investigate magnitudes and direct comparisons across specifications.

Table 5.1: Effect of ART availability on educational outcomes

	(1) Elementary	(2) High school	(3) Higher education
Vertical transmission	-0.272***	-0.422***	-0.102***
	(0.056)	(0.052)	(0.024)
Vertical transmission $\times f(\text{exposure})$	0.260***	0.432***	0.109***
	(0.072)	(0.064)	(0.028)
Sexual transmission	-0.138***	-0.228***	-0.091***
	(0.016)	(0.019)	(0.010)
Sexual transmission $\times f(\text{exposure})$	0.074***	0.190***	0.113***
	(0.013)	(0.014)	(0.013)
Fixed effects:			
Municipality $\times$ Year of birth	yes	yes	yes
Notification year	yes	yes	yes
Testing equality of coefficients			
Vertical T = Sexual T	0.010	0.000	0.672
Vertical T $\times f(\text{exposure})$ = Sexual T $\times f(\text{exposure})$	0.009	0.000	0.919
Observations	5,153,125	5,153,125	5,153,125

Source: 2010 National census public-use microdata sample, Sinan-AIDS 2007-2014. Dependent variables are elementary, high school and higher education completion in (1), (2) and (3) respectively. Standard errors are adjusted for cluster at the municipality level, reported in parentheses. Significance levels: $*$: 10% $**$:5% $***$: 1%

First, note that being HIV-positive (vertically or sexually) is negatively correlated with completion of all schooling levels. Second, the equality of coefficients tests reject the null hypothesis stating vertical and sexual transmission have similar impacts for elementary and high school completion. In other words, being HIV-positive vertically infected is correlated with lower educational outcomes compared to sexually infected. Third, the negative correlation between schooling and HIV-positiveness increases from elementary to high school, but it is significantly smaller in higher education and we cannot reject the equality of coefficients between sexual and vertical transmission.

Turning to our coefficients of interest, we see that ART availability is highly associated with an improvement in educational outcomes, especially for vertically infected individuals. We reject the equality between the effect of treatment exposure between vertical and sexual transmission at 5% level of significance for elementary and high school completion. Furthermore, the sexual transmission interaction on (1) is much smaller compared to all other interactions on (1) and (2). This result is of particular interest because it is less likely that a sexually infected AIDS patient was aware of her HIV status (or was not infected) when completing elementary school in comparison to a vertically infected counterpart. Hence, the existence of medication should not alter her schooling decision.

Assuming sexually infected individuals were in fact unaware of their HIV status at the time they completed their educational outcomes, we can understand their coefficient associated with ART availability as a change in educational outcomes over time. If that is the case, the life expectancy effect related to the treatment is large and significant: $0.260 - 0.074 = 0.186$ and $0.432 - 0.190 = 0.242$ which correspond to 68% and 57% of the vertical transmission coefficient in (1) and (2), respectively. Putting differently, ART availability offsets the negative association of vertical transmission to educational outcomes by more than half.

However, the comparison of magnitudes between the coefficients shall be seen with caution. The difference in magnitude can be driven by convergence effects, i.e., given the fact that vertically infected patients complete fewer years of schooling, the exposure function coefficient could capture simply a convergence in education where the less educated had a significantly higher improvement compared to the more educated respondents. In the following section, we perform four robustness tests in an attempt to overcome this problem only for elementary and high school completion.

5.1 Robustness tests

Our robustness tests explore heterogeneity in color of skin and vulnerability status within the country. First, we suppose treatment is given to the 2010 census respondents in our sample who declare themselves black. Second, we perform the same exercise using the census respondents who declare themselves mixed. Since they are HIV-negative, any coefficient statistically different from zero portrays differences in educational outcomes over time for these particular groups. Furthermore, we are able to compare the exposure function coefficients between vertical and sexual transmission with the color of skin exposure function coefficient. This comparison enables the disentanglement of the ART availability effect from the overall educational improvement in Brazil.

