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Evelyn Monteiro Pereira Nunes

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The dissertation of Evelyn Monteiro Pereira Nunes was reviewed and approved[1] by the following:

Russell Cooper

Professor of Economics

Dissertation Adviser

Chair of Committee

Kala Krishna

Professor of Economics

James Tybout

Professor of Economics

Liang Zhang

Associate Professor of Education

Barry Ickes

Professor of Economics

Head of the Department of Economics

[1] Signatures are on file in the Graduate School.

Abstract

The present dissertation consists of three essays related to economic development and human capital investment. The first essay investigates the choice between public and private schools in Brazil. I use cross-sectional survey data to show that families with higher income and schooling are less likely to enroll their children in public school. But if their race is black or brown, they are more likely to choose public schools, even when controlling for income, education and location. I do not find any evidence that this result comes from scarcity of private schools, race preferences, or residential segregation. But it is likely caused by the lower returns to education that black and brown individuals have. This essay shows that not only income and education matter for school choice in Brazil, but also race. The second essay explores the theory behind parental educational investments in the presence of heterogeneous returns. I build on the overlapping generations literature to study the investment that parents make on the education of their children, in a setting with private and public schools and different returns by group. This assumption is motivated by the findings in the first essay, and it results in different school choices based on income and returns. This difference in the educational investment leads to school segregation in equilibrium and may result in poverty traps. The third essay uses a quantitative approach to study the effects of implementing a voucher program in Brazil. I use simulated method of moments to estimate some parameters in a parental choice model, while calibrating others to the Brazilian economy. The estimation is used to evaluate how implementing private education vouchers compares with the non-voucher case. I find that vouchers increase

the average human capital of the economy and reduce inequality measured by the Gini coefficient and coefficient of variation. In some cases it improves the welfare of the first generation affected by the voucher, while in others it will impose a welfare cost. For future generations there are large welfare gains of continuing this policy.

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This doctoral dissertation is the outcome of my work and dedication in the previous years, but it would not exist without the help and support of many people that I have had the pleasure to meet and work with.

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To God, my dear husband and Sheldon

Chapter 1

Private School Choice and Race in Brazil

Abstract

This paper investigates the role of race in early educational choice in Brazil. Brazilian public schools typically offer low quality education, so the parental choice between the private and public educational systems is crucial for economic mobility and growth. Using two Brazilian survey data sets, I provide evidence that even when controlling for parent's education, income and location, black and brown families are more likely to place their children in public school, as opposed to private. This choice does not seem to be a result of availability, residential segregation or preferences. But, the lower returns to education that black and brown individuals have in the labor market can explain their educational choice. This paper shows that race matters for parental educational investment in Brazil, and better understanding the returns to this investment can help explain social mobility and shape future policies.

1.1 Introduction

Investment in human capital begins early in life and is a family-based decision. Several papers in the literature show that the most relevant period of investment is during childhood,

when these decisions are not made by the individual herself.[1] Therefore, it is critical to investigate the educational decisions parents make for their children in order to understand and promote development and higher educational attainment.

In this paper I show that race matters for parental educational decisions in Brazil, since blacks and browns are 4-5 percentage points on average more likely to enroll their children in public schools, even when controlling for schooling and income of the parents.[2] I also explore conditions that can be influencing this fact.

Public schools in Brazil are free, but they provide a low quality service. They lack in incentives for teacher's performance, or even attendance, they have deficiency in basic supplies and suffer frequent labor strikes when students stay long periods without classes. Since 2009, school enrollment is mandatory for individuals between 4 and 17 years old, so public schools receive resources in compliance with the minimum expenditure per student stipulated by the government, and these resources usually do not exceed this target.[3]

Alternatively, families can choose to pay for a private school which usually has exams to place students at the correct level. Considering the PISA 2012, students from private schools had a score in the math exam 22% higher than students in public schools, which is seven times the difference for American students.

So attending public school in Brazil adversely affects future educational opportunities.[4] Nevertheless, this quality disparity between public and private schools and how it affects educational investments, especially for non-white individuals who are the majority in public schools, has not been fully explored.

[1]For instance, Restuccia and Urrutia (2004) find that half of the intergenerational correlation in earnings is explained by parental investment in education, in particular early education. Duncan et al. (1998) show that early childhood is the stage in which family economic conditions matter the most for cognitive and behavioral development. Similarly, Caucutt and Lochner (2012) show that early income is a more important determinant of educational outcomes than is income at later ages, due to dynamic complementarity.

[2]In Brazil, race is a self-declared characteristic among 5 groups: white (Caucasians), black (Afro-descendants), brown (mixed race, white and black descendants), yellow (Asians) and indigenous (native).

[3]From kindergarten to fourth grade schools are operated by the municipal government, and after that by the state with a few federal secondary schools. They cannot raise more resources or compete against each other.

[4]Typically, only 20% of those admitted into higher education programs came from public schools, and that led some universities to establish quotas for those students to increase the share to around 30%.

This work contributes to the literature on school choice by showing that educational investment in Brazil is influenced by more than just income. Using the 2012 Brazilian National Household Survey (PNAD) and the 2011 National High School Exam (Enem), I estimate a binary choice model to analyze the probability that a household will enroll their offspring in public school, as opposed to private. I control for income, education, living in urban area and race. I show that the parents' schooling and income have a significant and negative impact on the probability of enrolling a child in public school. However, I also find that black or brown families are more likely to place their children in public school, even when controlling for those other characteristics.

To the best of my knowledge, no other paper investigates the role of race for educational choice in Brazil. Using data for the U.S., some papers analyze the decision between public and private schools and reach mixed results. Sander (2015) finds that in the Chicago area black students are less likely to attend private schools, likely because they are mostly Protestants while private schools in the area are mostly Catholic. On the other hand, Buddin et al. (1998) show that in California blacks are more likely to attend private elementary school, and Goldring and Phillips (2008) find no race effect for Nashville. In any case, it is important to keep in mind that the decision between public and private schools in the U.S. and in Brazil is quite different, and even though the median household income in Brazil is a tenth of the American one, it has a higher share of students in private schools due to the low quality of the public system.

I also investigate what factors could explain this educational decision. Hastings et al. (2007, 2009) investigate school choice in the U.S. and find that non-whites place a higher weight on school scores than whites, and are more likely to choose a school with a higher score. There is no school choice in Brazil, but I find in the data that among families who have children in both systems, the race distribution is very similar to the one observed in the population, so system preferences seem to be similar by race.

Alternatively, it can be an outcome of residential segregation. Even though in Brazil

you are not assigned to a specific school, it is natural to assume that parents will enroll their children close to their residence, where there can be a lack of private schools. I calculate the Dissimilarity Index to measure racial residential segregation across census tracts in a metropolitan area and find that it is low to moderate, and it is even lower if calculated only for those in school.[5]

Peer preferences can also explain this race effect. For instance, Hastings et al. (2007) show that African American students place a positive weight on the fraction African Americans at a given school, and Lankford and Wyckoff (2001) estimate a "white flight" to private school when there is school choice. But I find that the probability of choosing public school given the share of white students in local public schools (measured by their share in the census tract) does not vary with the race, and is actually positive, meaning; the higher the share of white students in local public schools the higher the probability of choosing it.

Returns to education may also influence the educational investment. In Chapter 2, I use an overlapping generations model to show that if returns to education vary with race, the old generation will make educational choices for the young one in equilibrium based not only on income but also on race, and the estimation in Chapter 3 predicts different returns by racial group. Also, the empirical literature shows that returns to education are usually lower for non-white individuals (Card and Krueger, 1992b; Silva, 2000; Arias et al., 2004), and I corroborate this finding using recent data and looking at total years of education for each racial group.[6]

Considering that on average returns to education are lower for blacks and browns, they may be less inclined to pay the premium associated with private education, especially when they are financially constrained, which can explain the observed educational choice. In sum, this research contributes to a better understanding of the relationship between race and social mobility through parental educational investment choices.

[5] As a reference, the segregation is basically half of what we observe in American metropolitan areas.

[6] Ideally we would be able to calculate the returns by school system, but this data is not available at the moment.

This paper is organized as follows. The next section describes the education context in Brazil. Section 1.3 details the data used and Section 1.4 contains the empirical results. Section 1.5 discusses possible causal effects for them and the last section concludes.

1.2 Education and Race in Brazil

Education is one of the most powerful instruments to reduce poverty, and countries with low levels of education typically observe low levels of development as well. Brazil has one of the lowest school attainments in Latin America (see Figure 3.2 in appendix A) and one the highest correlations of schooling between parents and children (Daude and Robano, 2015). These facts contribute to low economic mobility across generations and high inequality of opportunities. Also, education and income vary significantly across races. In 2012, the monthly median income for blacks or browns was 73% of the one for whites, and among individuals with at least some college 69% are white, while only 25% are brown and 5% are black (see Figure 3.5).[7]

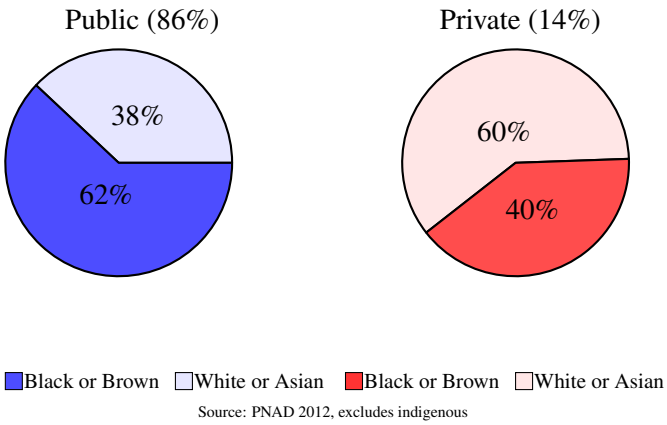
The type of school attended is also important. Public schools in Brazil generally perform much worse than private schools. In the PISA exam in 2012, public school students scored 18% lower than private students in the math exam. In the U.S.A. it was only 3% lower and the average difference for OECD countries was 10% lower, so there is a very significant gap between school systems in Brazil.[8] Besides, the majority of students enrolled in public schools are black or brown, and this ratio inverts when we look at private schools, as shown in Figure 1.1.

In terms of population, these racial groups are more evenly distributed (see Figure 3.3), but this composition across systems could just be a reflection of income differences, given

[7]Using the average exchange rate for that year, the annual median income was equivalent to $5,215 for whites and $3,816 for blacks and browns.

[8]PISA stands for "Programme for International Student Assessment". It is an international test given by OECD to 15-year-old students in 65 countries.

Figure 1.1: Enrollments by School System with Race Distribution



Source: PNAD 2012, excludes indigenous

that the income distribution for blacks and browns is more concentrated on the lower tail (Figure 3.4). Since education is such an important channel for social mobility, it is critical to investigate whether there are other factors that contribute to educational investment besides wealth constraints.

1.3 Data

The Brazilian National Household Survey (PNAD) provided by the Brazilian Institute of Geography and Statistics (IBGE) collects detailed information on individuals and family units. The survey has a complex sample design with multiple stages and stratification.The estimation here incorporates its complex sample design, i.e. sampling weights and stratification.

The PNAD survey for 2012 included 362,451 individuals representing 114,906 households. I drop observations without information on household income and individual's race.[9] After I define the survey design, I also drop single unit tracts since otherwise it would not be possible to calculate the variance for the estimates. I end up with 346,447 individu-

[9]Only 18 individuals did not inform race, but almost 4% did not inform household income.

als and 110,464 households, but only 38,867 households have children in school between kindergarten and 11th grade.[10]

Among households with children in school, I investigate those that have children in private or in public schools.[11] Table 1.1 shows that the median income per capita for families that have children in private school is more than twice the median for families with children in public, regardless of the race of the head of the household (HH).

Table 1.1: Median Household Monthly Income per capita

Race of HH	**Children in Private**	**Children in Public**
White	1112	424
Brown or Black	654	279
Total	875	320

Values are in R$.

I also use the National High School Exam (Enem) and its socioeconomic survey. This is a non-mandatory exam that since 2009 has been used as part of the entrance exam to most universities in Brazil. It consists of questions on math, science, languages and an essay. Some students answer a survey about their household and previous schooling.

The typical examinee is finishing high school and is taking the exam in order to be accepted by an undergraduate program. Passing the exam also gives them a high school diploma, therefore, not everyone taking it aspires to higher education, but there should be a selection of better students among those taking the exam.

The Enem sample for 2011 included 5,380,856 individuals, and 5,366,948 answered at least part of the socioeconomic survey. I drop observations without information on race and high school system.[12] I end up with 5,155,168 individuals. The average age is 23, average household size is 4, and average monthly household income is 2.72 times the minimum wage (R$1482 $\approx$ $756).

[10] In Brazil, high school has only 3 grades, totaling 11 years after kindergarten.

[11] It is not the focus of this paper, but out of all children between 4 and 17 years old (mandatory schooling ages), 7.5% are not in school. And there are 994 households (6% of those with more than one child) with children in both systems that were not included in the analysis.

[12] I also use information on the system for K-8 when available, and 7.8% of students changed systems between K-8 and high school, half of those being from public to private.

Table 1.2 shows the difference in the average math scores given the system of the high school. Black and brown students have a similar performance, and typically do worse than white students, regardless of school system.

Table 1.2: Mean Math Grade, by race

High School System	**Black**	**Brown**	**White**
Private	563.42	580.65	630.02
	(120.08)	(123.33)	(121.61)
Public	481.81	483.24	516.86
	(97.68)	(99.55)	(108.51)
Total	489.65	495.09	546.21
	(102.90)	(107.56)	(122.54)

Data Source: ENEM 2011. Standard deviation in parentheses.

1.4 Empirical Analysis

Since I am interested in comparing the educational investment decision across families, I use a binary choice model to calculate the probability that households with children in school choose public rather than private.[13] So for $y_i = 1$ when the household i chooses public, I am interested in $Pr(y_i = 1|X) = F(X_i'\beta)$, given the observable characteristics X.

The characteristics I control for are; monthly income of the household per capita, maximum level of schooling among parents, whether the family lives in an urban area or not (where there is a higher supply of private schools), and the race of the household head. I also include state dummies to control for regional differences.

1.4.1 Results using PNAD

Table 1.3 shows the results of a probit model using the PNAD data set. One can see that wealthier and more educated families have a lower probability of choosing public school

[13] I exclude the households with children in more than one system, so the choice is mutually exclusive.

over private. Nevertheless, if the household head declares herself as black or brown, she will be more likely to choose public schools. Location is also important since living in an urban area, with more options of schools, makes families less likely to choose public ones.

