INTERGENERATIONAL MOBILITY IN EARNINGS IN BRAZIL SPANNING THREE GENERATIONS AND OPTIMAL INVESTMENT IN ELECTRICITY GENERATION IN TEXAS

A Dissertation

by

CASSIA HELENA MARCHON

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2008

Major Subject: Economics

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ABSTRACT

Intergenerational Mobility in Earnings in Brazil Spanning Three Generations and
Optimal Investment in Electricity Generation in Texas. (August 2008)

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This dissertation contains three essays. The first and second essays examine intergenerational mobility in earnings in Brazil using a data set spanning three generations. I use data from PNAD–a nationally representative household survey in Brazil. I build a three-generations data set consisting of 5,125 grandfather-father-son triplets by restricting the sample to households with adult sons. The first essay estimates some relationships between a child's earnings and family background implied by the Becker-Tomes model. I find that the estimates contradict some of its predictions, like the negative relationship between child's earnings and grandparent's earnings when controlling for parent's earnings. I propose a modified version of the Becker-Tomes model and find that the estimates are consistent with its predictions. I find that family background explains 34.9% of the variation in earnings among young males who live with their parents. If it were possible to eliminate the differences in investment in the children's human capital, the variation in earnings would fall by no more than 21.1%. Additionally, if there were no differences in endowments among children, the variation in earnings would fall by no less than 26%. The second essay examines the evolution of the intergenerational elasticity across generations and implications of marriage, education and fertility on mobility. I find that the estimate of the intergenerational elasticity in earnings is 0.847. The elasticity of earnings between son-in-law and father-in-law, 0.89, is approximately the same as the elasticity between son and father, 0.9. Additionally, controlling for fathers' percentile in the earnings distribution, each additional sibling decreases the sons' percentile by 1.77 percentiles. The third essay estimates an indicator of the optimal investment in electricity generation in Texas, and the associated efficiency gains. The essay presents a method to estimate the optimal investment in each technology available to generate electricity. The estimation considers the expected entry and exit of generation plants, future fuel prices, different demand elasticities and a potential carbon allowance markets. Considering a carbon allowance price equal to two times the level in Europe, the optimal investment in electricity generation in Texas is zero.

To Ionete and Antonio, my family, friends and mentors. I will always love you.

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CHAPTER I

INTRODUCTION

This dissertation contains three essays. The first and second essays examines intergenerational mobility in earnings in Brazil. The third essay estimates an indicator of the optimal investment in electricity generation in Texas. Below, I introduce the three essays.

The bulk of the literature on mobility uses data on two generations to estimate children's earnings as a function of fathers' earnings. Solon [34] presents a theoretical derivation for this relationship adding the assumption of identical children's endowments to the Becker-Tomes [2] model. In the first essay, I estimate some additional relationships between a child's earnings and family background implied by the Becker-Tomes model. I find that the estimates contradict some of its predictions. I propose a modified version of the Becker-Tomes model and find that the estimates are consistent with its predictions. I use data from PNAD–a nationally representative household survey in Brazil–to build a data set spanning three generations. I find that family background explains 34.9% of the variation in earnings among males aged 16 to 27 who live with their parents. If there were no differences in endowments among children the variation in earnings would fall by no less than 26%. If it were possible to eliminate differences in investment in the children's human capital the variation in earnings would fall by no more than 21.1%.

In the second essay I continue exploring the mobility data from PNAD. Using data on two generations, I find that the estimate of the intergenerational elasticity in earnings is 0.847. Controlling for father's percentile in the earnings distribution, each

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This dissertation follows the style of Journal of Economic Theory.

additional year of schooling of the son increases his percentile by 4.35, on average. The elasticity of earnings between son-in-law and father- in-law, 0.89, is approximately the same as the elasticity between son and father, 0.9. Using data on three generations, I find that the intergenerational elasticity between grandfather and grandsons, 0.47, is about the same as the elasticity between father and grandsons, 0.46. Additionally, controlling for fathers' percentile in the earnings distribution, each additional sibling decreases the sons' percentile by 1.82 percentiles.

The third essay estimates an indicator of the investment that would occur under competitive procurement in Texas, and the associated efficiency gains. The essay presents a method to estimate the optimal investment in each technology available to generate electricity. The method determines the optimal investment by applying a similar logic that Borenstein [8] uses to find the optimal long run capacity, but takes into consideration the current capacity. The estimation considers the expected entry and exit of generation plants and the future fuel prices. I conclude that for demand elasticities between -0.025 and -0.5, the investment in baseload (or coal) units that would generate a positive social surplus for all years from 2006 to 2011, ranges from about 12 to 37 thousand megawatts hour. Independent of the realized investment in baseload units, it is not optimal to invest in new peak or mid-merit units from 2006 to 2011. In a given year, the associated efficiency gains lie between, approximately, 865 and 7,617 million dollars depending on the year and assumption of demand elasticity. The equivalent per consumer figure ranges from, approximately, 43 to 380 per year. Introduction of carbon emission costs reduces substantially the investment in coal units that maximizes the social surplus. Considering a carbon allowance price equal to two times that of the level in Europe, the optimal investment in coal units drops to zero. Introduction of carbon emission costs does not transform combined cycle or combustion turbine technologies into attractive technologies for investment.

CHAPTER II

A TEST OF THE BECKER AND TOMES MOBILITY MODEL INVOLVING THREE GENERATIONS

A. Introduction

Most studies of intergenerational mobility use data on two generations to estimate children's earnings as a function of fathers' earnings[1]. Solon [34] presents a theoretical derivation for this relationship adding the assumption of identical children's endowment or that the child's endowment is not related to the parent's endowment to a variant of the Becker and Tomes [2] model. (Examples of child's endowment are family connections, ability, race, skills, genetic characteristics and family culture.)

The Becker and Tomes model establishes additional relationships between the child's earnings and family background. For instance, the model predicts a negative relationship between the child's earnings and the grandparent's earnings when controlling for the parent's earnings. The model in this study yields more intuitive predictions by modifying some assumptions of the original Becker and Tomes model. For instance, the assumption that the child's endowment depends on the parent's endowment is replaced by the more relaxed assumption that it depends on the parent's and grandparent's endowment.

I use data on two and three generations from *Pesquisa Nacional por Amostra de Domicilios* (PNAD)–a nationally representative household survey for Brazil. A three-generations data set allows me to test the predictions established by both models–the original and the modified version–relaxing the assumption of identical children's

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[1] Solon [35], Table 1, Solon [34], tables 3 and 4, and Corak [12], Appendix tables, list articles that estimate the elasticity of child's earnings with respect to parental earnings. For Brazil, see Ferreira and Veloso [18] and Dunn [13].

endowment. In addition, a three-generations data set allows me to estimate a lower-bound for the variation in earnings explained by differences in endowments across families, and an upperbound for the variation in earnings explained by differences in human capital.

The mobility supplement of the 1996 PNAD provides data on 36,705 father-son pairs. I build a three-generations data set consisting of 5,125 grandfather-father-son triplets by restricting the sample to households with adult sons present. In Brazil individuals live with their parents until they marry, and quit school and begin working at an early age. There are many households with adult sons who are not at the very beginning of their working careers. A number of statistics support this argument. In the 1996 PNAD sample, at age 25 about 50.9% of the males lived in their parents' house. About 47.46% of the 25-year-old males were married. Among the 25-year-old males living with their parents only 3.74% were married. On average, males aged 20 to 35 have 6.6 years of education and began working at age 13.4.

To address potential sample selection problems, I apply the Heckman [23] estimation procedure.

The estimation results are consistent with the predictions of the modified model, but contradict some of the predictions of the Becker and Tomes model.

My estimate of the intergenerational elasticity in earnings in Brazil is about 0.84. Dunn's [13] estimate of the intergenerational elasticity in earnings in Brazil is 0.85 and Ferreira and Veloso's [18] estimate is 0.58. The estimates for the U.S. range between 0.4 and 0.5.

Estimating the main equation yielded by the modified model, I find that family background explains 34.9% of the variation in earnings among males between the ages of 16 and 27 who live with their parents. If it were possible to eliminate the differences in investment in the children's human capital, the variation in earnings would fall by no more than 21.1%. Additionally, if there were no differences in endowments among children, the variation in earnings would fall by no less than 26%.

This article is organized as follows. The first part of section B presents a variant of the Becker and Tomes model according to Solon [34]. The second part of section B presents my modification of the Becker and Tomes model. Section C describes the data and provides details of the estimation procedure. Section D presents the estimation results for the relationships established by both the original and the modified Becker Tomes model. Section E concludes.

B. Theoretical model

1. The Becker and Tomes model

In this section I present a variant of the Becker and Tomes [2] model presented by Gary Solon [34] in the "Handbook of Labor Economics". I have added some obvious derivations because they are relevant to this paper.

Consider the following assumptions and notation. A family consists of one child and one parent. Let y_t and c_t represent the parent's lifetime earnings and consumption, and let I_{t+1} represent investment at time t in the child's earning capacity at time $t+1$. The parent's budget constraint is given by $y_t = c_t + I_{t+1}$. The child's earnings depend on the parent's investment according to the equation $y_{t+1} = (1+r)I_{t+1} + A_{t+1}$, where r is the return to human capital investment and A_{t+1} represents all other determinants of the child's earnings besides human capital investment. Also $A_{t+1} = a_{t+1} + u_{t+1}$, where a_{t+1} represents the child's endowment of earning capacity, for instance, family connections, ability, race, skills, genetic heritage and family culture. The second component, u_{t+1}, is the child's market luck. u_t is uncorrelated with y_t and a_{t+1}. The child's endowment, a_{t+1}, is positively correlated with the parent's endowment, a_t. Becker and Tomes assume an AR(1) process where $a_{t+1} = \delta a_t + w_{t+1}$, $\delta \in [0,1)$ and w_{t+1} is white noise. Parents know their children's endowment and market luck at time t. Parents maximize the utility function $u(y_{t+1}, c_t) = (1-\beta)\text{ln}(c_t) + \beta\text{ln}(y_{t+1})$. Consider all variables in deviation from mean form.

At time t, parents solve the maximization problem

$$\begin{aligned}
&\max\{(1-\beta)\text{ln}(c_t) + \beta\text{ln}(y_{t+1})\} \\
&\text{subject to} \quad c_t = y_t - I_{t+1} \\
&\qquad\qquad\quad\; y_{t+1} = (1+r)I_{t+1} + A_{t+1}.
\end{aligned}$$

The solution to this optimization problem is

$$I_{t+1} = \beta y_t - \frac{(1-\beta)}{1+r} A_{t+1} \tag{2.1}$$

Substitute the above equation in the child's earnings equation to obtain,

$$y_{t+1} = (1+r)\beta y_t + \beta A_{t+1} \tag{2.2}$$

Substitute A_{t+1} by $a_{t+1} + u_{t+1}$ to obtain,

$$y_{t+1} = (1+r)\beta y_t + \beta a_{t+1} + \beta u_{t+1} \tag{2.3}$$

Substitute a_{t+1} by $\delta a_t + w_{t+1}$ in equation (2.3) to obtain the child's earnings as a function of family background (y_t, a_t) and child's market and endowment luck (w_{t+1}, u_{t+1}),

$$y_{t+1} = (1+r)\beta y_t + \beta\delta a_t + \beta w_{t+1} + \beta u_{t+1} \tag{2.4}$$

From the above derivation it is clear that, in this model, family background drives child's earnings through two channels. First, the child's earnings depend on human capital investment that depends on parent's earnings. Second, the child's earnings depend on child's endowment that depends on parent's endowment.

Since a_t and a_{t+1} are usually unobservable variables, the focus from now on will be on relationships predicted by the model that do not include those two variables. The term A_{t+1} in equation (2.2) can be eliminated solving equation (2.1) for A_{t+1} and plugging it in equation (2.2),

$$y_{t+1} = \frac{(1+r)\beta}{(1-\beta)} y_t - \frac{(1+r)\beta}{(1-\beta)} I_{t+1} \tag{2.5}$$

Note that, $\frac{\partial y_{t+1}}{\partial I_{t+1}} < 0$ in the above equation. Also, the coefficient on y_t is equal to the coefficient on I_{t+1}, except for the latter's negative sign.

The model also yields a relation between child and grandparent's earnings that does not include endowment of earnings capacity. First, consider equation (2.4) one period ahead,

$$y_{t+2} = (1+r)\beta y_{t+1} + \beta\delta a_{t+1} + \beta w_{t+2} + \beta u_{t+2}$$

Then, solve equation (2.4) for a_{t+1} and substitute in the above equation to obtain

$$y_{t+2} = [(1+r)\beta + \delta] y_{t+1} - (1+r)\beta\delta y_t + \phi_{t+2} \tag{2.6}$$

where $\phi_{t+2} = \beta(w_{t+2} + u_{t+2} - \delta u_{t+1})$.

Note that, in the above equation, parents' market luck (u_{t+1}) is related to parents' earnings (y_{t+1}). Becker and Tomes [3] considered the above equation in a model with no variance in market luck. Under this assumption the model predicts a negative relation between y_{t+2} and y_t.

a. Assuming $\delta = 0$ or $Var(a_{t+1}) = 0$

Ignoring the possibility that children inherit part of the parent's endowment ($\delta = 0$) or assuming that there is no variance in endowments ($Var(a_{t+1}) = 0$), equation (2.4) simplifies to

$$y_{t+1} = (1+r)\beta y_t + \epsilon_{t+1} \tag{2.7}$$

where $\epsilon_{t+1} = \beta w_{t+1} + \beta u_{t+1}$ if $\delta = 0$ and, $\epsilon_{t+1} = \beta u_{t+1}$ if $Var(a_{t+1}) = 0$[2].

Several papers estimate equation (2.7) to assess intergenerational mobility. An interesting aspect of the above specification is that the coefficient on parent's earnings can be interpreted as the intergenerational correlation between parent's earnings and child's earnings if the variances of earnings are the same for the parent and child generations. Yet, the assumption that all individuals have the same endowment or the assumption that the child's endowment is not related to parent's endowment can be considered strong assumptions for an intergenerational mobility model[3].

2. A Modification of the Becker and Tomes model

The variant of Becker and Tomes model previously presented yields some counter-intuitive predictions. For instance, the model predicts that the child's earnings are

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[2] Equation (i) can also be obtained from equation (2.3) considering father's earnings as a proxy for child' endowment.

[3] In the same study Solon obtained an equation equivalent to equation (2.6) considering an alternative model. He assumes that a sibling's lifetime earnings is determined by a family component (f_i) and a sibling specific component (b_{ij}) according to the equation $y_{ij} = f_i + b_{ij}$. The family component can be decomposed into parent i's long run earnings (X_i) and the combined effect of family background characteristics uncorrelated with parent's earnings (z_i), $f_i = \rho X_i + z_i$. So, the earnings of sibling j from family i can be written as $y_{ij} = \rho X_i + \epsilon_{ij}$, where $\epsilon_{ij} = z_i + b_{ij}$. By construction Cov($Xi, \epsilon_{ij}$)=0. But, note that the assumption that X_i is not correlated to z_i is equivalent to the assumption that $\delta = 0$ in the model presented in this subsection.

Assuming $\delta \neq 0$ and $Var(a_{t+1}) \neq 0$ equation (2.6) can be the obtained solving the parents' maximization problem if parents' preferences are represented by the utility function

$$u(c_t, E(y_{t+1})) = \begin{cases} 0 & \text{if} \quad E(y_{t+1}) < \beta y_{t+1} + \alpha \\ f(c_t) & \text{if} \quad E(y_{t+1}) > \beta y_{t+1} + \alpha, \end{cases}$$

where $f'(c_t) > 0$. These preferences imply that parents compensate perfectly with investments in children's human capital any difference between the children's endowment from their own endowment.

negatively related to grandparent's earnings when controlling for parent's earnings (see equation (2.5)). Moreover, the child's earnings are negatively related to the investment in the child's human capital after controlling for the parent's earnings (see equation (2.4)). It is reasonable to imagine that those variables have a positive impact on the child's earnings. In the next two paragraphs, I explain in words how the model in the previous section yields those predictions.

Consider two sets of child-parent-grandparent. Suppose that the two parents have the same earnings but one grandparent is wealthier than the other. The wealthier grandparent had more money to invest in his child than the poor grandparent, and yet their children have the same earnings. In the model this happens because the child of the wealthy grandparent is less endowed than the child of the poor grandfather. In the next generation, the child of the grandparent is a parent. The parents of the second generation of children have the same earnings to invest in their children's human capital. But, the grandchild of the wealthy grandparent is expected to inherit at least part of his parent's relatively low endowment, yielding a negative relation between child's and grandparent's earnings when controlling for the parent's earnings. This happens because in the model the grandparent can only affect the grandchild though the parent, but common sense would suggest that wealthy grandparents may also have a positive direct impact on the grandchild's earnings.

The Becker and Tomes model yields a simple compensation scheme in which parents partially compensate for the child's endowment (or market luck) with investment in human capital. Since the child's earnings are positively related to the child's endowment (or market luck) this compensation yields a negative relationship between the child's earnings and investment in human capital when controlling for the parent's earnings. Different assumptions yields more complex compensation structures.

In fact, the data disagree with the predictions of the original Becker and Tomes model. In section D, I show that after controlling for the parent's earnings, the impact of the grandparent's earnings on the grandchild's earnings is positive. The same is true for investment in human capital.

In this section I obtain more intuitive predictions by introducing a more general assumption and replacing some assumptions by others more in accordance with economic theory.

I modify three aspects of the previous model. First, I assume parents know their children's endowment but not their children's market luck. Second, I assume that parents' utility function depends on their children's consumption instead of their children's earnings. Third, I assume that the child's endowment depends on the parent's and grandparent's endowment according to the equation $a_{j+2} = \delta a_{j+1} + \theta a_j + w_{j+2}$ for all $j \in \mathbb{N}$.

The first assumption is reasonable if we expect that the realization of the child's market luck happens at the time the child reaches the job market and not before. Solving the parents' maximization problem under this assumption, requires an extra assumption about the parent's preference toward risk. Alone, the assumption that parents do not know the child's market luck combined with the assumption that parents are risk neutral will not change the basic results of the previous model.

Economist believe that consumption, not income, provides utility. That is the reason why I replace the assumption that parents' utility depends on their children's earnings[4] for the assumption that parents' utility depends on children's consumption. It is interesting to note that, since parents' utility depends on their children's consumption and their children' utility depends on their grandchildren's consumption,

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[4] Becker and Tomes assume that parents' utility depends on children's quality or economic success that is measured by the children's wealth.

and so on, parents' utility indirectly depends on all their descendants consumption[5].

The assumption that the child's endowment also depends on the grandparent's endowment is more general. The assumption in the previous section can be reestablished at any point by setting $\theta = 0$. The advantage of a more general assumption is that it introduces a relation between children's and grandparents' earnings that does not work through parents' earnings or endowments. If the parameters of the model satisfy some conditions, this assumption introduces a positive relation between the child's and grandparent's earnings. For specifications that do not require proxies for the child's endowment, this assumption requires at least three generations in order to estimate the importance of family background in explaining variation in earnings.

At time t=0, the parent solves the maximization problem

$$\begin{aligned} &\max\{(1-\beta)\ln(c_0) + \beta\ln(c_1)\} \\ &\text{subject to} \quad y_0 = (1+r)I_0 + A_0 \\ &\qquad\qquad\quad c_0 = y_0 - I_1 \\ &\qquad\qquad\quad y_1 = (1+r)I_1 + A_1 \\ &\qquad\qquad\quad c_1 = y_1 - I_2. \end{aligned}$$

As before, $A_t = a_t + u_t$ for all $t \in \mathbb{N}$ and the expected value of u_t is zero.

Suppose parents are risk neutral and maximize expected values. Let the superscript e_t refer to the parent's expectation at time t. So, the parent's maximization problem can be written as

$$\max_{\{I_1\}}\{(1-\beta)\ln((1+r)I_0 + A_0 - I_1) + \beta\ln((1+r)I_1 + a_1 - I_2^{e_0})\} \tag{2.8}$$

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[5] One could argue that parents care about their children's earnings because they care about the investment in their grandchild. But it is the consumption that today's investment will make affordable in the future that improves utility, not the investment per se.

Assume that parents believe that their descendants' preferences are the same as their own preferences, and the future rates of return to human capital investment will be equal to r. Then, the solution to the maximization problem (8) is

$$I_1 = \beta y_0 + \frac{\beta(1+r) - \delta - r}{r(1+r)} a_1 - \frac{\theta}{r(1+r)} a_0 \tag{2.9}$$

Derivations appear in Appendix A.

The model predicts a relationship in which an individual's earnings depends on his/her family background that does not include endowment of earnings capacity as one of the dependent variables. First, in the grandchild's earnings equation, $y_2 = (1+r)I_2 + a_2 + u_2$, substitute a_2 by $\delta a_1 + \theta a_0 + v_2$ to find

$$y_2 = (1+r)I_2 + \delta a_1 + \theta a_0 + v_2 + u_2 \tag{2.10}$$

It is possible to replace the terms a_1 and a_0 in the above equation with functions of I_1, I_2, y_0 and, y_1. Solve equation (2.9) for one period ahead to obtain

$$I_2 = \beta y_1 + \frac{\beta(1+r) - \delta - r}{r(1+r)} a_2 - \frac{\theta}{r(1+r)} a_1$$

Substitute a_2 by $\delta a_1 + \theta a_0 + v_2$ in the above equation to find

$$I_2 = \beta y_1 + \frac{[\beta(1+r) - \delta - r]\delta - \theta}{r(1+r)} a_1 + \frac{\beta(1+r) - \delta - r}{r(1+r)} \theta a_0 + \frac{\beta(1+r) - \delta - r}{r(1+r)} v_2$$

Use the above equation and equation (2.9) to find a_1 and a_0 as functions of I_1, I_2, y_0 and, y_1. Substitute those equations in (2.10) to find

$$\begin{aligned} y_2 = \frac{(1+r)}{[\beta(1+r) - \delta - r][\beta(1+r) - r] - \theta} \Big[& [(\beta(1+r) - r)(\beta(1+r) - \delta) - \theta] I_2 \\ & - r(\beta(1+r) - r)\beta y_1 - r\theta(\beta y_0 - I_1) + \frac{\theta_0}{(1+r)} v_2 \Big] + u_2 \end{aligned} \tag{2.11}$$

Note that $\frac{\partial y_2}{\partial I_2} > 0$, $\frac{\partial y_2}{\partial y_1} > 0$, $\frac{\partial y_2}{\partial y_0} > 0$ and, $\frac{\partial y_2}{\partial I_1} < 0$ for $r < \beta(1+r) < \delta$.

In equation (2.10), the grandchild's earnings are a function of I_2, a_1 and a_0. In order to obtain equation (2.11) the terms a_1 and a_0 are replaced by functions of I_1, I_2, y_0 and, y_1. The terms I_1, y_0 and, y_1 are introduced for the first time in equation (2.10) to capture the impact of heritage of endowment on the grandchild earnings. Therefore, the share of variation in grandchildren's earnings explained by variations in I_1, y_0 and y_1 in equation (2.11) represents a lowerbound for the variation in grandchildren's earnings explained by variation in endowment capacity across families. Analogously, the share of variation in grandchildren's earnings explained by variation in I_2 in equation (2.11) represents an upperbound for the variation in grandchildren's earnings explained solely by variation in investment in the grandchild's human capital.

a. Assuming $Var(a_{t+1}) = 0$

Assuming that $Var(a_j) = 0$ for all $j \in \mathbb{N}$, equation (2.9) simplifies to $I_1 = \beta y_0$. Substitute it in the the child's earnings equation to obtain

$$y_1 = (1+r)\beta y_0 + u_1 \tag{2.12}$$

This equation is equivalent to equation (2.6). But, again, the assumption that all individuals have the same endowment is strong for an intergenerational mobility model.

b. Assuming $\theta = 0$ (no skipping generations effect)

Assuming that the child's endowment does not depend on the grandparent's endowment ($\theta = 0$), equation (2.9) simplifies to

$$I_1 = \beta y_0 + \frac{\beta(1+r) - \delta - r}{r(1+r)} a_1 \tag{2.13}$$

Substitute the above equation in the child's earnings equation to obtain,

$$y_1 = (1+r)\beta y_0 + \frac{\beta(1+r)-\delta}{r} a_1 + u_1 \tag{2.14}$$

The term a_1 in the above equation can be eliminated solving equation (2.13) for a_1 and plugging it in equation (2.14),

$$y_1 = -\frac{\beta(1+r)r}{\beta(1+r)-\delta-r} y_0 + \frac{(1+r)(\beta(1+r)-\delta)}{\beta(1+r)-\delta-r} I_1 + u_1 \tag{2.15}$$

Note that $\frac{\partial y_1}{\partial I_1} > 0$ and, $\frac{\partial y_1}{\partial y_0} > 0$ for $r < \beta(1+r) < \delta$.

A relationship between the child's and the grandparent's earnings can be obtained. First, substitute $a_1 = \delta a_0 + w_1$ in equation (2.14),

$$y_1 = (1+r)\beta y_0 + \frac{\beta(1+r)-\delta}{r} \delta a_0 + \frac{\beta(1+r)-\delta}{r} w_1 + u_1$$

Then, solve the above equation for one period ahead,

$$y_2 = (1+r)\beta y_1 + \frac{\beta(1+r)-\delta}{r} \delta a_1 + \frac{\beta(1+r)-\delta}{r} w_2 + u_2$$

Finally, solve equation (2.14) for a_1 and substitute in the above equation to obtain,

$$y_2 = [\beta(1+r)+\delta] y_1 - \beta(1+r)\delta y_0 - \delta u_1 + \frac{\beta(1+r)-\delta}{r} w_2 + u_2 \tag{2.16}$$

Note that $\frac{dy_2}{dy_1} > 0$ and, $\frac{dy_2}{dy_0} < 0$, that is, the grandchild's earnings are positively related to the parent's earnings but, negatively related to the grandparent's earnings.

Table I summarizes the assumptions and predictions of the models presented. In section D, I estimate the four equations presented in Table I.