Table 5.2 exhibits the estimates of our robustness tests. The first two columns refer to the estimation where all black respondents in the census sample are allegedly exposed to the medication. The third and fourth columns present the estimation assuming mixed individuals in the census are exposed. Tout ensemble, signs and magnitude of vertical and sexual transmission coefficients and their interactions are very similar across specifications. Moreover, the equality tests show evidence that their impacts (vertical and sexual transmission interactions terms) are statistically different at 1% level of significance for all specifications.

Focusing on the results for elementary school completion, the black coefficient is similar to the sexual transmission one while their interaction terms are very disparate (p-value $= 0.000$). The high school results point to a small change in high school completion for black respondents in the 2010 census throughout the last two decades of the 20^{th} century. The elementary school result is a piece of evidence against the hypothesis that our result might be driven by convergence in the educational outcomes since we have a group who exhibits no change in elementary school completion. Turning to the mixed robustness results, the coefficients are of similar magnitudes to the sexual transmission. Their interaction terms follow the same pattern. Therefore, we cannot conclude much on convergence effects. This result simply indicates robustness of our estimates.

Our next robustness test makes use of the heterogeneity within the Brazilian geopolitical division. The North, Northeast, Center-West, South and Southeast regions underline an economic disparity within the country. North and Northeast regions bare the largest amount of people living in poverty. Since vertical transmission of HIV is largely more prevalent among vulnerable individuals, our third exercise assigns treatment to census respondents residing in those regions. In order to avoid collinearity between the North and Northeast regional dummy and the municipality-year fixed effects, these regressions do not include the North and Northeast regional dummy as a regressor, only its interaction.

The fifth and sixth columns of table 5.2 display the results for elementary and high school completion. We observe no change in elementary school completion through time for those residing in the North and Northeast regions. High school completion, on the other hand, exhibited a worsening in the North and Northeast regions of relevant magnitude and significant at 5%. Note that the vertical and sexual transmission coefficients remain very similar to our main estimates and we can reject equality of coefficients at 5% level of significance. Hence, we have a group whose results are clearly not driven by convergence effects.

Table 5.2: Robustness tests: black, mixed, residing in North and Northeast regions and living in a municipality whose HDI falls at the 20^{th} percentile

Var x	Black		Mixed		North and Northeast		HDI p(20)	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
	Elementary	High school	Elementary	High school	Elementary	High school	Elementary	High school
Vertical transmission	-0.290***	-0.446***	-0.319***	-0.495***	-0.275***	-0.429***	-0.272***	-0.423***
	(0.054)	(0.056)	(0.059)	(0.052)	(0.057)	(0.030)	(0.056)	(0.052)
Vertical transmission $\times f(\text{exposure})$	0.262***	0.441***	0.280***	0.487***	0.255***	0.421***	0.259***	0.428***
	(0.070)	(0.066)	(0.075)	(0.062)	(0.071)	(0.064)	(0.072)	(0.063)
Sexual transmission	-0.152***	-0.248***	-0.182***	-0.297***	-0.137***	-0.227***	-0.138***	-0.230***
	(0.017)	(0.020)	(0.016)	(0.018)	(0.016)	(0.019)	(0.016)	(0.019)
Sexual transmission $\times f(\text{exposure})$	0.077***	0.201***	0.089***	0.238***	0.056***	0.151***	0.072***	0.183***
	(0.013)	(0.014)	(0.013)	(0.014)	(0.017)	(0.019)	(0.014)	(0.015)
Var x	-0.122***	-0.182***	-0.116***	-0.179***				
	(0.003)	(0.005)	(0.002)	(0.006)				
Var x $\times f(\text{exposure})$	-0.001	0.085***	0.042***	0.126***	-0.054	-0.119**	-0.032	-0.120***
	(0.003)	(0.004)	(0.002)	(0.006)	(0.048)	(0.052)	(0.042)	(0.037)
Fixed effects:								
Municipality $\times$ Year of birth	yes	yes	yes	yes	yes	yes	yes	yes
Notification year	yes	yes	yes	yes	yes	yes	yes	yes
Testing equality of coefficients								
Vertical T = Sexual T	0.007	0.000	0.010	0.000	0.013	0.000	0.011	0.000
Vertical T $\times f(\text{exposure})$ = Sexual T $\times f(\text{exposure})$	0.009	0.000	0.015	0.000	0.008	0.000	0.010	0.000
Vertical T = Var x	0.002	0.000	0.000	0.000				
Vertical T $\times f(\text{exposure})$ = Var x $\times f(\text{exposure})$	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000
Observations	5,153,125	5,153,125	5,153,125	5,153,125	5,153,125	5,153,125	5,153,125	5,153,125