Table 1.3: Probit Estimates for Public School Choice - PNAD 2012

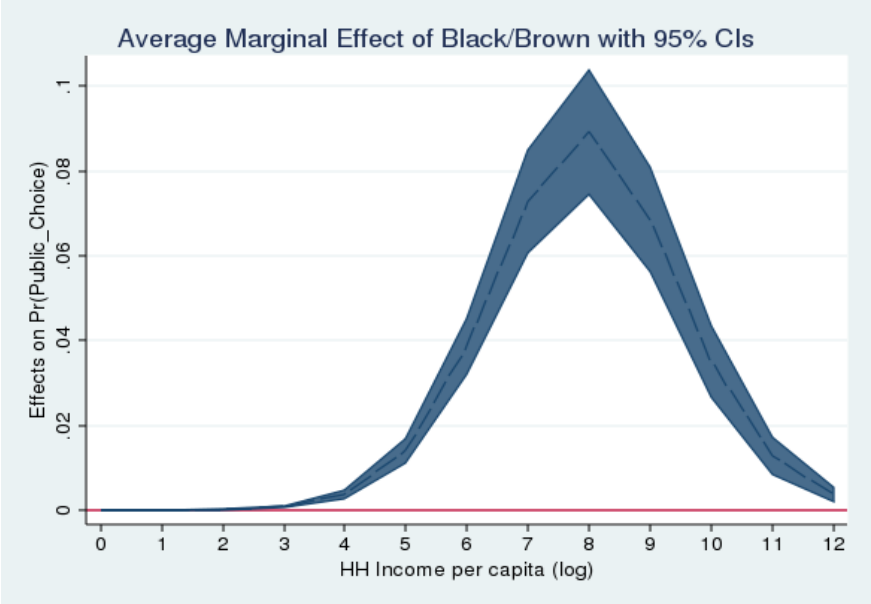
	(1) Coefficient	(2) Coefficient	(3) Average Mg. Effect
Income per capita (log)	-0.82***	-0.80***	-0.12***
	(0.02)	(0.02)	(0.00)
Parents Schooling	-0.13***	-0.13***	-0.02***
	(0.00)	(0.00)	(0.00)
HH black	0.17***		
	(0.04)		
HH black or brown		0.27***	0.04***
		(0.02)	(0.00)
Urban Area	-0.77***	-0.77***	-0.09***
	(0.06)	(0.06)	(0.01)
Constant	8.87***	8.58***	
	(0.17)	(0.17)	
State dummies	Yes	Yes	Yes
Observations	37621	37621	37621

Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The third column presents the average marginal effect. It is no surprise that income plays the biggest role in the educational choice, but the fact that households where the head is black or brown are 4 percentage points more likely to choose public schools, even when controlling for income and education, is quite surprising. Figure 1.2 shows this marginal effect across income levels.

This result indicates that not only income, education and location influence the educational choice, but also race. Hereunder I try other specifications to test if the race effect is robust.

Figure 1.2: Marginal Effect by Income level



1.4.2 Robustness Checks

The size of the household is accounted for by the income per capita. But to see its effect separately, in Table 3.18 in the appendix I control for income and total number of children studying, which can be more representative of the cost of the educational choice. Income still has a significant and negative effect on the probability of choosing public, and the number of children has a significant positive effect. This is expected since the more children studying the higher the cost of private education. The race dummy is still significant and positive for non-whites.

As I have showed, living in an urban area is an important factor in choosing private school. So I run the same probit estimation but only on the sample of households living in urban areas (Table 3.19), and even for that group race matters.

The focal group might be relevant too, so in Table 3.21 I look at families and students themselves, instead of households, and in both cases the race of the head of the family or the student is still significant.[14]

[14]IBGE distinguishes between the family and household, defining that there can be more than one family living in the same household.

The only relevant change is found when I look at the sample of households with income per capita above R$1,000 per month (see Table 3.22).[15] For this group, race is not significant anymore. This can be explained by the fact that above some wealth level the income effect starts to be stronger than the substitution one. Non-white rich families will choose private school that is typically better, but for those who struggle to afford the private tuition, they are not willing to make the sacrifice. Or at least are less willing than white families.

Interestingly, Goldring and Phillips (2008) find that parents of black children are not less likely to send them to private schools in the U.S.A, even without controlling for income and education. But they use a sample of families that are actively choosing schools, so there is a selection bias there, which can be similar to looking at the higher income families in Brazil.

1.4.3 Results using Enem

Since the Enem data set provides grades, which are correlated with ability, I proceed with the same estimation to compare the results with the ones obtained using PNAD. Then I add the exam score as an explanatory variable.

In the survey, students report the household income as a proportion of the minimum wage, so for the income per capita I multiplied the answer by the minimum wage in 2011 and divided by the size of the household. The race dummy is the race self-declared by the student.

Table 1.4 presents the estimation of the same probit model using the Enem survey data. The results are strikingly similar to the ones obtained using PNAD in Table 1.3. Higher the income and education of the parents, smaller the probability that the exam taker went to a public high school. But if she is black or brown, this probability is 5 percentage points higher. This result is also robust to other grades besides high school as displayed in Table 3.23 in the appendix.

[15]This value is close to an average monthly tuition of a private school, and around twice the median household income. Among this group, 35% of the household heads are black or brown.

Table 1.4: Probit Estimates for Public High School Choice - ENEM 2011

	(1) Coefficient	(2) Average Mg Effect	(3) Coefficient	(4) Average Mg Effect
Income per capita (log)	-0.74***	-0.12***	-0.72***	-0.12***
	(0.00)	(0.00)	(0.00)	(0.00)
Parents Schooling	-0.12***	-0.02***	-0.12***	-0.02***
	(0.00)	(0.00)	(0.00)	(0.00)
Black	0.19***	0.03***		
	(0.00)	(0.00)		
Black or Brown			0.28***	0.05***
			(0.00)	(0.00)
Urban area	-0.29***	-0.04***	-0.29***	-0.04***
	(0.00)	(0.00)	(0.00)	(0.00)
Constant	7.39***		7.13***	
	(0.01)		(0.01)	
State Dummies	Yes	Yes	Yes	Yes
Observations	4951002	4951002	4951002	4951002

Standard errors in parentheses.* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

As I showed in the previous section, even considering that there is a selection of higher ability students taking the exam, the math score varies not only across systems but also across races. So Table 1.5 displays the same estimation but controlling for the student's score.

In the first and second column, I control for the log of the math score and the log of the essay score, respectively. The last column has the percentile of the math score within each system, so I am comparing the relative position of the student given the school system.

The race effect is similar to the one observed in Table 1.4, so it is not an outcome of the ability, or expected ability, of the child. But the higher the grade, the less likely it is that the exam taker went to a public high school, which demonstrates the difference in quality of the systems despite the selection bias coming from taking the exam. Notice that the percentile score has a positive coefficient. I believe this is the case because most students go to public schools, so there are more students at the top percentile from public schools.

Table 1.5: Probit Coefficients for Public High School Choice - ENEM 2011

	(1) Math	(2) Essay	(3) Math Percentile
Income per capita (log)	-0.65***	-0.71***	-0.84***
	(0.00)	(0.00)	(0.00)
Schooling of Parents	-0.11***	-0.11***	-0.13***
	(0.00)	(0.00)	(0.00)
Black or Brown	0.26***	0.28***	0.32***
	(0.00)	(0.00)	(0.00)
Urban area	-0.29***	-0.30***	-0.34***
	(0.00)	(0.00)	(0.00)
Grade	-1.24***	-0.62***	0.01***
	(0.00)	(0.00)	(0.00)
Constant	14.30***	10.86***	7.45***
	(0.03)	(0.03)	(0.01)
State Dummies	Yes	Yes	Yes
Observations	3595378	3435700	3595378

Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Overall, the role of race for educational investment is a significant and relevant finding. One that can explain poverty traps and should be taken into account when designing public policies. Next I discuss possible explanations for this race effect on school decisions.

1.5 Discussion of the Race Effect

I have shown that early parental educational decisions vary across races, even when controlling for income and schooling. This suggests that additional heterogeneity among racial groups must exist in order to explain this choice.

Educational investment can be affected by preferences or technology, I discuss these assumptions below.[16]

[16]It could also be due to an exogenous factor, like scarcity or discrimination, but I don't believe that to be the case. For instance, half of the schools in the urban area of the Rio de Janeiro state are private and the race

1.5.1 Preferences

Hill (2014) finds that blacks from urban areas in Africa are more likely to transfer to better schools, and Hastings et al. (2007) show that African Americans are more likely to ask for a school with higher score than the guaranteed one.

But if black and brown families in Brazil place a lower value on education, they may be less inclined to pay for it. There is not much data available to test this hypothesis, but Table 3.22 shows that above some level of income the race effect disappears, so if this effect were coming from different tastes for education, tastes would have to vary not only with race but also income. Besides, I find that among the Brazilian families that have children in both school systems, 47% are brown, 12% black and 38% are white, which resembles the race distribution in the country (see Figure 3.3). This can indicate that there is not much difference on how they value each system.

In addition to that, since the majority of students in public school are non-white (Figure 1.1), non-white families may prefer to send their children there. For the U.S., Hastings et al. (2007) show that African American families place a positive weight on the fraction African Americans at a given school, and Sander (2015) finds that whites in the Chicago area are more likely to attend private schools in areas with a higher share of school-age African Americans.

There is also a literature on the "acting white" theory (Austen-Smith and Fryer, 2005; Fryer and Torelli, 2010). This theory states that some African Americans would perceive as a betrayal of their culture to have social behaviors associated with whites, such as high grades in school, or living in some neighborhoods. This could be represented by attending private schools in Brazil. And there is also some evidence (Lankford and Wyckoff, 2001; Sikkink and Emerson, 2008) of "white flight": given the choice, white students are more likely to leave schools with a higher share of black students.

effect is still present. Also, about 8% of the students who took the ENEM exam changed school systems, with almost half of those who moved from public to private being black or brown.

If families prefer when their children attend schools with peers of the same race, this can lead to the school choice we observe in the data. So in Table 1.6 I estimate the same probit model as before using the PNAD data and add an interaction term between race and the share of white students attending public school in the same census tract, which is related with their location.

Table 1.6: Probit Estimations with with Racial Peers

	(1) Coefficient	(2) Coefficient
Income per capita (log)	-0.82***	-0.80***
	(0.02)	(0.02)
Parents Schooling	-0.13***	-0.13***
	(0.00)	(0.00)
White Share in Public	0.25	0.49***
	(0.13)	(0.14)
HH black	0.19**	
	(0.07)	
HH black or brown		0.35***
		(0.05)
White Share in Public Schools * HH Black	-0.07	
	(0.20)	
White Share in Public Schools * HH Black/Brown		-0.17
		(0.13)
State and Urban Area dummies	Yes	Yes
Observations	37621	37621

Standard errors in parentheses. Constant term not displayed. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

I find that the head of the household's race effect does not change when I control for the proportion of whites in local public schools. And being black or brown does not affect the probability of choosing a public school when there are more white students attending them. Actually, there is a positive effect for studying with whites when I control for blacks and browns. Also, Firpo et al. (2015) show that there is a positive peer effect for studying with white students, which may be a reflection of studying with higher quality peers.

Alternatively, some can argue that this school choice may actually reflect a residential segregation and the availability of private schools in those areas. For instance, Logan et al. (2003) claim that the exclusion of minority children from suburban neighborhoods and schools is the most significant factor for racial inequality in the Boston region.

A traditional and commonly used measure of segregation is the Index of Dissimilarity, which measures the segregation across spacial units. It ranges from 0 (complete integration) to 1 (complete segregation), and the number indicates the percentage of a group's population that would have to move between tracts to match the group's share in the metropolitan area.

Table 1.7 shows that for the 10 biggest metropolitan areas in Brazil, the dissimilarity index among white and black/brown individuals varies between 0.24 and 0.43, which is considered low to moderate by the literature and is much lower than what is observed in the U.S. (Sabatini, 2006). It is also not correlated with the relative share of white students in public school.

Table 1.7: Racial Segregation by Brazilian Metropolitan Areas

Metropolitan Area	**Dissimilarity Index**	**Share of Whites in Public School Relative to their Share in the Area**
Belém	0.241	0.88
Recife	0.293	0.74
Distrito Federal	0.298	0.80
Fortaleza	0.313	0.82
Curitiba	0.323	0.93
Belo Horizonte	0.342	0.74
Rio de Janeiro	0.364	0.72
São Paulo	0.373	0.85
Porto Alegre	0.393	0.91
Salvador	0.433	0.53

Source: PNAD 2012.

Since there is no strong residential segregation, it is unlikely to explain the school decision observed.[17]

[17] In the appendix I also calculate this index by income group.

1.5.2 Technology

An important variable that affects investment decisions is the rate of return. If returns to education are lower, there will be less investment in education, so if that is the case for black and brown individuals we would observe different educational choices for them.

Incidentally, in Chapter 2 I use an overlapping generations model with parental educational investment decisions to show that if returns to education vary with race, the old generation will make different educational choices for the offspring based on their race.

In order to calculate the returns to education, I estimate the following standard Mincer equation where y is the personal income for male individuals between 17 and 65 years old:

$$\ln y = \beta_0 + \beta_1 Education + \beta_2 Experience + \beta_3 Experience^2 + \mu. \tag{1.1}$$

The PNAD survey reports the age the individual started to work for most people, so experience is current age minus the initial working age. When this information is missing, I use the "potential" experience, which is represented by the individual's age minus the schooling years minus 6.[18] Table 1.8 shows the results.

If the individual is brown or black, she receives on average two thirds of the returns to education of whites.The difference in returns to education can be a result of unobservables or discrimination in the labor markets (Darity and Mason, 1998; Arcand and D'hombres, 2004). Arias et al. (2004) try to control for other characteristics by adding the parent's education (which I do not have in this sample) and a proxy for quality of education that varies across states. They still find lower (92%) returns for blacks and browns, though the difference is smaller than what I find.[19]

I focus on males to avoid the selection issue with female labor force participation, but the results with them included also provide different returns to education across races. Unfortunately, due to lack of data availability I cannot calculate the returns to private versus public because there is only data on the school system for those who are currently studying.

[18] Assuming the schooling years started at 6 years of age.

[19] Behrman and Birdsall (1983) and Teixeira and Menezes-Filho (2012) estimate returns to schooling in Brazil using a proxy for quality, but they do not estimate returns by race.

Table 1.8: Log of Personal Income - males aged 17-65

	(1) Blacks	(2) Browns	(3) Whites
Years of Schooling	0.05***	0.06***	0.09***
	(0.00)	(0.00)	(0.00)
Years of Experience	0.03***	0.03***	0.04***
	(0.00)	(0.00)	(0.00)
Years of Experience^2	-0.00***	-0.00***	-0.00***
	(0.00)	(0.00)	(0.00)
Married	-0.02	0.01	-0.03
	(0.03)	(0.02)	(0.02)
Constant	5.41***	5.17***	5.42***
	(0.18)	(0.09)	(0.13)
State and Occupation Controls	Yes	Yes	Yes
R^2	0.405	0.418	0.421
N	8199	40904	36741

Standard errors in parentheses.* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

If I look separately at different levels of schooling (Table 1.9), the difference in returns is statically significant at all levels.This gap in returns even for higher levels of schooling can reduce the parent's incentives to invest more in early education and make them more likely to choose free public schools.

In sum, it seems that the race effect for educational investment in Brazil is a result of differences in the returns to education. Black and brown families are less likely to enroll their children in private school because the additional financial burden may not produce enough returns to compensate it.

1.6 Conclusion

The quality of public institutions is distinctively low in developing countries. This contributes towards inequality since only those who can afford private schools will have access to better education and higher wages, creating a vicious cycle.