Table I. Summary of assumptions and predictions of the Becker and Tomes and the modified models

Equation	Equation number in text	Becker and Tomes	Modified Model
(i) $y_{t+1} = \gamma y_t + \epsilon_{t+1}$	(7) & (12)	Assumption Added to the Model: $\delta = 0$ or $Var(a_j) = 0$	Assumption Added to the Model: $Var(a_j) = 0$
(ii) $y_{t+1} = \eta_1 y_t + \eta_2 I_{t+1} + \epsilon_{t+1}$	(5) & (15)	Predictions: $\frac{\partial y_{t+1}}{\partial I_{t+1}} < 0$ and $\frac{\partial y_{t+1}}{\partial y_t} = -\frac{\partial y_{t+1}}{\partial I_{t+1}}$	Assumption Added to the Model: $\theta = 0$. Predictions: $\frac{\partial y_{t+1}}{\partial I_{t+1}} > 0$ and $\frac{\partial y_{t+1}}{\partial y_t} > 0$
(iii) $y_{t+2} = \tau_1 y_{t+1} + \tau_2 y_t + \epsilon_{t+1}$	(6) & (16)	Assumption Added to the Model: $Var(u_{t+1}) = 0$. Prediction: $\frac{\partial y_{t+2}}{\partial y_t} < 0$	Assumption Added to the Model: $\theta = 0$. Prediction: $\frac{\partial y_{t+2}}{\partial y_t} < 0$
(iv) $y_{t+2} = \pi_1 y_{t+1} + \pi_2 y_t + \pi_3 I_{t+2} + \pi_4 I_{t+1} + \epsilon_{t+1}$	(11)	The equation is not predicted in the model.	for $r < \beta(1+r) < \delta$. Predictions: $\frac{\partial y_2}{\partial I_2} > 0$, $\frac{\partial y_2}{\partial y_1} > 0$, $\frac{\partial y_2}{\partial y_1} > 0$ and, $\frac{\partial y_2}{\partial I_1} < 0$

Table II. Selected characteristics of males aged 16 to 64

Number of Observations	96,788
	Average
Monthly Earnings (reais)	580.40
	(952.4)
Years of Education	5.9
	(4.3)
Age Started Working	12.9
	(3.8)
	Percentage
Black/Mixed Race	43.9
Living in Rural Areas	20.1
Region of Residence:	
Southeast	45.8
Northeast	27.0
South	15.8
Midwest	7.0
North	4.4
Aged 16 to 24	29.2
Aged 25 to 34	25.3
Aged 35 to 44	21.4
Aged 45 to 54	14.7
Aged 55 to 64	9.5

*S*ource: 1996 PNAD.

Note: Standard deviations in parenthesis.

C. Data

The *Pesquisa Nacional por Amostra de Domicilios* (PNAD) is a nationally representative household survey conducted almost every year in Brazil. Survey participants are asked about the age, /education, occupation and earnings of all members in the household. Also, they are asked to specify the relationship of each member to the reference person in the household, allowing identification of the father, sons and brothers for most households. Tables II and III presents some descriptive statistics for males in the 1996 PNAD.

In Table II, note the low educational achievement (5.9 years on average) and

Table III. Selected characteristics of males in the 1996 PNAD, by age

		Percentages				
Age	Number of Observations	Living with Parents	Married	Working	Living with Parents and Married	Living with Parents and Working
12	3,305	99.97	0.03	4.36	0.00	4.36
13	3,496	99.94	0.06	7.18	0.00	7.15
14	3,519	99.94	0.03	12.45	0.03	12.39
15	3,492	99.71	0.14	21.05	0.06	20.85
16	3,482	99.25	0.78	31.68	0.26	31.05
17	3,226	98.17	1.77	40.67	0.65	39.03
18	3,048	95.44	3.97	47.34	1.08	43.47
19	2,883	91.47	9.02	58.20	2.43	50.78
20	2,706	85.37	14.34	64.63	2.92	51.66
21	2,495	81.48	18.48	66.77	3.37	50.06
22	2,530	71.07	28.74	74.55	4.11	47.94
23	2,404	65.43	33.69	77.04	3.74	45.26
24	2,396	56.30	41.90	79.34	3.09	39.44
25	2,244	50.89	47.46	82.26	3.74	36.50
26	2,388	45.48	53.43	82.79	3.64	32.29
27	2,308	36.83	60.10	84.10	2.38	25.52
28	2,212	30.65	67.04	87.66	2.22	22.65
29	2,164	27.45	68.76	86.92	2.22	19.45
30	2,513	24.11	71.55	86.87	1.59	16.39
31	2,265	19.91	75.89	88.52	1.59	14.04
32	2,350	19.40	77.19	88.21	1.66	13.28
33	2,358	16.96	78.29	89.31	1.06	11.87
34	2,214	14.91	81.21	90.24	0.99	10.75
35	2,152	13.75	81.83	89.41	1.12	9.53
36	2,222	12.83	82.49	90.37	0.72	8.51
37	2,115	11.11	83.88	90.54	0.57	7.85
38	2,111	9.95	84.37	89.82	0.47	6.40

*S*ource: 1996 PNAD.

the early age at which Brazilians start working (age 12.9 on average). In Table III, note that the percentage of males living with parents is high even among older males. For instance, at age 25, 50.9% of the males are still living with their parents. The percentage of males living with parents falls for older ages and the percentage of married males raises with age, and the sum of those percentages yields a number close to one for all ages. Among the males living with their parents only a small percentage is married. The numbers suggest that most males live with their parents until they marry.

The 1996 PNAD includes a mobility supplement with information on both the parents of the reference person and his/her spouse. It provides information on the parents' education and the father's occupation when the son was 15 years old. That information allows estimation of equations (i) and (ii) in Table I.

Estimation of equations (iii) and (iv) requires a data set that covers at least three generations within a family. I take advantage of two specific characteristics of Brazil to build a data set with three generations. First, typically, sons live with their parents until they marry. Second, individuals quit school and start working at an early age. The first characteristic implies that it is likely that there are many households with adult sons in the basic sample of PNAD. The second characteristic suggests that those adult sons are not at the very beginning of their working careers.

Therefore, it is possible to build a nearly representative data set spanning three generations for Brazil by restricting the sample to households with adult sons. For those households, information is available on the reference person of the household (father), the son of the reference person (son) and the father of the reference person (grandfather)[6].

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[6] For the households in which a woman is the reference person, her spouse, if any, is considered the father and, his father the grandfather. Only about 2% of the

I built the three-generations data by focusing on sons aged 16 to 27 years[7]. The reason for the age restriction is to exclude the extremely unusual sons. As shown in Table III, it is somewhat common and normal for males in the selected age interval to be working, living with parents and single[8].

Sample selection problems may arise when dealing with a subsample consisting of households with adult sons. I use Heckman's estimation procedure to deal with this problem. I discuss the selection equation later in this section.

Note that the mobility supplement in PNAD does not provide the earnings of the father of the reference person (or spouse) in the household. Instead, it provides information on the fathers' occupation and education when the son was 15 years old.

To estimate a father's earnings, first, I calculate the year the son was 15-year-old and use the PNAD of that year (or the closest available year) to estimate the earnings equation of males. I assume earnings depend on education, 46 occupation category, experience (up to a quartic term), interaction dummies between 8 more broad occupation categories and experience, race and, state of residency. Second, I apply the estimated equation to the corresponding set of characteristics of the father to estimate the father's earnings.

Ferreira and Veloso [18] and Dunn [13] applied similar procedure. In Ferreira and Veloso [18], the earnings equation depend on education, 6 occupational categories, dummies for cohort and interactions for cohort-occupation and cohort-education. In

---

households have a married woman as the reference person.

[7] I discuss the results for different age intervals in section D.

[8] Participants of the 1996 survey are not explicitly asked about their marital status. But, they are asked to specify the relationship of each member with the head of the family. Married couples are identified if one member in the family is the spouse of the head of the family. Everyone else is assumed to be single. The accuracy of this procedure is checked for the 1995 PNAD that explicitly ask about each member marital status. The procedure identified 64,427 of the 64,766 married males.

Dunn [13], earnings depends on education and age (up to a quadratic term).

The mobility supplement does not inform the race or state of residence of the father. I estimate the father's expected earnings conditional on son's race. For instance, consider the father of a white male. I calculate the percentage of fathers in each race group conditional on the son's race being white. Then, I use those percentages as weights to calculate the weighted average earnings. Because the incidence of interracial marriage may differ over time, I calculate those percentages for all the years that all the necessary information are available, the appropriate year is chosen according to the son's age.

The migration segment informs the number of year the individual have being living in the current state (up to ten years), which allows identification of the state of residence at age 15 for some males. For the remaining males, I estimate the father's expected earnings conditional on son's state of birth. For instance, suppose the son was born in Rio de Janeiro. I calculate the percentage of males in the age interval 13-17 living in each Brazilian state conditional on being born in Rio de Janeiro. Then, I use those percentages as weights to calculate the weighted average earnings. Because migration flows may differ over time, I calculate those percentages for all the years that all the necessary information are available, the appropriate year is chosen according to the son's age[9].

Note that the father of the reference person (or spouse) corresponds to the grandfather in the data set for three generations.

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[9] I describe in details the procedure to impute the father's earnings in the paper "Intergenerational mobility in earnings in Brazil with data on three generations".

1. Selection equation in the three-generations data set

I assume that the probability that a male lives in his parents' house depends on age, marital status, whether he is enrolled in school, and his father's earnings.

$$P(\text{son live with parents}) = f(\text{age, marital status, school enrollment, father's ernings})$$

As shown in Table III, older males are less likely to live with their parents and few males stay in their parents' house after getting married. I expect that sons enrolled in school are more likely to live with their parents and, I expect that better paid fathers can afford having their children at home for a longer time.

Note that the fathers' earnings in September of 1996 are available only for males living with their parents. For both groups, males living with parents and males that do not, the set of variables used to impute the fathers' earnings are available. The difference is that for a male living with his parents, I have data on the father's occupation and education in 1996 instead of the father's occupation and education when the son was 15 years old. Assuming that the father's occupation and education does not change while the son is aged between 15 and 27, I can impute the fathers' earnings for both groups repeating the same procedure applied before.

The top panel of Figure 1 shows the percentage of males living with their parents by age and marital status: the bulk of the married sons do not live with their parents, regardless of their age. The bottom panel of Figure 1 shows there is a higher percentage of sons enrolled in school among the sons living with their parents than among the ones that do not. Figure 2 shows that the fathers of sons living with parents are better paid than the fathers of sons not living with parents, for all ages considered[10].

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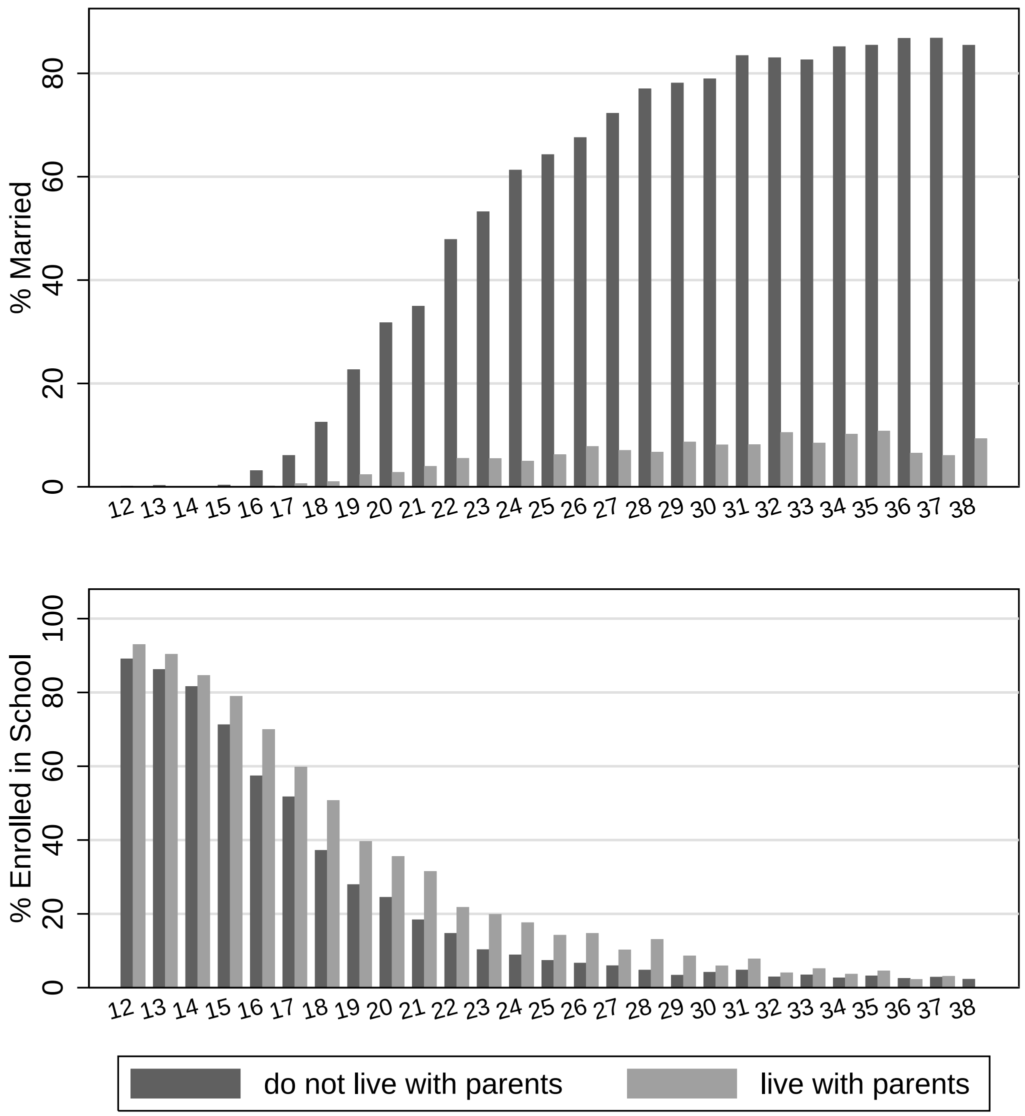
[10] The general shape of Figure 1 and 2 does not change for the sample used in the regressions.



Source : 1996 PNAD

Fig. 1. Living arrangements of sons, by age, marital status and school enrollment status

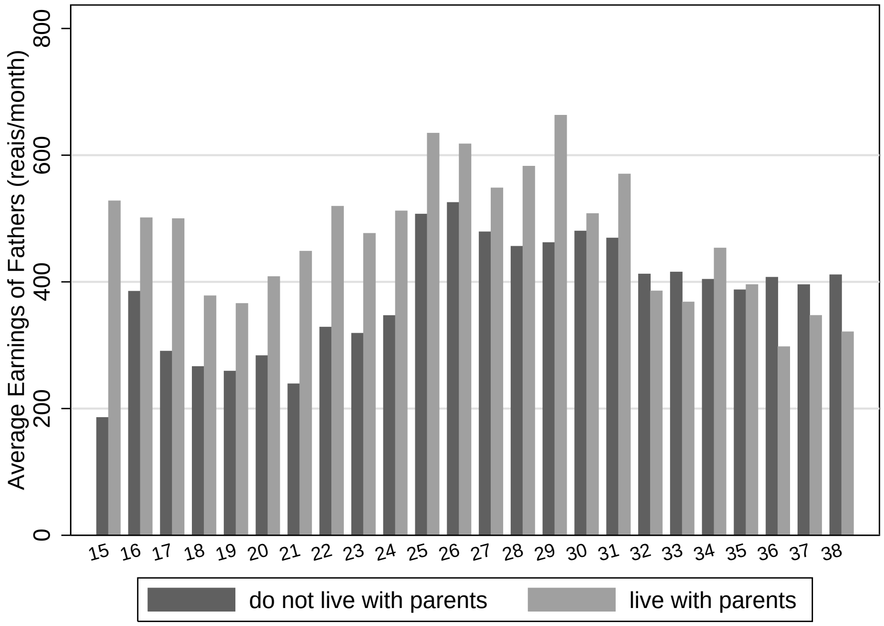


Fig. 2. Average earnings of fathers by living arrangements of sons and sons' age

One may argue that the males that succeed in the job market are more likely to marry and leave their parents' house, while the males that stay with their parents have lower earnings and worse marriage perspectives. Figure 3 shows that conditional on age, the average earnings of sons living with parents is not lower than the average earnings of sons who have moved out. The same is true for the average earnings of single and married males. Conditional on age, the average earnings of married males is not higher than the average earnings of single males[11].

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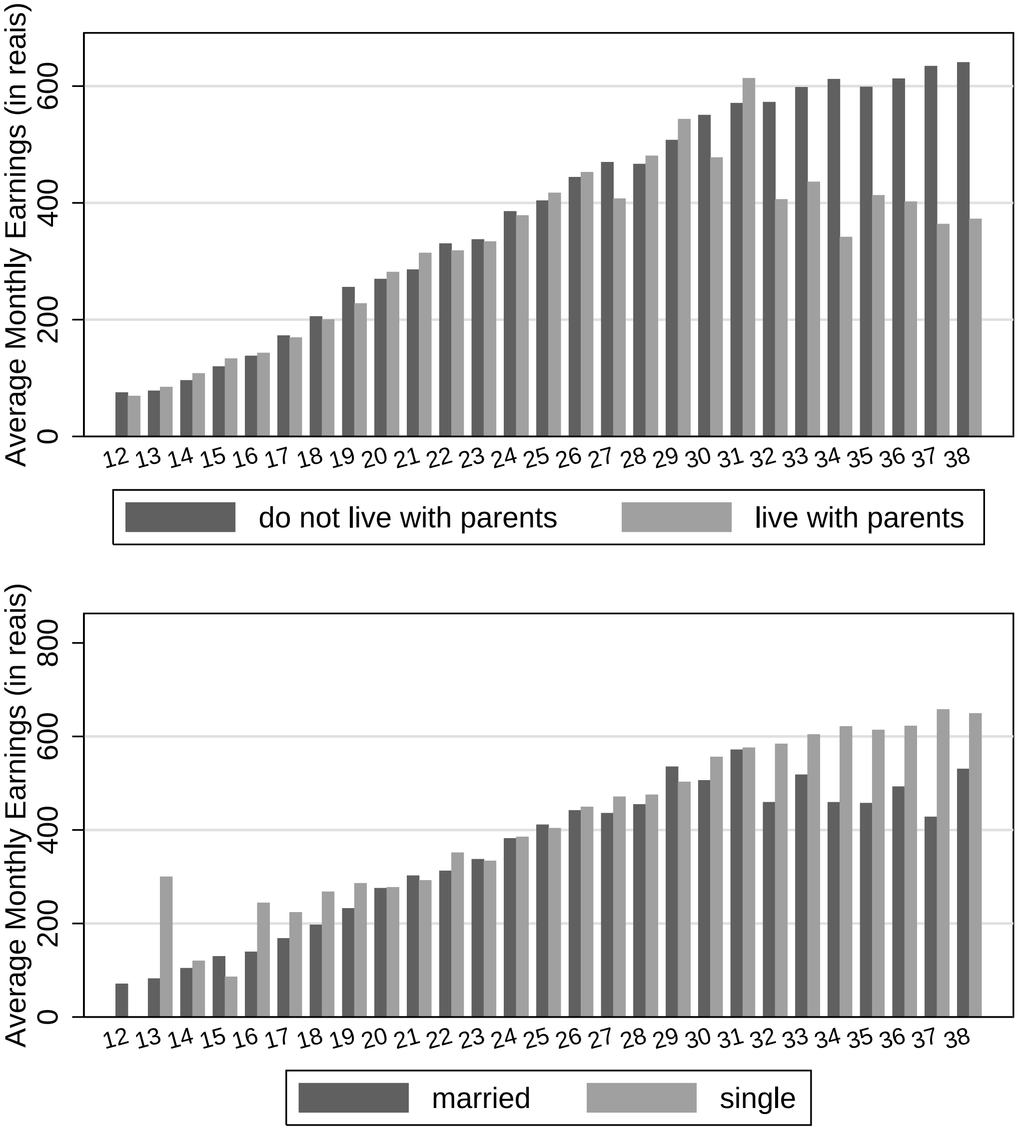
[11] Figure 31 in Appendix A presents the equivalent figure for the sample used in the regressions. There is a difference in average years of education. For sons aged 16 to 27, average years of education is 6.41 if they live with their parents; it is 5.94 if they live by themselves. Considering only the sons who are not enrolled in school, the averages are basically the same, 5.62 and 5.59. The averages are also similar when considering only the sons who are enrolled in school, 7.57 and 7.46. Therefore, only enrollment in school is kept in the selection equation. Among the sons not living with parents the percentage of blacks or mixed race is higher than the percentage of whites but the coefficient in the selection equation is not significant when controlling for father's earnings.



Source : 1996 PNAD

Fig. 3. Average earnings of sons by living arrangements, marital status and age

D. Estimation results

Estimation of equations (i) and (ii) requires data on at least two generations. Estimation of equations (iii) and (iv) requires data on at least three generations.

The PNAD combined with the 1996 Mobility Supplement provides information on two generations: all male heads of household (or spouse) and his father. The subsample consisting of households with adult sons contains information on a third generation[12].

I apply OLS when dealing with the sample of all heads of household (or spouse) and Heckman's estimation procedure when dealing with the subsample of households with adult sons.

I drop sons working fewer than 15 hours a week and those with no paid jobs[13].

1. Estimation of equation (i): $y_{t+1} = \gamma y_t + \epsilon_{t+1}$

a. Sample of males head of household (or spouse) and their fathers

Consider first the sample of males head of household (or spouse) and their fathers. I restrict the sample to sons aged 16 to 64. The proxy for the son's lifetime earnings is his earnings in September of 1996. The fathers' earnings are not available. I impute their earnings at age 47 as described in the previous section.

A control for sons' age is necessary to avoid bias of the estimate of the intergen-

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[12] Others papers have used a three-generations data set to study intergenerational mobility. They estimate mobility tables or the probability that an individual belongs to a certain socioeconomic stratum as a function of parents and grandparents' characteristics. Recent papers include Erola and Moisio [15], Warren and Hauser [36] and Biblarz et al. [6]. Peters [32] uses data from the National Longitudinal Surveys to estimate the grandson's earnings as a function of parents' characteristics and grandfathers' education and finds no significant effect for the grandfathers' education.

[13] The percentage of males working part time (15-39 hours) in the three generations sample used in the regressions is not high among males living with parent (13.7%) or for males head of the household (7.9%).

erational elasticity. To illustrate the point, consider a society in which every son has exactly the same lifetime earnings as his father. Because of the age difference among sons, at any given year they are in different points of their career paths. Estimation the intergenerational elasticity using the fathers' earnings at age 47 and the sons' earnings in 1996 without any control for sons' age would yield an estimate lower than one. To control for sons' age, the specification includes an indicator variables for every five-year age intervals.

Estimation results of equation (i), presented in Table IV, column (a), suggest a highly immobile society. The intergenerational elasticity in earnings is 0.84, meaning that a difference in earnings among fathers of 100% is perpetuated by a difference in earnings among sons of 84%[14]. The estimated intergenerational elasticity range from 0.4 to 0.5 for U.S.

Dunn [13] and Ferreira and Veloso [18] also use data from PNAD and find the intergenerational elasticity in earnings in Brazil of 0.85 and 0.58, respectively[15]. Behrman et al. [4] and Ferreira and Veloso [17] use data from PNAD and find that the correlation between parent's and child's education in Brazil is 0.7 and 0.79, respectively.

As shown in column (b) the intergenerational elasticity increases with age. There are two interpretations for the higher elasticity for older males. First, the intergener-

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[14] Note that equation (i) does not have a constant term. A constant was included in the estimations to account for the fact that average earnings of fathers and sons are not necessarily the same. For instance, the constant is positive in a society that experienced per capita economic growth.

[15] In the paper "Intergenerational mobility in earnings in Brazil with data on three generations", I show that most of the difference between the estimate in this paper and in Ferreira and Veloso [18] is explained by three differences in the estimation criteria. Fist, Ferreira and Veloso exclude the rural areas and the sons working between 15 and 39 hours a week. Second, they include indicator variables for race and region in the regressions. Third, they estimate the fathers' earnings ignoring the difference in earnings across race and state.

Table IV. OLS estimation of equation (i): $y_{t+1} = \gamma y_t + \epsilon_{t+1}$

(A)

	(a)	(b)	(c)
Dependent Variable: Son's Earnings			
Father's Earnings	0.843***	0.596***	1.195***
	(0.01)	(0.03)	(0.03)
Father's Earnings*Son's Age 25-34		0.150***	
		(0.03)	
Father's Earnings*Son's Age 35-44		0.289***	
		(0.03)	
Father's Earnings*Son's Age 45-54		0.371***	
		(0.03)	
Father's Earnings*Son's Age 55-64		0.381***	
		(0.04)	
Father's Earnings*Father's Earn. Above the Median			–0.559***
			(0.03)
Constant	0.795***	2.117***	–1.040***
	(0.07)	(0.15)	(0.16)
Fathers Earnings Above the Median			3.239***
			(0.17)
Adjusted R^2	0.297	0.302	0.310
N. of Observations	36,705	36,705	36,705

Note: Standard errors in parentheses. Omitted age: 16-24 years old. Coefficients of indicator variables for age are not presented.

* significant at 10%, ** significant at 5%, *** significant at 1%.

Table IV. Continued

(B)

	(d)	(e)	(f)
Dependent Variable: Son's Earnings			
Father's Earnings	0.755***	0.740***	0.724***
	(0.01)	(0.01)	(0.01)
Father's Earnings*Black/Mixed	0.021		
	(0.02)		
Father's Earnings*North		–0.143***	
		(0.03)	
Father's Earnings*Northeast		0.194***	
		(0.02)	
Father's Earnings*South		0.004	
		(0.02)	
Father's Earnings*Midwest		–0.078***	
		(0.02)	
Father's Earnings*Rural			0.171***
			(0.02)
Constant	1.444***	1.527***	1.606***
	(0.07)	(0.09)	(0.07)
Black/Mixed	–0.427***		
	(0.09)		
North		0.711***	
		(0.18)	
Northeast		–1.423***	
		(0.10)	
South		–0.083	
		(0.12)	
Midwest		0.369***	
		(0.14)	
Rural			–1.540***
			(0.12)
Adjusted R^2	0.316	0.319	0.352
N. of Observations	36,705	36,705	36,705

Source: PNAD.

Note: Standard errors in parentheses. Omitted region: Southeast. Coefficients of indicator variables for age are not presented.

* significant at 10%, ** significant at 5%, *** significant at 1%.

ational elasticity is decreasing over time. Second, the elasticity between father's and son's earnings increases over the son's life cycle. Mayer [29] finds that for U.S. "the strength of the relationship between parental features and the wages of sons increases over the life cycle of the sons." He points out that the second interpretation is consistent with wage evolution models like Ben-Porath [5] and Jovanovic [28]. Haider and Solon [21] suggest that for U.S. the son's one-year-earnings is a better proxy for lifetime earnings when measured in the early thirties and mid forties because the attenuation bias associated to one-year-earnings is small in this age interval. According to Grawe [19], the life cycle bias when estimating the intergenerational elasticity in lifetime earnings is likely to be reduced by observing both fathers and sons near midlife. Dunn [13] estimate the intergenerational elasticity using sons' earnings at age 40 and find that the elasticity is lower for younger cohorts.

The remaining columns of Table IV show that intergenerational elasticity is higher among the sons of males with earnings below the median than above the median, it is higher among the sons currently living in rural than urban residencies and, it is higher among the sons currently living in the southeast than the northeast– a poor region in Brazil. The elasticity is not significantly different for for blacks or individuals of mixed race than for other race groups[16].

b. How bad is the selection problem?

As mentioned earlier, I can impute fathers' earnings for both sons living with parents and sons that do not. The difference is that for sons living with parents I have information on the father's occupation and education in 1996 rather than at the time

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[16] The paper "Intergenerational mobility in earnings in Brazil with data on three generations" provides a detailed discussion about the estimation results for equation (i).

the son was 15 years old.