Source: 2010 National census public-use microdata sample, Sinan-AIDS 2007-2014. Dependent variables are elementary high school and high school completion in (1) and (2) respectively. Var x refers to characteristics exclusive to census respondents. Standard errors are adjusted for cluster at the municipality level, reported in parentheses. Significance levels: $*$: 10% $**$:5% $***$: 1%

Lastly, we use the human development index (HDI) calculated at the municipal level as a measure of vulnerability. Unfortunately, this index is only available for specific years in sparse intervals. We use the 1991 HDI and select the respondents living in the municipalities whose HDI falls at the 20^{th} percentile as a comparison group. Once again, we include only an interaction between an indicator variable of municipality whose HDI falls at the 20^{th} percentile and the exposure function in order to avoid collinearity issues. The idea behind such test is the same as the last exercise: vertical transmission of HIV is more prevalent among vulnerable individuals.

The last two columns of table 5.2 show estimates of our last robustness test. First, note that these results are very similar to the North and Northeast exercise, including significance of coefficients and magnitude. The estimates for elementary school completion show no change and a worsening in high school completion. Once again, vertical and sexual transmission coefficients present similar magnitudes and significance. The equality of coefficients tests indicate we can reject equality at 5% for all coeficients.

Overall, the vertical transmission interaction is statistically different from all groups interactions at 5% level of significance for all specifications. Moreover, blacks, North and Northeast residence and living in a municipality with low HDI exercises indicate convergence is not driving our results.

Nevertheless, there are some potential confounding factors that can pollute our findings: (i) policies providing broader access to health and education and (ii) changes in the composition of groups (sexually and vertically infected and along the Brazilian population). However, we do not possess data that allow us to investigate these factors any further.

6 Concluding remarks

There is a growing body of literature seeking to understand to what extent life expectancy impacts investment decisions in education. Using a unique data set on AIDS patients, this paper presents individual-level evidence on the effect of life-extending AIDS medication availability on educational investment in Brazil. Our study adds to the literature being among the few which try to disentangle individual morbidity effect from life expectancy and parents' morbidity combined effect. However, we are not able to isolate the individual life expectancy from parents and potential parents' morbidity alleviation.

We employ a difference-in-differences approach using the 2010 Brazilian census respondents as a control group in order to estimate the impact of ART availability on elementary, high school and higher education completion. Our findings point to a large impact of increased life expectancy on educational outcomes. Comparing two similar vertically infected AIDS patients, one fully exposed to the treatment and the other completely unaware of its existence, we find the exposure to the medication offsets the negative association between vertically HIV transmission and elementary and high school completion by more than half. This effect is large and significant across several specifications.

In addition, exploiting color of skin heterogeneity and vulnerability status within the country, we perform robustness tests. Our results suggest the impacts found are not driven by convergence effects. Furthermore, we provide evidence that the effect of ART availability on completion of lower schooling levels (i.e. elementary school) is larger compared to high school completion. We also find that the correlation between medication availability on sexually infected individuals and schooling is considerably small for elementary school completion. This finding is of particular importance because it gives credibility to our identification hypothesis.

Our findings are in line with the recent literature of ART availability effects on educational investment. Moreover, it supports the idea that full provision of AIDS medication alongside with other diseases which shorten largely life expectancy is of extreme importance. However, further research is required to fully address the mechanisms through which life-expanding medications impact investment decisions on education.

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