In this paper, I use Brazilian survey data to provide evidence that not only parental schooling and

Table 1.9: Log of Personal Income - males aged 17-65

	(1) Black/Brown	(2) Whites
More than Primary	0.22***	0.28***
	(0.01)	(0.02)
Some/Completed High School	0.42***	0.53***
	(0.01)	(0.02)
At least some College	0.87***	1.10***
	(0.02)	(0.02)
Years of Experience	0.03***	0.04***
	(0.00)	(0.00)
Years of Experience^2	-0.00***	-0.00***
	(0.00)	(0.00)
Married	0.01	-0.03
	(0.02)	(0.02)
Constant	5.32***	5.64***
	(0.09)	(0.13)
State and Occupation Controls	Yes	Yes
R^2	0.411	0.419
N	49267	36843

More than primary, 4-8 years of education, some high school, 9-11 years of education, at least college, more than 12 years.
Standard errors in parentheses.* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

income impact school choice but also race. I show that non-white families are more likely to enroll their children in public schools as opposed to private ones. I also show that there is no compelling evidence towards the assumptions of differences in preferences for education, peer preference or residential segregation. Instead, this educational choice is likely a result of different returns to education.

Given that browns and blacks receive lower returns for their schooling years, they are less likely to invest in private education for their children, even though it has better quality. This effect dissipates at higher income levels, when the income effects is stronger than the substitution one.

This is an important finding since this difference in educational investment may exacerbate the racial gap and contribute towards low intergenerational mobility and poverty traps. This shows that there is room for public policies in this context, which should be the goal of future research.

Chapter 2

Parental Educational Investment and Social Mobility with Heterogeneous Returns

Abstract

This work analyzes the role of returns to education for parental investment in human capital and social mobility. I employ an overlapping generations framework to model the parental investment in children's human capital in an educational setting with private and public schools. Human capital is produced according to a learning technology that takes into account ability, parent's human capital stock, and returns to education. I provide conditions under which there will be a human capital threshold separating households between the two systems. If racial groups differ only in their initial distribution of human capital the model does not generate the different school choices observed in the data. Evidence from Brazil suggests that parents make educational investments in their children based not only on their income and schooling but also on their race because of different returns (Chapter 1). So I extend the framework to allow for heterogeneity in the returns to education across racial groups and find that this assumption brings the model closer to the data as segregation appears in equilibrium, which may lead to poverty traps.

2.1 Introduction

Intergenerational mobility is particularly low in Latin America, and so is school attainment (see Behrman et al., 2001; Daude and Robano, 2015). Moreover, in countries like Brazil, income and education differ significantly when you compare whites and blacks, and this difference reflects on the social mobility of these racial groups.[1] For instance, Ferreira and Veloso (2006) show that black and brown individuals observe large persistence at low wages, while white ones have larger persistence at higher wages. Since education is the most significant pathway by which earnings are transmitted across generations in Brazil, it is important to analyze the early educational choices that parents make for their children.[2]

This paper contributes to the literature by modeling early educational investment in order to analyze the effect of returns to education for parental investment, and uncover the implications to intergenerational mobility. In Chapter 1, I show that non-white families in Brazil are more likely to choose public schools, even when controlling for income and education of the parents. And lower returns to education in the labor market seem to be the reason. This is a relevant finding because Brazilian public schools are free but have much lower quality when compared to private ones.

So here I build a model that helps explaining this educational decision and allows for policy analysis. I develop an overlapping generations (OLG) model to capture the interaction across generations and to study parental school choice in a mixed educational system.

In the model, each household is comprised of an individual from the young population and another from the old one. The young individual does not make any decisions and has an ability that is randomly assigned by nature and is realized in the next period. The old generation allocates the income after taxes between consumption and investment in the human capital accumulation of the offspring. This investment is represented by an educational choice between a public or private school, and each option will have a different cost and return, which are exogenous to the family. This binary choice results in a human capital threshold that sorts parents between the private and

[1] In Brazil, race is usually a self-declared characteristic among 5 groups: white (Caucasians), black (Afro-descendants), brown (mixed race, white and black descendants), yellow (Asians) and indigenous (native Brazilians).

[2] Lam and Levison (1992) calculate that education explains 50% of the earnings of a 30-year old male in Brazil. In the US it explains only 10% for the same group, for instance.

public system.

The assumption that parents decide the investment in human capital for the young generation seems to be reasonable for early stages of education, and in the literature can be traced back to Becker and Tomes (1979) and Loury (1981). On top of that, some studies (e.g. Glomm and Ravikumar, 1992; Glomm, 1997) analyze the effects of different educational systems focusing on comparing between non-simultaneous public and private educational models.[3] Nevertheless, in most economies both systems coexist and families are free to choose between them.

Some examples of other studies that analyze the outcomes of coexisting public and private regimes are namely Epple and Romano (1998); Glomm and Ravikumar (1996, 1998); Caucutt (2002); Cardak (2004). Yet, most of these papers assume that the offspring's ability is constant, which limits the dynamic analysis, and that taxes arise from majority voting, which is consistent with the American context where people choose the school quality by choosing where to live, but not with the Brazilian one.

Using this binary choice model of parental school decision in an OLG framework, I show that with quasi-linear preferences there is no interaction across agents, so there is always an equilibrium with positive taxes and it is unique. Moreover, depending on the distribution of ability, there will be convergence to a unique stationary distribution of human capital in steady state. So if I assume that racial heterogeneity only appears in the human capital distribution, the school choice will not depend on race, so given a human capital level everyone will make the same decision, and any initial differences disappear in the long run.

In order to match the educational choice patterns observed in the data, additional heterogeneity must be considered. In Chapter 1 I do not find evidence of different preferences, residential segregation or peer preference, but the literature shows that non-white families receive lower returns to education. So I extend the model to allow for different returns across racial groups, and show that if a group receives lower returns they will have a higher human capital threshold to choose private schools. Then, even controlling for the human capital level, families can make different school choices based on their race.

[3]There are also some papers that focus on the education and growth problem but without assuming parental choice, e.g. Iyigun (1999); Chen (2005); Blankenau et al. (2007).

So I provide theoretical evidence on the effects of heterogeneous returns to education on parental educational investments. This paper uses economic theory to guide the interpretation of data and to help shape public policy.

The remainder of the paper is structured as follows. The next section describes the model and discusses the equilibrium outcomes. Then Section 2.3 discusses how to extend the model in order to capture the school choice outcome observed in the Brazilian context. The final section presents some additional discussions.

2.2 School Choice Model

Consider an OLG framework where agents live for two periods. In the second period of life, each individual gives birth to another, resulting in no population growth. Agents accumulate human capital when young and supply labor when old.

Following Loury (1981) and Borjas (1992), I focus on parental school decisions since early schooling represents the relevant educational choice for most families and is typically determined by the parents. Therefore, the investment in education for the accumulation of human capital of the young generation will be decided by the old generation.

The parent's choice is between a public (u) or private (i) school, which coexist in this economy similarly to Epple and Romano (1996, 1998), Glomm and Ravikumar (1998), Cardak (2004) and Caucutt (2002). Human capital accumulates according to a learning technology that is common to all families and depends positively on the child's unobserved innate ability (θ), the parent's human capital stock (h) and the returns of their educational choice (e); $h' = L(\theta, h, e)$. The learning technology characterizes social mobility in this economy and is corroborated by empirical evidence.[4]

Following the literature, I will assume that $L(\cdot)$ is a Cobb-Douglas function of the form; $\theta h^{\alpha} e^{\gamma}$, where $\alpha, \gamma \in (0, 1)$. In addition, I assume that ability follows a time invariant distribution independent of the parent's human capital, $\theta \overset{iid}{\sim} G$. Returns to public and private education, $\{e^u, e^i\}$, also represent the system's quality and are the same for every student.

[4]See Card and Krueger (1992a); Behrman et al. (2001).

So ability, or productivity shock, is the stochastic component and the family has two channels of influence; the exogenous one coming from the parents' human capital impact on the offspring's human capital accumulation, and the discretionary one, via the choice of investment in the child's education.

Public education expenditure per student is given by $e^u = \frac{\tau_t H_t}{P_t}$, where P_t is the size of the population choosing public education and $H_t = \int h \, dF_t(h)$ is the aggregate human capital stock at t, given the distribution of human capital, F_t. The tax level is adjusted every period to achieve the targeted per-student expenditure of public schools.[5] I assume that there is a technology to produce education in the private sector with a cost of q units per student.

The cost of education, $Q(s)$ for school choice $s \in \{u, i\}$, depends on the system chosen. With public schools being free for everyone ($Q(u) = 0$) while financed by taxes, and private schools charging a tuition ($Q(i) = q$).

I assume parents to be altruistic and care about not only their consumption, but also the bequest left to the offspring in terms of human capital. So the old generation at t takes as given the level of taxes and their own human capital and solves the following problem:

$$\max_{\{c_t, s_t\}} \ \mathbb{E}_\theta\{U(c_t, h_{t+1})\} \tag{2.1}$$

$$s.t. \quad c_t + Q(s_t) = (1 - \tau_t)h_t, \tag{2.2}$$

$$h_{t+1} = \theta h_t^\alpha e(s_t)^\gamma, \tag{2.3}$$

$$given \ h_t, \tau_t.$$

The optimal choice of consumption and educational investment are subject to the old generation's budget constraint, (2.2), which depends on the current taxes and the human capital stock of the old generation.[6] The human capital stock of the old generation cannot be modified in the current

[5]The public sector is passive in this model for simplicity, but this is quite consistent with the Brazilian case. In Brazil there is a fund per state to finance education (Fundeb). State and municipal governments transfer the education-bound taxes, and resources are then redistributed according to enrollments for each school. The federal government supplements the budget when necessary to reach the minimum annual per student expenditure (see Brasil, 2008).

[6]I assume they supply their labor inelastically and wages are normalized.

period, and is determined by the realized ability shock and her parent's human capital and school choice in the previous one, as in (2.3). The school choice is independent across generations.

Replacing (2.2) and (2.3) into (2.1), the problem of the old generation at t can be simplified to:

$$\max_{\{s_t\}} \mathbb{E}_\theta\{U\left((1-\tau_t)h_t - Q(s_t),\ \ \theta h_t^\alpha e(s_t)^\gamma\right)\} \tag{2.4}$$

$$given\ h_t, \tau_t.$$

So the expected utility of a parent with capital stock h_t, paying τ_t in taxes, and choosing an arbitrary school system is:

$$V(h_t, \tau_t, i) = \mathbb{E}_\theta\left\{U\left((1-\tau_t)h_t - q,\ \theta h_t^\alpha e^{i\gamma}\right)\right\}, \tag{2.5}$$

$$V(h_t, \tau_t, u) = \mathbb{E}_\theta\left\{U\left((1-\tau_t)h_t,\quad \theta h_t^\alpha e^{u\gamma}\right)\right\}. \tag{2.6}$$

Private school will be an optimal choice if $V(h_t, \tau_t, i) > V(h_t, \tau_t, u)$. Given that it is only optimal to spend a positive amount on education when there are higher returns, the quality of a private school must be higher than the quality of a public school ($e^i > e^u$) to allow for private schools in equilibrium.

Assumption 1 *For $\Delta V(h_t, \tau_t) \equiv V(h_t, \tau_t, i) - V(h_t, \tau_t, u)$ continuous and $h_1, h_2 \in \mathbb{R}_+$, if $h_1 > h_2$ then $\Delta V(h_1, \cdot) > \Delta V(h_2, \cdot)$.*

Assumption 1 means that $\Delta V(h_t, \tau_t)$ is increasing in h, which implies that households with higher human capital will have a higher expected utility for choosing private education.[7]

I show in Appendix C the following result:

Proposition 1 *If Assumption 1 holds, there exists a unique $h^*(\tau_t)$ such that $\Delta V(h^*(\tau_t), \tau_t) = 0$. And for all $h_t \geq h^*(\tau_t)$, $s(h_t, \tau_t) = i$. In addition to that, with additively separable preferences, $h^*(\tau_t)$ is increasing in τ_t.*

[7] This assumption is similar to the single-crossing condition or supermodularity.

Proposition 1 states that, for a given tax rate, there will be a unique human capital threshold sorting households between the public and private system. This result is similar to the income threshold in Glomm and Ravikumar (1998) and Cardak (2004), and the minimum inheritance amount in Galor and Zeira (1993) necessary for individuals to decide to invest in human capital. The equilibrium is defined next.

2.2.1 Equilibrium

Given an initial distribution of human capital, F_0, preferences and the learning technology, an equilibrium for this economy is given by a sequence of school choices $\{s(h_t, \tau_t)\}_t$, public education outcomes $\{P_t, \tau_t\}_t$, and distributions of human capital $\{F_{t+1}\}_t$ such that:

1. Given q, (2.4) is maximized by $s(h_t, \tau_t)$
2. Distribution of human capital is given by $F_{t+1}(\tilde{h}) = \int \int \mathbb{1}_{[\theta h^{\alpha} e(s_t)^{\gamma} < \tilde{h}]} \, dF_t(h) dG(\theta)$
3. The government maintains a balanced budget; $\tau_t H_t = e^u P_t$

This economy is fully characterized by the distribution of human capital. Every period starts with a distribution of human capital for the old generation (F_t). Then, given taxes and individual human capital, the old generation chooses the optimal school choice, $s(h_t, \tau_t)$, depending on the sign of $\Delta V(h_t, \tau_t)$. Simultaneously, equilibrium taxes are determined by the aggregate level of human capital and the amount of public school students:

$$\tau_t(h_t^*) = \frac{e^u P_t}{H_t} = \frac{e^u N \int_0^{h_t^*} dF_t(h)}{H_t} = \frac{e^u N F_t(h_t^*)}{H_t}, \tag{2.7}$$

where N is the size of the population and h_t^* is the human capital threshold for a given tax rate at t that solves

$$\Delta V(h^*(\tau_t), \tau_t) = 0. \tag{2.8}$$

Given τ_t, the threshold is pinned down as shown in Proposition 1. But the equilibrium τ_t, or more precisely P_t (the number of agents for whom public education is optimal), will depend on h_t^* itself.

After the school choice has been made, and the ability shocks are realized, the next period distribution of human capital (F_{t+1}) is determined. Following Assumption 1, the school choice is monotonic in the human capital of the parents. If the household head has human capital below (above) the threshold, the young one will attend public (private) school and will accumulate human capital according to:

$$h_{t+1}(\theta) = \begin{cases} \theta h_t^{\alpha} e^{u\gamma}; & if\ h_t < h^*(\tau_t), \\ \theta h_t^{\alpha} e^{i\gamma}; & if\ h_t \geq h^*(\tau_t). \end{cases} \tag{2.9}$$

For an equilibrium to exist, the tax-threshold pair must satisfy equations (2.7) and (2.8) simultaneously. So when Assumption 1 holds, for a given tax rate, the human capital threshold will be unique. But, given the human capital threshold, there may not be a positive tax rate that solves equation (2.7) because the tax rate is increasing on the threshold itself.