Using the imputed father's earnings, I can estimate the intergenerational elasticity in earnings among young sons (living with parents or not) and compare the result with the elasticity obtained using the subsample of young sons living with parents. The results are presented in Table V.

Among the sons aged 16 to 21, the intergenerational elasticity in earnings is 0.389 for the full sample[17]. It is about the same for the sample of sons living with their parents: 0.393 (OLS), 0.398 (Heckman two step), and 0.398 (Heckman maximum likelihood).

Among the sons aged 22 to 27, the intergenerational elasticity is higher for the full sample (0.22) than for the subsample of sons living with parents (about 0.19). I obtain similar results applying OLS (0.185), Heckman two step (0.189) or Heckman maximum likelihood (0.188).

The Heckman estimation is justified by the high chi-squared value for a test of the Heckman model versus a model with no selection problem. The p-value is 0.0016.

As expected, married and older sons are less likely to live with their parents. Sons of better paid fathers and sons enrolled in school are more likely to live with their parents.

2. Estimation of equation (ii): $y_{t+1} = \eta_1 y_t + \eta_2 I_{t+1} + \epsilon_{t+1}$

I use years of formal education as a proxy for investment in human capital[18].

---

[17] Note that I am dealing with a young cohort and, as previously discussed, the intergenerational elasticity is lower for younger cohorts.

[18] I am assuming that parents who care about quality of education also care about years of education. So more years of formal education implies more investment in human capital because parents invest for a longer period of time, and because parents invested in more quality.

Table V. Estimation of equation(i): $y_{t+1} = \gamma y_t + \epsilon_{t+1}$ for fathers and grandsons

(a) Sons living with parents - OLS
(b) Sons living with parents - Heckman Two Step Estimation
(c) Sons living with parents - Heckman Maximum Likelihood Estimation
(d) All Sons (living or not with parents) - OLS

	(a)	(b)	(c)	(d)
Dependent Variable: Grandson's Earnings				
Father's Earnings (Imputed)	0.393***	0.398***	0.398***	0.389***
	(0.018)	(0.016)	(0.018)	(0.016)
Father's Earnings (Imputed)*Older Coh.	0.185***	0.189***	0.188***	0.220***
	(0.028)	(0.025)	(0.028)	(0.021)
Constant	2.912***	2.869***	2.872***	3.007***
	(0.099)	(0.091)	(0.100)	(0.090)
Older Cohort	–0.788***	–0.843***	–0.840***	–0.877***
	(0.162)	(0.146)	(0.161)	(0.119)
Selection Equation				
Married		–2.570***	–2.558***	
		(0.042)	(0.042)	
Age		–0.157***	–0.157***	
		(0.007)	(0.007)	
Enrolled in School		0.144**	0.152**	
		(0.054)	(0.055)	
Father's Earnings (Imputed)		0.190***	0.186***	
		(0.027)	(0.028)	
Constant		3.474***	3.484***	
		(0.184)	(0.186)	
R^2	0.286			0.309
LR Test of Indep. Equations			12.657	
N. of Observations Censored		5,125	5,125	
N. of Observations	5,125	10,176	10,176	10,176

Source: 1996 PNAD.

Note: Standard errors in parentheses. Cluster: family (except for the two step regression).

* significant at 10%, ** significant at 5%, *** significant at 1%.

Consider first the sample of males head of household (or spouse) and their fathers. Controlling for father's earnings, the impact of the son's education on his own earnings, η_2 in equation (ii), is positive (see Table VI), contrary to the negative sign predicted by the Becker and Tomes model.

The sign is also positive across cohorts, race groups, regions and rural versus urban areas. It is also positive for the sample of sons living in their parents' house.

I obtain equation (ii) in the (partially) modified model by assuming there is no skipping generations effect ($\theta = 0$). Under this assumption, the sign of the estimated coefficient agrees with the predictions of the model. But the assumption that $\theta = 0$ is contradicted in the estimation of equation (iii).

3. Estimation of equation (iii): $y_{t+2} = \tau_1 y_{t+1} + \tau_2 y_t + \epsilon_{t+1}$

The rest of the estimations require a three-generations data set.

To account for the fact that two sons may be at different points in their careers in 1996 just because one is older than the other, I use an indicator variable for the older cohort between 16 and 21 years old.

Two fathers may have different earnings in 1996 just because one is older than the other. If all fathers were the same age when their sons were born, an indicator variable for the sons' age would control for the fact that not all father-son pairs are at the same stage of their careers in 1996. Although the father's and son's age are related, this is not a one to one relation. The coefficient in a regression of the sons' age on the father's age is 0.16 and the R^2 is 0.15. To correct for the fact that not all fathers are at the same stage of their careers in 1996 an indicator variable for son's cohort may not perfectly characterize the father's cohort, I use the father earnings minus the average earnings for his age group. The age groups for the fathers are aged 45 and younger, aged 46 to 55, and older than 55.

Table VI. OLS estimation of equation (ii): $y_{t+1} = \eta_1 y_t + \eta_2 I_{t+1} + \epsilon_{t+1}$

	(a)	(b)
Dependent Variable: Son's Earnings		
Father's Earnings	0.334***	0.375***
	(0.008)	(0.028)
Son's Years of Education	0.120***	0.073***
	(0.001)	(0.005)
Father's Earnings*Son's Age 25-34		–0.048
		(0.031)
Father's Earnings*Son's Age 35-44		–0.036
		(0.031)
Father's Earnings*Son's Age 45-54		–0.037
		(0.032)
Father's Earnings*Son's Age 55-64		0.004
		(0.038)
Son's Education*Son's Age 25-34		0.036***
		(0.006)
Son's Education*Son's Age 35-44		0.049***
		(0.006)
Son's Education*Son's Age 45-54		0.057***
		(0.006)
Son's Education*Son's Age 55-64		0.058***
		(0.006)
Constant	2.942***	2.949***
	(0.059)	(0.142)
Adjusted R^2	0.478	0.481
N. of Observations	36,705	36,705

Source: PNAD.

Note: Standard errors in parentheses. Omitted age: 17-24 years old. Coefficients of indicator variables for age are not presented.

* significant at 10%, ** significant at 5%, *** significant at 1%.

Controlling for father's earnings, the estimated impact of the grandfather's earnings on the grandson's earnings is positive. It is positive for all three estimations: OLS, Heckman Two Step and Heckman Maximum Likelihood (see Table VII). It is positive for different cohorts, race groups, regions and rural versus urban areas.

The results suggest that grandfathers with high earnings have a positive impact on their grandsons' earnings through a channel other than the fathers. In other words, the grandfathers with high earnings have a direct positive impact on their grandsons' earnings. One possibility, examined in the modified model, is that the grandfather's endowment directly impacts the grandson' endowment or $\theta > 0$.

Assuming that there is no variation in market luck, the Becker and Tomes model predicts a negative coefficient for the grandfather's earnings. The positive sign can be evidence against the assumption of no variation in market luck.

Assuming that the grandson's endowment does not directly depend on the grandfather's endowment ($\theta = 0$), the (partially) modified model predicts a negative coefficient for the grandfather's earnings. I interpret the positive estimated coefficient as evidence in favor of a less restrictive assumption or $\theta > 0$.

4. Estimation of equation (iv): $y_{t+2} = \pi_1 y_{t+1} + \pi_2 y_t + \pi_3 I_{t+2} + \pi_4 I_{t+1} + \epsilon_{t+1}$

The signs of the estimated coefficients agree with the predictions of the (fully) modified model. They are all positive except for the coefficient on father's education. See Table VIII [19].

I examine whether the coefficients in equation (iv) differ across age or race groups, among the sons of (relatively) poor and wealthy fathers, among sons currently living

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[19] The plot of the grandfathers' earnings versus grandsons' earnings suggests a concave relationship between the two variables. Table XXI in Appendix A presents the results when including a quadratic term for grandfathers' earnings in the equation.

Table VII. Estimation of equation (iii): $y_{t+2} = \tau_1 y_{t+1} + \tau_2 y_t + \epsilon_{t+1}$

(a) OLS
(b) Heckman Two Step Estimation
(c)-(d) Heckman Maximum Likelihood Estimation

	(a)	(b)	(c)	(d)
Dependent Variable: Grandson's Earnings				
Grandfather's Earnings	0.195***	0.200***	0.200***	0.174***
	(0.024)	(0.018)	(0.024)	(0.027)
Father's Earnings	0.331***	0.333***	0.333***	0.304***
	(0.013)	(0.010)	(0.013)	(0.015)
Grand. Earnings*Older Coh.				0.062
				(0.046)
Father's Earnings*Older Coh.				0.074***
				(0.025)
Constant	4.084***	4.042***	4.045***	4.182***
	(0.133)	(0.102)	(0.134)	(0.149)
Older Cohort	0.368***	0.338***	0.339***	–0.008
	(0.020)	(0.020)	(0.021)	(0.257)
Selection Equation				
Married		–2.570***	–2.561***	–2.560***
		(0.042)	(0.035)	(0.035)
Age		–0.157***	–0.157***	–0.157***
		(0.007)	(0.004)	(0.004)
Enrolled in School		0.144***	0.155***	0.156***
		(0.054)	(0.030)	(0.030)
Father's Earnings (Imputed)		0.190***	0.174***	0.175***
		(0.027)	(0.018)	(0.018)
Constant		3.474***	3.544***	3.545***
		(0.184)	(0.111)	(0.111)
R^2	0.334			
LR Test of Indep. Equations			11.729	14.476
N. of Observations Uncensored		5,125	5,125	5,125
N. of Observations	5,125	10,176	10,176	10,176

Source: PNAD.

Note: Standard errors in parentheses. Cluster: family (except for the two step regression). Omitted age: 16-21 years old.

* significant at 10%, ** significant at 5%, *** significant at 1%.

Table VIII. Estimation of equation (iv): $y_{t+2} = \pi_1 y_{t+1} + \pi_2 y_t + \pi_3 I_{t+2} + \pi_4 I_{t+1} + \epsilon_{t+1}$

(A)

(a) OLS
(b) Heckman Two Step Estimation
(c)-(g) Heckman Maximum Likelihood Estimation

	(a)	(b)	(c)	(d)
Dependent Variable: Grandson's Earnings				
Grandfather's Earnings	0.146***	0.149***	0.149***	0.147***
	(0.023)	(0.019)	(0.024)	(0.023)
Father's Earnings	0.244***	0.244***	0.244***	0.246***
	(0.015)	(0.011)	(0.015)	(0.015)
Son's Years of Education	0.061***	0.061***	0.061***	0.050***
	(0.003)	(0.003)	(0.003)	(0.004)
Father's Years of Education	–0.008**	–0.007**	–0.007**	–0.010***
	(0.003)	(0.003)	(0.003)	(0.004)
Son's Education*Older Coh.				0.023***
				(0.006)
Father's Education*Older Coh.				0.009
				(0.006)
Constant	4.000***	3.956***	3.958***	4.052***
	(0.127)	(0.103)	(0.127)	(0.126)
Older Cohort	0.306***	0.268***	0.269***	0.065*
	(0.019)	(0.020)	(0.020)	(0.039)
Selection Equation				
Married		–2.570***	–2.555***	–2.552***
		(0.042)	(0.035)	(0.035)
Age		–0.157***	–0.156***	–0.157***
		(0.007)	(0.004)	(0.004)
Enrolled in School		0.144***	0.177***	0.180***
		(0.054)	(0.031)	(0.031)
Father's Earnings (Imputed)		0.190***	0.173***	0.176***
		(0.027)	(0.018)	(0.018)
Constant		3.474***	3.531***	3.528***
		(0.184)	(0.111)	(0.110)
R^2	0.386			
LR Test of Indep. Equations			19.195	23.424
N. of Observations Uncensored		5,125	5,125	5,125
N. of Observations	5,125	10,176	10,176	10,176

Source: PNAD.

Note: Standard errors in parentheses. Cluster: family (except for the two step regression). Omitted age: 16-21 years old.

* significant at 10%, ** significant at 5%, *** significant at 1%.

Table VIII. Continued

(B)

	(e)	(f)	(g)
Dependent Variable: Grandson's Earnings			
Grandfather's Earnings	0.229***	0.132***	
	(0.037)	(0.024)	
Father's Earnings	0.343***	0.233***	0.258***
	(0.028)	(0.016)	(0.023)
Son's Years of Education	0.059***	0.058***	0.063***
	(0.003)	(0.003)	(0.005)
Father's Years of Education	–0.004	–0.006*	–0.010*
	(0.004)	(0.004)	(0.005)
Grandfather's Earn.*Above the Median Earn.	–0.112**		
	(0.046)		
Father's Earn.*Above the Median Earn.	–0.145***		
	(0.037)		
Grand. Earnings*Rural		0.189**	
		(0.087)	
Father's Earnings*Rural		0.025	
		(0.035)	
Average Between Maternal and			0.178***
Paternal Grandfather's Earnings			(0.043)
Constant	3.613***	4.089***	3.797***
	(0.200)	(0.132)	(0.233)
Older Cohort	0.276***	0.275***	0.184***
	(0.021)	(0.020)	(0.036)
Father's Earnings Above the Median	0.556**		
	(0.253)		
Rural		–1.094**	
		(0.474)	
Selection Equation			
Married	–2.555***	–2.555***	–2.446***
	(0.035)	(0.035)	(0.053)
Age	–0.156***	–0.156***	–0.184***
	(0.004)	(0.004)	(0.006)
Enrolled in School	0.177***	0.178***	0.193***
	(0.031)	(0.031)	(0.044)
Father's Earnings (Imputed)	0.174***	0.174***	0.193***
	(0.018)	(0.018)	(0.025)
Constant	3.527***	3.527***	3.486***
	(0.111)	(0.111)	(0.157)
LR Test of Indep. Equations	19.359	19.529	11.661
N. of Observations Uncensored	5,125	5,125	2,025
N. of Observations	10,176	10,176	7,076

Source: PNAD.

Note: Standard errors in parentheses. Cluster: family. Omitted age: 16-21 years old.

* significant at 10%, ** significant at 5%, *** significant at 1%.

in (relatively) poor versus wealthy regions or in rural versus urban areas.

At a 10% significance level, I cannot reject the hypothesis that the coefficients in equation (iv) are the same for males living in poor versus relatively wealthy regions[20].

At a 10% significance level, I reject the hypothesis that the coefficients in equation (iv) are the same for: (1) old and young cohorts, (2) Blacks and non Blacks, (3) the sons of poor and wealthy fathers and (4) for males living in urban versus rural areas.

For the same significance level, I cannot reject the hypothesis that the coefficients for father's and grandfather's education are the same for (1) Blacks and non Blacks, (2) the sons of poor and wealthy fathers and (3) males living in urban versus rural areas. Also, I cannot reject the hypothesis that the coefficients for son's and father's earnings are the same for (1) Blacks and non Blacks and (2) old and young cohorts.

I reject the hypothesis that the coefficients for son's and father's education are the same across age groups. Also, I reject the hypothesis that the coefficients for father's and grandfather's earnings are the same for (1) sons living in urban and rural areas and (2) among the sons of poor and wealthy fathers. Columns (d), (e) and (f) in Table VIII present the estimation results.

Replacing paternal grandfather's earnings by an average between maternal and paternal grandfather's earnings I obtain the results in column (g) in Table VIII.

As explained in section B, the variation in earnings explained by variations in y_{t+1}, y_t and I_{t+1} in equation (iv) represent a lowerbound for the variation in earnings explained by variation in endowment across families. Besides, the variation in earnings explained by variation in I_{t+2} represents an upperbound for the variation in earnings explained by variation in human capital.

Among the sons living with their parents, about 34.9% of the variation in earnings

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[20] I consider Northeast and North as poor region and the remaining regions as relatively wealthy regions.

is explained by differences in family background. If it was possible to eliminate all variation in human capital within cohorts, the variation in the *predicted* earnings would fall by no more than 60.5%. This implies that if every son had the same human capital, the variation in earnings would drop in no more than 21.1%. If there was no variation in endowment across families within cohorts, the variation in the *predicted* earnings would fall by no less than 74.5%, implying that the variation in sons' earnings would be at least 26% lower.

Using the estimates in column (d), Table VIII, I calculate the percentage of the variation in earnings explained by differences in family background for young and old cohorts. I repeat the same procedure for sons living in rural and urban areas using the results in column (f). The percentages are presented in Table IX.

Family background explains a higher share of the variation in earnings for older males and males living in rural areas. The results presented in Table IX are consistent with the results for equation (i). Family background explains 44% of the variation in earnings among males aged 22 to 27 living with parents and 28.7% among males aged 16 to 21. It explains 35.6% of the variation in earnings among the males living in rural areas and 29.6% of the variation in earnings among males living in urban areas.

Replacing paternal grandfather's earnings by an average between maternal and paternal grandfather's earnings, I find that family background explains 40.4% of the of the variation in earnings among males aged 16 to 27 living with parents. Eliminating all the differences in endowment the variation in earnings would fall by no less than 30.9%. Eliminating variations in investment in human capital the variation in earnings among them would fall by no more than 24.0%

Table IX. Drop in the variation in earnings among males aged 16 to 27 living with parents after eliminating differences in: (a) family background, (b) human capital, and (c) endowment (percentages)

	Family Background	Human Capital (upperbound)	Endowment (lowerbound)
Males Between 16 And 27 Years Old	34.9	21.1	26.0
Males Between 16 And 21 Years Old	28.7	14.9	23.0
Males Between 22 And 27 Years Old	44.0	29.8	30.7
Males Living In Rural Areas	35.6	18.5	27.7
Males Living In Urban Areas	29.6	17.4	22.1
Using Average Between Maternal Paternal Grandfather's Earnings - Males Between 16 And 27 Years Old	40.4	24.0	30.9

Source: PNAD.

a. Different age groups

Table X presents the Heckman estimation of equation (iv) for two different age intervals: a broader interval from 12 to 40 years old, and a narrower interval from 18 to 25. For ease of comparison, the results for males aged 16 to 27 appear in the table as well.

The estimated coefficients are stable for the three age groups, except for the coefficient of the father's education which is no longer significant for the narrower age group (ages 18 to 25).

Among males aged 12 to 40 living with their parents, family background explains about 35.3% of the variation in earnings. The percentage is 34.9% for the males aged 16 to 27 and 33.4% for those aged 18 to 25. If it was possible to eliminate all variation in human capital within cohorts for every male aged 12 to 40, the variation in earnings would fall by no more than 21.7%. The percentage is 21.1% for those aged 16 to 27 and 20.1% for those aged 18 to 25. If it was possible to eliminate variation in endowments across families, the variation in earnings would fall by no less than 26.0% for those aged 12 to 40, and those aged 16 to 27, and 25.0% for those aged 18 to 25.

E. Conclusion

I estimate several relationships established by the Becker and Tomes [2] model presented by Gary Solon [34], and the modified version of the model proposed in this article. The relationships are listed below.

(i) $y_{t+1} = \gamma y_t + \epsilon_{t+1}$

(ii) $y_{t+1} = \eta_1 y_t + \eta_2 I_{t+1} + \epsilon_{t+1}$

(iii) $y_{t+2} = \tau_1 y_{t+1} + \tau_2 y_t + \epsilon_{t+1}$

(iv) $y_{t+2} = \pi_1 y_{t+1} + \pi_2 y_t + \pi_3 I_{t+2} + \pi_4 I_{t+1} + \epsilon_{t+1}$

Table X. Heckman maximum likelihood estimation of equation (iv): $y_{t+2} = \pi_1 y_{t+1} + \pi_2 y_t + \pi_3 I_{t+2} + \pi_4 I_{t+1} + \epsilon_{t+1}$

(a) Sons living with their parents from 13 until 38 years old
(b) Sons living with their parents from 16 until 27 years old
(c) Sons living with their parents from 18 until 25 years old

	(a)	(b)	(c)
Dependent Variable: Grandson's Earnings			
Grandfather's Earnings	0.141***	0.149***	0.120***
	(0.022)	(0.024)	(0.026)
Father's Earnings	0.251***	0.244***	0.237***
	(0.014)	(0.015)	(0.017)
Son's Years of Education	0.063***	0.061***	0.058***
	(0.003)	(0.003)	(0.004)
Father's Years of Education	–0.007**	–0.007**	–0.005
	(0.003)	(0.003)	(0.004)
Constant	3.784***	3.958***	4.232***
	(0.117)	(0.127)	(0.143)
Selection Equation			
Married	–2.490***	–2.555***	–2.577***
	(0.030)	(0.035)	(0.039)
Age	–0.132***	–0.156***	–0.162***
	(0.003)	(0.004)	(0.007)
Enrolled in School	0.208***	0.177***	0.129***
	(0.027)	(0.031)	(0.036)
Father's Earnings (Imputed)	0.099***	0.173***	0.221***
	(0.016)	(0.018)	(0.021)
Constant	3.400***	3.531***	3.392***
	(0.095)	(0.111)	(0.152)
LR Test of Indep. Equations	9.665	19.195	1.813
N. of Observations Uncensored	6,111	5,125	3,696
N. of Observations	23,180	10,176	6,901

Source: PNAD.

Note: Standard errors in parentheses. Cluster: family. Coefficients of indicator variables for cohort of sons are not presented. In (a) the estimation includes level dummies for the age intervals 18-22, 23-27, 28-32 and 33-38. In (b) it is 22-27. In (c) it is 22-25.

* significant at 10%, ** significant at 5%, *** significant at 1%.

where y represents earnings and I represents investment in human capital. The subscript t represents generation t, $t+1$, their sons and $t+2$, their grandsons.

Equation (i), commonly estimated in intergenerational mobility studies, can be obtained from the Becker and Tomes model (original and modified) adding the assumption of identical children's endowments. This is probably a strong assumption for an intergenerational mobility model since it is reasonable to think that the children of wealthy parents are in average wealthy not only because their parents could afford a high investment in their human capital but also because those children inherit characteristics from their parents that explain why their parents are wealthy in the first place. Those characteristics can be talent, good health, IQ, physical appearance, attitudes toward work, leisure activities that enhance their productivity at work, family connections and family culture in general.

The estimate of the intergenerational elasticity in earnings in Brazil is about 0.84, suggesting a highly immobile society. The elasticity in earnings is higher if the father earnings are below the the median than above median, among the sons currently living in the northeast than in the southeast and, among the sons currently living in rural than urban residencies.

Estimation results of equation (ii) contradict the predictions of the Becker and Tomes model presented by Solon [34]. Controlling for parent's earnings, the child's earnings are positively related to investment in the child's human capital contrary to the negative relationship predicted by the model.

Estimation results of equation (iii) contradict the prediction of the Becker and Tomes model and the partially modified model. Controlling for parent's earnings, the child's earnings are positively related to grandparent's earnings contrary to the negative relationship predicted by Becker and Tomes model and the partially modified model. The positive sign can be interpreted as evidence against the assumption of no variation in market luck across individuals in the Becker and Tomes model, and as evidence against the assumption of no skipping generation effect in the partially modified model.

Estimation results of equation (iv) are consistent with the predictions of the (fully) modified model and indicate that family background explains 34.9% of the variation in earnings among males aged 16 to 27 who live with parents. Eliminating all the differences in endowment the variation in earnings would fall by no less than 26%. If every male in Brazil living with his parents had the same investment in human capital the variation in earnings among them would fall by no more than 21.1%.

In this article the 1996's earnings of the father and sons are used as proxies for lifetime earnings although the transitory component of one year earnings may be quite large at young ages. Some males in the sample are still enrolled in school and their earnings at this stage may not be a good proxy for their lifetime earnings[21]. Another limitation is that differences in the quality of education are ignored assuming that parents who care about years of education also care about quality of education.

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[21] See Haider and Solon [21] for a discussion about the attenuation bias caused by using one-year-earnings as a proxy for lifetime earnings.

CHAPTER III

INTERGENERATIONAL MOBILITY IN EARNINGS IN BRAZIL WITH DATA ON THREE GENERATIONS

A. Introduction

Based on per capita income one can not say Brazil is a poor country, yet, about one third of the population is poor. Using data for several countries, Barros, Henriques and Mendonca [1] estimate a relation between a country's per capita income and percentage of the population below the poverty line. Conditional on income per capita, this relation predicts that 8% of Brazilians would be poor. The actual percentage is 22 points higher. The high inequality in earnings is aggravated by its persistency over the years. They find that the Gini coefficient for Brazil is around 0.6 during the years from 1976 through 1999. In a country with high and stable inequality in earnings it is particularly relevant to investigate the role of family background in explaining such inequality.

This paper examines intergenerational mobility in earnings in Brazil. Using data on two and three generations I estimate the intergenerational elasticity in earnings across cohort, regions, race, urban versus rural residences and high-earnings versus low-earnings fathers. I examine the evolution of the intergenerational elasticity across generations and implications of marriage and fertility on mobility.

Ferreira and Veloso [18] use data from *Pesquisa Nacional por Amostra de Domicilios* (PNAD) to examine intergenerational mobility in Brazil. Using the fathers' education and fathers' occupation (6 occupational categories) to predict the fathers' earnings, they estimate that the intergenerational elasticity in earnings is about 0.58.

Dunn [13] uses the same data and finds a higher intergenerational elasticity in earnings, about 0.85. He uses the sons' and fathers' education to predict the sons' and fathers' lifetime earnings as opposed to one month earnings.

Like the two previous papers, I use data from PNAD. Here, I use the fathers' education, fathers' occupation (46 occupational categories) and information on race and migration of the sons to impute the fathers' earnings. Imputation of the fathers' earnings without any control for father's race and place of residence can underestimate the earnings of fathers of better paid races and places of residence, and vice versa. This can cause a downward bias in the estimate of the intergenerational elasticity and lead to incorrect conclusions about the difference in mobility across races and regions.

This paper extends the research on intergenerational mobility in Brazil by examining three generations within the same family and studying the implications of marriage and fertility on mobility.

PNAD is a nationally representative household survey for Brazil. In the year of 1996, a mobility supplement was added to the basic questionnaire providing information on parents' education and father's occupation for the head of the household and the spouse of the head. The mobility supplement and the basic questionnaire provide information on 36,705 father-son pairs.

Data on three generations is available restricting the sample to the households with adult sons. In Brazil, sons tend to live in their parents' house until they marry, and join the labor market at early ages. As a result, there are several households with adult sons who are not at the very beginning of their working careers.

Using data on two generations, I find that the estimate of the intergenerational elasticity in earnings among males is about 0.847. (The estimate for the US ranges between 0.4 and 0.5.) The estimate of intergenerational elasticity is higher for older cohorts, starting at 0.59 for the younger cohort aged 16-24 and ending at almost one for the older cohorts aged 45 to 64. The estimate is higher if the father's earnings is below the median, 1.2, than if the father's earnings is above the median, 0.64. The elasticity is higher among the sons currently living in the northeast–a poor region in Brazil that accounts for 27% of the adult males–than the southeast. It is 0.94 for the northeast and 0.74 for the southeast. It is also higher among the sons currently living in rural areas, 0.9, than urban areas, 0.73. The results are inconclusive about differences in the elasticity across races.