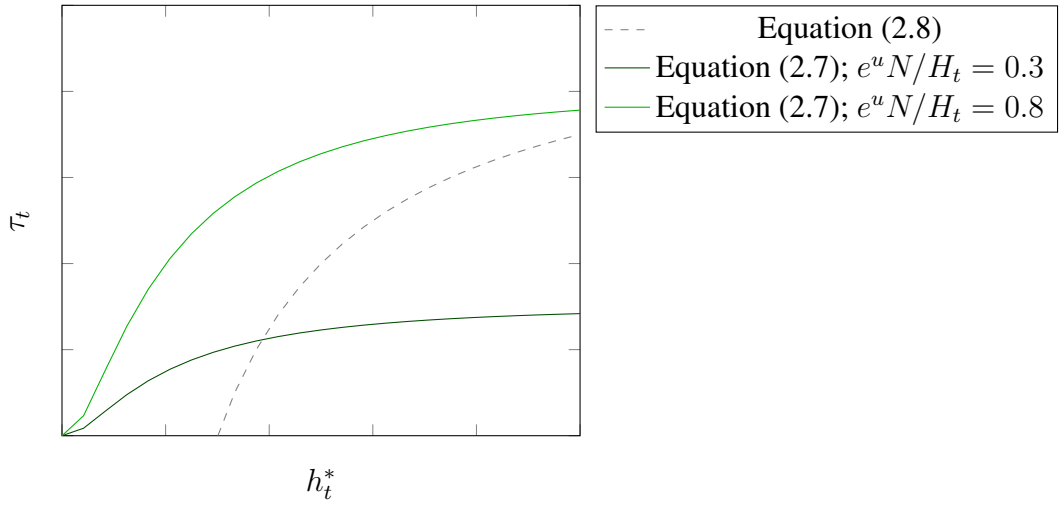
Lemma 1 *Given a concave and separable utility function and assuming* $\frac{\partial \Delta V(h,\cdot)}{\partial h} > 0$*,* $h^*(\tau_t)$ *is increasing in* τ *so the budget surplus,* $\tau_t H_t - e^u N F_t(h^*(\tau_t))$*, is not monotonic in* τ_t*.*

The higher the taxation the lower the disposable income, and the higher the human capital threshold needs to be to make agents indifferent. But the higher the human capital threshold, the more people will be enrolling in public schools, so taxes must increase to finance public education. So the fraction of agents choosing publicly provided education (P_t) also depends on the public sector taxation.

A numerical example can provide some helpful intuition. Assume preferences are such that $U(c_t, h_{t+1}) = \ln c_t + \ln h_{t+1}$, so the threshold is given by $h^*(\tau_t) = \frac{e^{i\gamma}}{[e^{i\gamma} - e^{u\gamma}]} \frac{q}{(1-\tau_t)}$, and that F is the cumulative density of a lognormal distribution. Figure 2.1 illustrates $\tau_t = 1 - \frac{e^{i\gamma} q}{[e^{i\gamma} - e^{u\gamma}] h^*}$ (Equation 2.8) and $\tau_t = \frac{e^u N F_t(h_t^*)}{H_t}$ (Equation 2.7) for some parameter combinations.

In this example, when $e^u = 0.3 H_t/N$ there is a tax-threshold pair that satisfies both equations. But when the returns to public school are high ($e^u = 0.8 H_t/N$), for a given tax rate, the associated share in public school that balances the government budget results in a human capital threshold lower than the one implied by the individual's school choice rule (Equation (2.8)). Meaning that for a given level of taxes, there will be too many people choosing public, creating a deficit in the

Figure 2.1: Equilibrium human capital threshold and tax rate



Graphic representation of equations (2.7) and (2.8) assuming $U(c_t, h_{t+1}) = \ln c_t + \ln h_{t+1}$, $e^u = 4$, $e^i = 9$, $\gamma = 0.5$ and $q = 10$, and F is the cumulative density of a lognormal distribution with average 3 and standard deviation 1.

budget. So an equilibrium with a positive tax rate does not exist.

If $\tau_t = 0$, then $e^u = 0$ and the human capital threshold is given by $\Delta V(h^*, 0) = 0$. So, given Assumption 1, there is always an equilibrium with zero taxes and no public schools, but there may not be one with positive taxes.

Quasi-linear preferences

When public policy affects individual's choice, it creates an intragenerational link. In this section I characterize the equilibrium assuming quasi-linear preferences to shut down the income channel which turns this economy into a single-agent problem.

Quasi-linear preferences have the simplifying property that the marginal rate of substitution does not depend on the linear argument. So if $U(c_t, h_{t+1}) = c_t + u(h_{t+1})$ for u increasing and strictly concave, the school choice is independent of taxes. In this case, the human capital threshold only depends on the returns to education and the expected ability of the offspring.

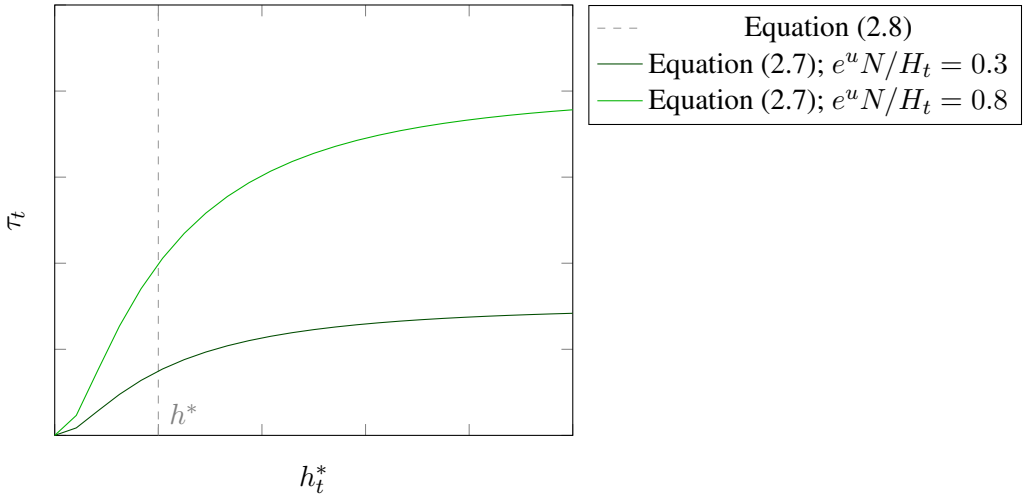
Lemma 2 *With quasi-linear preferences, the human capital cutoff for the school choice does not depend on taxes. It is given by* $\Delta V(h^*) = 0 \Rightarrow \mathbb{E}_\theta \left\{ u(\theta h^{*\alpha} e^{i\gamma}) - u(\theta h^{*\alpha} e^{u\gamma}) \right\} = q$.

This assumption on preferences, together with Assumption 1, implies that there exists a unique

human capital level that solves equation (2.8) and is time-independent.[8] Given this threshold and assuming that the distribution of human capital is continuous, there will be a tax rate $\tau_t(h^*) \in (0,1)$ which satisfies equation (2.7), and the equilibrium will be given by $(\tau_t(h^*), h^*)$.

And because the government budget surplus is strictly monotonic in τ_t in this case, the equilibrium is also unique. An example is illustrated in Figure 2.2.

Figure 2.2: Equilibrium human capital threshold and tax rate



Graphic representation of equations (2.7) and (2.8) assuming $U(c_t, h_{t+1}) = c_t + h_{t+1}^{\sigma}$ for $\sigma \in (0,1]$, $e^u = 4$, $e^i = 9$, $\gamma = 0.5$ and $q = 10$, and F is the cumulative density of a lognormal distribution with average 3 and standard deviation 1.

Proposition 2 *Assuming quasi-linear preferences, for any $\tau_t \in (0,1)$ there exists a unique h^* which solves equation (2.8). And given this h^*, there exists a unique $\tau(h^*)$ which solves equation (2.7).*

Proposition 2 implies that an equilibrium school choice for this economy is given by $s(h_t) = u$ if $h_t < h^*$ and $s(h_t) = i$ otherwise, for any τ_t.

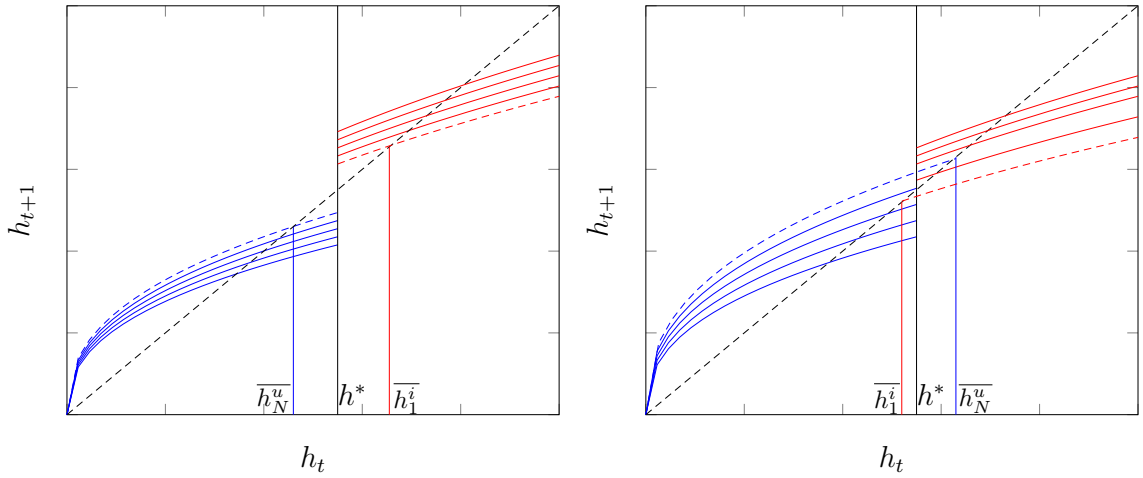
To illustrate the evolution of human capital under these conditions, let θ be distributed in the ordered set $\{\theta_1, ..., \theta_5\}$. Figure 2.3 shows the transition for h_{t+1} with the curves in red (top) representing individuals that attended private school and in blue (bottom) a public one. The different levels depict the distribution of ability, and h^* is the human capital threshold for the school choice.[9]

[8] Examples of functions that satisfy both properties are discussed in Appendix C.

[9] Meaning that each line in each color block represents one value of θ, and the ones in blue have returns e^u while the ones in red have e^i.

I represent the fixed point for each of these curves as $\overline{h_n^s}$ where $s \in \{u, i\}$ and $n \in \{1, ..., 5\}$. So, for instance, $\overline{h_1^u}$ is the convergence point for the dynasty that only received the lowest shock θ_1 and always attended the public system.[10]

Figure 2.3: Human Capital Evolution



Graphic representation of equation (2.9). The graph on the left reflects an economy without mobility across systems and with two steady state distributions. The right one depicts an economy with mobility, implying in a unique stationary distribution.

If the distribution of the shocks has a small variance, depicted in the graph on the left, we can observe multiple steady states resembling the threshold effect in Azariadis and Drazen (1990) and the technological non-convexity in Galor and Zeira (1993). In this case, there will be two stationary human capital distributions and dynasties that start with human capital below (above) the human capital cutoff will remain in that area. This scenario implies in a poverty trap and virtually no mobility since a lineage that is initially poor (rich) ends up poor (rich) in the long run as well.

But empirical evidence shows that some degree of mobility is observed, and some parents who attended public schools may enroll their children in private ones. Assuming a higher variance in the ability shocks, as depicted in the graph on the right of Figure 2.3, individuals who inherit less than h^* will go to a public school but may also receive a high ability shock that will increase their human capital next period. If this happens for several sequential periods, eventually one descendant will cross the threshold and enroll her offspring in a private school with higher returns. The inverse is also true, so with enough mixing there is a positive probability of having a sequence of bad or good

[10]Notice that I am assuming that h^* is between the lowest and highest fixed points. If this does not hold, long-run distributions of human capital are concentrated in either the public sector or in the private one.

shocks, which would make a dynasty's accumulation of human capital cross the threshold at some point in time.

In this case, there will be convergence to a unique stationary distribution, independent of the initial one. This result is summarized in the next proposition.[11]

Proposition 3 *Assuming quasi-linear preferences that satisfy Assumption 1, a continuous distribution of human capital and a distribution of ability shocks with enough variance (reflecting some mobility in the economy), if $\{F_t\}_t$ is a sequence of human capital distributions originating from an initial distribution F_0, then F_t will converge to a unique equilibrium distribution $\overline{F}$ with support in $[\overline{h_1^u}, \overline{h_N^i}]$.*

The reason for equilibrium uniqueness in this case is the lack of interaction across agents, similar to the *laissez-faire* case in Glomm and Ravikumar (1996). The distribution of ability allows for convergence, which does not happen in Cardak (2004). But regardless of the assumptions on the ability distribution, this model has the optimal school choice depending only on human capital differences. So even if one assumes that the initial human capital distribution differs between some groups, it will not result in different school choices across them once we control for income.

If additional heterogeneity is introduced into the model, it may generate different school choices. This additional assumption is discussed in section 2.3.

2.3 Heterogeneous Returns

If differences in endowments fully explain school choice, behavioral differences are not relevant. However, in Chapter 1 I show that not only human capital and schooling affect parental educational investment in Brazil but also race, since non-white families are more likely to enroll their children in public schools, which have low quality. Thus, a model that intends to analyze parental educational investment and socioeconomic mobility in that context must be able to generate this race effect in equilibrium.

[11] Details of the proof can be found in appendix C.

If I assume that human capital distribution differs across racial groups, the benchmark model presented in the previous section would fail to deliver a school choice that depends on the race. In the case depicted on the leftward graph in Figure 2.3, the racial share would be different in each steady state distribution, but the school choice would not depend on the race. For instance, if black families start with a human capital distribution skewed towards the left side of the threshold, there will be a concentration of blacks in the public school system, but the threshold itself does not depend on the race.

Under the assumptions behind the rightward graph, even if the initial distribution of human capital differs across racial groups, this initial difference will disappear with time and there will not be a poverty trap. However, the school choice threshold still does not depend on race. This means that additional heterogeneity must be considered so the model is not rejected by the data.

Controlling for differences in endowments, educational investment can be a result of preferences and technology. Taking into account the empirical evidence in Chapter 1, I assume that it is coming from the technology side with returns to education varying with the racial group (R).[12]

Assumption 2 *Returns to the school choice vary with race (e^R). In particular, whites receive higher returns; $e^W > e^B$.*

The new problem is given by:

$$\max_{\{s_t\}} \mathbb{E}_\theta \left\{ U\left((1-\tau_t)h_t - Q(s_t),\ \theta h_t^\alpha e^R(s_t)^\gamma\right)\right\} \tag{2.10}$$
$$given\ h_t, \tau_t.$$

Given Assumption 2, the optimal investment in education depends on race, since the human capital threshold for the school choice will be different for each group.

Moreover, by assuming quasi-linear preferences I close the income channel and focus only on the role of racial heterogeneity on the school choice threshold. This becomes a single-agent problem

[12] One reason for this can be discrimination in the labor market, see Darity and Mason (1998), Arcand and D'hombres (2004).

and an equilibrium always exists, as mentioned in the previous section. For $U(c,h) = c + h^{\sigma}$, the human capital threshold for race (R) is given by:

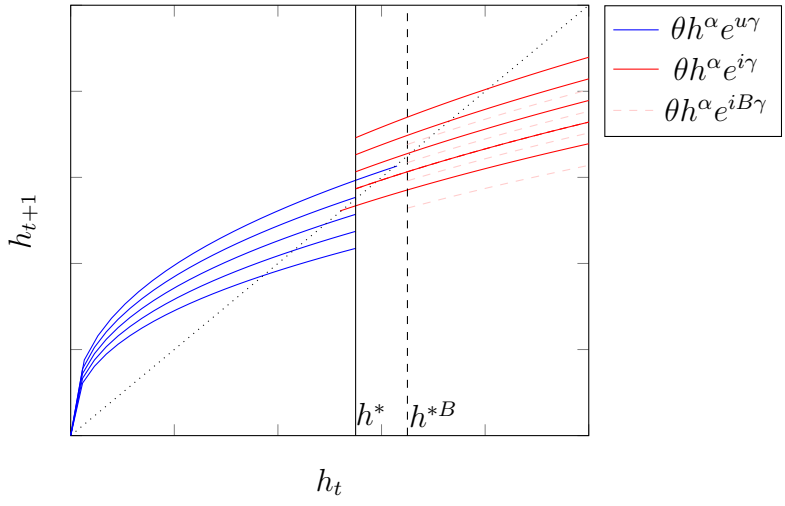
$$h^{*R} = \left\{ \frac{q}{\mathbb{E}(\theta^{\sigma})[(e^{iR})^{\gamma\sigma} - (e^{uR})^{\gamma\sigma}]} \right\}^{1/\alpha\sigma}. \tag{2.11}$$

Proposition 4 *If Assumption 2 holds for the returns to private education and preferences are quasi-linear, the human capital threshold for the parental choice will be higher for non-white individuals.*

Since $e^{iW} > e^{iB}$, we have $h^{*W} < h^{*B}$. So even at the same human capital level, the school choice may be different across races.[13]

Figure 2.4 depicts the human capital evolution with two thresholds due to different returns to private school. The blue (left) lines represent the human capital accumulated after public school and the red (right) ones after private. The pink (light) curves represent the accumulation with the lower private returns. For individuals between h^* and h^{*B}, the school choice will be different depending on their race.

Figure 2.4: Human Capital Evolution - Heterogeneous Returns



Graphic representation of equation (2.9). The graph depicts an economy with mobility and two human capital thresholds, h^* and h^{*B}.

This assumption seems to bring the model closer to the school decision observed in Brazil where blacks and browns are more likely to choose public school.

[13] Higher return to private education is a sufficient condition, but not necessary. As long as $(e^{iW})^{\gamma\sigma} - (e^{uW})^{\gamma\sigma} > (e^{iB})^{\gamma\sigma} - (e^{uB})^{\gamma\sigma}$, the result holds.

2.4 Discussion

This paper analyzes human capital investment, focusing on early education with parental choice and heterogeneous returns. I provide a simple OLG model where the old generation chooses consumption and investment in the education of the offspring, which is a binary choice between coexisting public and private school. I characterize the equilibrium and show that only differences in human capital do not account for the fact that in Brazil non-white parents are more likely to choose public school even when controlling for income.

So I add a data-motivated assumption that the returns to education are not the same for everyone to bring the theoretical result closer to the data. With the assumption of different returns, the model is able to reconcile with the observed school choice.

I should acknowledge the limitations of the model. It uses simple functional forms and ignores differences in the intensive margin of schooling, progressive taxation and educational choices for other life stages. Extending the model in that direction would enrich the understanding of intergenerational mobility.

However, the model presented here can help evaluate the consequences of policies that seek to promote early interventions, which tend to be more successful than later interventions in improving human capital outcomes (Keane and Wolpin, 2000; Restuccia and Urrutia, 2004). Equalizing endowments would not completely change the race driven school choice but some policies, such as a conditional cash transfer or a voucher program, could spur parents to make better educational investments, which would contribute to build human capital and help break the intergenerational cycle of poverty, improving opportunities later on.

This paper contributes to the literature on educational choice and helps to bring evidence to the importance of returns to education for parental choice, social mobility and public policy.

Chapter 3

Parental Educational Choice and School Vouchers

Abstract

This paper studies an overlapping generations model of parental educational choice with public and private education alternatives. I use survey data from Brazil to estimate the technology parameters via a simulation-based method, and then use those estimations to perform conterfactuals to analyze the impact of private education vouchers. The results indicate that vouchers generally increase income and reduce inequality, but the welfare gains depend on size and design.

3.1 Introduction

Economists have long been interested in educational vouchers since Friedman (1962) argued that vouchers would raise the quality of the public sector through increased competition and at the same time improve education for the poor. In countries like Brazil, where educational attainment is low and the quality of public schools is much inferior compared with their private counterparts, there are even greater potential gains to be extracted with policy interventions in education.

This paper studies the implications of private education vouchers for wealth, inequality and welfare. I use an overlapping generations model where the parents make an educational investment in their children by choosing between a public or private school. Public education is tax financed and provides a uniform return equivalent to the per student expenditure. Private schools charge a flat rate tuition and provide a higher return than the public sector. Human capital evolves according to a learning technology that includes the ability of the young generation, the human capital stock of the old generation, and the return of the school system chosen by the parents.

I use the 2012 Brazilian National Household Survey (PNAD) to draw the initial distribution of human capital, and the 2011 National High School Exam (ENEM) is used to obtain the distribution of abilities. The parameters are chosen to minimize the distance between the model generated moments and the ones observed in the data. Since evidence from Brazil (Chapter 1) suggests that parents make educational investments in their children based not only on their income and schooling but also on their race, I allow the returns to vary with the racial group. The simulated method of moments estimates lower returns for non-white individuals and matches the race effect in the data.

The estimation is done without vouchers in the model to match the Brazilian context, but they are introduced in the policy analysis section as a counterfactual. The voucher represents a subsidy to private-education households only, and I compare different designs such as universal or targeted, with a flexible government budget or fixed.

The policy analysis identifies two main results. First, private education vouchers increase average income and reduce inequality. Second, the welfare cost of introducing vouchers is increasing in the voucher size, but for small values the welfare cost is actually negative which represents a welfare gain. Besides, a targeted voucher could reduce school segregation while providing welfare gains, and future generations always benefit from the introduction of a voucher program.

There is a wide range of empirical and theoretical work on school vouchers.[1] My work is most closely related to Cardak (2005), however, there are a few key differences. Namely, I have agents differing in not only income but also ability like in Epple and Romano (1998), and parents receive utility from the human capital that the child accumulates, like in Caucutt (2002).

[1] For a review of the latter, former and both literatures see Epple and Romano (2012); West (1997); Epple et al. (2015) respectively.

Among the empirical papers the findings diverge depending on where and how the vouchers are implemented.[2] Rouse (1998) shows evidence of achievement gains in math among students selected for a voucher program in Wisconsin, while Wolf et al. (2010) find no effect for math but a significant one for graduation rates in Washington, DC. Epple et al. (2015) review the literature on the School Choice Scholarship program and find that they were able to improve test scores, graduation rates and college enrollments, but only for African American students.

In the developing world, there has been some successful programs as well. Angrist et al. (2002) show that the winners of a voucher lottery in Colombia scored higher on achievement tests and were more likely to graduate.[3] Large scale programs like the one in Chile pose a challenge in terms of a clear identification of a counterfactual, but most of the evidence points towards an increase in stratification but with an increase in 8th-grader's math and science scores.

To summarize, the existing empirical evidence, while uneven, is sufficiently encouraging for continued experimentation and evaluation of voucher programs. The fact that the empirical evidence typically uses reduced-form models and sometimes faces difficulties in obtaining a clear control group spurs the development of quantitative analysis to evaluate the possible effects of vouchers before they are implemented.

This paper is organized as follows. The model is described in the next section. In Section 3.3 I present the estimation results, and in Section 3.4 I compare the effects of different designs of a voucher program using the estimated model. Section 3.5 concludes.

3.2 Environment

Consider an overlapping generations framework where agents live for two periods. In the first period agents only accumulate human capital. In the second period of life they supply labor inelastically, pay taxes and choose how to distribute their income between consumption (c) and investment

[2]Among the several voucher programs that exist around the world, some are local while others are available for the whole country, some have been explicitly designed as experiments, others use lotteries to allocate the slots when over-subscribed, and they can be publicly or privately funded.

[3]It is important to note that public schools in Colombia are probably much worse than the private ones, like in Brazil, and the program required students to maintain satisfactory academic progress.

in the education of the offspring ($Q(s)$).

The parental investment in education is binary and their choice is between a public ($s = u$) or private ($s = i$) school, that coexist in this economy similarly to Epple and Romano (1996, 1998), Glomm and Ravikumar (1998), Cardak (2004) and Caucutt (2002). Public schools are free for everyone and are financed by taxes, while private schools charge a flat rate tuition (q). Each school system will deliver a different return that will enter in the human capital accumulation function of the offspring.

Human capital accumulates according to a learning technology that is common to all families and depends positively on the child's innate ability (θ), the parent's human capital stock (h) and the returns of their educational choice $\left(e(s) \in \{e^u, e^i\}\right)$, such that $h' = \theta h^\alpha e(s)^{1-\alpha}$. I assume that parents observe the ability of the child to facilitate the estimation procedure.[4]

The return to public school is characterized by the public education expenditure per student and is given by $e^u = \frac{\tau_t H_t}{P_t}$, where P_t is the population choosing public education and $H_t = \int h \, dF_t(h)$ is the aggregate human capital stock at t, given the distribution of human capital, F_t. I assume that there is a private-education production technology that charges q and delivers e^i to every student.

Parents are altruistic in the sense that they care about the human capital accumulated by the offspring (similar to Caucutt, 2002) and have quasi-linear preferences given by $U(c, h') = c + \sqrt{h'}$.[5]

So the old generation at t takes as given the level of taxes and their own human capital and solves the following problem:

$$\max_{\{c_t, s_t\}} \; c_t + \sqrt{h_{t+1}} \tag{3.1}$$

$$s.t. \quad (1 - \tau_t)h_t = c_t + Q(s_t), \tag{3.2}$$

$$h_{t+1} = \theta h_t^\alpha e(s_t)^{1-\alpha}, \tag{3.3}$$

$$given \; h_t, \tau_t.$$

[4]This creates variance in the school choice across families and avoids the complete separation issue that would happen when calculating some of the moments.

[5]With quasi-linear preferences it becomes a single agent problem and a unique equilibrium always exists, as shown in Chapter 2.

Because the school choice binary, there is a human capital threshold that makes the agent indifferent between public and private education, and above this level they prefer private and below public. Given the quasi-linear preferences, this threshold only depends on the cost and returns to education and the ability of the offspring, and is independent of taxes, as shown in Lemma 3.[6]

Lemma 3 *Given the optimization problem in equations* (3.1)-(3.3)*, the human capital threshold that makes the old generation indifferent between the school choices is defined by*

$h^*(\theta) = \left[\frac{q}{\sqrt{\theta}(e^{i(1-\alpha)/2} - e^{u(1-\alpha)/2})}\right]^{2/\alpha}$.

Given an initial distribution of human capital, F_0, preferences and the learning technology, an equilibrium for this economy is given by a sequence of school choices $\{s(h_t, \tau_t)\}_t$, public education outcomes $\{P_t, \tau_t\}_t$, and distributions of human capital $\{F_{t+1}\}_t$ such that: 1) Given q, (3.1) is maximized by $s(h_t)$ subject to (3.2) and (3.3); 2) the distribution of human capital at $t+1$ is given by $F_{t+1}(\tilde{h}) = \int\int \mathbb{1}_{[\theta h^\alpha e(s_t)^\gamma < \tilde{h}]}\, dF_t(h) dG(\theta)$; 3) and the government maintains a balanced budget.

Notice that if the returns are different for some groups (like racial groups), the threshold will depend on the group as well, so the educational investment will be different even for individuals with the same human capital level. I continue to estimate some key parameters using Brazilian data, and I allow these returns to vary with race, as suggested in Chapter 1.

3.3 Estimation

I use simulated methods of moments to estimate the model and match some key facts from the data. The goal in this approach is to choose a set of structural parameters to minimize the weighted distance between selected moments from the observed sample and the estimated model.

Let M^d denote the vector of moments obtained from the data, and $M^m(p)$ an average vector of moments calculated from S simulated data sets given a vector of parameters p. Then the estimated parameters, $\hat{p}$, are obtained from:

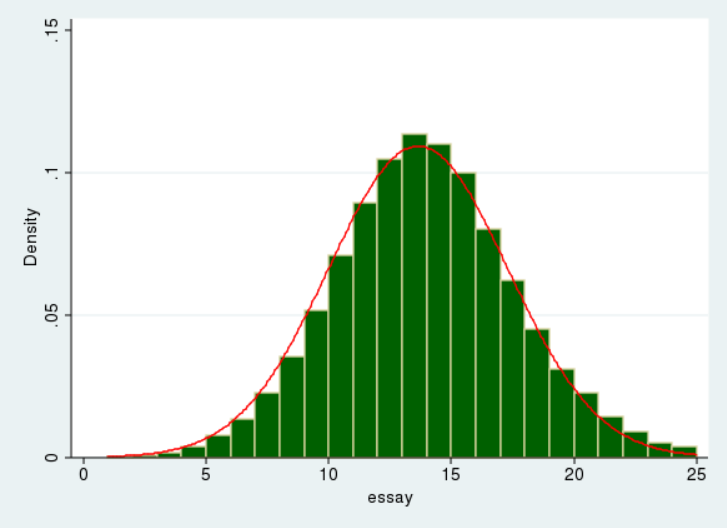
$$\hat{p} = \arg\min_p \left(M^d - M^m(p)\right)' W \left(M^d - M^m(p)\right). \tag{3.4}$$

[6]For an analysis with more general preferences see Chapter 2.

where W is the weighting matrix. I set W to be the identity matrix, which provides consistent estimations.

The agent's type, θ, is assumed to be summarized by her cognitive abilities, so I calibrate it according to the distribution of the essay scores in the 2011 National High School Exam (Figure 3.1).[7]

Figure 3.1: Histogram of Normalized Essay grades



Average 13.65 and sd 3.65. Density with same sized bins and fitted Normal.

In Chapter 1 I show that the parental educational choice varies with race and is likely a result of different returns to education. So in the estimation I allow the returns to private education to be different for each racial group (whites and blacks/browns).[8] I normalize the return to public school to 1 for both racial groups, and the cost of private education is set to be 15.[9] All calibrated parameters can be seen in Table 3.1.

The parameters left to be estimated are the share of the parent's human capital in the learning technology and the returns to private school for whites and non-whites $\{\alpha, e^{iW}, e^{iB}\}$. For a given vector of parameters, I solve the model numerically and compute the human capital threshold which will generate the school choice (Lemma 3) at a given moment in time, out of steady state.

[7]This is a national non-mandatory exam that since 2009 has been used as part of the entrance exam to most universities in Brazil. It consists of questions on math, science, languages and an essay part.

[8]Race in Brazil is self-declared among 5 groups; white (Caucasians), black (Afro-descendants), brown (mixed race), yellow (Asians) and indigenous (native Brazilians). I will look at Browns and Blacks as one group versus Whites, together they represent 99% of the population.