About 51.4% of the sons whose fathers are in the lowest quartile of the earnings distribution belong to the same quartile as their fathers. Only about 35% of the sons whose fathers are in the lowest quartile moved up 25 percentiles or more in the earnings distribution.

Conditional on fathers' percentile in the earnings distribution, the average sons' percentile increases with sons' and parents' educational achievements. Controlling for father's percentile in the earnings distribution, each year of schooling of the son increases his percentile by 4.35, on average.

The elasticity in earnings between son-in-law and father-in-law, 0.89, is approximately the same as the elasticity between son and father, 0.9.

About 78.2% of the marriages happen between families of similar earnings: the absolute difference in percentiles between the wife's father and husband's father is 25 or lower. Upperward mobility through marriage happens for about 32.8% of the married women whose father are in the lowest quartile. For them, the husband's percentile exceeds the father's percentile by 25 or more.

Using data on three generations I estimate the intergenerational elasticity across generations within the same family. I find that the intergenerational elasticity in earnings between grandfather and grandson, 0.47, is about the same as the elasticity between father and grandson, 0.46. The estimate of the intergenerational elasticity for the three generations sample is lower than the estimate for the two generations sample. It happens because the intergenerational elasticity increases with age and the three generations sample consist of young grandsons, aged 16 to 27. In addition, for the cohort aged between 16 and 27, the three generations sample have a higher concentration of younger grandsons than the two generations sample.

Number of siblings has a negative impact on son's earnings after controlling for father's earnings. Consider the sons of fathers in the same percentile of the earnings distribution, each additional sibling decreases the sons' percentile by 1.98. The magnitude of the impact is not significantly different for brothers compared with sisters.

B. Data

I use data from *Pesquisa Nacional por Amostra de Domicilios* (PNAD)–a nationally representative household survey for Brazil. The survey has been conducted on an annual basis since 1976. Only the years of 1980 and 1991 were skipped.

The data contains information on the relationship between members in a household, location of the household, sex, age, education, occupation and earnings of all members in the household.

In 1996, a mobility supplement was added to the basic questionnaire. The head of the household and his/her spouse were asked about their parents' education and father's occupation at the time they were 15 years old. I impute the father's earnings using the fathers' occupation and education and information on sons' race and migration. I explain the procedure used to estimate the father's earnings below.

The mobility supplement and information on the head of the household provide information on two generations. Data on three generations is available restricting the sample to the households with adult sons.

In Brazil, typically, sons stay in their parents home until they marry. For instance, consider the 25-year-old males, about 50.9% of them live in their parents house and 47.5% of them are married. Among the ones living with parents the percentage married drops to 3.74%. As they grow older, the percentage of married sons increases and the percentage living with parents decreases. For all ages the two percentages add to a number close to 1. Among the ones living with parents the percentage married never exceeds 4%. See Table II in Chapter II. Because most sons leave their parents' house at the age they marry, there are many households with adult sons.

Since Brazilian males drop out of school and join the labor market at an early age, the adult sons living with parents will not be at the very beginning of their working careers. On average, males aged 20 to 35 have 6.6 years of education and joined the labor market at age 13.4.

The three generations data consist of households with adult sons between 16 and 27 years old. The age restriction is necessary to avoid the sons with little working experience and the extremely unusual sons. Most of the sons will find a job, marry and leave their parents home as they get older, the ones that do not follow this tendency, I consider unusual sons.

Selection problems may arise when restricting the sample to the households with adult sons. To deal with the problem I use the Heckman [23] estimation procedure. Though, the Heckman and OLS estimates are similar.

In the sample, the percentage of sons living with parents decreases with the son's age. The sons living with parents tends to be single. For all ages considered, the percentage of sons enrolled in school is higher among the sons living with parents than the ones not living with parents. For all ages considered, the average earnings of the father is higher among the sons living with parents than the ones not living with parents. Therefore, In the selection equation, the probability of a son to live with his parents depends on son's age, marital status, school enrollment and father's earnings[1].

1. Estimating the earnings of the fathers of the reference person or spouse

The fathers' earnings are imputed using a two steps estimation procedure. In the first step, one estimates an earnings function using a sample that contains individuals' earnings and other variables that explain earnings. In the second step, the function is applied to the correspondent set of variables for the fathers in order to estimate the fathers' earnings.

In the first step regression in Ferreira and Veloso [18], log wages depend on education, 6 occupational categories, cohort and interactions of cohort and occupation, and cohort and education. In the first step regression in Dunn [13], log earnings depend on education, age and age squared[2].

Here, in the first step regression, log earnings depend on occupation, education, race, state of residence in Brazil and experience[3]. I measure occupation at a very disaggregated level, using 46 occupational categories in total[4]. The specification includes

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[1] I discuss in more detail about three generations data set, its potential selection problems and the selection equation in the Chapter II.

[2] Because of the low educational achievement of fathers in Brazil, to differentiate fathers by education will, mostly, split the fathers in four educational groups. Dunn considered three year 1982, 1988 and 1996. In 1982, 37.05% of the fathers are illiterate, 21.09% are literate, 19.23% have incomplete primary and 14.76% have complete primary. In 1988, the percentages are 38.49%, 22.87%, 16.56% and 13.59%. In 1996 the question is reformulated, 33.30% never attended school, 18.95% have incomplete primary, 17.29% have complete primary and 13.26% incomplete middle school.

[3] Experience is calculated according to the formula: experience = age – 6 – years of schooling.

[4] Occupational categories are available in up to three digits. I use the two digits occupational category. Within the same one-digit-occupation, some two-digit-occupation are combined if they have similar average earnings, resulting in the 46

interaction dummies between 8, more general one-digit, occupational categories and experience. It also includes a quartic function for work experience[5]. I do not allow for interactions between education and experience[6]. I use total earnings from work. Males working less than 15 hours a week are dropped from the data. Earnings are bottom coded.

A mobility study about Brazil that ignores race and region of residence when estimating the fathers' earnings may lead to wrong conclusions for two reasons. First, it may result in an estimated intergenerational elasticity in earnings that is biased downwards. Second, it may bias the estimated difference in the elasticity across regions or races. I explain the two issues in the following paragraphs.

On average people living in the southeastern states of Brazil are significantly better paid than are people in the northeastern states. Suppose one estimates the fathers' earnings using a specification that does not control for the difference in earnings across states or regions. Most likely, it would result in an overestimate of the northeastern fathers' earnings and an underestimate of the southeastern fathers' earnings. In an extreme case of no mobility at all in Brazil, these estimated fathers' earnings would

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occupational categories mentioned.

[5] I examined two other specifications for work experience: a quadratic and a spline. The quartic and the spline fit the data slightly better than does the quadratic specification, since their adjusted-R^2's are slightly higher. Following Murphy and Welch [30], I check for the three specifications, if the plot of the residuals against experience shows any pattern like under/overstating of earnings at different stages of the career. The plot shows no evidence of any pattern or that one of those three specifications is better or worse than the others. Considering the adjusted-R^2 and the residuals plots, the quartic and the specification with splines seem to fit the data equally well. I chose the quartic specification.

[6] To check if the effect of experience on an individual's earnings depends on the individual's educational level, I estimated a specification with interactions between educational dummies and experience. Figure 32 in Appendix B shows the predicted earnings as a function of experience for different levels of education. Because the curves seems to be parallel to each other, I dropped the interactions between education and experience from the final specification.

imply that, on average, the northeastern sons moved downward in the distribution of earning compared to their fathers and the southeastern sons moved upward. Consequently, the estimated coefficient of intergenerational elasticity in earnings would be lower than the true value.

In addition, the omission of relevant variables (state/region and race) in the first step regression may bias the estimated coefficients. As a result, the average upward bias in the estimated northeastern father's earnings may not represent an equal upward movement of all imputed earnings. The same applies for the average downward bias in the southeastern fathers's earnings. That may cause a bias in the estimated gap in the intergenerational elasticity in earnings across regions, misleading the conclusions about difference in mobility across regions.

A similar argument applies for blacks and whites, since whites are better paid than blacks in Brazil. An accurate estimation of mobility in Brazil and comparison of mobility across races and regions requires some controls for fathers' race and region (or even better, state) when imputing the fathers' earnings.

The mobility supplement provides fathers' education and occupation, but gives no information on the fathers' age, race or state of residence.

Most likely a son and his father share the same race but, it is also possible that the father belongs to a different race group. For instance, consider the father of a black son. Among the fathers of black sons there is a high percentage of blacks, a small percentage of whites and, so on. I estimate the earnings of a father of a black son as the weighted average earnings of males with the same occupation, education, experience etc. as the father in question for all race groups. The weights are the percentages of fathers of black sons in each race group. It is possible that the incidence of interracial marriage varies over time. To deal with that possibility, I calculate the percentage of fathers of black sons in each race group for all years in which all the information is available. They are 1976, 1990, 1992, 1993, 1995 and 1996. The appropriate year is selected according to the son's age. The same applies for other races. Any small race group is combined with another major group with similar average earnings (after controlling for occupation, education, experience etc.). Table XXII in Appendix B presents the percentages of fathers in each race group given the sons' race, for sons between 13 and 17 years old.

The 1996 PNAD's questionnaire contains a migration segment with information on place of birth, length of residence in the current state (up to ten years), and previous state of residence if any. For many males, this information allows identification of the state of residence at age 15. As showed in Table II in Chapter II, most sons live with their fathers at age 15. Therefore, a good proxy for the father's state of residence when the son was aged 15 is the son's state of residence at that age.

For some individuals it is not possible to identify the state of residence at age 15. In that case, the state where an individual was born can help predict his father's state of residence. For instance, consider males aged 15 in 1976 and born in Brasília. The last entry in Table XXIII in Appendix B shows that a high percentage of them are still living in the Brasília. There is also a positive percentage of individuals living in other places. I estimate the earnings of the father of a son who was born in the capital and is 15 years old in 1976 as the weighted average earnings of males in all Brazilian states with the same occupation, education, experience etc., as his father, where the weights are the percentages presented in the last entry of Table XXIII . Since the migratory flow can change in a 20-year interval, for each year in which all the necessary information is available (1976-7, 1989-90, 1992-3 and 1995), I build a table similar to Table XXIII. I select the appropriate year according to the son's age.

I estimate the coefficients in the first step regression for each year in which the

PNAD was conducted and the variable race is available[7]. The years included in the sample are 1976, 1986-90, 1992-3, 1995 and 1996. Depending on the year in which the son was 15 years old, the estimated equation for a given year is chosen and applied to the set of variables for his father. For instance, if a son is 35 years old in 1996, implying that he was 15 years old in 1976. I estimate the coefficients of the earnings function in 1976 and apply the function to the set of variables of the father of the son in question to estimate his father's earnings.

I calculate the age of the father when the son was born for all PNAD's in which all the necessary information is available (1976, 1990, 1992, 1993, 1995 and 1996). For all years, the average age is about the same, 32 years old. That makes the father 47 years old when the son was 15.

I use the national consumer price index (INPC) to update the nominal values. From November 1976 until April 1979, I use the consumer price index for Rio de Janeiro, since the INPC is not available for that period.

C. Estimation results

In this section, I use data on two generations to estimate the intergenerational elasticity in earnings. I check if the elasticity differs across race groups, regions, rural versus urban areas and earnings groups. I examine the relation between the earnings distribution of the sons and the earnings distribution of their fathers and the impact of education on mobility. Using the subsample of married males, I examine the relation between marriage and mobility.

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[7] Before 1996, the PNAD was conducted in the years of 1976-9, 1981-90, 1992-3 and 1995. But for the years of 1977-9, 1981 and 1983-5 the variable race is not available. The 1982 PNAD had 3 reference months and the data does not specify the reference month or week for each observation. In a high inflation period, earnings can differ significantly in three months. So, I exclude 1982 from the estimations.

Using the subsample of adults sons living with parents I examine the evolution of the intergenerational mobility across generations within the same family and the impact of fertility on mobility.

1. Estimation of the intergenerational elasticity in earnings

I use the two generations sample consisting of 36,705 father-son pairs to I estimate the equation

$$y_{t+1} = \eta + \gamma y_t + \text{ controls for son's age} + \epsilon_{t+1},$$

where y_{t+1} is the son's log-earnings in September of 1996, y_t is the imputed father's log-earnings, γ is the intergenerational elasticity in earnings and ϵ_{t+1} is the error term.

Estimation of the above equation without controls for the son's age can bias the estimate of the intergenerational elasticity. For instance, consider a society consisting of two fathers and two sons. Assume that the four are identical in permanent earnings, education, occupation, region etc., but differ in age. Independent of the age difference among the fathers, their imputed earnings are similar because they are imputed for a male aged 47. But the sons' earnings at any given year will differ since one son has more work experience. Estimation of the above equation without controls for son's age would lead to the wrong conclusion that this society enjoys some degree of mobility. To control for son's age, the specification includes indicator variables for every age.

Note that the above equation does not include controls for race or place of residence of the son. Like family connections, family culture, ability and skills, the two attributes–race and place of residence–are possibly among the attributes an individual inherits from his father. Suppose an indicator variable for bad family connections was available. The specification to estimate the intergenerational elasticity should not include the indicator variable because the elasticity is supposed to capture the fact that most of the poor father-son pairs belong to families with bad connections. The same reasoning applies to race and place of residence.

The estimated elasticity of the sons' earnings with respect to the fathers' earnings, or the intergenerational elasticity or persistence in earnings, is 0.847. The estimation results are presented in Table XI, column (a). The estimates predict that a 10% difference in earnings among fathers results in a 8.47% difference in earnings among sons of similar age.

Other papers estimate the intergenerational elasticity for Brazil. The estimate of the intergenerational elasticity in earnings is 0.58 in Ferreira and Veloso [18] and 0.85 in Dunn [13][8]. The estimate of the correlation between parent's and child's education is about 0.7 in Behrman, Gaviria and Szekely [4] and 0.79 in Ferreira and Veloso [17][9].

Because the fathers' earnings are estimated, the OLS standard errors are inconsistent. Table XI presents the Murphy-Topel estimate of the standard errors–a robust standard errors estimator for two-stage models[10].

I examine whether the intergenerational mobility differs across cohorts including interactions between fathers' earnings and sons' cohorts in the original specification.

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[8] In Appendix B, I partially replicate Ferreira and Veloso estimation and I argue that most of the difference in the estimates are explained by three differences in estimation criteria: (1) dropping from the sample the sons working between 15 and 39 hours a week or living in rural areas, (2) inclusion of indicator variables for race and region in the specification and (3) imputing the fathers' earnings ignoring the difference in earnings across race and state.

[9] Corak [12] and Solon [34] present a list of papers that estimate the intergenerational elasticity in earnings for US. Corak preferred estimate is 0.47. They also present a list of papers that estimate the elasticity for other countries. See also "Cross-Country Differences in Intergenerational Earnings Mobility"–Solon [35].

[10] Greene [20], page 508, provides an explanation of the Murphy-Topel variance estimator. Hardin [22] and Hole [24] present Stata commands to estimate the Murphy-Topel variance. Ferreira and Veloso [18] and Dunn [13] estimate the bootstrap standard errors. For 200 replications, I find that the bootstrap standard errors for the intergenerational elasticity is 0.0076.

Table XI. OLS estimation of the intergenerational elasticity in earnings

(A)

	(a)	(b)	(c)
Dependent Variable: Son's Earnings			
Father's Earnings	0.847***	0.589***	0.643***
	(0.019)	(0.026)	(0.013)
Father's Earnings*Son Aged 25-34		0.170***	
		(0.030)	
Father's Earnings*Son Aged 35-44		0.298***	
		(0.033)	
Father's Earnings*Son Aged 45-54		0.377***	
		(0.036)	
Father's Earnings*Son Aged 55-64		0.388***	
		(0.041)	
Father's Earnings*Father's Earn. Below the Median			0.547***
			(0.049)
Fathers Earnings Below the Median			–3.178***
			(0.270)
Constant	0.698***	2.115***	2.033***
	(0.243)	(0.262)	(0.229)
Adjusted R^2	0.300	0.305	0.314
N. of Observations	36,705	36,705	36,705

Source: PNAD.

Note: Murphy-Topel standard errors in parentheses. Omitted cohort in column (b): sons aged 16 to 24. In all Columns, coefficients of indicator variables for every age of the sons are not presented.

* significant at 10%, ** significant at 5%, *** significant at 1%.

Table XI. Continued

(B)

	(d)	(e)	(f)
Dependent Variable: Son's Earnings			
Father's Earnings	0.758***	0.742***	0.727***
	(0.017)	(0.017)	(0.015)
Father's Earnings*Black/Mixed	0.025		
	(0.017)		
Black/Mixed	–0.448***		
	(0.098)		
Father's Earnings*North		–0.139***	
		(0.031)	
Father's Earnings*Northeast		0.196***	
		(0.021)	
Father's Earnings*South		0.008	
		(0.021)	
Father's Earnings*Midwest		–0.076***	
		(0.025)	
Father's Earnings*Rural			0.175***
			(0.024)
Rural			–1.561***
			(0.132)
Constant	1.383***	1.459***	1.482***
	(0.236)	(0.235)	(0.227)
Adjusted R^2	0.319	0.322	0.354
N. of Observations	36,705	36,705	36,705

Source: PNAD.
Note: Murphy-Topel standard errors in parentheses. Omitted region in column (b): Southeast. In all Columns, coefficients of indicator variables for every age of the sons are not presented. Coefficients of indicator variables for regions in column (b) are not presented.
* significant at 10%, ** significant at 5%, *** significant at 1%.

As shown in column (b) the estimate of γ differs significantly across cohorts. It starts at 0.6 for the youngest cohort aged 16 to 24 in 1996, increases continually for older cohorts, and reaches almost the value one for the two older cohorts aged 45 to 54 and 55 to 64 in 1996.

The lower estimate of the intergenerational elasticity for younger cohorts may indicate more mobility over time or an increasing correlation between son and father's earnings over the life cycle. Mayer [29] points out that an increasing correlation between son and father's earnings over the life cycle is consistent with some models that examine the evolution of wages, like models of human capital accumulation (e.g. Ben-Porath [5]) and matching or learning models (e.g. Jovanovic [28]).

Dunn [13] uses information on fathers' education in the 1982, 1988 and 1996 PNAD to separate the age effect from the cohort effect. He finds that the intergenerational elasticity in earnings grows at a high rate until it reaches a maximum at age 38 for 1982, 47 for 1988 and 51 for 1996. "At almost any age between 20 and 45, the elasticity estimated for 1982 is significantly greater than that estimated for 1988, which in is in turn great than that estimated for 1996." He also shows that the intergenerational elasticity estimated across cohorts using sons' earnings at age 40, has been decreasing continually for the cohorts born in 1935 through 1975. The elasticity for the cohort born in 1935 is 38% higher than for the cohort born in 1975[11].

In column (c) in Table XI, I examine whether the intergenerational elasticity in earnings differs across earnings groups. The estimate of γ is 1.2 if the father earns

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[11] Ferreira and Veloso [18] use the sons' education and occupation to estimate the sons' wages. The son's and father's wages are imputed for a 40-year-old male. They argue that the imputed wage is a measures of permanent wage. Estimating the intergenerational elasticity between father's and son's permanent wages, they find that "the mobility pattern of permanent wages across cohorts is similar to the observed for son's current wages..." The elasticity of permanent earnings decreases continually for cohorts born after the cohort 1942/1946.

below median earnings and 0.64 if he earns above median earnings[12]

I check whether mobility differs across races, regions and rural versus urban areas. The results are presented in Table XI, columns (d), (e) and (f). I find no evidence that mobility is different for blacks or individuals of mixed race compared to other race groups. The estimate of γ is 0.74 among the sons currently living in the southeast and 0.94 in the northeast–a poor region in Brazil that accounts for 27% of males aged 16 to 64 in the 1996 PNAD.

About 12% of males aged 16 to 65 living in the southeast in 1996 were born in the northeast. This migration flow suggests the need for caution in the interpretation of the difference in the estimated intergenerational elasticity between northeast and southeast. For instance, consider the sons that migrate at an age above 15. Because the average earnings of a male with certain characteristics is higher in the southeast than in the northeast, the immigrants probably have higher earnings in the southeast than their fathers in the northeast. This would cause the estimated mobility in the southeast to be higher than it would be otherwise.

Mobility is lower among the sons currently living in rural areas compared to urban areas. The intergenerational elasticity is about 0.9 for sons in rural areas and 0.73 for urban areas.

2. Transition matrix and cumulative distributions

The transition matrix is an alternative measure of mobility. It is a table presenting the percentage of sons in a given economic position by fathers' economic position. For instance, it presents the percentage of the sons of low-earnings-fathers who moved up

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[12] Ferreira and Veloso [18] provides a detailed discussion about the non-linear pattern of the intergenerational mobility in Brazil. Their graph of the mean sons' log wages against fathers' log wages suggests that "persistence is stronger at the extremes of the father's wage distribution."

in the distribution of earnings.

Note that a correction for the sons' earnings is necessary. A 16-year-old and a 64-year-old may have different earnings because they are in different points of their career's paths. I correct for that subtracting from the son's earnings the average earnings of males in the same cohort. For instance, consider a male of a certain age, I subtract from his earnings the average earnings of males in the same age, two years older and two years younger.

Table XII presents the percentage of sons in each quartile by fathers' quartile. Among the sons of fathers in the lowest quartile of the earnings distribution, about 51.4% belong to the same quartile as their fathers. Among the sons of fathers in the highest quartile, about 56.7% belong to the same quartile as their fathers.

The percentages are not dramatically different across cohorts. Note that for each cohort the quartiles are calculated considering the earnings distribution of the sons in that cohort and the earnings distribution of their fathers.

The upper part of Figure 4 shows the cumulative distribution of the sons' percentile by the fathers' quartile. For a society in which the son's percentile is not related to his father's quartile, the four curves would coincide. The fact that the distribution of the sons of low-earnings-fathers is positioned far from the left of the distribution of sons of high-earnings-fathers illustrates the low mobility in Brazilian society. The percentage of the sons below the median is 4 times higher for the sons of the males in the lowest quartile (75.05%) than in the highest quartile (18.45%).

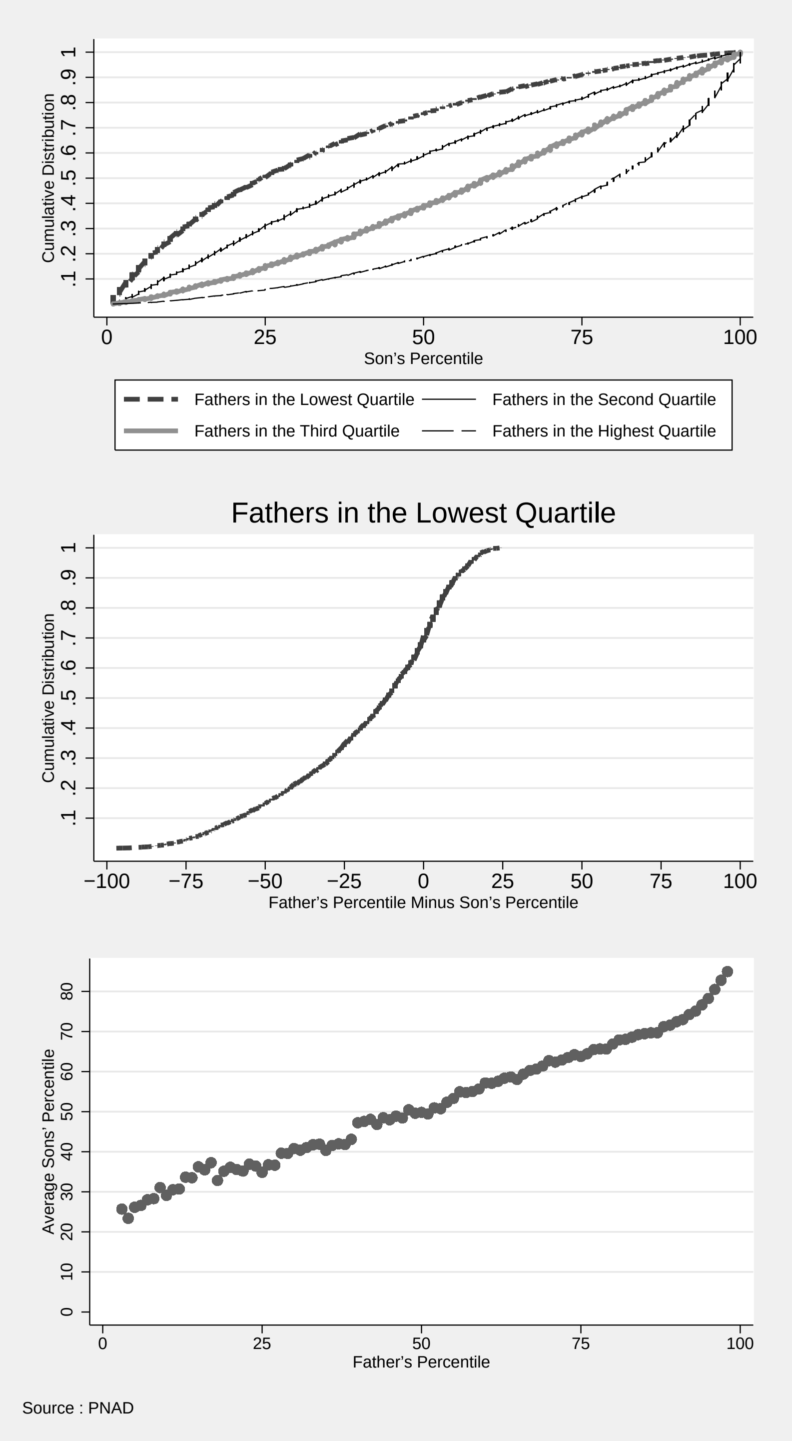
The middle part of Figure 4 presents the cumulative distribution of the difference between the father's and the son's percentile for the sons of fathers in the lowest quartile. The horizontal axis presents the father's percentile minus the son's percentile. A negative number means that the son moved up in the distribution of earnings compared to his father. The figure shows that only about 35% of the sons of fathers in

Table XII. Transition matrix of earnings: sons' quartile by fathers' quartile, in percentage

	Father's Quartile			
Son's Quartile	1° Quartile	2° Quartile	3° Quartile	4° Quartile
1° Quartile	51.41	31.78	15.33	6.07
2° Quartile	24.72	27.99	23.82	13.02
3° Quartile	15.30	22.37	29.28	24.18
4° Quartile	8.57	17.85	31.57	56.74
Son's Age 16-24				
1° Quartile	55.49	29.83	13.39	5.28
2° Quartile	22.19	26.33	20.38	12.60
3° Quartile	14.22	23.45	30.15	24.36
4° Quartile	8.10	20.39	36.08	57.76
Son's Age 25-34				
1° Quartile	50.02	23.77	11.38	5.44
2° Quartile	25.92	31.51	24.40	12.79
3° Quartile	16.32	26.04	32.88	25.04
4° Quartile	7.73	18.68	31.35	56.74
Son's Age 35-44				
1° Quartile	50.90	26.15	12.10	5.21
2° Quartile	25.84	32.48	25.13	11.23
3° Quartile	15.95	25.04	32.29	25.67
4° Quartile	7.32	16.33	30.48	57.89
Son's Age 45-54				
1° Quartile	47.87	29.52	13.58	5.85
2° Quartile	26.13	32.84	28.21	12.91
3° Quartile	17.42	23.75	29.09	24.61
4° Quartile	8.59	13.89	29.13	56.62
Son's Age 55-64				
1° Quartile	47.85	27.25	15.39	7.37
2° Quartile	27.27	35.90	23.07	15.08
3° Quartile	16.08	25.03	31.66	24.28
4° Quartile	8.81	11.82	29.89	53.27

Source: PNAD.