[9]This price is also normalized by the returns to public, and was set to better match the total shares in public.

Table 3.1: Calibrated Parameters

Parameter	Value
θ	$N(13.65, 3.65^2)$
e^u	1
q	15

I simulate a series of human capital distributions for the old generation S times, and the human capital is randomly drawn from a lognormal distribution with mean and standard deviation taken from the 2012 PNAD.[10] I simulate the distribution for blacks/browns and whites separately to match the average and standard deviation of the household income per capita in the data, and this distribution does not change throughout the estimation procedure. After guessing an initial value for the parameters, I run the minimization procedure to estimate the optimal parameters on the transition between the old and young generation.

The moments I am targeting are the aggregate share in public school for both racial groups, a probit estimation of the probability that the child in school age went to public school and not private (Table 3.2), and the degree of intergenerational persistence in the population. The first two I calculate from the 2012 PNAD and the degree of persistence I take from Ferreira and Veloso (2006) who use the 1996 PNAD supplemental survey.

Table 3.2: Empirical Probit Coefficients for Public School Choice - PNAD 2012

	(1) Students
Household Income per capita (log)	**-0.76*****
	(0.02)
Household head black or brown	**0.28*****
	(0.02)
Parents Schooling	-0.10***
	(0.00)
State and Urban Area dummies	Yes
Observations	70445

Standard errors in parentheses. Constant omitted. Sample of K-11 students. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The degree of intergenerational persistence is given by β in[11]

[10] I chose S to be 20, but other choices did not affect the results.

[11] Also known as intergenerational elasticity of earnings, it is calculated over the entire population.

$$\ln y'_j = b_0 + \beta \ln y_j + u_j, \tag{3.5}$$

where y and y' are the father's and son's permanent wage respectively, and $1 - \beta$ is known as the intergenerational mobility degree. A higher β implies higher persistence and thus lower intergenerational mobility. I try to match the coefficient provided in table 6 of Ferreira and Veloso (2006) with all the controls, but it is fairly similar to the one with only a dummy for race, which is the one I estimate from the model.[12]

To take the model to the data, after I calculate the human capital threshold and derive the the school choice, I estimate a probit model of school choice where the dependent variable is 1 if the old generation chose public school and 0 otherwise. I also calculate the aggregate shares in public in the young population by race, and regress the logged human capital of the old generation next period on the current old generation's human capital. The results can be found below.

3.3.1 Results

The model fits the data quite well. Table 3.3 shows the data and model moments. I first estimate a benchmark model where the only racial difference is in the income distribution. This model is able to come close to the total shares in the public system, but fails to match the coefficient on race in the probit. Once I estimate the model allowing for the returns to differ per race, I am able to match the race effect and the other moments are still consistent.

Table 3.3: Model Moments

	Data	Benchmark	Extended
HH Income per capita (log)	-0.76	-0.79	-0.78
Race dummy	0.28	0.00	0.27
Share in Public School among Whites	0.81	0.78	0.75
Share in Public School among Blacks/Browns	0.91	0.87	0.89
Intergenerational Persistence Degree	0.58	0.53	0.52

The benchmark model has the same return to private school for everyone, the extended model estimates it separately by race.

[12] Typically, when β is calculated over years of education and without controls it is higher, around 0.7 (see Behrman et al., 2001; Daude and Robano, 2015).

The estimated parameters can be found in Table 3.4. When allowed to differ, the estimation results in higher returns to private school for white individuals, since that results in a better matching of the data moments. The share of the parent's human capital is virtually the same.

Table 3.4: Estimated Parameters

Parameter	Benchmark	Extended
α	0.148	0.146
	(0.000)	(0.000)
e^i	14.482	14.776
	(0.072)	(0.025)
e^{iB}		14.186
		(0.021)

Monte Carlo generated standard errors in parentheses.

In order to evaluate the model predictions and capture nonlinear patterns of intergenerational mobility, I also derive the transition matrices by race. This matrix gives the probability that the son will belong to a particular income category given the father's income category. I used the parameters in the third column of Table 3.4 to generate the transition matrices displayed in Table 3.5 and 3.6.

Table 3.5: Transition Matrix for Human Capital - Whites

Old/Young	**1st Quintile**	**2nd Quintile**	**3rd Quintile**	**4th Quintile**	**Top Quintile**
First Quintile	0.42	0.28	0.19	0.09	0.02
Second Quintile	0.24	0.26	0.24	0.19	0.07
Third Quintile	0.17	0.21	0.23	0.23	0.16
Fourth Quintile	0.11	0.16	0.20	0.26	0.27
Top Quintile	0.06	0.09	0.14	0.23	0.48

For instance, for white individuals there is a 42% chance that the young generation will stay at the bottom quintile of the human capital distribution if the old generation is in that same category. Whereas the probability of belonging to the second quintile is 28%, given that the old generation was in the first (see Table 3.5).

Comparing with the results in Ferreira and Veloso (2006), the model is able to come close to most entries in the transition matrix, but it fails to generate that whites have lower intergenerational persistence at the bottom quintile, while blacks and browns have lower persistence at the top quintile. This may be a shortcoming of some simplifications made in the model, such as the absence of different levels of schooling and homogeneous wages.

Table 3.6: Transition Matrix for Human Capital - Blacks/Browns

Old/Young	1st Quintile	2nd Quintile	3rd Quintile	4th Quintile	Top Quintile
First Quintile	0.40	0.29	0.18	0.10	0.03
Second Quintile	0.24	0.25	0.24	0.19	0.08
Third Quintile	0.17	0.20	0.24	0.23	0.16
Fourth Quintile	0.12	0.16	0.20	0.25	0.27
Top Quintile	0.07	0.10	0.15	0.22	0.46

In terms of inequality, the Gini coefficient for Brazil was 52 in 2012, according to the World Bank, and I obtain 49 for the first old generation, and 62 for the second one.

3.4 Policy Analysis

This model can help evaluate the consequences of policies that seek to improve human capital outcomes by promoting early interventions. In this section I use the estimation in Section 3.3 to explore the effects of vouchers on early human capital investment and subsequent earnings and inequality.

A voucher is defined as a tax-financed cash award given to those who choose private school. It motivates intergenerational spending by reducing the cost of private education and because parents gain utility from their children's human capital. I take the existence and characteristics of vouchers as exogenous, and focus on the effects that the introduction of a voucher program will have on the distribution of outcomes and students across systems, welfare and taxes.

The government budget must account for the expenditure of resources with public education and vouchers (v), so the new tax rate is given by

$$\tau_t = \frac{e^u P_t + v(N - P_t)}{H_t}, \tag{3.6}$$

where P_t is the size of the population choosing to attend public school, as before, and $N - P_t$ is the one in private.

I assume that taxes will change in order to finance the new expenditure, while maintaining the return to public school the same (I relax this assumption in section 3.4.3). So the tax rate will be

increasing in the voucher size, but given that individuals move to private school, it will decrease with the new equilibrium share in public school (P_t). The final effect depends on how much the voucher size will affect the distribution of students across systems.

Since the voucher is provided only to families who choose private education, it will change the school choice of parents and as a consequence the human capital accumulated by the offspring. The human capital threshold that makes the old generation indifferent between the public-private choice is now given by $h^*(\theta) = \left[\frac{q-v}{\sqrt{\theta}(e^{i(1-\alpha)/2}-e^{u(1-\alpha)/2})}\right]^{2/\alpha}$.[13]

I used the parameters in the third column of Table 3.4 to generate the optimal school choices for a given voucher size, and to calculate the new distribution of human capital for the future generation. These changes in the educational investment from the non-voucher case will promote changes in taxes as well as affect the welfare of the old generation.

For the human capital of the current period, that agents take as given, I use the same distribution from Section 3.3. I also use the same distribution of ability, as well as the other parameters in Table 3.1. This way I replicate the economy with no vouchers, and compare it with the results if vouchers were introduced now.

Table 3.7 shows the comparative statics for four different cases; no voucher (same as previous section), a voucher of 10% of the cost of private education (v=1.5), 33% (v=5) and 100% (v=15). I consider five measures pertaining to the human capital of the first generation affected by the voucher: mean; coefficient of variation, which is the standard deviation of the distribution divided by the mean; Gini coefficient; percentile ratio 90-10; and coefficient of intergenerational persistence, calculated as the β in equation (3.5).

Table 3.7: Statistics for Human Capital Distribution at $t+1$

Statistics/Voucher	v=0	v=1.5	v=5	v=15
Average (R$)	129	243	388	393
Coefficient of Variation	1.55	0.94	0.30	0.26
Gini	0.62	0.50	0.16	0.15
Percentile Ratio 90-10	19.35	19.35	1.98	1.98
Persistence	0.52	0.66	0.20	0.15

The average income for the next old generation is increasing in the voucher amount since there

[13] Compare it with Lemma 3.

are more individuals are attending private school which provides higher returns.[14] The coefficient of variation and the Gini coefficient are decreasing in the voucher value. This indicates a reduction in inequality as the voucher increases. The percentile ratio shows that the tails of the distribution are stable for smaller values, so the main movement occurs in the middle of the human capital distribution. Intergenerational persistence has an interesting response, for lower voucher values it increases, but for higher ones it actually decreases showing a smaller correlation between generations. At higher voucher values the dependance of the school choice on the parent's income is smaller because the voucher allows more families to choose private school in spite of their income.

Table 3.8 describes the new equilibrium for public outcomes and the welfare cost of each voucher size. As expected, the share of the population in public schools decreases with the introduction of vouchers. But even though there are fewer people attending public school, taxes increase in order to balance the government budget and finance the voucher program.

Table 3.8: Public Outcomes and Welfare

Variable/Voucher	v=0	v=1.5	v=5	v=15
Share of whites in public school	0.75	0.43	0.02	0.00
Share of blacks/browns in public school	0.89	0.63	0.04	0.00
Taxes (%)	0.14	0.21	0.83	2.55
Welfare Cost		-4.73	43.68	51.56

Small vouchers produce a modest change in the tax rate, which results in an increase in welfare (reduction in welfare cost) measured by compensating variation divided by average human capital.[15]

While there are gains with low voucher values, not everyone is better off. Those who enroll their child in public school even with the voucher are always worse off for the higher taxes. Those who chose private school before will make the same choice with the program and will be better off if the extra taxed income is lower than the voucher, so they are paying less than what they receive from the government.[16] And the ones who switch from the public to the private system will experience welfare gains if the cost of the private education (higher taxes and tuition) is lower than the gains

[14]Note that income is in household per capita monthly values and e^u was normalized to 1.

[15]I choose to measure the welfare cost of a policy in an environment with heterogeneity by adding up the income each individual requires, or is willing to give up, after the policy in order to attain the same utility level under the benchmark case with no voucher (Compensating Variation). I then divide this sum by the average human capital in the economy to get the welfare cost as a fraction of average resources.

[16]In the case of a 1.5 voucher, there is an increase of 0.0007 in the tax rate, so for those with income above 2,142 they are paying more than receiving back with the voucher.

with the higher return for the offspring.

The switchers who are made worse off could stay in public paying higher taxes or move to private and still pay higher taxes, plus discounted tuition, but get higher returns, they choose the latter since it gives higher utility, but are worse off compared with the non-voucher case. Since parents are altruistic and care about the human capital of the child, there is a transfer between generations. So in the case of small vouchers, there is a majority with relatively small losses and a minority with relatively large gains like in Epple and Romano (1998).

For a voucher that covers a third of the private tuition (v=5), in my computations almost everyone is in private school, but since taxes are six times higher, there is a welfare cost when comparing with the non-voucher case (v=0).

In the extreme case where there are no public schools and everyone attends a private school financed by taxes revenue (v=15), the welfare cost is high and in terms of inequality it does not present a significant improvement from a 33% voucher (v=5) because in that case the share in public school is already really small. So in this model, a full voucher does not imply in much better outcomes than a partial voucher program.

This exercise shows that small values of voucher can produce a significant impact in inequality and still improve welfare when comparing with a non-voucher economy, proving to be a viable educational policy in a mixed system.

3.4.1 Targeted Voucher

Generally, policy makers are trying to target a disadvantageous segment of the population. In the Brazilian context where race matters for school choice, a targeting strategy can be to offer vouchers only to black and brown families who choose private education.

Tables 3.9 and 3.10 show human capital statistics and equilibrium results of such targeted voucher program. The targeted voucher also produces higher income and lower inequality in terms of the Gini coefficient and the coefficient of variation as the voucher size increases. Similar to the non-targeting case (Table 3.7), low values of voucher do not affect the percentile ratio but increase the intergenerational persistence.

If the voucher targeting blacks and browns in private school is equal to the public per student

Table 3.9: Statistics for Human Capital Distribution at $t+1$

Statistics/Voucher	v=0	v=1	v=1.5
Average (R$)	129	161	181
Coefficient of Variation	1.55	1.34	1.22
Gini	0.62	0.61	0.59
Percentile ratio 90-10	19.35	19.35	19.35
Persistence	0.52	0.61	0.63

Assuming that vouchers are given only to black and brown families.

Table 3.10: Public Outcomes and Welfare

Variable/Voucher	v=0	v=1	v=1.5
Share of whites in public	0.75	0.75	0.75
Share of blacks/browns in public	0.89	0.74	0.63
Taxes (%)	0.14	0.15	0.16
Welfare Cost		-4.42	-2.40

Assuming that vouchers are given only to black and brown families.

expenditure ($v = 1$), then the race distribution in the school systems are basically equalized. The tax rate (0.15%) would be virtually the same as the case *without* vouchers, but average income would be higher, inequality lower and there would be a gain in welfare similar to the one of a universal voucher of 1.5 given to all races attending private school.

Comparing the targeted 1.5 voucher with the case of a universal 1.5 voucher (Column 3 in Table 3.7 and 3.8), the universal voucher delivers higher wealth, lower inequality and higher relative welfare gain. But there would be more segregation in terms of race distribution in the public school. With the targeted voucher there would actually be a majority of white students in public school.

Depending on the objective of the policy maker, a voucher equal to the public per student expenditure targeting specific racial groups would be preferable to a universal voucher of higher value, since it can produce similar welfare effects with a more integrating effect in schools.

It must be noted that most voucher policies in the U.S. target low-income students. So I run the same experiment but targeting families with per capita monthly income below R$140, a similar threshold used for *Bolsa Família*, a cash transfer program in Brazil.[17] But, unlike *Bolsa Família*, the voucher here is not given conditional on the child attending school, but rather on being spent on private education.

[17]Given the simulated distribution, it affects 14% of population.

Table 3.11 shows that a voucher targeted at the poor to attend private schools would increase income and reduce inequality compared with the non-voucher economy. But these changes occur in a much slower pace than with a universal voucher (see Table 3.7).

Table 3.11: Statistics for Human Capital Distribution at $t+1$

Statistics/Voucher	v=0	v=1.5	v=5	v=15
Average (R$)	129	135	166	168
Coefficient of Variation	1.55	1.50	1.24	1.22
Gini	0.62	0.62	0.59	0.59
Percentile ratio 90-10	19.35	19.35	18.31	17.89
Persistence	0.52	0.46	0.03	-0.02

Assuming vouchers are given to families with per capita monthly income below R$140.

It is interesting to note that the intergenerational persistence in this case could become very small and even negative at higher voucher values, since the government aid improves the offspring future outcome despite the parents low income. Also, it is able to affect the tails of the distribution, depicted in the percentile ratio, but at a much lower degree.

In terms of the race distribution in the school systems, Table 3.12 shows that it becomes more equalized but the marginal change is very small. This small change in the public share implies in a small impact on future human capital, but since taxes are higher to finance the voucher to the poor, there is a loss of welfare in all cases when comparing with the non-voucher case, almost as high as that of a universal voucher of size 5.

Table 3.12: Public Outcomes and Welfare

Variable/Voucher	v=0	v=1.5	v=5	v=15
Share of whites in public	0.75	0.73	0.67	0.66
Share of blacks/browns in public	0.89	0.87	0.72	0.70
Taxes (%)	0.14	0.17	0.24	0.47
Welfare Cost		30.89	38.59	37.91

Assuming vouchers are given to families with per capita monthly income below R$140.

3.4.2 Dynamic Effects

In this section I evaluate the effects of a universal voucher program on future generations. I compare the effects of a voucher policy introduced today and continued for 10 generations. The results can be seen in Tables 3.13 and 3.14.

Table 3.13: Statistics for Human Capital Distribution at $t + 10$

Statistics/Voucher	v=0	v=1.5	v=5
Average (R$)	58	363	509
Coefficient of Variation	1.86	0.65	0.18
Gini	0.44	0.35	0.10
Percentile ratio 90-10	1.64	19.44	1.59
Persistence	0.64	0.73	0.17

After ten periods without vouchers, the result is an economy with very low income because most individuals are attending public school and for several generations. Once I introduce vouchers and continue the program for 10 generations, income increases but inequality has an ambiguous effect. For lower values of the voucher the Gini reduces but the percentile ratio increases, since there are more people with higher income. But the coefficient of variation always decreases due to the significant increase on average human capital.

Table 3.14: Public Outcomes and Welfare

Variable/Voucher	v=0	v=1.5	v=5
Share of whites in public	0.93	0.23	0.0006
Share of blacks/browns in public	0.98	0.42	0.0009
Taxes (%)	1.6	0.37	0.98
Welfare Cost		-52.21	-120.29

With a continuous voucher policy of 1.5, the first generation would already have a small welfare gain (see Table 3.8), but after 10 periods the welfare gain would be much higher because the human capital accumulated has a significant increase since most agents are attending private school. Taxes are actually lower than they would be without the voucher program, since the higher human capital levels increase the tax base, providing more resources without the cost of increasing taxes. Also, the welfare cost is decreasing on the voucher value, showing that it can greatly benefit future generations, even if at the cost of the current one.

3.4.3 Fixed Government Budget

In this section I analyze the effects of a voucher program while maintaining a fixed budget. Instead of allowing the tax rate to fluctuate in order to balance the government budget, here I allow the return to public school to change in order to adjust the expenditure on education for a given

voucher size.

Since taxes are constant, the budget will be balanced by the transfer of students to private school and by changes in e^u, but in this model this is only possible when the voucher is lower then 1 (or the return to public school in the benchmark case). Otherwise there is no value of e^u that could balance the budget $(\tau H_t - e^u P_t - v(N - P_t))$.

Table 3.15 shows that, like before, as the voucher goes up so does the average income while inequality goes down for most measures. One difference here is the percentile ratio that goes up, even for small values of voucher. Since the difference between the returns to public and private is larger now (see Table 3.16), attending one or the other produces a stronger impact on wealth.

Table 3.15: Statistics for Human Capital Distribution at $t + 1$

Statistics/Voucher	v=0	v=0.5	v=0.8
Average (R$)	129	179	232
Coefficient of Variation	1.55	1.26	1.00
Gini	0.62	0.60	0.52
Percentile ratio 90-10	19.35	20.66	23.55

Assuming that taxes are constant.

With the returns to public school being smaller, there is a welfare cost despite more students attending a private school without having to pay higher taxes for it, as can be seen in Table 3.16. Trying to maintain the same government revenue while introducing a voucher program demonstrates to be challenging and costly in this model.

Table 3.16: Public Outcomes and Welfare

Variable/Voucher	v=0	v=0.5	v=0.8
Share of whites in public	0.75	0.60	0.45
Share of blacks/browns in public	0.89	0.79	0.65
Welfare Cost		3.13	11.88
e^u	1	0.92	0.79

Assuming that taxes are constant.

Cardak (2005) also finds that right after the introduction of vouchers there is an increase in income, reduction in per student public expenditure and welfare gains only for lower voucher levels. He finds, however, an increase in the Gini coefficient and very subtle increase in the percentile ratio. Possibly due to the fact that his parameters in the human capital accumulation function are the opposite of mine.

For Caucutt (2002), welfare cost is decreasing in the voucher size but there are only welfare gains for higher sizes of voucher. One of the main differences is that in her model there are peer effects, and the per student expenditure is endogenous and increases with the voucher.

3.5 Conclusion

I have structurally estimated a parental human capital investment model using data on school choice, race and income in Brazil. Parents make an educational investment in their children when they decide between private and public school. Each choice will have a different cost and impact in the human capital of the offspring. By allowing the returns to vary with race, I better match the targeted data moments. And the estimated return to private school are 4% higher for white individuals. I use these estimates to explore the impact of different designs of a voucher program.

I find that vouchers increase human capital levels and reduce inequality. For the current generation, there are only welfare gains for small values of voucher, but for future ones all voucher sizes are welfare increasing. A voucher program targeting the poor is costly in terms of welfare, and a voucher program targeting minorities at private schools is the best way to mitigate segregation while providing welfare gains.

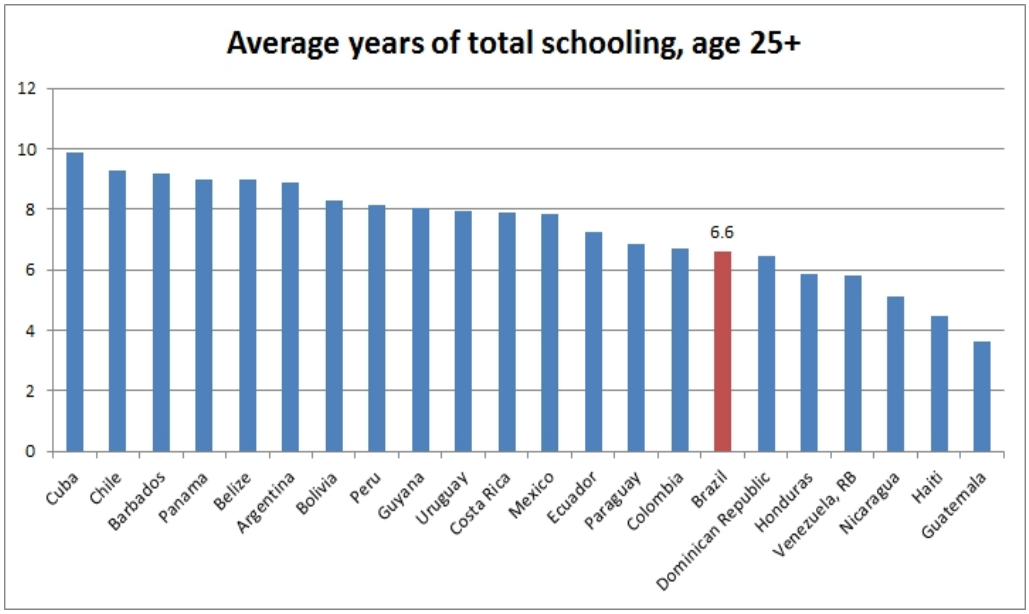
The model abstracts from relevant issues like between-school competition (Epple and Romano, 1998) and peer effects (Caucutt, 2002), important factors in the voucher debate. Incorporating competition for students with vouchers is argued to generate better educational outcomes for students in both private and public schools, which would increase returns and income in both the public and private systems, strengthening the increased growth identified here. Whereas peer effects may have an adverse effect of cream-skimming the top students to the private schools. However, the effects presented here can be underestimated since this model does not account for the effects on subsequent investments in education (see Caucutt and Lochner, 2012).

Overall, I show that vouchers can have significant distributional consequences and there are potential short-term gains with some voucher designs and large long-term ones by having a continued policy.

Appendix

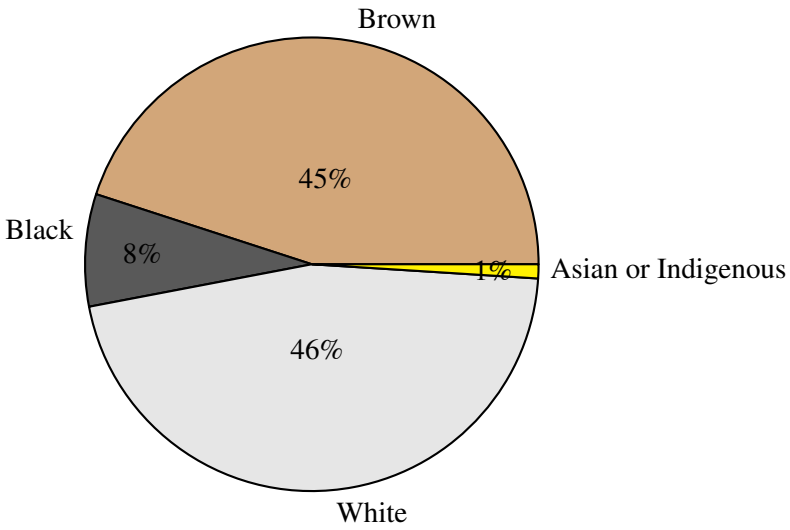
A Additional Statistics for Chapter 1

Figure 3.2: Schooling in Latin America - selected countries



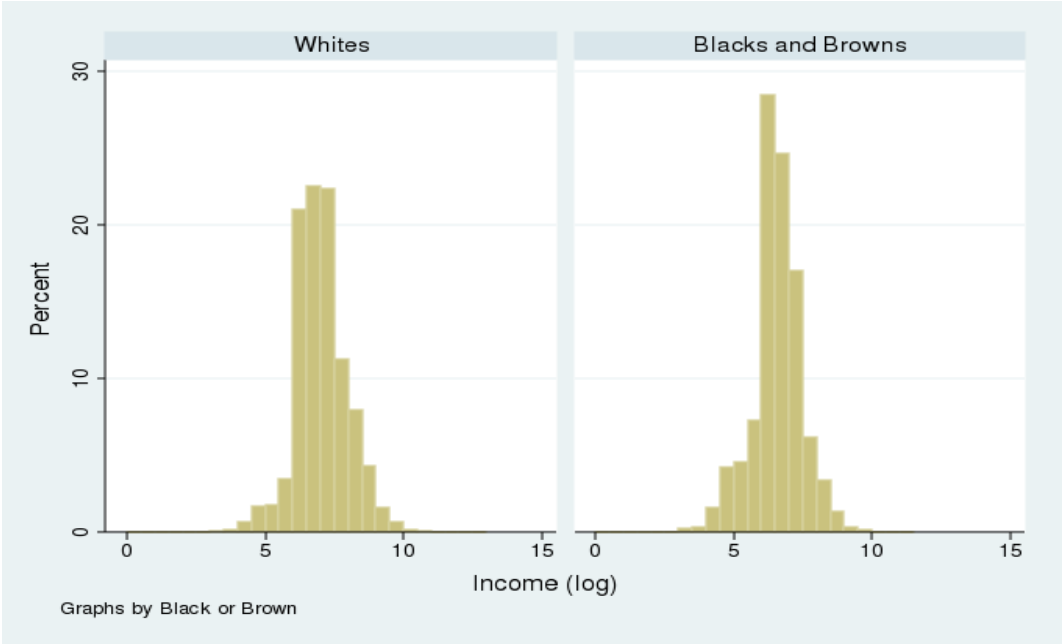
Data Source: World Bank (Robert J. Barro and Jong-Wha Lee) 2005

Figure 3.3: Race Distribution in Brazil



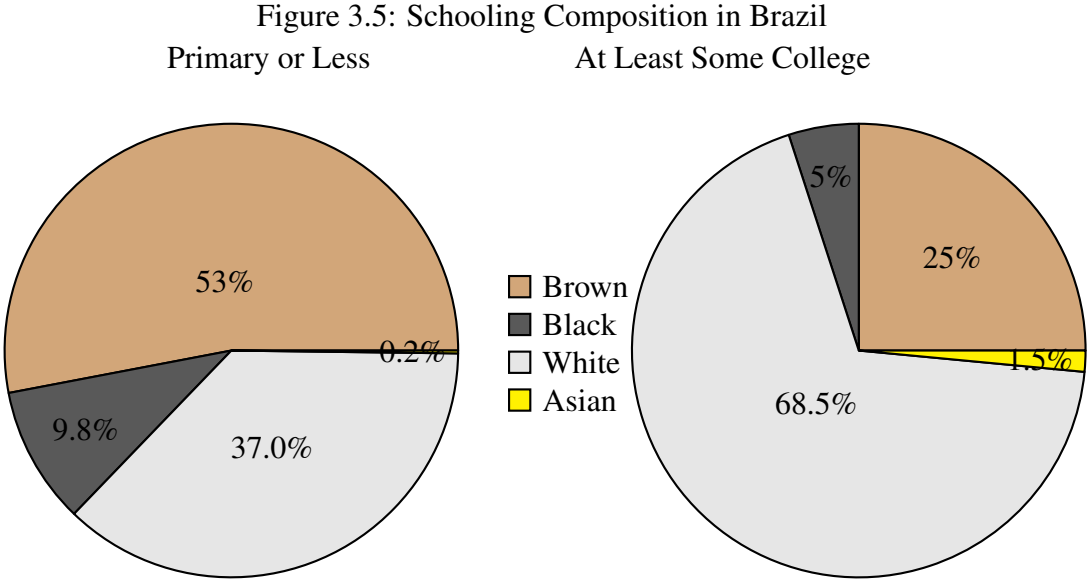
Source: PNAD 2012, % over total population

Figure 3.4: Income Distribution



Data Source: PNAD 2012. Individuals above 15 years old with positive personal income.

Figure 3.5: Schooling Composition in Brazil



Source: PNAD 2012, individuals with age between 15-70. Excludes indigenous.