*N*ote: For each cohort the quartiles are calculated considering the earnings' distribution of the sons in that cohort and the earnings' distribution of their fathers. The percentages refers to sons between 16 and 64 years old. The earnings of the sons are corrected by subtracting the average earnings of males in the same cohort.



Source : PNAD

Fig. 4. Cumulative distribution of the sons' percentile by fathers' quartile, cumulative distribution of the difference between father's and son's percentile, and plot of average sons' percentile against fathers' percentile

the lowest quartile moved up 25 percentiles or more in the earnings distribution.

The bottom part of Figure 4 presents the fathers' percentile against the average sons' percentile. Consider a father in the x-th percentile. The graph presents the average percentile of the sons of fathers who belong to the percentile interval [x-2,x+2][13].

3. Education and mobility

Figure 5 presents the fathers' percentile against the average sons' percentile by sons' and parents' educational attainment. The average sons' percentile is calculated in the same way as in the bottom part of Figure 4. Conditional on the fathers' percentile, the average sons' percentile is higher for more educated sons than less educated sons, for literate sons than illiterate sons, for the sons of literate parents than the sons of illiterate parents.

I estimate the average increase in the sons' percentile for each year of schooling of the son, controlling for fathers' percentile. Note that specifications in which the sons percentile is the dependent variable, the predicted values of the sons percentile may be a number below 1 or above 100. To avoid such predictions, I transform the son's percentile in a variable that can assume any real value. I estimate the equation

$$ln(-ln(P_{t+1}/100)) = \beta_0 + \beta_1 P_t + \beta_2 YS + \epsilon^{14}$$

where P_{t+1} is the son's percentile, P_t is the father's percentile, YS is years of schooling of the son and ϵ is the error term.

The predicted increase in the sons' percentile for each additional year of schooling is

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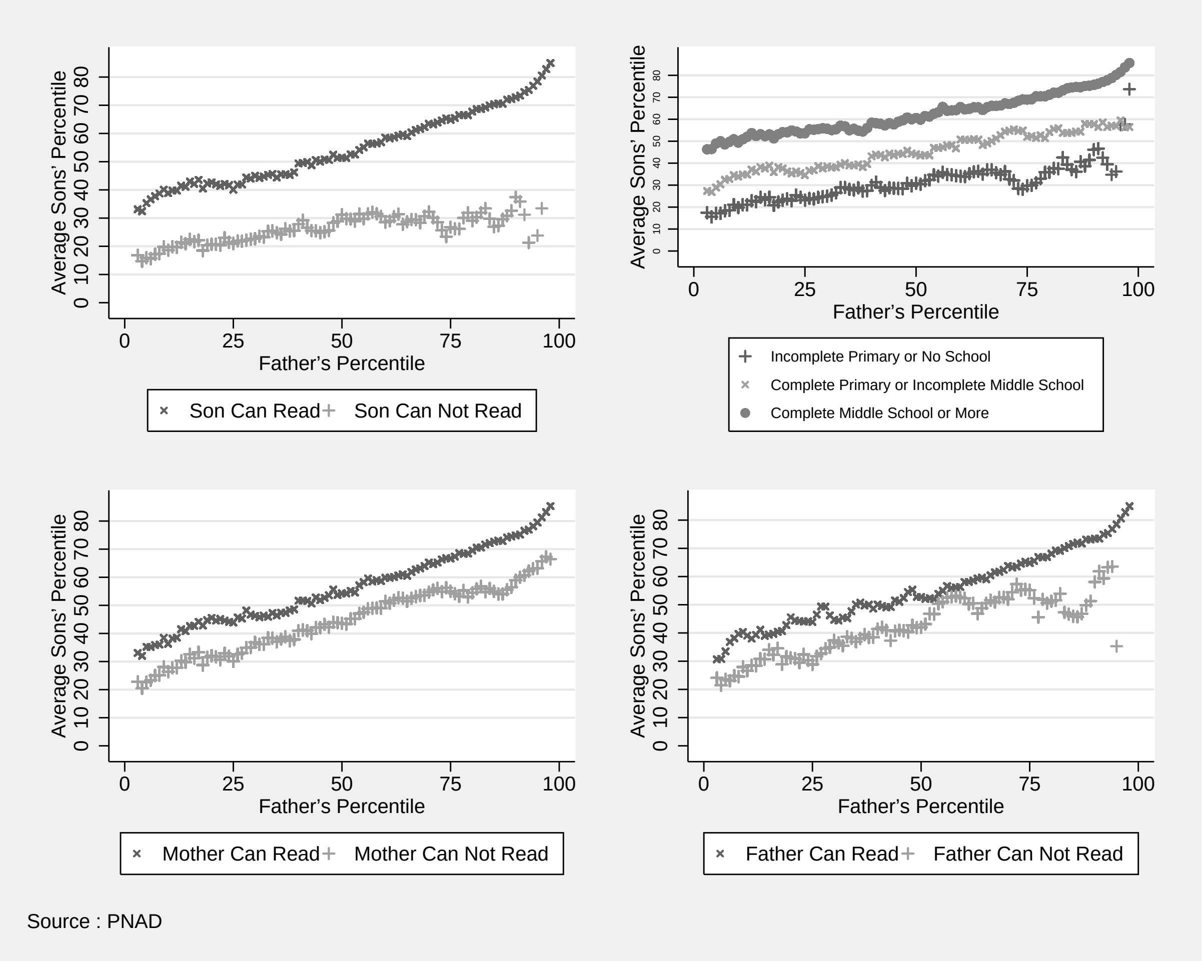
[13] The slope of the regression line in the graph, is 0.55 and the standard error is 0.0003.

[14] I replace the son's percentile by 99 if the son's percentile is 100



Source : PNAD

Fig. 5. Plot of average sons' percentile against fathers' percentile by educational achievement

Table XIII. OLS estimation of the elasticity in earnings between males and their fathers-in-law

	(a)	(b)	(c)
Dependent Variable: Husband's earnings			
Earnings of the Father of the Husband	0.901*** (0.022^{MT})		
Earnings of the Father of the Wife		0.892*** (0.018^{MT})	
Average between Earnings of the Father of the Husband and Wife			1.083*** (0.011)
Adjusted R^2	0.330	0.332	0.394
N. of Observations	15,689	15,689	15,689

Source: 1996 PNAD.

Note: Standard errors in parenthesis. The superscript MT stands for Murphy-Topel standard errors. In all Columns, coefficients for constant and indicator variables for every age of the husbands are not presented.

* significant at 10%, ** significant at 5%, *** significant at 1%.

$$-100\beta_2 exp(\beta_0 + \beta_1 P_t + \beta_2 YS) exp(-exp(\beta_0 + \beta_1 P_t + \beta_2 YS))$$

Figure 6 presents the estimated increase as a function of the fathers' percentile. Controlling for father's percentile, on average, each year of schooling of the son increases his percentile by 4.35.

4. Marriage and mobility

For the sample of married sons, I find that the elasticity between son-in-law's and father-in-law's earnings (0.9) is approximately the same as the elasticity between son's and father's earnings (0.89). See Table XIII.

The upper part of Figure 7 shows the cumulative distribution of the difference in percentiles between the father of the wife and the father of the husband. Most of the marriages happen between families of similar earnings. About 78.2% of the marriages happen between families in which the difference in percentiles is 25 or lower.

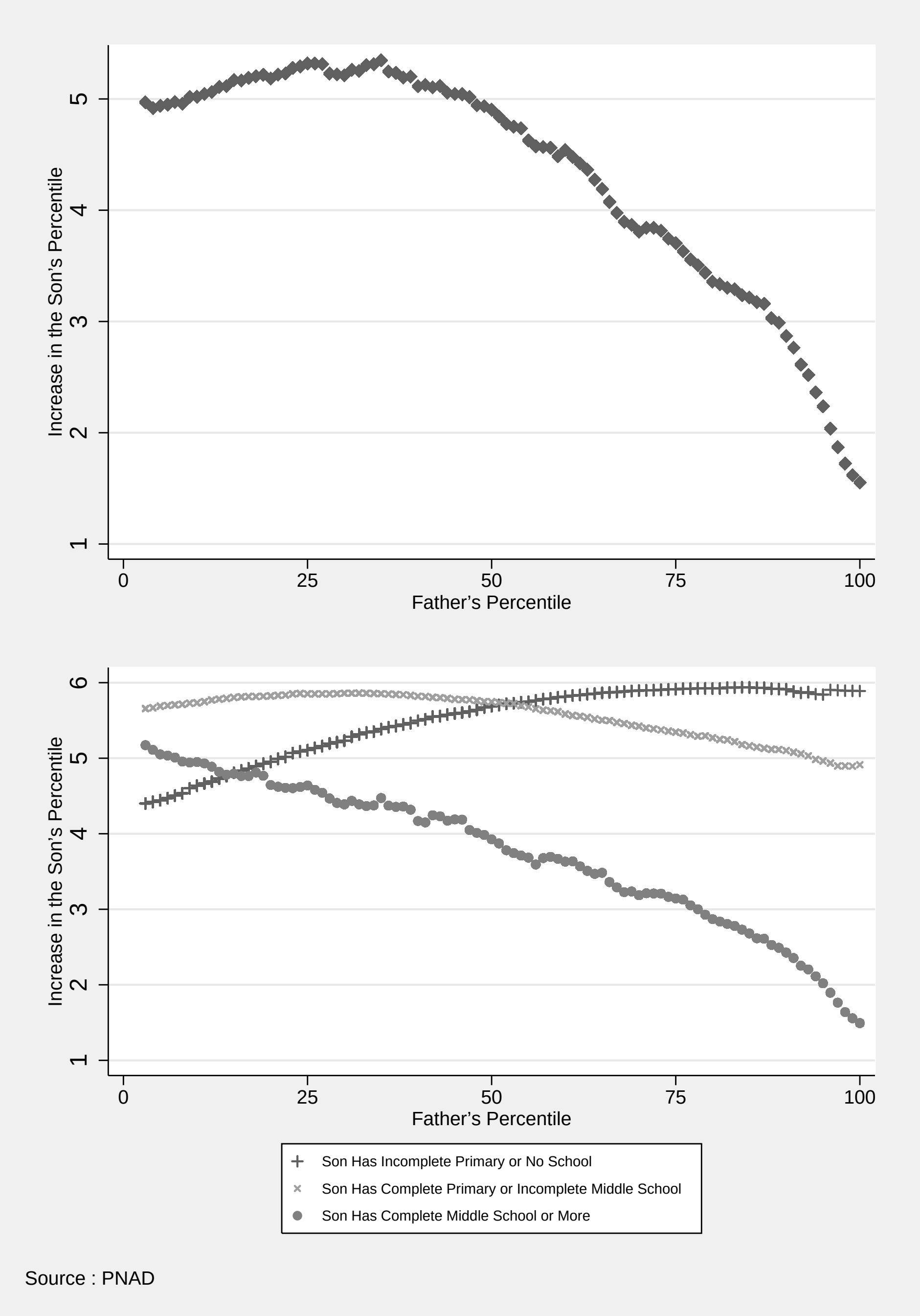
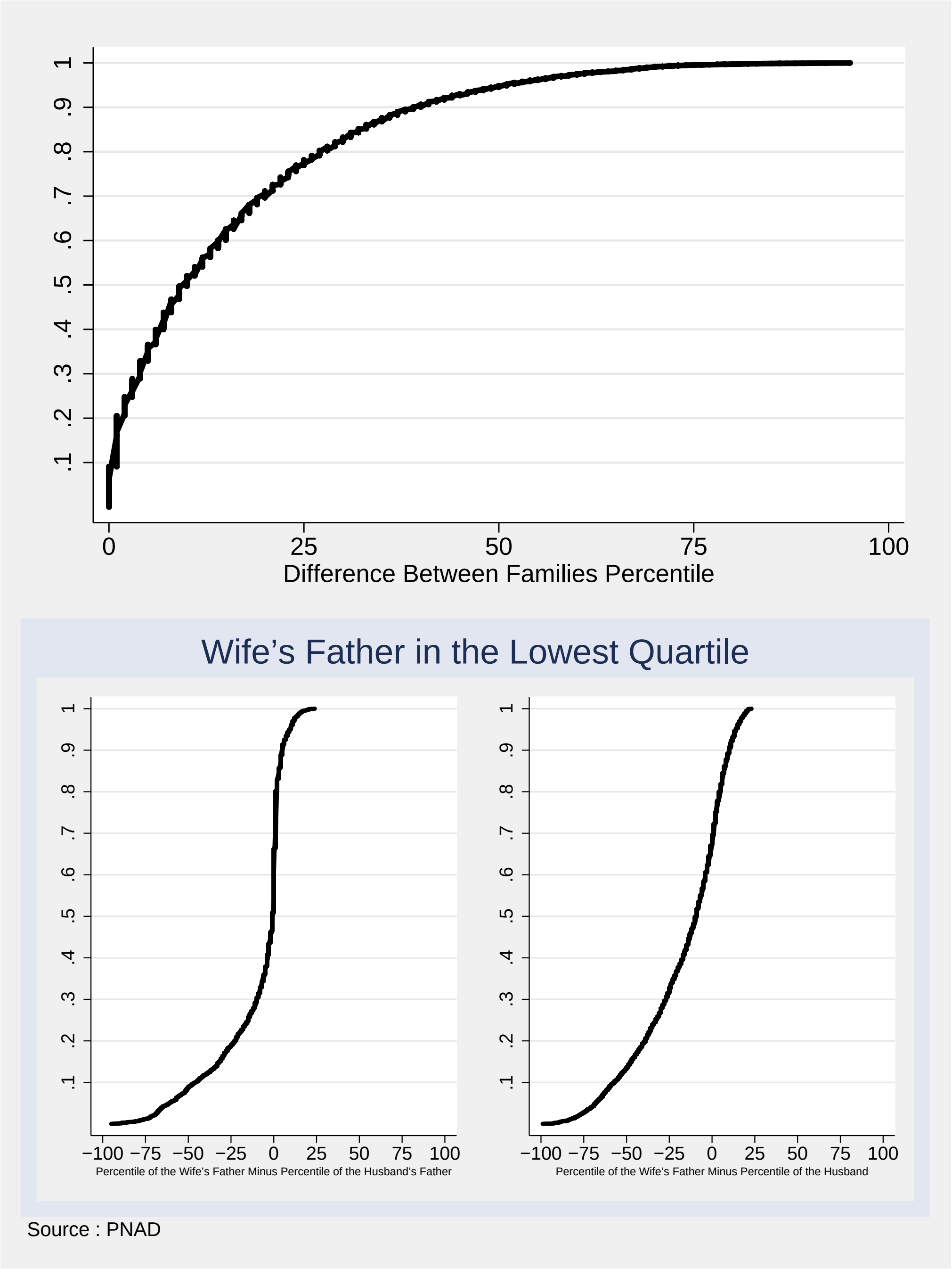


Fig. 6. Increase in the son's percentile for each additional year of education



Source : PNAD

Fig. 7. Cumulative distribution of the difference in percentiles between the wife's father and the husband's father and the difference in percentiles between the wife's father and the husband

It is possible that a son moved up in the distribution of earnings before he married a woman whose family is wealthier than his own family. This is not a marry up example. I do not expect a similar problem for women, since in most families the man's earnings is the principal source of income.

The bottom-left part of Figure 7 presents the cumulative distribution of the difference between the family's percentile for the daughter of fathers in the lowest quartile of the distribution of earnings. The horizontal axis presents the percentile of the wife's father minus the percentile of the husband's father. A negative number means that the wife married up. The figure shows that about 19.1% of the married women with fathers in the lowest quartile married someone from a family at least 25 percentiles up. Among them, about 1/3 ended up with a husband in the lowest quartile.

The bottom-right part of Figure 7 presents the cumulative distribution of the difference in percentiles between the wife's father and the husband's. Again, a negative number means that the wife married up. The figure shows that about 32.8% of the married women with fathers in the lowest quartile married someone at least 25 percentiles up. Upper mobility through marriage is a possibility among the daughters of fathers in the lowest quartile of the distribution of earnings.

5. Subsample of sons living with parents

The subsample of adult sons living with parents contains data on three generations allowing estimation of the intergenerational elasticity in earnings across generations and estimation of the elasticity skipping one generation. In addition, the subsample contains data on number of children of the wife of the head of the household allowing estimation of the impact of fertility on mobility.

a. Mobility across generations

I call the adult males living with parents, grandsons, the head of the household (or spouse), fathers, and the fathers of the head of the household, grandfathers.

The 1996's earnings of the fathers are available for the subsample of sons living with parents but, to maintain the comparability of results across generations, I impute the father's earnings following the same procedure used to impute grandfather's earnings.

To account for the fact that two grandsons may be in different points in their career's paths in 1996 just because one is older than the other, I use an indicator variable for the older cohort aged 16 to 21. For the fathers, I use indicator variables for the cohorts aged 45 to 59 and 60 or older.

For the households with more than one grandson, I drop the younger grandsons to avoid repetition of some father-grandfather pairs.

Table XIV presents the intergenerational elasticity in earnings for the pairs grandfather-father, father-grandson and grandfather-grandson.

The intergenerational elasticity between grandfathers and fathers in Table XIV (0.89) is higher than the coefficient in Table XI (0.84). This is expected because of the higher concentration of older fathers in the three generations data.

The intergenerational elasticity between fathers and grandsons (0.46) is much lower than the coefficient for the previous generation (0.89). There are two interpretations of this the result. First, the intergenerational elasticity is decreasing over time and generations. Second, the intergenerational elasticity increases during an individual's life cycle. Under the second interpretation, the intergenerational elasticity would be higher for the grandfather-father pairs than for the father-grandson pair because in 1996 the fathers are older than the grandsons. Maybe it is just a matter

Table XIV. Intergenerational mobility across generations

Grandfather and Father	
OLS	
Dependent Variable: Father's Earnings in 1996	
Grandfather's Earnings (Imputed)	0.891***
	(0.027)
Father's Age 45-59	0.030
	(0.034)
Father's Age ≥60	–0.338***
	(0.051)
N. of Observations	3,899
Father and Grandson	
Heckman Maximum Likelihood Estimation	
Father's earnings calculated like grandfather earnings	
Dependent Variable: Grandson's Earnings in 1996	
Father's Earnings (Imputed)	0.464***
	(0.014)
Son's Age 22-27	0.262***
	(0.024)
N. of Observations Uncensored	3,899
Grandfather and Grandson	
Heckman Maximum Likelihood Estimation	
Dependent Variable: Grandson's Earnings in 1996	
Grandfather's Earnings (Imputed)	0.477***
	(0.021)
Son's Age 22-27	0.402***
	(0.025)
N. of Observations Uncensored	3,899

Source: PNAD.

Note: Standard errors in parenthesis. Coefficients for constants are not presented.

* significant at 10%, ** significant at 5%, *** significant at 1%.

of time until the younger generation reaches the same intergenerational elasticity in earnings of the previous generation[15].

The intergenerational elasticity between father and grandsons (0.46) is about the same as the elasticity skipping one generation (0.47).

In Table XIV, I estimate the intergenerational elasticity in earnings between paternal grandfathers and grandsons. I can also estimate the elasticity for maternal grandfathers. Table XV shows that the intergenerational elasticity between grandfathers and grandsons is higher for the maternal grandfathers (0.56) than for the paternal grandfather (0.49). The elasticity with respect to the average earnings of both grandfathers, 0.64, is higher than the elasticity with respect to each individual grandfather's earnings. In a regression with both maternal and paternal grandfather's earnings, the elasticity for the maternal grandfather, 0.4, is higher than for the paternal grandfather, 0.24.

b. Fertility and mobility

For all females aged 15 or older, the fertility module of the 1996 PNAD contains information on number of biological sons and daughters living in the same and in a different household. I use the number of children of the wife of the head of the household minus one as a proxy for the number of siblings competing for family resources during the son's childhood. I do not subtract number of children by one if the wife has no biological son living in the same household. (It is the case for 57 sons in the sample.)

I split the sample in three groups: the sons with 2 or fewer siblings (40.67% of the sample), sons with 3 or 4 siblings (26.82%), and son with 5 or more siblings

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[15] I obtain similar elasticities across generations replacing the indicator variables for age by age and age squared.

Table XV. Intergenerational elasticity in earnings skipping one generation for paternal and maternal grandfathers

	(a)	(b)	(c)	(d)
Heckman Maximum Likelihood Estimation				
Dependent Variable: Grandson's Earnings				
Son's Earnings				
Paternal Grandfather's Earnings	0.485***			0.239***
	(0.041)			(0.046)
Maternal Grandfather's Earnings		0.562***		0.402***
		(0.038)		(0.047)
Average Between Maternal and Paternal Grandfather's Earnings			0.636*** (0.043)	
N. of Observations Uncensored	2,025	2,025	2,025	2,025
N. of Observations	7,076	7,076	7,076	7,076

Source: 1996 PNAD.
Note: Standard errors in parenthesis. Coefficients for constant and indicator variables for cohort of grandsons are not presented. Cluster: family. The selection equation is not presented.
* significant at 10%, ** significant at 5%, *** significant at 1%.

(32.51%)[16]. Figure 8 shows the average sons' percentile against fathers' percentile for the three groups. Consider the fathers in the x-th percentile. The graph presents the average percentile of the sons of males who belong to the percentile interval [x-5, x+5][17]. Conditional on fathers' percentile, the average sons' percentile is lower for the sons with 5 or more siblings than the other groups. It is lower for the sons with 3 or 4 sibling than for the sons with 2 or less siblings, for most fathers' percentile.

I estimate the average drop on sons' percentile of each additional sibling, controlling for fathers' percentile. Because a son's percentile is a number between 1 and

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[16] About 2% of the sons in the sample have no sibling, 14% have one sibling, 24% two siblings, 16% three, 10% four, 8% five, 8% six and, 16% seven or more.

[17] Two males may have different earnings just because they are at different points of their career's paths. To address the problem, I subtract from the male's earnings the average earnings of males in the same cohort before calculating the male's percentile. For instance, consider a male of a given age, I subtract from his earnings the average earnings of males in the same age, two year older and two years younger.

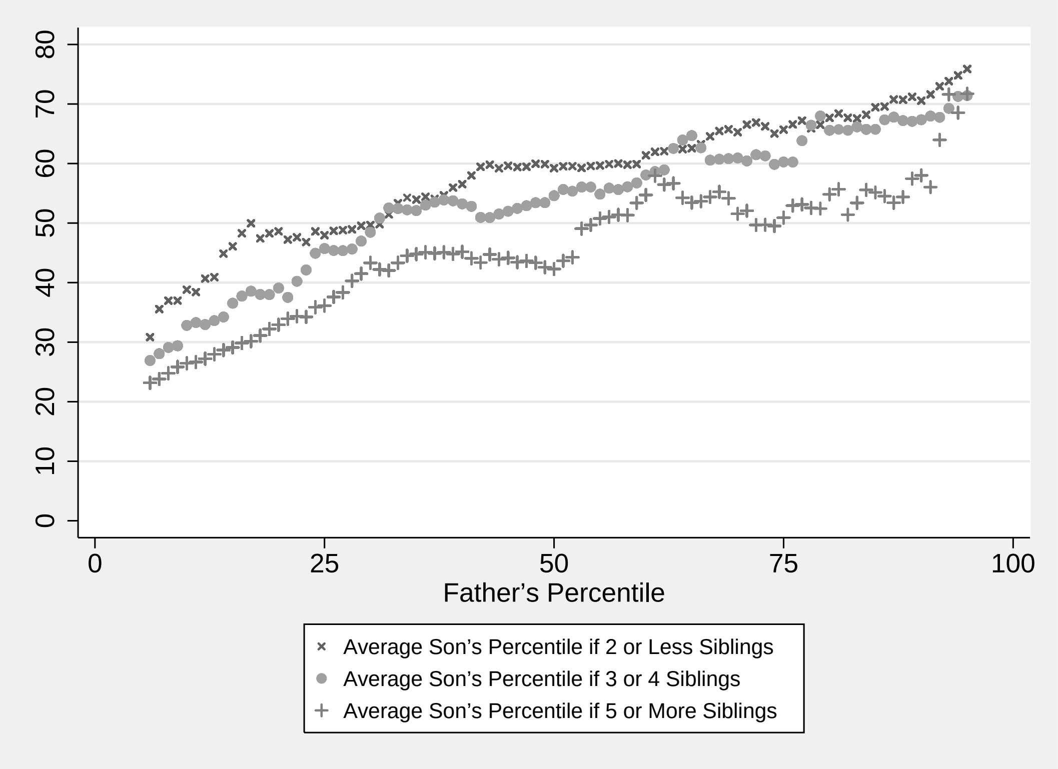

Fig. 8. Plot of average sons' percentile against fathers' percentile by number of siblings

100, a transformation of the sons' percentile is necessary. I estimate the equation

$$ln(-ln(P_{t+1}/100)) = \beta_0 + \beta_1 P_t + \beta_2 NC + \beta_3 I_c + \epsilon$$

where P_{t+1} is the son's percentile, P_t is the father's percentile, NC is number of siblings, I_c indicator variable for females with at least one biological child[18] and ϵ is the error term.

The predicted drop in sons' percentile of each additional sibling is

$$-100\beta_2 exp(\beta_0 + \beta_1 P_t + \beta_2 NC + \beta_3 I_c) exp(-exp(\beta_0 + \beta_1 P_t + \beta_2 NC + \beta_3 I_c)).$$

Figure 9 presents the predicted drop as a function of the fathers' percentile for three groups: sons with 2 or fewer siblings, sons with 3 or 4 siblings and son with 5 or more siblings. Controlling for fathers' percentile, on average, each sibling decreases the sons' percentile by 1.98. The coefficient for brothers and sisters are not significantly different[19].

D. Conclusion

Like Ferreira and Veloso [18] and Dunn [13] I use data from PNAD to estimate the intergenerational elasticity in earnings in Brazil. Differently from the previous papers, I use information on the sons' race and migration to estimate the fathers' earnings. I argue that omission of race and place of residence may cause a downward bias in the estimate of the intergenerational elasticity.