Table 3.17: Average Score on Essay

Race	**Public High School**	**Private High School**
White	541.48	624.85
Black	519.01	592.47
Brown	522.21	606.07
Total	529.61	617.32

Source: Enem 2011

B Robustness Checks for Chapter 1

Table 3.18: Probit Estimation for Public School Choice - PNAD 2012

	(1) Coefficient	(2) Average Mg. Effect	(3) Coefficient	(4) Average Mg. Effect
Household Income (log)	-0.68***	-0.11***	-0.67***	-0.10***
	(0.02)	(0.00)	(0.02)	(0.00)
Parents Schooling	-0.15***	-0.02***	-0.14***	-0.02***
	(0.00)	(0.00)	(0.00)	(0.00)
Total Children in K-11	0.39***	0.06***	0.39***	0.06***
	(0.02)	(0.00)	(0.02)	(0.00)
HH black	0.19***	0.03***		
	(0.04)	(0.01)		
HH black or brown			0.29***	0.05***
			(0.02)	(0.00)
Urban area dummy	-0.80***		-0.81***	
	(0.06)		(0.06)	
Constant	8.57***		8.25***	
	(0.19)		(0.19)	
State dummies	Yes	Yes	Yes	Yes
Observations	37622	37622	37622	37622

Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3.19: Probit Estimation for Public School Choice - PNAD 2012 (Urban Area)

	(1)	(2)
Income per capita (log)	-0.82***	-0.80***
	(0.02)	(0.02)
Parents Schooling	-0.13***	-0.13***
	(0.00)	(0.00)
HH black	0.17***	
	(0.04)	
HH black or brown		0.28***
		(0.02)
Constant	8.16***	7.86***
	(0.16)	(0.16)
State dummies	Yes	Yes
Observations	37669	37669

Standard errors in parentheses.* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3.20: Probit Estimation for Public School Choice - PNAD 2012 (Rio de Janeiro Urban)

	(1)	(2)
	Coefficient_RJ	Average Mg. Effect
Income per capita (log)	-0.77***	-0.18***
	(0.05)	(0.01)
Parents Schooling	-0.13***	-0.03***
	(0.01)	(0.00)
HH black or brown	0.24***	0.06***
	(0.06)	(0.02)
Constant	6.68***	
	(0.33)	
Observations	2234	2234

Standard errors in parentheses.* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3.21: Probit Estimation for Public School Choice - PNAD 2012

	(1) Families	(2) Students
Income per capita (log)	-0.75***	-0.76***
	(0.02)	(0.02)
Parents Schooling	-0.14***	-0.10***
	(0.00)	(0.00)
HH black or brown	0.32***	0.28***
	(0.02)	(0.02)
Constant	8.43***	7.85***
	(0.17)	(0.15)
State and Urban Are dummies	Yes	Yes
Observations	37758	71128

Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3.22: Probit Estimation for Public School Choice - PNAD 2012 (High Income)

	(1) Coefficient	(2) Coefficient
Income per capita (log)	-0.96***	-0.95***
	(0.06)	(0.06)
Parents Schooling	-0.16***	-0.16***
	(0.01)	(0.01)
HH black	0.02	
	(0.09)	
HH black or brown		0.06
		(0.04)
Constant	9.10***	9.03***
	(0.43)	(0.43)
Observations	34664	34664

Standard errors in parentheses. Household income per capita above R$1000.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3.23: Probit Estimates for Public School - ENEM 2011

	(1) K-8	(2) K-11	(3) K-11 - Only Urban
Income per capita (log)	-0.62***	-0.87***	-0.87***
	(0.00)	(0.00)	(0.00)
Schooling of Parents	-0.14***	-0.18***	-0.18***
	(0.00)	(0.00)	(0.00)
Black or Brown	0.24***	0.36***	0.36***
	(0.00)	(0.00)	(0.00)
Math grade (log)	-1.32***	-1.86***	-1.86***
	(0.00)	(0.01)	(0.01)
Urban area	-0.44***	-0.52***	
	(0.00)	(0.01)	
Constant	15.19***	20.96***	20.49***
	(0.03)	(0.05)	(0.05)
State Dummies	Yes	Yes	Yes
Observations	3594022	2904167	2583592

Standard errors in parentheses.* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3.24: Racial Segregation by Brazilian Metropolitan Areas and Income

Metropolitan Area	**Income Group**	**Spacial Dissimilarity Index**	**Metropolitan Area**	**Income Group**	**Spacial Dissimilarity Index**
Belém	1	0.3884	Rio de Janeiro	1	0.4702
	2	0.3434		2	0.4020
	3	0.3530		3	0.4339
Fortaleza	1	0.4111	São Paulo	1	0.5230
	2	0.3945		2	0.4373
	3	0.4037		3	0.4264
Recife	1	0.3855	Curitiba	1	0.5265
	2	0.3580		2	0.4002
	3	0.4219		3	0.3895
Salvador	1	0.3990	Porto Alegre	1	0.5790
	2	0.4084		2	0.5277
	3	0.4153		3	0.5102
Belo Horizonte	1	0.4496	Distrito Federal	1	0.3760
	2	0.3651		2	0.3669
	3	0.3838		3	0.3222

Source: PNAD 2012.

C Proofs and Results for Chapter 2

C.1 Assumption 1

Assuming $\frac{\partial \Delta V(h,\cdot)}{\partial h} > 0$ is similar to assuming single-crossing condition, or supermodularity. It will be satisfied depending on the concavity of the utility function.

- Example: CRRA Preferences

Assuming that $U(c, h') = \frac{c^{(1-\eta)}+h'^{(1-\eta)}}{(1-\eta)}$ with $\eta \geq 0$, we have

$$\Delta V(h,\tau) = \frac{[(1-\tau_t)h_t - q]^{(1-\eta)} - [(1-\tau_t)h_t]^{(1-\eta)}}{(1-\eta)} + \frac{\mathbb{E}\left(\theta^{1-\eta}\right) h_t^{\alpha(1-\eta)}}{(1-\eta)}[e^{i\gamma(1-\eta)} - e^{u\gamma(1-\eta)}] \tag{3.7}$$

$$\frac{\partial \Delta V(h,\tau)}{\partial h} = \frac{(1-\tau_t)}{[(1-\tau_t)h_t - q]^{\eta}} - \frac{(1-\tau_t)}{[(1-\tau_t)h_t]^{\eta}} + \frac{\alpha \mathbb{E}\left(\theta^{1-\eta}\right)}{h_t^{1-\alpha(1-\eta)}}[e^{i\gamma(1-\eta)} - e^{u\gamma(1-\eta)}] \tag{3.8}$$

If $\eta = 0$ they are perfect substitutes and equation (3.8) is positive for any level of human capital.

If $\eta \in (0,1)$, in order to have $\frac{\partial \Delta V(h,\tau)}{\partial h} > 0$ it is sufficient that $(1-\tau_t)h_t - q > 0$ (but not necessary). If that does not hold, the household cannot afford private education and therefore will choose the public one.

For $\eta = 1$ preferences are logarithmic, which results in the same expression in (3.8) with $\eta = 1$, so again it is sufficient that $(1-\tau_t)h_t - q > 0$.

For $\eta > 1$, the third term in equation (3.8) is negative, then $\Delta V(h,\tau)$ is likely decreasing in h.

- *Lemma 2 - Quasi-linear Functions*

Now, if $U(c, h') = c + u(h')$ for u strictly increasing and concave, then $\Delta V(h_t) = -q + \mathbb{E}_\theta\left\{u(\theta h_t^\alpha e^{i\gamma}) - u(\theta h_t^\alpha e^{u\gamma})\right\}$. So it results in a human capital threshold independent of τ_t.

For instance, if $U(c, h') = c + (h')^\sigma$ for $\sigma \in (0, 1]$, Assumption 1 is always satisfied;

$$\Delta V(h) = -q + \mathbb{E}(\theta^{\sigma}) h^{\alpha\sigma} [e^{i\gamma\sigma} - e^{u\gamma\sigma}] \tag{3.9}$$

$$\frac{\partial \Delta V(h)}{\partial h} = \frac{\alpha\sigma \mathbb{E}(\theta^{\sigma})}{h^{1-\alpha\sigma}} [e^{i\gamma\sigma} - e^{u\gamma\sigma}] \; > \; 0 \tag{3.10}$$

Note that if instead we had $U(c, h') = c + \ln(h')$, then $\Delta V(h) = -q + \ln(e^{i\gamma}) - \ln(e^{u\gamma})$ which does not depend on h. Therefore everyone would make the same school choice.

C.2 Proposition 1

If $\Delta V(h_t, \tau_t) \equiv V(h_t, \tau_t, i) - V(h_t, \tau_t, u)$ is continuous and strictly increasing in h, there will be a unique human capital value for which the household head will be indifferent between the public and private school choice, and above this threshold she will choose private and below, public.

Proof:

For U strictly increasing on both arguments, if $h_t = 0$, $\Delta V(0, \tau_t) = U(-q, 0) - U(0, 0) < 0$.

But for $\overline{h}(\tau_t)$ sufficiently large such that $(1 - \tau_t)\overline{h} - q \approx (1 - \tau_t)\overline{h}$, it is easy to see that $\Delta V(\bar{h}(\tau_t), \tau_t) = \mathbb{E}_{\theta} \left\{ U\left((1-\tau_t)\overline{h} - q, \theta \overline{h}^{\alpha} e^{i\gamma} \right) - U\left((1-\tau_t)\overline{h}, \theta \overline{h}^{\alpha} e^{u\gamma} \right) \right\} > 0$.

Then, assuming $\Delta V(h_t, \tau_t)$ is continuous, exists $h^*(\tau_t) \in (0, \bar{h}(\tau_t))$ such that $\Delta V(h^*(\tau_t), \tau_t) = 0$. And if $\Delta V(h_t, \tau_t)$ is strictly increasing, $h^*(\tau_t)$ is unique, so for every parent with human capital stock above that level, $\Delta V(h_t, \tau_t)$ is positive so she will choose private education. And below it, $\Delta V(h_t, \tau_t)$ is negative so she will choose public.

Besides, assuming that the utility function is also separable (and that Assumption 1 holds), from equation (2.8) we can apply the implicit function theorem to show that $h^*(\tau)$ is increasing in τ;

$$\begin{aligned}
\frac{dh^*(\tau)}{d\tau} &= - \frac{\partial \Delta V(h^*(\tau), \tau)/\partial \tau}{\partial \Delta V(h^*(\tau), \tau)/\partial h}, \\
&= \frac{h_t \overbrace{[u'((1-\tau_t)h_t - q) - u'((1-\tau_t)h_t)]}^{+}}{+}, \\
&> 0.
\end{aligned}$$

■

C.3 Equilibrium Conditions

Any equilibrium tax-threshold pair must satisfy equations (2.7) and (2.8) simultaneously. If Assumption 1 holds, for a given tax rate there is a unique human capital level that solves equation (2.8), but there may not be a positive tax rate that balances the budget.

- *Lemma 1*: Given a concave, separable utility function and $\frac{\partial \Delta V(h,\cdot)}{\partial h} > 0$, the budget surplus equation, $\tau_t H_t - e^u F_t(h^*(\tau_t))$, is not monotonic in τ_t because $h^*(\tau_t)$ is increasing in τ_t.

Proof:

The derivative of the government surplus with respect to the tax rate is $\frac{\partial[\tau_t H_t - e^u F_t(h^*(\tau_t))]}{\partial \tau_t} = H_t - e^u f(h^*(\tau_t))\frac{dh^*(\tau)}{d\tau}$. Since proposition 1 showed that $h^*(\tau_t)$ is increasing in τ_t for separable utility functions, this expression will only be monotonic in τ for some parameter combinations.

So we cannot guarantee that there exists a positive τ such that $\tau H - e^u F(h^*(\tau)) = 0$.

■

C.4 Proposition 2

Assuming quasi-linear preferences, for any $\tau_t \in (0, 1)$, there exists a unique h^* which solves equation (2.8). And given this h^*, there exists a unique $\tau_t(h^*)$ which solves equation (2.7).

Proof: Assuming quasi-linear preferences, h^* will be unique and independent of τ_t, given by $\mathbb{E}_\theta \left\{ u(\theta h^{*\alpha} e^{i\gamma}) - u(\theta h^{*\alpha} e^{u\gamma}) \right\} = q$ (Lemma 2). Moreover $\tau_t H_t - e^u F_t(h^*)$ is continuous and strictly increasing in τ_t, so there exists a unique pair $(\tau_t(h^*), h^*)$ which satisfies equations (2.7) and (2.8) simultaneously. ■

C.5 Proposition 3

Assuming quasi-linear preferences that satisfy Assumption 1, a continuous distribution of human capital and a distribution of ability shocks with enough variance (reflecting some mobility in the economy), if $\{F_t\}_t$ is a sequence of human capital distributions originating from an initial distribution F_0, then F_t will converge to a unique equilibrium distribution $\overline{F}$ with support in $[\overline{h_1^u}, \overline{h_N^i}]$.

Proof: Without loss of generality, let $\theta \in \{\theta_1, ..., \theta_N\}$, where $\theta_1 < \theta_2 < ... < \theta_N$. Define $a = (\theta_1 e^{u\gamma})^{1/1-\alpha} = \overline{h_1^u}$ as the lowest fixed point for the capital transition with public school choice, and $b = \left(\theta_N e^{i\gamma}\right)^{1/1-\alpha} = \overline{h_N^i}$ as the highest fixed point with private school choice. Similarly, $\left(\theta_1 e^{i\gamma}\right)^{1/1-\alpha} = \overline{h_1^i}$ and $(\theta_N e^{u\gamma})^{1/1-\alpha} = \overline{h_N^u}$. Also, let $c = h^*$ be the school choice cutoff.

If $\overline{h_1^i} < c < \overline{h_N^u}$ (as depicted in Figure 2.3, right graph), then $\exists T$ such that if $\theta_t = \theta_N \; \forall t \leq T$, $h_T^u(a) \overset{T\to\infty}{\longrightarrow} \overline{h_N^u}$. Meaning that for an initial state a and a sequence of high shocks $\{\theta_t = \theta_N\}_{t=1}^T$, h_t^u will converge to a point on the opposite side of the cutoff. Similarly, $\exists T$ such that if $\theta_t = \theta_1 \; \forall t \leq T$, $h_T^i(b) \overset{T\to\infty}{\longrightarrow} \overline{h_1^i}$.

So for any initial distribution in the interval $[a, b]$ there is convergence to a unique stationary distribution in $[a, b]$.[18] ■

In summary, assuming enough variance in the distribution of θ such that $\overline{h_1^i} < \overline{h_N^u}$, and a constant $c \in [a, b]$, it can be shown that a dynasty that starts with human capital below the cutoff, after receiving enough high ability shocks will cross this cutoff and start accumulating more capital in the private educational sector. The inverse is also true.

[18] This proposition is equivalent to theorem 12.12 in Stokey and Lucas (1989).

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CURRICULUM VITAE

EVELYN MONTEIRO PEREIRA NUNES

303 Kern Building
Pennsylvania State University
University Park - PA, 16802
Email: enunes@psu.edu

Cellphone : (814) 470-3724
Date of Birth: November 30, 1983
Citizenship: Brazilian
www.evelynnunes.com

Education

Ph.D. in Economics, Penn State University, USA, 2016

M.S. in Economics, Getúlio Vargas Foundation, Brazil, 2010

B.S. in Economics, Federal University of Rio de Janeiro, Brazil, 2008

Fields

Primary: Development

Secondary: Economics of Education, Labor, Economic Policy

Research

Working Papers

Parental Educational Choice and School Vouchers, 2016.

Private School Choice and Race in Brazil, 2015.

Parental Educational Investment and Social Mobility with Heterogeneous Returns, 2016.

Exports and CO_2 Emissions in the Absence of Regulations, 2015.

Teaching Experience

Instructor at PSU, Undergraduate Courses, Summer of 2012/2013/2014.

Teaching Assistant at PSU, Undergraduate Courses, 2010-2015.