Divergences may rise with respect to the proper way to estimate the fathers' earnings and the intergenerational elasticity. I discuss some possibilities and examine

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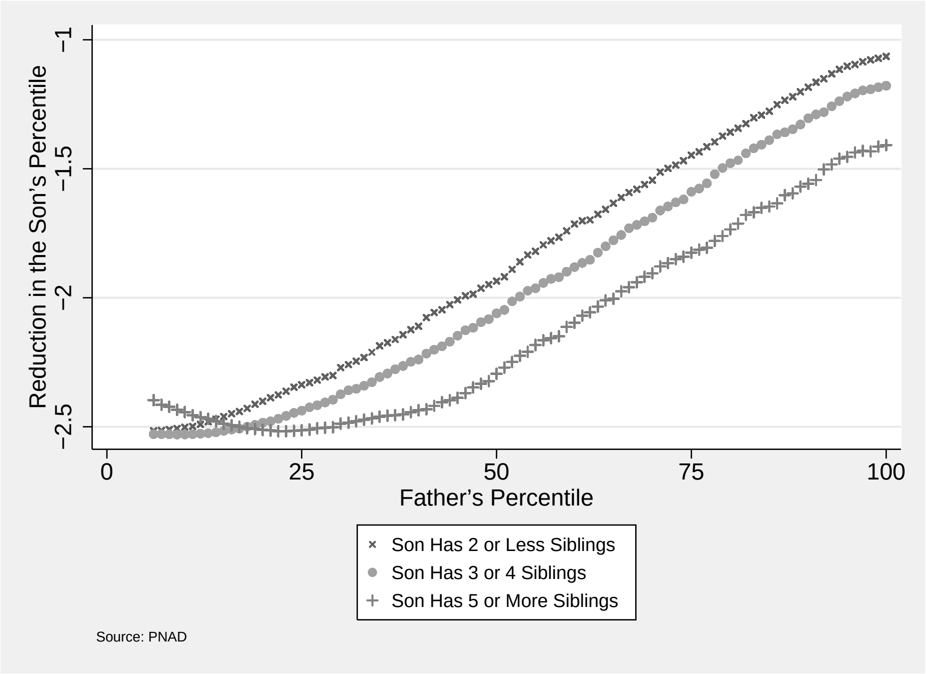
[18] The data include three females with no biological children and married to a male with an adult son living in his house. I replace the son's percentile by 99 if the son's percentile is 100

[19] Number of brothers is top coded for 6 brothers. The same for number of sisters.



Source: PNAD

Fig. 9. Reduction in the son's percentile for each additional sibling

changes to the conclusions in Appendix B. In Appendix B, I discuss the problems that may rise from comparisons of the sons' earnings in September of 1996 with the estimated fathers' earnings, and how the lower variance of the latter compared to the true earnings may bias the estimated intergenerational elasticity. I suggest a possible solution to address the problem and examine the changes in the conclusions.

One major contribution of this paper is the extension of the research on intergenerational mobility in Brazil to three generations within the same family. I build a nearly representative data set for three generations exploiting two characteristics of Brazilian people. First sons tend to live in their parents' house until they marry. Second, Brazilians join the labor market at early ages. Those two characteristics imply that there are several households with adult sons who are not at the very beginning of their working careers.

This paper extends the research on intergenerational mobility in Brazil by examining the relationship between fertility and mobility. Has the high fertility rate among the low-earnings individuals contributed to the perpetuation of poverty? Siblings may impact positively and negatively an individual earnings. For instance, they may expand the individual's network, the older siblings may invest in the human capital of the young ones, they may help developing social skills during childhood, etc. On the other hand, siblings may increase competition for scarce family resources during childhood. I estimate the average impact of an additional sibling on the son's percentile using data on fertility, available for the sample of adult sons living with parents, and applying a transformation on the sons' percentile that corrects for the fact that the sons' percentile is a number between 1 and 100. I use the same correction to estimate the average impact of additional years of education on the son's percentile after controlling for father's percentile.

This paper also extends the research on intergenerational mobility in Brazil by examining the implications of marriage on mobility. The estimated elasticity in earnings between fathers and sons is about the same as the elasticity between fathers-in-law and sons-in-law. There are two possible interpretation for the similarity of the two elasticities. First, individuals marry in the same economic class. Second the father-in-law may be an important determinant of the individual's earnings.

CHAPTER IV

OPTIMAL INVESTMENT IN ELECTRICITY GENERATION IN THE TEXAS MARKET

A. Introduction

In the last two decades, a deregulation process has been initiated in many electricity markets around the world. One economic and political motivation for deregulation is that a system of competitive procurement of electricity provides better incentives for investment than the incentives created by either rate-of-return regulation or state-owned enterprizes.

Much of the existing literature on deregulated electricity markets has focused on the short-run inefficiencies created by imperfectly competitive electricity spot markets[1]. Less research has focused on the longer-run incentives for optimal investment under competitive procurement[2]. This study addresses long run implications of deregulation – optimal investment in electricity generation.

The optimal investment is the investment that maximizes the social welfare. In a perfectly competitive market, private and social incentives are perfectly aligned, and there should be no gap between optimal and actual investment profile. Since most electricity markets are not perfectly competitive markets, comparison between optimal and observed investment provides a measure of how far the current system is from its optimal or ideal path. Moreover, the efficiency gains associated to the optimal investment provides a measure in dollars of the possible gains associated

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[1] For example, see Wolfram [37], Borenstein, Bushnell and Wolak [7], Puller [33], Bushnell, Mansur and Saravia [11], and Hortacsu and Puller [25].

[2] One paper that has studied the effects of deregulation on the efficiency of operations is Fabrizio, Rose, and Wolfram [16].

with decisions that favor a more competitive electricity market.

There are different technologies available to generate electricity. Natural gas-fired units include traditional single-cycle as well as new combined cycle gas turbines. Other generating units are fueled by coal and uranium. Finally, various renewable sources of energy include hydroelectric, wind, solar and geothermal technologies. The existing technology mix was largely determined under a more regulated regime. This paper estimates the change in technology mix that would occur in the long run under competitive procurement in Texas.

This paper introduces a methodology to estimate the optimal investment in each technology type. The method determines the optimal investment by applying a similar logic that Borenstein [8] uses to find the optimal long run capacity, but takes in consideration the current capacity[3]. The estimation procedure allows the system's capacity to change constantly to accommodate entry and exit of units, depending on the unit's schedule. Also the fuel prices change according to the expected future prices.

After having introduced the suggested method, I estimate an indicator of the optimal investment in electricity generation in Texas, more precisely, the subarea of Texas which is covered by the Electric Reliability Council of Texas (ERCOT) system. ERCOT manages the electricity market that covers about 75% of the state's land area, and 85% of the state's demand (load). The ERCOT market is not a competitive market, at least on the demand side. Most of the consumers are in the flat rate service, meaning that they pay fixed, previously established prices in peak and off peak hours.

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[3] Joskow and Tirole [27] also show how to find the optimal long run capacity. In contrast to Borenstein, they make some continuity and differentiability assumptions about the functions involved in the maximization problem.

Assuming that energy suppliers are price takers, charging the Real Time Price (RTP)[4] would implement the optimal investment. The results suggest significant efficiency gains.

Limitations of the paper include the assumption of zero starting up costs[5] and, no uncertainty about demand or costs.

Subsection 1 reviews Borenstein's method to find the optimal long run composition. Subsection 2 explains the method proposed in this paper. Section C presents general aspects of the data used in this paper and the estimated marginal cost and demand curves. Section D discusses some characteristics of the plants operating in the ERCOT market that encourages consideration of the current composition when estimating the optimal investment. Finally, Section E presents some estimation criteria and an indicator of the optimal investment in the ERCOT market.

B. Method to find the optimal investment profile

1. Borenstein's method: N demands and K technologies

Borenstein [8] suggests a method to find the optimal long run capacity of each technology type for any specific distribution of demand functions. Before revising the method, I define a few terms. I call a vector of installed capacity for each technology type the current composition. Equivalently, I call a vector of optimal capacity for each technology type the optimal composition.

Suppose the electricity system faces different demands at different hours in a year. Assume there are N demands where $p^1(q)$ is the highest demand; $p^2(q)$ is the second highest demand; and so on. During α_n hours in a year, the system faces

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[4] The price that clears the market at any time.

[5] The cost of turning on a unit.

demand $p^n(q)$.

Assume that the capacity of each unit is 1 megawatt (MW) and the cost function of a unit that adopts technology i can be represented by the equation

$$C_i(q_i) = MC_i q_i,$$

where MC_i is the marginal cost of a unit that adopts technology i and q_i is the quantity produced by the unit.

The annual capital cost of building one unit of technology i is ACC_i.

Suppose there are K technologies available to generate electricity. Technology 1 is the technology associated to the highest marginal cost; technology 2 is the technology associated to the second highest marginal cost; and so on. The order is reversed for the capital costs, technology 1 has the lowest capital cost; technology 2 has the second lowest capital cost; and so on. This inverse relationship between marginal cost and fixed capital costs is consistent with technologies for electricity generation (e.g. natural gas peaking units have a high marginal cost but low fixed cost, while baseload coal-fired units have low marginal costs and high fixed costs).

The goal is to find the number of generators of each technology that maximizes the total welfare. First, imagine that all the production is provided by units that adopt the technology type associated with the highest marginal cost, technology 1. Then, add peak units into the system, one by one, until the introduction of one more unit would make the social surplus of the extra unit negative.

Start checking if it is socially optimal to invest in the first type-1-unit. For ease of graphical illustration, suppose that N=4. Imagine a case like the one represented in Figure 10. During α_4 hours, the unit will generate no surplus. During α_1 hours, the unit generates a social benefit of $\int_0^1 p_1(q)dq - MC_1$. During α_2 hours, the unit will generate a social benefit of $\int_0^1 p_2(q)dq - MC_1$, and so on. In the general case, it

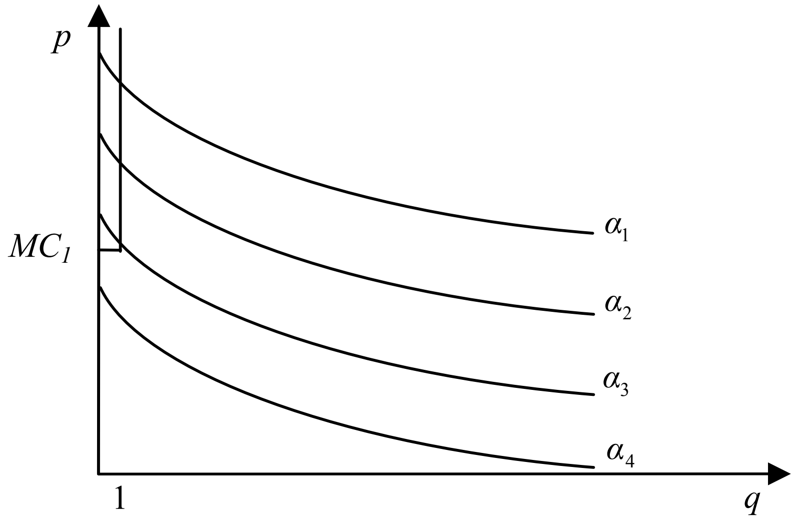


Fig. 10. Borenstein's method to find the long run optimal composition - 1 MW in technology 1

is welfare-increasing to invest in one type-1-unit if

$$\sum_{n=1}^{N} \alpha_n Max\Big\{ \int_0^1 p^n(q)dq - MC_1; 0\Big\} \geq ACC_1.$$

Now imagine that for the first γ_1 units, the social benefit and the annual capital cost were already compared, and it is optimal to invest in them. Now check if it is optimal to invest in one more unit, the $(\gamma_1 + 1)^{th}$ unit.

Calculate the social benefit for each demand and then add the social benefit for every demand multiplied by the number of hours in a year that the system faces this demand curve. For each demand curve, the social benefit generated by the extra unit is simply the area between the marginal cost curves, before and after the introduction of the extra type-1-unit, that lies below the demand curve.

Imagine a case like the one represented in Figure 11. During $(\alpha_4 + \alpha_3)$ hours, the extra unit generates no extra benefit. During α_1 hours, the extra unit will generate a social benefit of $\int_{\gamma_1}^{\gamma_1+1} p^1(q)dq - MC_1$. During α_2 hours, the benefit is $\int_{\gamma_1}^{\gamma_1+1} p^2(q)dq - MC_1$.

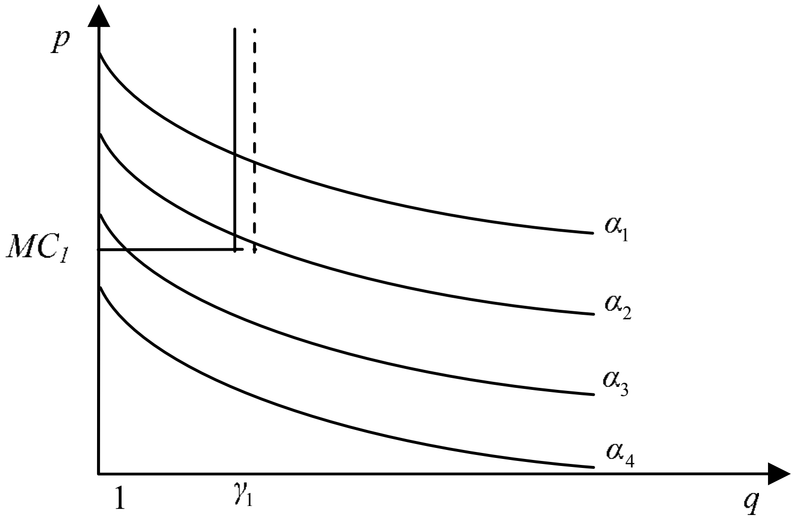


Fig. 11. Borenstein's method to find the long run optimal composition - 1+γ_1 MW in technology 1

Generalizing, for any positive integer number j, it is welfare-increasing to invest in the $(j+1)^{th}$ type-1-unit if

$$\alpha_1 Max\Big\{\int_j^{j+1} p^1(q)dq - MC_1; 0\Big\} + \cdots +$$
$$\alpha_N Max\Big\{\int_j^{j+1} p^N(q)dq - MC_1; 0\Big\} \geq ACC_1.$$

Equivalently,

$$\sum_{n=1}^{N} \alpha_n Max\Big\{\int_j^{j+1} p^n(q)dq - MC_1; 0\Big\} \geq ACC_1.$$

Let C_{TO} be the number at which it is optimal to stop adding type-1-units to the system. When the number of type-1-units is equal to $(C_{TO}+1)$, the annual capital cost is higher than the benefit of an extra type-1-unit. Since each unit's capacity is 1 MW, C_{TO} is also the total capacity. Now consider the technology associated with the second highest marginal cost, technology 2. If replacing one type-1-unit for one type-2-unit increases the social welfare, it is optimal to replace it. Since $MC_1 > MC_2$,

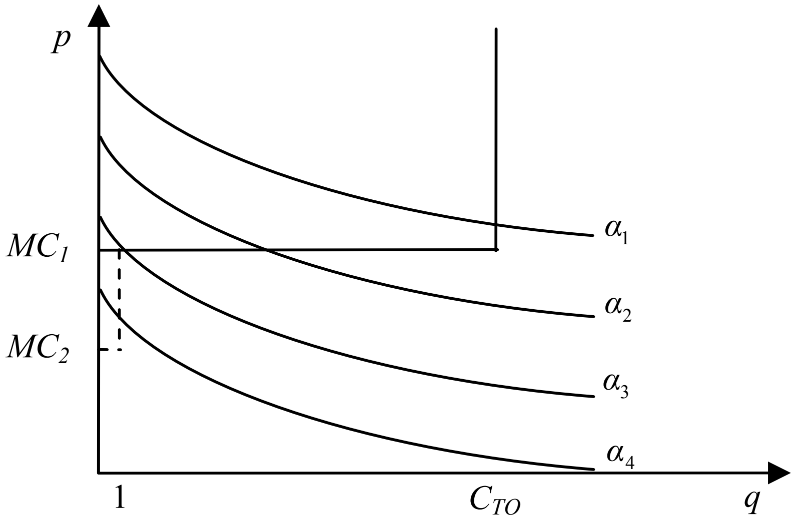


Fig. 12. Borenstein's method to find the long run optimal composition - 1 MW in technology 2

the type-2-unit will be operating before any type-1-unit.

Imagine a case like the one represented in Figure 12. The social benefit of replacing one type-1-unit for one type-2-unit is $(\alpha_1+\alpha_2+\alpha_3)(MC_1-MC_2)+\int_0^1 p_4(q)dq-MC_2$. The cost is ACC_2-ACC_1. If the benefit is greater than the cost, then there is a social gain by replacing one more type-1-unit for one type-2-unit.

Now imagine that for the first γ_2 type-2-units, the social benefit and the annual capital cost were already compared, and it is optimal to replace γ_2 type-1-units with γ_2 type-2-units. Now check if it is optimal to replace, one more time, one type-1-unit for one type-2-unit, the $(\gamma_2+1)^{th}$ unit. Imagine a case like the one represented in Figure 13. During $(\alpha_4+\alpha_3)$ hours, the replacement of one type-1-unit for one type-2-unit generates no extra surplus. During α_1 hours, the replacement generates a social benefit of MC_2-MC_1. During α_2 hours, the social benefit is $\int_{\gamma_2}^{\gamma_2+1} p^2(q)dq-MC_2$. It is welfare-increasing to replace, one more time, one type-1-unit for one type-2-unit

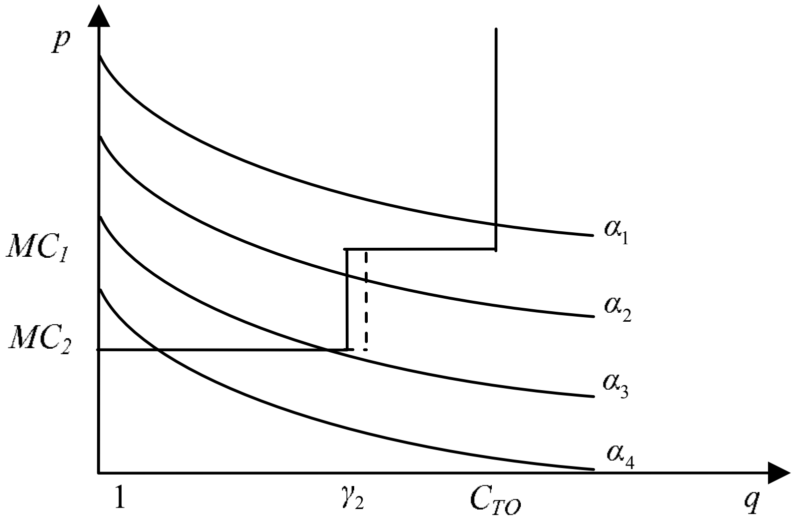


Fig. 13. Borenstein's method to find the long run optimal composition - 1+γ_2 MW in technology 2

if

$$\alpha_1\Big(MC_1 - MC_2\Big) + \alpha_2\Big(\int_{\gamma_2}^{\gamma_2+1} p^2(q)dq - MC_2\Big) \geq ACC_2 - ACC_1.$$

Keep replacing type-1-units for type-2-units until the benefit is greater of equal to the additional fixed cost of type-2-units.

Repeat the procedure above for units of type 3, 4, and so on.

The trick is that replacing type-1-units for type-2-units does not change the optimal total capacity of the system. The reason is that, at any stage of the replacing process, the benefit and the cost of adding one extra type-1-unit to the system is always the same. At any stage the conclusion is the same: the benefit of adding one extra type-1-unit to the system does not pay its additional cost.

Borenstein assumes that the optimal composition contains strictly positive numbers of units for all technology types. In the case that the above procedure generates an optimal composition with null units for some technology, drop this technology from the set of possible technologies and start over again.

One might think that today's optimal investment in units that adopt a given technology type can be obtained simply subtracting its current capacity from its optimal capacity. This is true, only if, for each technology type, the current capacity is not greater than the optimal capacity. For purposes of today's optimal investment, the difference between optimal and current capacity is uninformative if for some technology, achieving the optimal capacity involves units shutting down. The following subsection will make this point clear.

2. Technological innovation and optimal investment in the short run: simple case

Consider a very simple environment in which the electricity system faces two kinds of demand, peak and off peak demands. Initially, there is only one technology to generate electricity, and a new technology is introduced. Call the old technology, technology 1, and the new technology, technology 2. Suppose that the new technology is better than the old one in the sense that it has a lower marginal cost and capital cost.

$$MC_1 > MC_2$$

$$ACC_1 > ACC_2$$

where the subscripts 1 and 2 refer to the old and new technologies.

Figure 14 represents the system's marginal cost curve before the technological advance. The long run optimal composition of technology types predicted by Borenstein implies replacement of all type-1-units for type-2-units. Imagine that the dashed line in Figure 15 represents the system's marginal cost curve associated to the long run optimal composition.

In this example, the comparison between the long run optimal composition and the current composition can not help us to find today's optimal investment. The

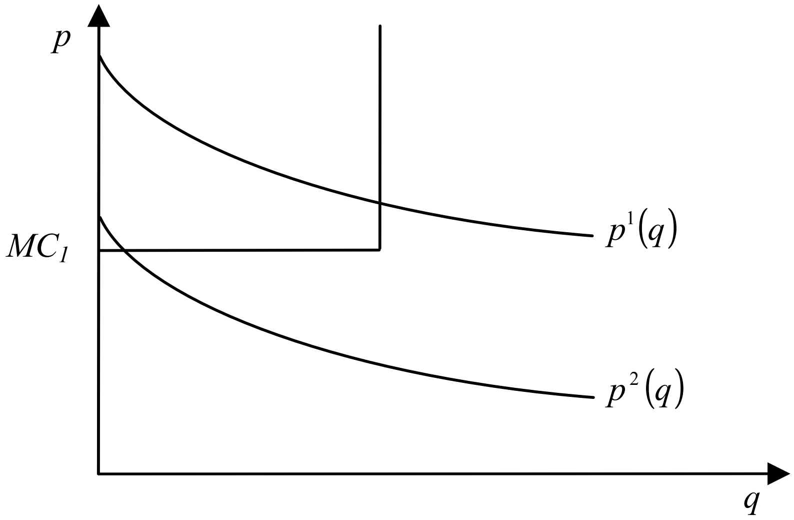


Fig. 14. The long run optimal composition before the technological innovation

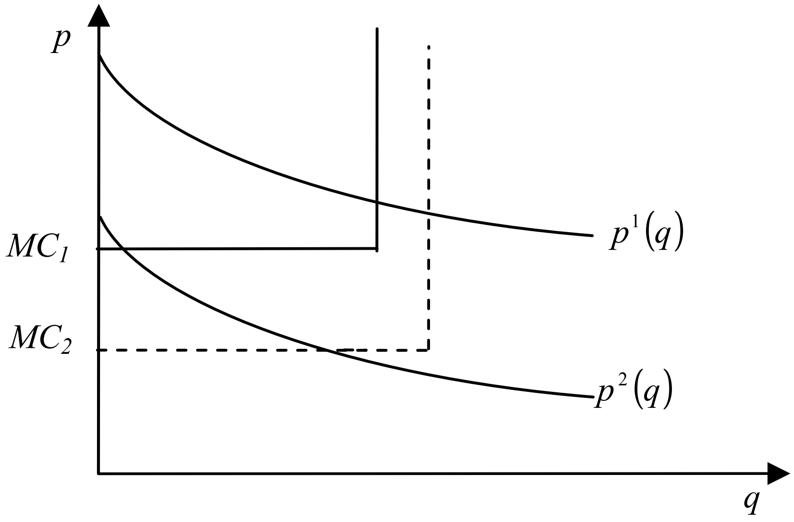


Fig. 15. The long run optimal composition after the technological innovation

reason is that the calculation of the long run optimal composition does not consider that all units adopting the surpassed technology were already built. Their capital costs are already incurred at this stage; they are sunk costs.

If the goal is to find today's optimal investment, the relevant question is: Given the current composition, what is the optimal number of type-2-units that should be added to the system? Figure 16 shows the system's marginal cost for the current composition (solid line) and the system's marginal cost after adding one type-2-unit (dashed line). Adding one type-2-unit to the system will shift the system's marginal cost curve to the right and attach a segment of lower marginal cost to the first unit. Technology 2 is a baseload unit and will be operating before any type-1-unit.

During off peak hours, the social benefit of adding one type-2-unit to the system is equal to $MC_1 - MC_2$. During peak hours, the social benefit is equal to $MC_1 - MC_2$ plus the shaded area in Figure 16. The cost of adding one type-2-unit to the system is equal to the capital cost of type-2-units. If the benefit is greater than the cost it is optimal to add one type-2-unit to the system.

Now repeat the same procedure for the second type-2-unit, the third type-2-unit, and so on. The optimal solution will depend on the specific parameters of this problem. Figure 17 represents one possible solution for this case.

Note that, differently from the long run optimal capacity, the optimal investment in the short run does not involve complete replacement of the old units.

The reason for the optimal investment in the short run not being equal to the difference between the long run optimal composition and the current composition is that the optimal long run composition involves closing some units currently operating.

Not only technological innovations can lead to a violation of the condition that for all technologies the optimal capacity is greater than its current capacity. For instance, an unexpected increase in the price of a fuel may reduce the optimal capacity of a

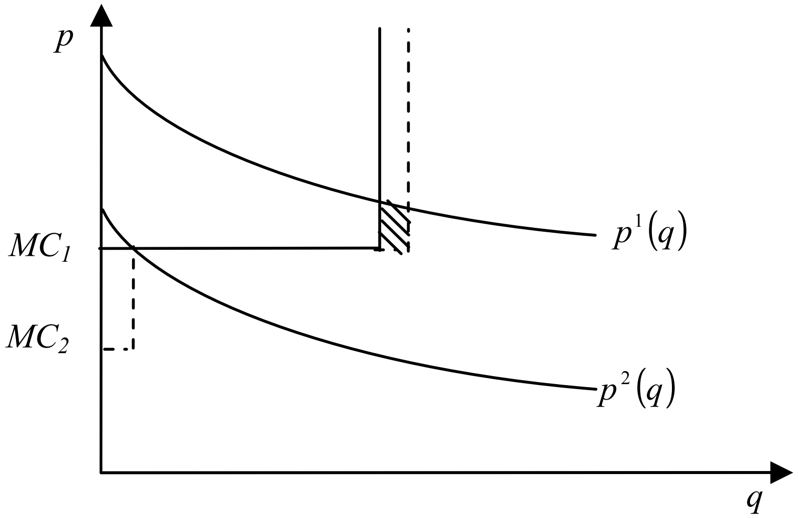


Fig. 16. Method to find the optimal investment in the short run after the technological innovation - 1 MW in technology 2

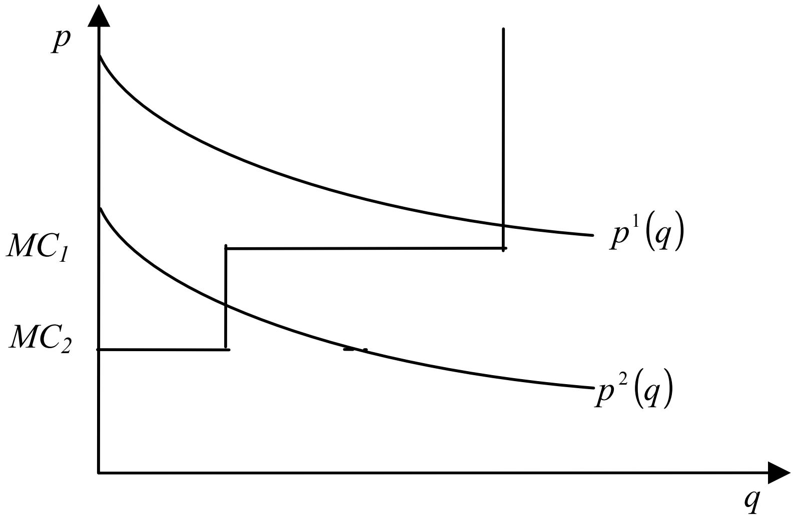


Fig. 17. Method to find the optimal investment in the short run after the technological innovation - at the final solution

given technology type to a level below the current capacity. Also, the electricity market in Texas is not a perfectly competitive market and The First Theorem of Social Welfare does not necessary hold. So, it is possible that either the regulatory authority (under the traditional regulatory regime) or profit maximizing agents (since restructuring began) over invested in some technologies in the past.

No matter what the current composition of generators is, the method introduced in this paper allows us to calculate today's optimal investment in each technology type. In the following section, I extend the method introduced in this subsection to N demands, K technologies currently being used and L technologies qualified to receive positive investment.

3. Optimal investment in the short run: N demands, K technologies currently being used and L technologies qualified to receive positive investment

Assume there are N demands. $p^1(q)$ is the highest demand, $p^2(q)$ is the second highest demand, and so on. During α_n hours in a year the system faces demand $p^n(q)$. There are K different technologies currently being used to generate electricity. Technology 1 is the technology associated to the highest marginal cost and lowest capital cost; technology 2 is the technology associated to the second highest marginal cost and second lowest capital cost; and so on. It is possible that some of the technologies currently being used to generate electricity do not belong to the optimal long run composition.

Suppose there are L technologies qualified to receive positive investments. By qualified, I mean the technologies belonging in the optimal long run composition. The set of qualified technologies can contain all, none or some of the technologies currently being used. It can also contain some technologies that were not yet used (i.e. new technologies). Let $L1$ be the qualified technology associated to the highest

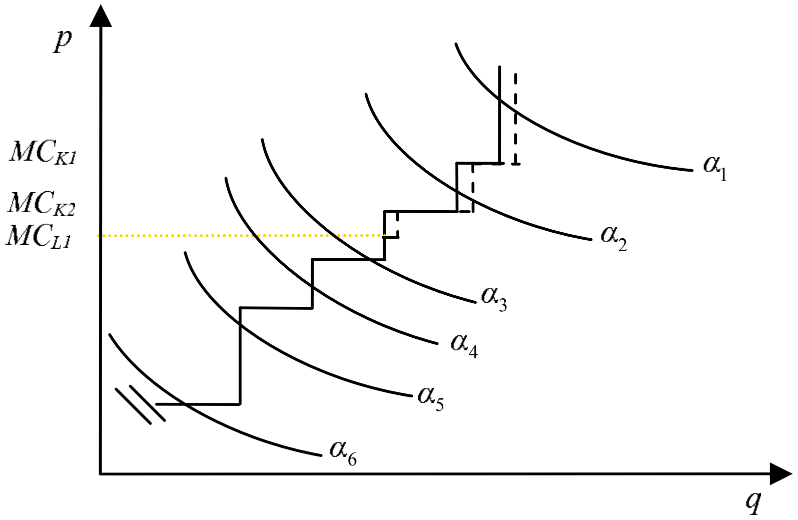


Fig. 18. Method to find the optimal investment in the short run - adding 1 MW of technology L1

marginal cost and lowest capital cost among the qualified technologies; $L2$ be the qualified technology associated with the second highest marginal cost and second lowest capital cost, and so on.

For simplicity, assume that no generation unit will close or open during the covered period.

For matters of graphical illustration, suppose that the full line in Figure 18 represents the system's marginal cost. Also, suppose that $N = 6$.

Consider the qualified technology with the highest marginal cost, $L1$. The goal is to check if adding one type-$L1$-unit to the system will generate a social surplus. For each demand function, calculate the social benefit and then just add the social benefit for every demand multiplied by the number of hours in a year that the system faces each demand curve. The social benefit generated by the extra unit is simply the area between the marginal cost curves before and after the introduction of the extra type-$L1$-unit, that lies below the demand curve.

Let MC_{L1} in Figure 18 represents the marginal cost of type-$L1$-units and MC_{Ki}

represent the marginal cost of type-Ki-units. Adding one type-$L1$-unit, will shift the segment of the system's marginal cost curve above MC_{L1} to the right (dashed line in Figure 18).

During $\alpha_6 + \alpha_5 + \alpha_4 + \alpha_3$ hours in a year, there is no extra benefit in adding one type-$L1$-unit to the system. During α_2 hours, the benefit of adding one type-$L1$-unit is $\int_{\sum_{k=2}^{K} \psi_k}^{\sum_{k=2}^{K} \psi_k + 1} p^2(q)dq - MC_{K2} + \Big(MC_{K2} - MC_{L1}\Big)$, where ψ_k is the number of units of technology type k currently operating. During α_1 hours, the benefit of adding one type-$L1$-unit is

$$\int_{\sum_{k=1}^{K} \psi_k}^{\sum_{k=1}^{K} \psi_k + 1} p^1(q)dq - MC_{K1} + \Big(MC_{K1} - MC_{K2}\Big) + \Big(MC_{K2} - MC_{L1}\Big).$$

It is socially optimal to invest in one type-$L1$-unit if the total benefit is greater or equal to the capital cost of type-$L1$-units.

Add type-$L1$-units to the system, one by one, until the benefit is equal or smaller to the cost. Call ψ_{TO}^{L} the number at which it is optimal to stop adding type-$L1$-units to the system. When the number of type-$L1$-units is equal to ψ_{TO}^{L} the cost of one extra type-$L1$-unit is higher than its benefit. Since each firm produces 1 MW, ψ_{TO}^{L} is also the total capacity added to the system. Now consider the qualified technology associated with the second highest marginal cost, technology $L2$. Now, check if replacing one type-$L1$-unit for one type-$L2$-unit increases the social welfare, if so; it is optimal to replace it. Since $MC_{L1} > MC_{L2}$ the type-$L2$-unit will be used before any type-$L1$-unit.

Consider the case illustrated in Figure 19. During α_6 hours in a year, there is no extra benefit in replace one type-$L1$-unit for one type-$L2$-unit. During α_5 hours the benefit of replacing one type-$L1$-unit for one type-$L2$-unit is $\int_{\sum_{k=5}^{K} \psi_k}^{\sum_{k=5}^{K} \psi_k + 1} p^5(q)dq - MC_{L2}$. During α_4 hours the social benefit is $\int_{\sum_{k=4}^{K} \psi_k}^{\sum_{k=4}^{K} \psi_k + 1} p^4(q)dq - MC_{K4} - \Big(MC_{K4} - MC_{L2}\Big)$. During α_3 hours the social benefit is $\Big(MC_{K3} - MC_{K4}\Big) + \Big(MC_{K4} - MC_{L2}\Big)$.

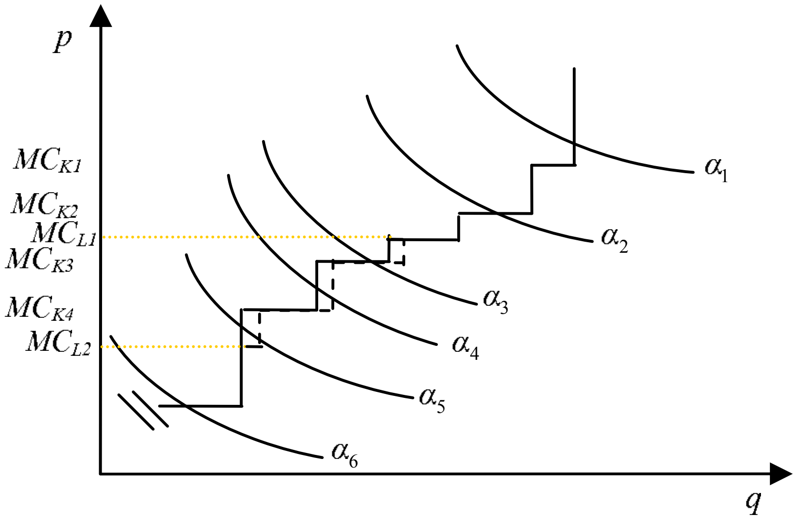


Fig. 19. Method to find the optimal investment in the short run - at the optimal amount of technology L1

During $(\alpha_1+\alpha_2)$ hours the social benefit is $\Big(MC_{L1}-MC_{K3}\Big)+\Big(MC_{K3}-MC_{K4}\Big)+\Big(MC_{K4}-MC_{L2}\Big)$. The difference in cost is $ACC_{L1}-ACC_{L2}$. If the benefit is greater or equal to the cost there is a social gain in replace one type-$L1$-unit for one type-$L2$-unit.

Keep replacing type-$L1$-units for type-$L2$-units until the benefit is equal or lower than the extra capital cost of type-$L2$-units.

The trick is that the optimal total capacity *added* to the system does not change when type-$L1$-units are replaced by type-$L2$-units. At any stage of the replacing process, the benefit and cost of adding one more type-$L1$-unit to the system is always the same. At any stage, the conclusion is the same: the benefit of adding one extra type-$L1$-unit to the system does not pay its cost.

Repeat the procedure above for units of type $L3$, $L4$, and so on. The solution is a profile of investment that specifies the optimal investment today in all types of qualified technologies, $\Big(\delta_1,\ldots,\delta_L\Big)$.

So far, it was assumed that no unit will close or open in the covered year. In general, this assumption will not hold. In this case, when calculating the social benefit that an extra unit will generate in a given hour of the year, one has to consider the capacity available at that same hour.

For simplicity, it was assumed that the marginal cost of any unit is constant over the year. The marginal cost depends on inputs prices, and those varies significantly over the year. The solution is straightforward, when calculating the social benefit that an extra unit will generate in a given hour of the year, one has to consider the marginal costs in that same hour.

The above procedure works fine if the optimal investment profile consists of strictly positive numbers of units for all Li technologies. If at some stage of the above procedure it is not optimal to invest in some technology Li, this technology should be dropped from the set of technologies qualified to receive positive investments, L, and the procedure should be restarted.

Note that, under perfect competition, social and private interests are perfect aligned. Profit maximizing agents have no incentive to invest differently from the optimal investment level. Nevertheless, electricity markets, usually, are not competitive markets.

C. Data, marginal cost and demand curves

1. Data description

Data from PLATTS, an energy information service, provide information on all electricity generator units opened or planned to be opened from 1990 until 2050 in the ERCOT system. They are 1067 units in total. For each unit, data are available on the date it started or will start operating in the ERCOT system; if the plant is now operating, out of service, retired or planned to be retired soon, its production capac-

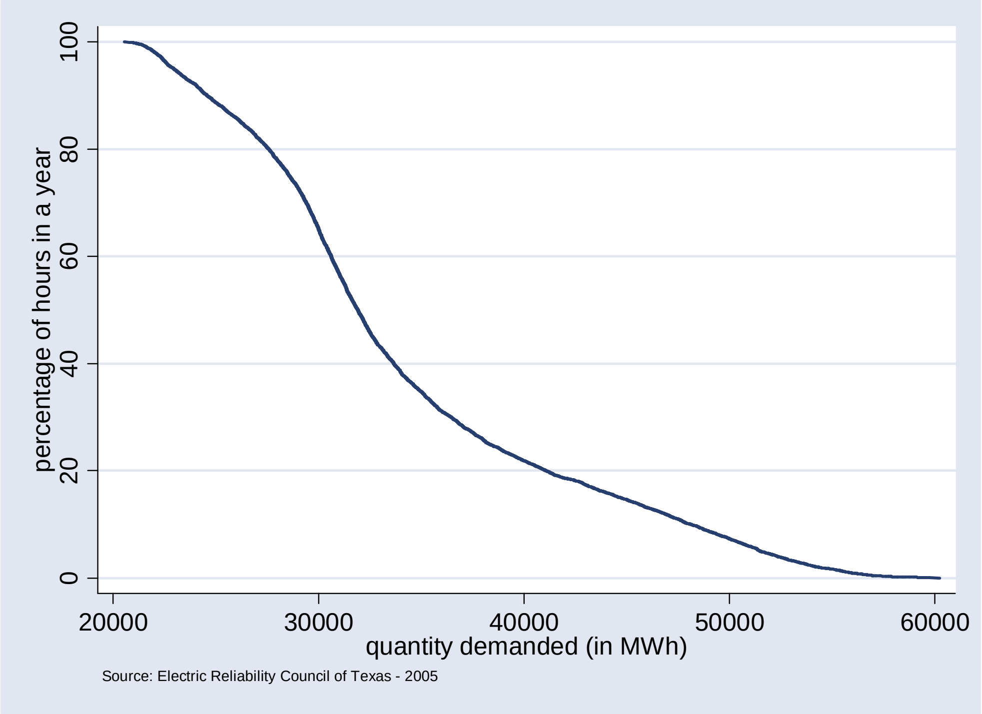
Table XVI. Basic statistics for the electricity generation units operating in Texas in 2005

primary turbine mover	primary fuel	number of Plants	total capacity (in MWh)	percentages of total capacity
COMBINED CYCLE	Natural Gas	105	31,592.43	34.59
STEAM	Natural Gas	151	28,345.55	31.03
STEAM	Lignite (coal)	14	8,523.20	9.33
STEAM	Sub-bituminous (coal)	18	7,069.29	7.74
GAS TURBINE	Natural Gas	141	7,040.55	7.71
NUCLEAR	Uranium	8	5,138.60	5.63
WIND	Wind	35	1,700.30	1.86
STEAM	Bituminous (coal)	1	600.40	0.66
HYDRO	Water	44	423.84	0.46
OTHERS	NA	128	900.25	0.99
TOTAL		645	91,334.41	100.00

Source: PLATTS - 2005

ities in MW, the primary turbine mover used to generate electricity, the primary fuel used by this unit, and the amount of the corresponding fuel necessary to generate one MW of electricity (heat rate). Table XVI presents the combinations of turbine mover and fuel observed in ERCOT, as well as, the percentage of each combination in the total production capacity in ERCOT and some basic statistics.

The data for demand were obtained from the ERCOT website. For every day of 2005, the data provides the electricity demand for each 15 minutes interval starting from midnight. The load duration curve for 2005 is represented in Figure 20. For any quantity Q in the horizontal axis, the vertical axis shows the percentage of hours a year in which the demand is equal or greater than Q.



Source: Electric Reliability Council of Texas - 2005

Fig. 20. ERCOT load in 2005

2. Marginal cost

The marginal cost of electricity consist of two components: the fuel cost and other variable operating or maintenance cost. The marginal cost of a unit i is given by the equation:

$$MC_i = \text{maintenance cost} + \text{heat rate}_i \text{ x fuel price}_i$$

The maintenance costs are assumed to be two dollars per MW, which is an appropriate figure for the ERCOT system.

The heat rates are unknown for about 30% of the units operating in 2005. A missing value is replaced by the average heat rate of units with the same turbine mover and fuel needs. The average is calculated considering the units opened two years before, two years after and in the year that the considered unit were opened.

Another variable in the marginal cost equation is the fuel price. A high share of the electricity generated in the ERCOT system is supplied by plants that use as inputs coal, natural gas or uranium. According tho Ux Consulting Company, the estimated price of uranium on March 20^{th} was 40.50[6] dollars per lb.

The future prices for coal and gas was obtained at PLATTS website. It is available monthly gas price and yearly coal prices, both for Texas, until 2025. Figure 21 presents the evolution of gas and coal prices during the period.

The prices for all other fuels are not available. The fuel cost of all units with missing heat rate and/or missing fuel price is set to zero. This makes our final results a lower bound estimator of the optimal investment in each technology type. To deal differently with the missing values should not change our results significantly, since the combined production capacity of all units with missing heat rate and/or missing fuel price do not represent a significant share of the total capacity, 2,789.1 MW out

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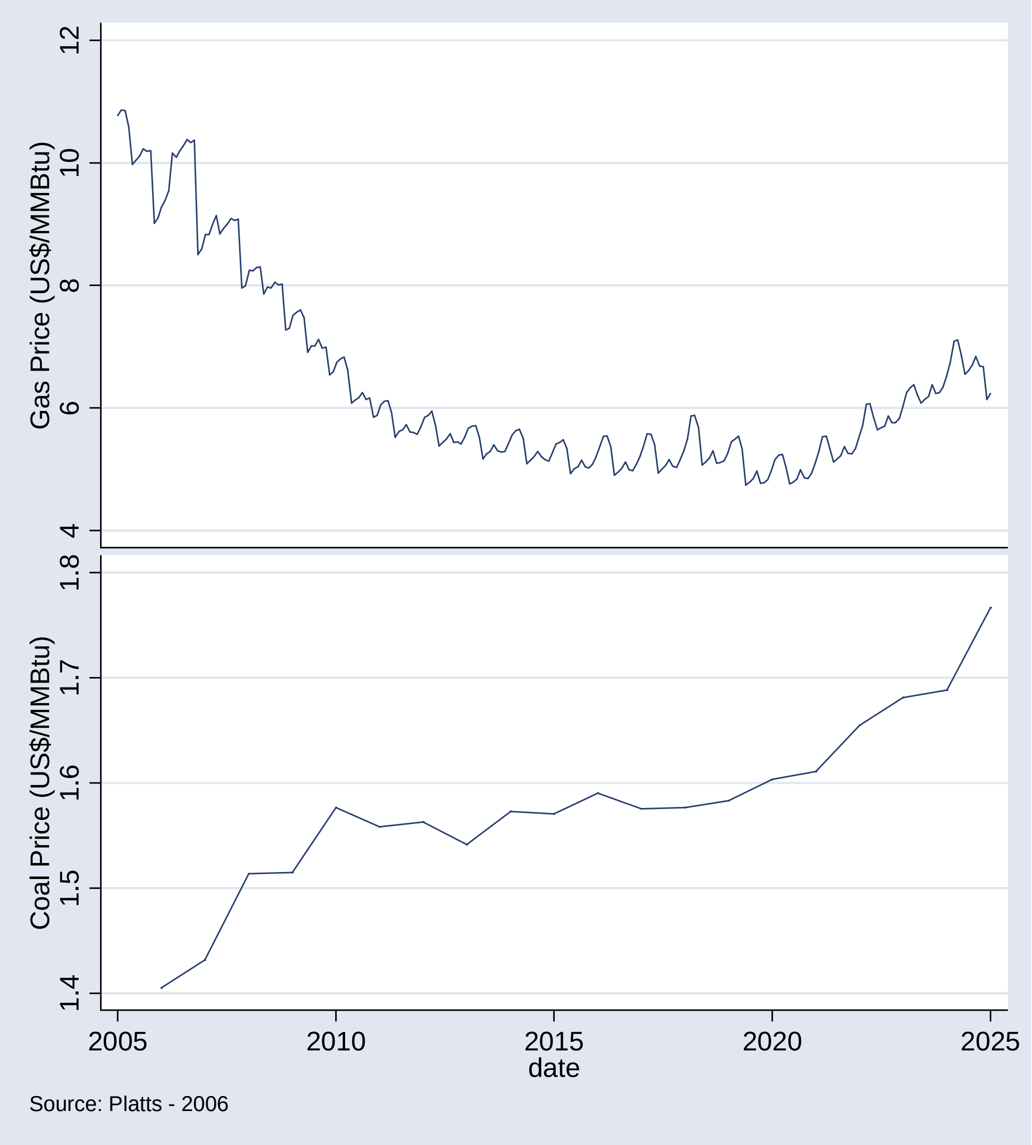
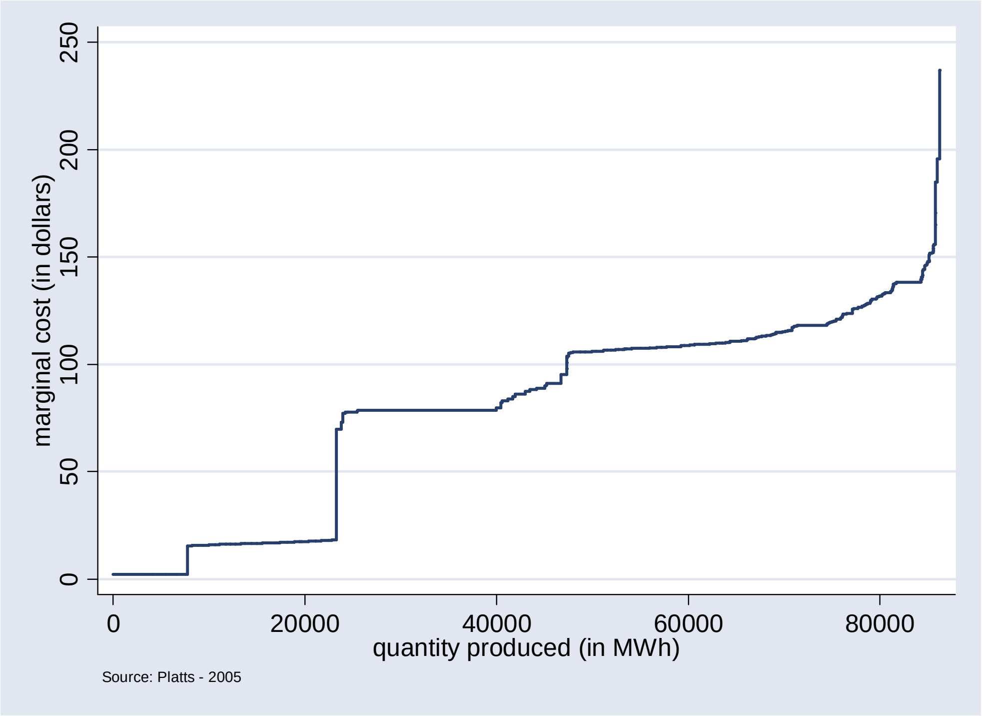
[6] See http://www.uxc.com.



Source: Platts - 2006

Fig. 21. Gas and coal future prices



Source: Platts - 2005

Fig. 22. Estimated ERCOT system's marginal cost in January 2006

of 94,571.51 MW.

The estimated marginal cost curve in January of 2006 is represented in Figure 22[7]. Note that much more than 2,789.1 MW of generation capacity are associated with marginal cost of about two dollars. This happens for two reasons. First, the marginal cost of nuclear units is just slightly higher than two dollars. Second, the heat rate of units that use water, wind or sun as a primary mover is zero.

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[7] In 2006, the difference between Summer and Winter capacities was 2,607 MW. Since this difference does not represent a significant percentage of total capacity, I do not consider variations between Summer and Winter capacities.

3. Demand curves

Like in Borenstein [8], the assumed hourly demand specification is given by the equation:

$$D_h(p_h, \overline{p}) = aA_h p_h^{\epsilon} + (1-a)A_h \overline{p}^{\epsilon}$$

where a represents the share of the demand in real time price (RTP), p_h represents the RTP of electricity at hour h, $\overline{p}$ represents the price charged to consumers in flat rate service, and ϵ represents the elasticity of demand.

a is assumed to be equal to one percent[8]. The price charged to consumers on the flat rate service used in the estimations was 14 cents per kWh of electricity[9]. Following Borenstein, the cost of transmission & distribution is set equal to 4 cents per kWh, and should be deducted from the flat rate and the RTP when estimating the hourly demand curves. Estimations of the demand elasticity are not available. Like in Borenstein, a wide range of possible values assumed by ϵ[10] is considered. This way, the final result is a range for the optimal investment in each technology type.

Knowing the real time prices and the hourly quantity demanded, the only pa-

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[8] I did not find any data or study that estimate the percentage of consumers in the RTP. This number was suggested by an industry analyst.

[9] The price considered was given by an industry analyst. This number is also consistent withe the prices available at the site http://www.electricitytexas.com. For each zip code in Texas, this site informs the electricity prices charged by some electricity providers in the corresponding area. For instance, in September, 26th of 2006, the simple average of electricity prices were 13.98 cents per kWh in Dallas and Waco and, 14.98 in Houston. Depending on the area, provider and payment plan; Summer and Winter rates may differ. But the difference does not seems to be significant. For instance, the Summer and Winter rates differ in 0.14 cents per kWh in College Station. Depending on the plan, this difference goes from zero to 1.5 cents per kWh for the Reliant Energy in Houston.

[10] The demand elasticities considered are -0.025, -0.15, -0.3 and -0.5. According to Borenstein, the demand elasticities -0.025 and -0.15 should capture the short run impact of RTP and are consistent with the elasticities estimated in Patrick and Wolak [31] and Braithwait and O'Sheasy [10]. In the long run, a greater response of consumers to price changes is expected. The demand elasticities of -0.3 and -0.5 are intended to capture the long run impact of RTP.

rameter left to be estimated in the demand equation is A_h. In fact, the data do not provide information on real time prices. The RTP is estimated assuming that the real time market is a perfectly competitive market[11]. For a given quantity demanded, the RTP is set equal to the marginal cost at that quantity. Whenever a quantity demanded is associated to a vertical segment in the marginal cost curve, the price is set equal to the medium point in the vertical segment.

Knowing $a, \overline{p}, D_h, p_h$, one can calculate A_h for different values of elasticity. Once A_h is calculated, it is possible to calculate the demand curves for any value of a between zero and one. For matters of calculating consumer surplus for the optimal investment algorithm, a can only assume the value one. This is because when calculating the social surplus, what matters is the price the consumers are willing to pay for each MW and not the price they actually pay. So, a is set equal to one when the optimal investment is calculated.

The marginal cost curve in January of 2006, the predicted real time prices (for a equal to 0.01), as well as, some estimated demand curves (for a equal to 1) are represented in Figure 23. The upper part of Figure 23 shows the estimated demand curves assuming the demand elasticity level of -0.025, and the bottom shows the demands for the elasticity level of -0.5. The highest and the lowest demand curves are represented in both cases.

Before proceeding with the estimations, the following section discuss some aspects of the plants operating in the ERCOT market that raise concerns about estimations of the optimal investment that do not take in consideration the current composition.

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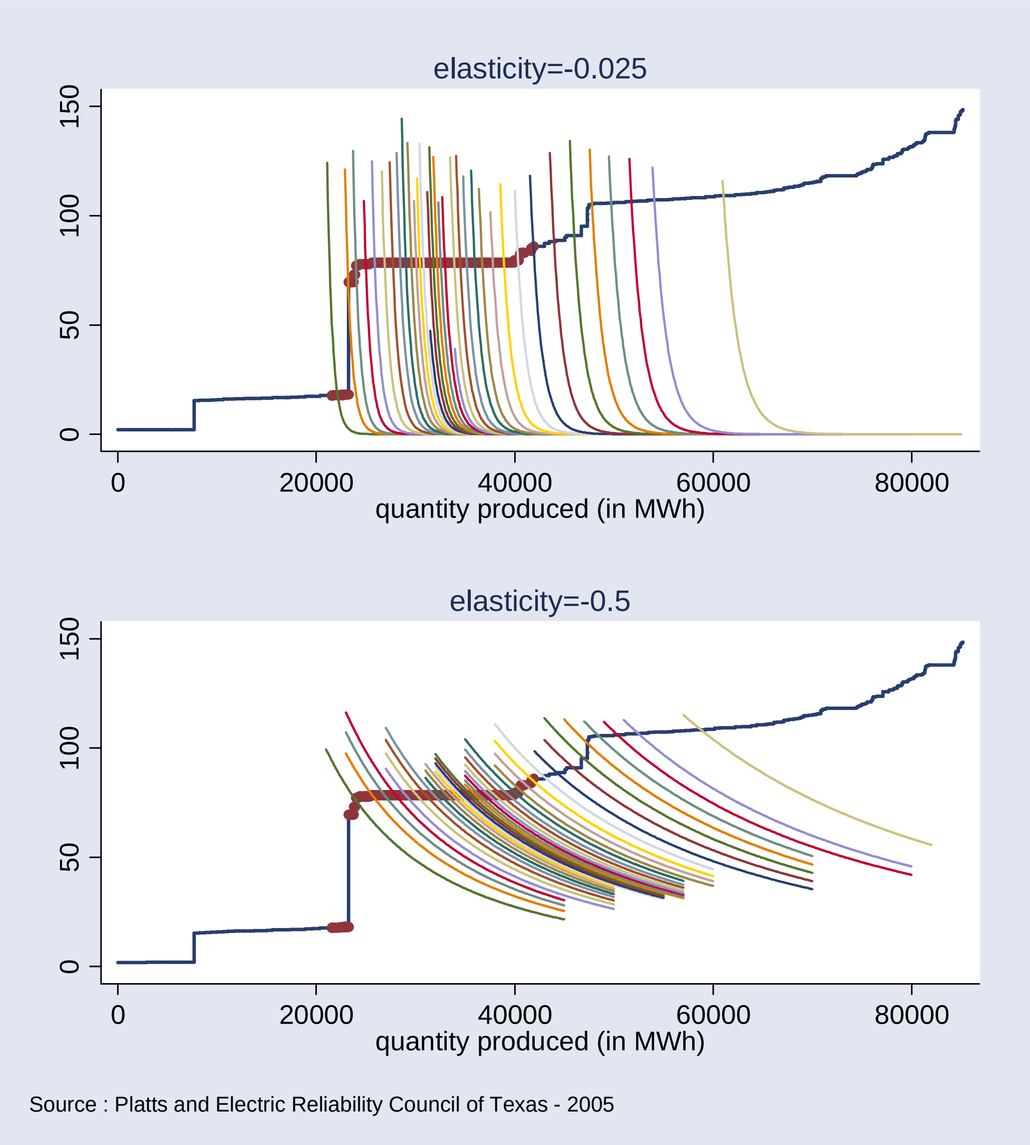
[11] Other price setting, like Cournot Model, can be considered. Nevertheless, the result should not change significantly. Since the share of consumers in the RTP is very small, variations in the RTP have little impact in the parameter A_h.



Source : Platts and Electric Reliability Council of Texas - 2005

Fig. 23. System's marginal cost curve in January of 2006, and some estimated demand curves in 2006 for $a = 1$ (The upper part of the graph shows the estimated demand curves assuming the elasticity level of -0.025, and the bottom shows the demands for the elasticity level of -0.5. the estimated RTP for $a = 0.01$ in January 2006 are represented by the red dots in the marginal cost curve)

D. High versus low depreciation rate

This paper focus in optimal investment while Borenstein's paper discuss optimal long run capacity. Assuming that the depreciation rate is higher than a certain threshold, today's optimal investment is simply the optimal long run composition. Finding evidence supporting the hypothesis of a high depreciation rate, would suggest a fast adjustment toward the long run optimal composition. In this case, considerations of the current capacity are unnecessary, and the optimal investment would be equal the optimal long run capacity.

If all units in the ERCOT market last just a few years, it would suggest a pretty high depreciation rate. The upper part of Figure 24 shows the histogram of the age of units that already closed or have established a retirement date. The bottom part shows the same histogram weighted by capacity. Once a capacity is installed, in general, it will be operating for forty years. The histograms suggest a low depreciation rate.

If the current composition consist of relatively new units, it can be an argument in favor of the hypothesis of a high depreciation rate. Figure 25 shows how much of the current total capacity is supplied by units built before or in the corresponding year in the horizontal axis. For instance, more than 40% of 2005's capacity was built in 1980 or before. The fact that a large fraction of the 2005's capacity is supplied by relatively old units supports the hypothesis of a low depreciation rate.

The supply composition experienced great changes during the period covered as shown in Figure 26. For each year in the horizontal axis, it shows the percentage of the total capacity that year that is produced by a specific combination of turbine and fuel type [12]. For instance, in 1900, 100% of the total capacity was supplied by

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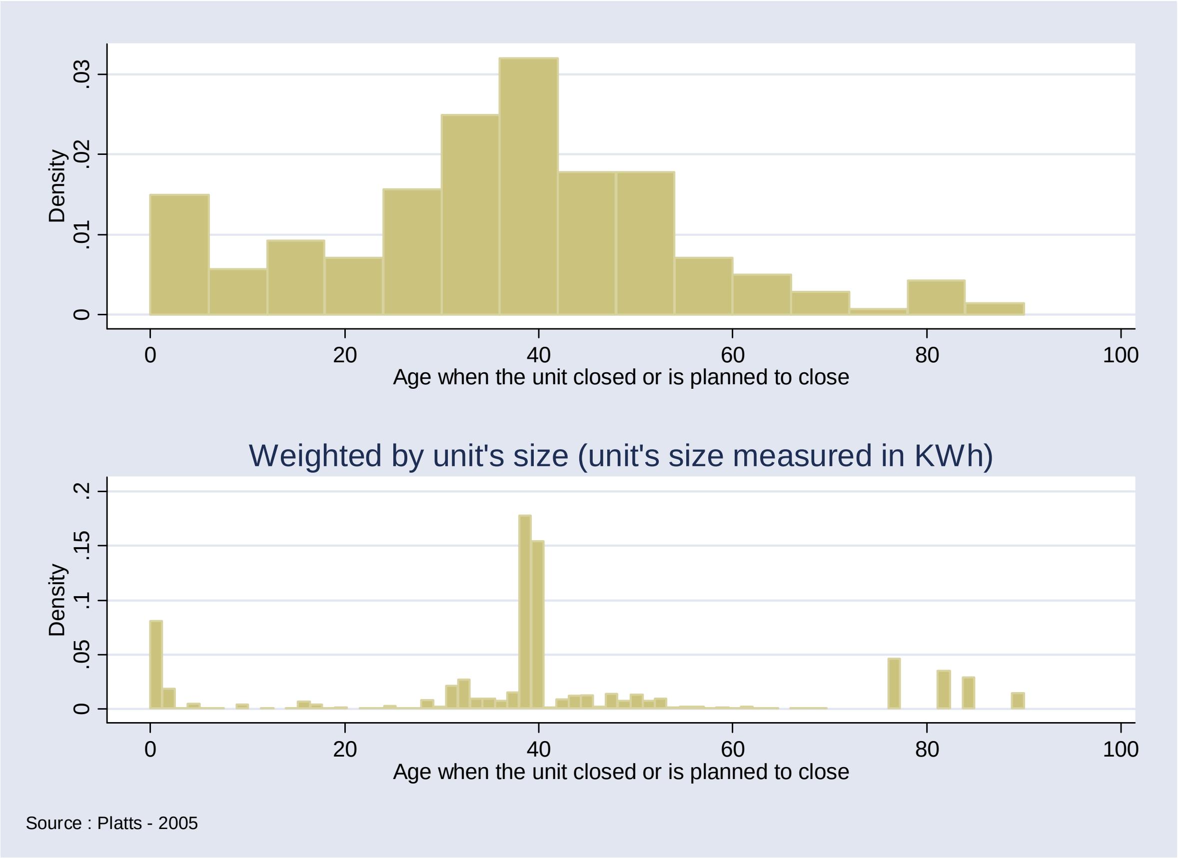
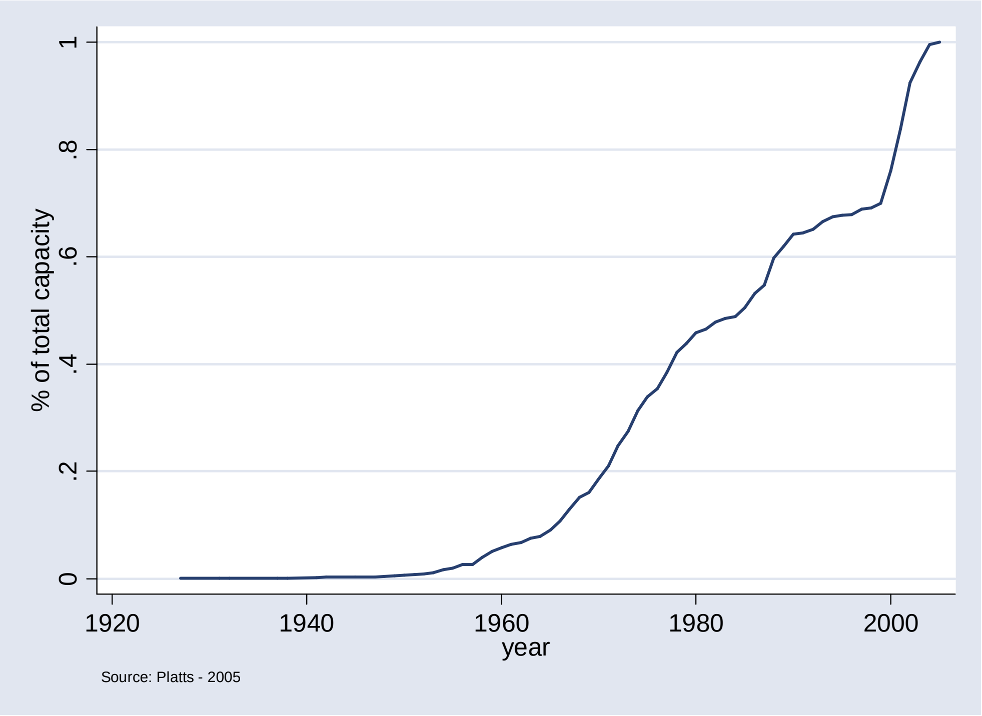
[12] The figure is split in two parts because of the great differences in the y-axis scale



Source : Platts - 2005

Fig. 24. Histograms of the age of the units that already closed or have established a retirement date (The bottom part shows the histogram weighted by capacity)



Source: Platts - 2005

Fig. 25. The vertical axis shows how much of 2005's total capacity supplied by units built before or in the corresponding year in the horizontal axis (Only the units operating in October 2005 were considered)

hydroelectric units. Most of the movements in the curves in Figure 26 were driven by the addition of new capacity. Retirement explains just a tiny part of the movement. Figure 27 and 28 show, for each combination of turbine and fuel, the evolution of the capacity added and retired, respectively. Despite the major structural changes in the electricity supply over the years, the adjustment seems to happen via addition of new capacity and, seldom, via retirement of capacity.

This section presents some evidence supporting the hypothesis of a low depreciation rate[13]; consequently a slow adjustment process toward the optimal long run composition. Therefore, considerations of the current capacity are recommended when estimating the optimal investment[14].

E. Estimation's procedure and results

Borenstein [8] applies the method presented in section 1 to calculated the optimal long run capacity while, this section, apply the method presented in section 3 to calculate the optimal investment.

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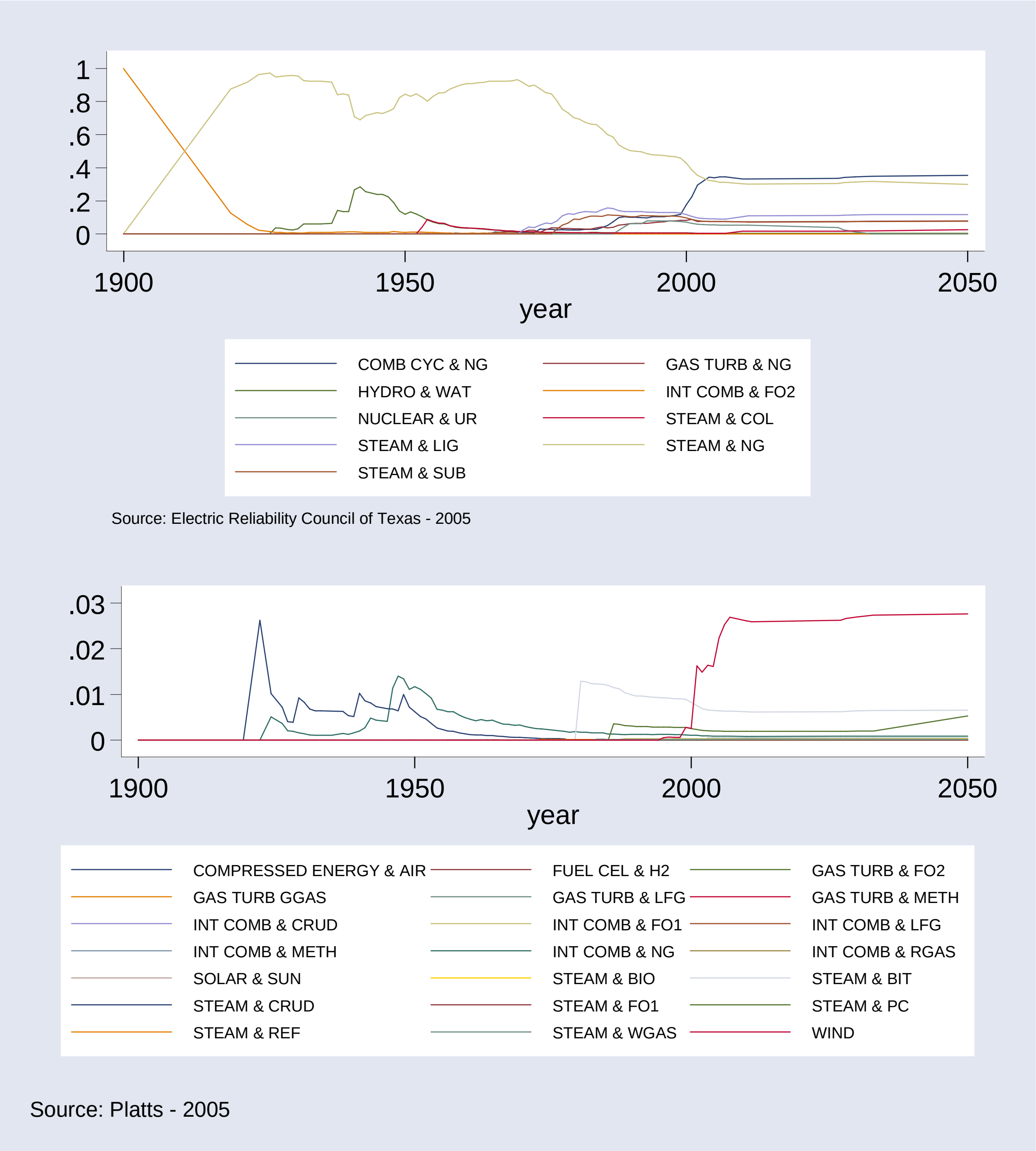
across combinations over time. In a given year the the capacities shown in the figure include the capacity of units operating, in stand by, retired, under construction, in early development and proposed if the unit is open or planned to be open in that year. The capacity of canceled units and planned units indefinitely postponed were excluded.
Description of the codes in the figure: BIT (Bituminous), COL (Coal), CRUD (Crude Oil), FO1 (Fuel Oil 1), FO2 (Fuel Oil 2), GGAS (Generic Gas), LFG (Landfill gas), LIG (Lignite), METH (Methane), NG (Natural Gas), PC (PetCoke), RGAS (Refinery Gas), REF (Refuse - trash), STM (Steam), SUB (Sub-Bituminous), UR (Uranium), WAT (Water) and, WGAS (Waste Gas).

[13] Caution is recommended here, since it is possible that all units currently operating belong to the composition that minimizes production costs. Maybe some of the old units currently operating in the ERCOT market have been completely remodeled since their inauguration; and that is the reason why they remained in the market in the first place.

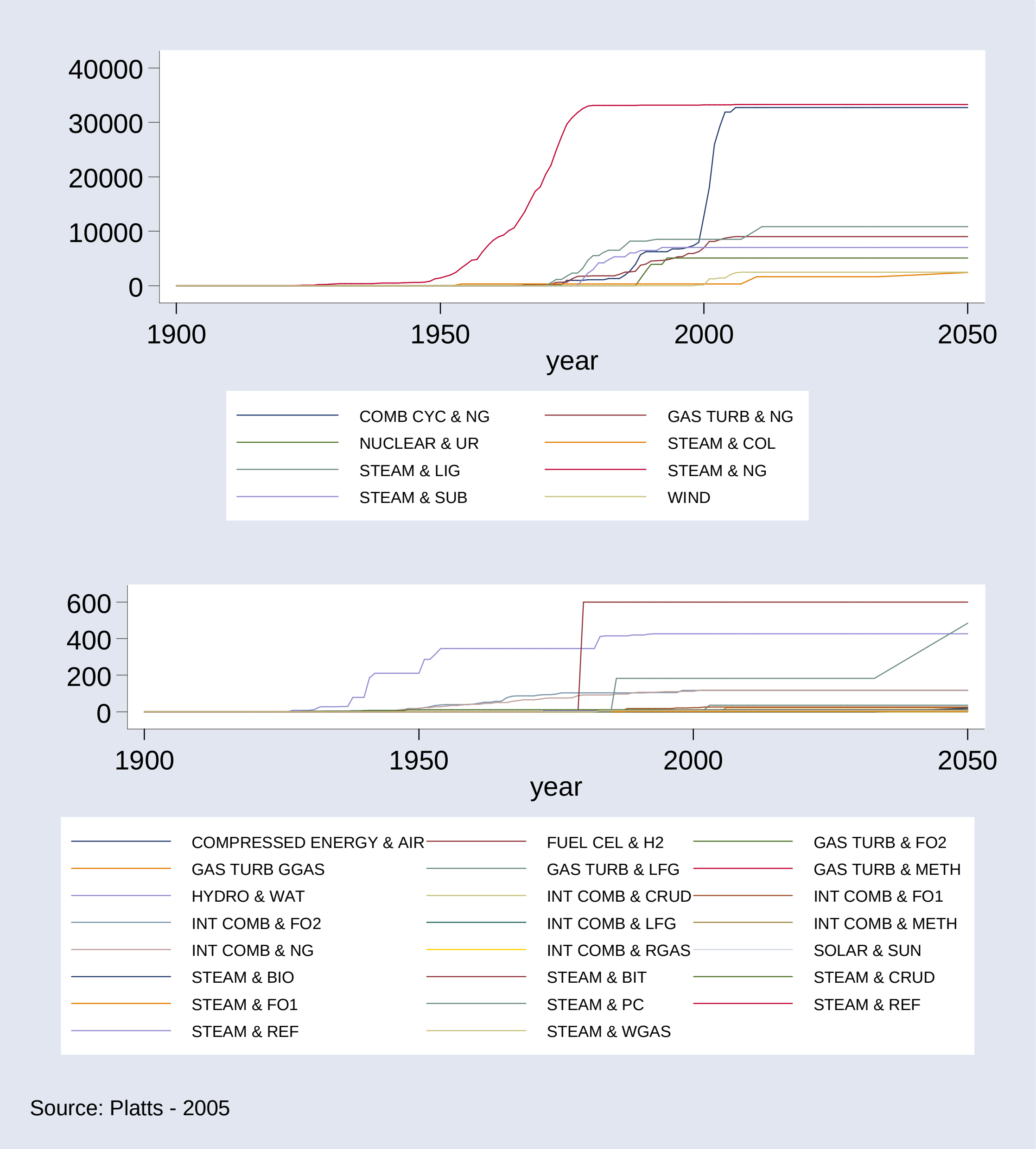
[14] If we assume that the optimal investment is equal to the optimal long run capacity we will obtain an upper bound value for investment and respective efficiency gains, most likely, extremely far from the real values.



Source: Electric Reliability Council of Texas - 2005

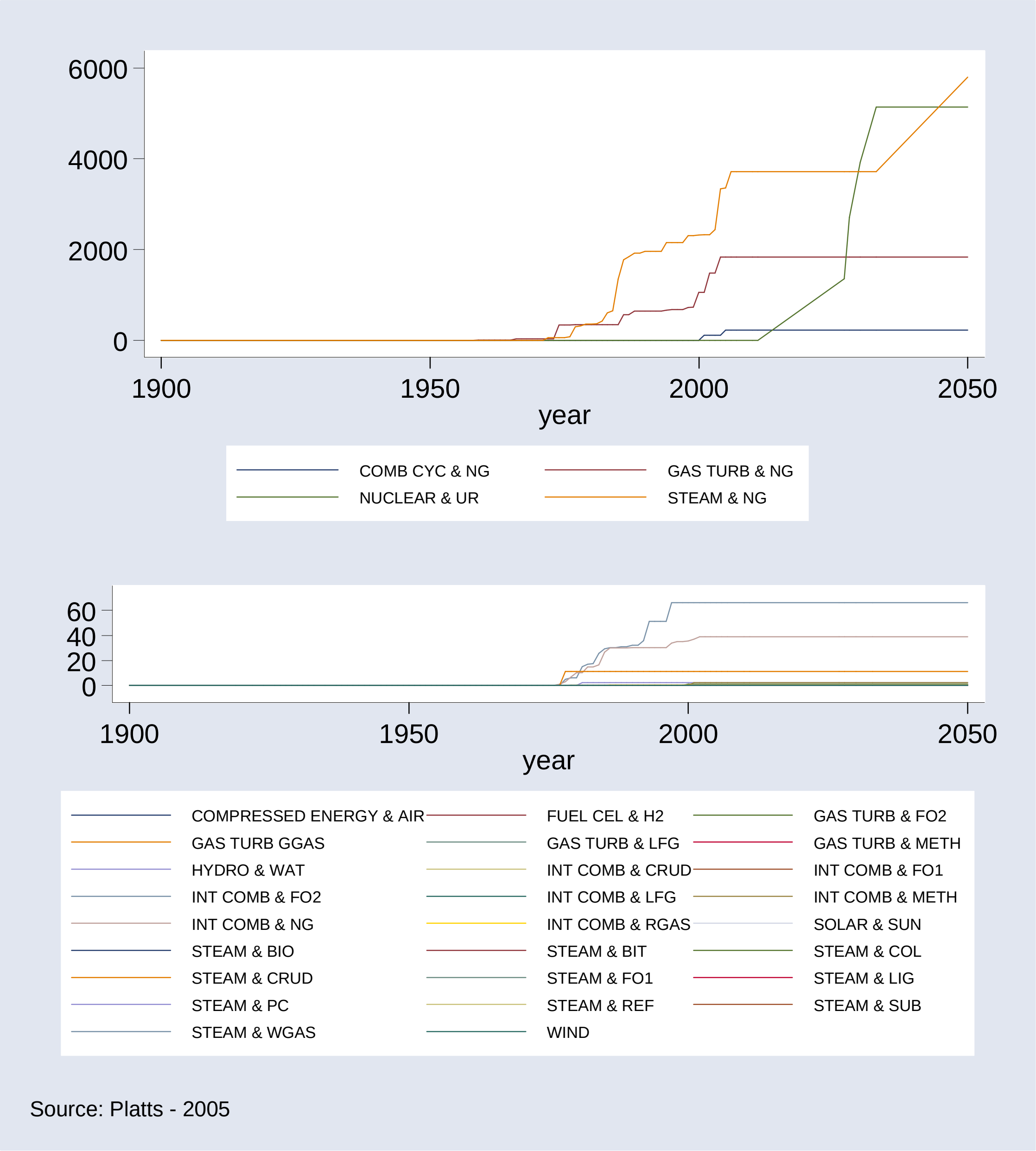
Source: Platts - 2005

Fig. 26. For each year, the graph shows the percentage of total capacity in that year that is supplied by a specific technology



Source: Platts - 2005

Fig. 27. Capacity added (in MW) over year by technology



Source: Platts - 2005

Fig. 28. Capacity retired (in MW) over year by technology

Borenstein [8] consider three technologies in the set of optimal long run composition. They are: coal units, combined-cycle gas turbine, and combustion turbine generation, representing baseload, mid-merit, and peak technologies, respectively. Here the three technologies are considered as technologies qualified to receive positive investments. The the annual capital cost adopted are the ones provided by Borenstein they are 155,000, 75,000, and 50,000 dollars per MW for coal, combined-cycle, and combustion turbine units.

The heat rates for the new combustion turbine and combined-cycle units used in the estimations are the ones provided by Borenstein. Borenstein implicitly assumed the heat rates to be 13,882.35 Btu/kWh for combustion turbine units and 8,000 Btu/kWh for combined-cycle units. Also, Ishii [26] using world-wide sales data from 1980 to 2001, argues that, for the latter years of his data, the heat rate of combined-cycle turbines seems to be around 8000 Btu/kWh if capacity is limited to 50 MW. The heat rate for the new coal units used in the estimations is an average heat rate of coal units opened in the ERCOT market in the year of 1980 or later. That is, 10,325.68 Btu/kWh.

The estimation allow the system capacity to change whenever entry or exit of new units are expected. A unit is expected to be operating in a given future date if its inauguration happened or is planned to happen before that date and there is no plan of retiring the unit before that date. Only the units under construction or in an early development stage were considered for futures openings.

The estimation allows the fuel prices to change according to the available data for future fuel prices.

In October of 2005, there were 36 plants out of service . Together they represent 6.027% of the total capacity in 2005. For all units, including the new ones, the probability of a break down, at any point in time, is also assumed to be to 6.027%[15].

The future loads were estimated according to the forecasted load growth rates presented in Report on Existing and Potential Electric System Constraints and Needs (ERCOT, [14]). "...ERCOT load forecasters consider a wide range of variables such as population, weather, land usage, general business economy, government policy, and societal trends in terms of both historical actuals and the best predicted future indicators available[16]." The report predicts a load increase of 2.1% per year and peak load increase of 1.6% per year until 2011. The forecasted loads are represented in Figure 29[17].

I calculate the annual surplus of adding (replacing) one unit of a given technology type to the system in January 1st. The benefit generated by this extra unit in a given hour of the year is calculated considering the prices of gas in that month, the price of coal in that year, the demands at that hour and, the units operating at that date. The annual total benefit is calculated adding the benefit generated by the unit at each hour of the considered year, starting in the first hour of January 1st and ending in the last hour of December 31st.

The optimal investment profile in a given year is the investment profile that maximizes the social surplus. The social surplus is equal the summation of the present value of the social surplus provided by the new units for all years they are expected

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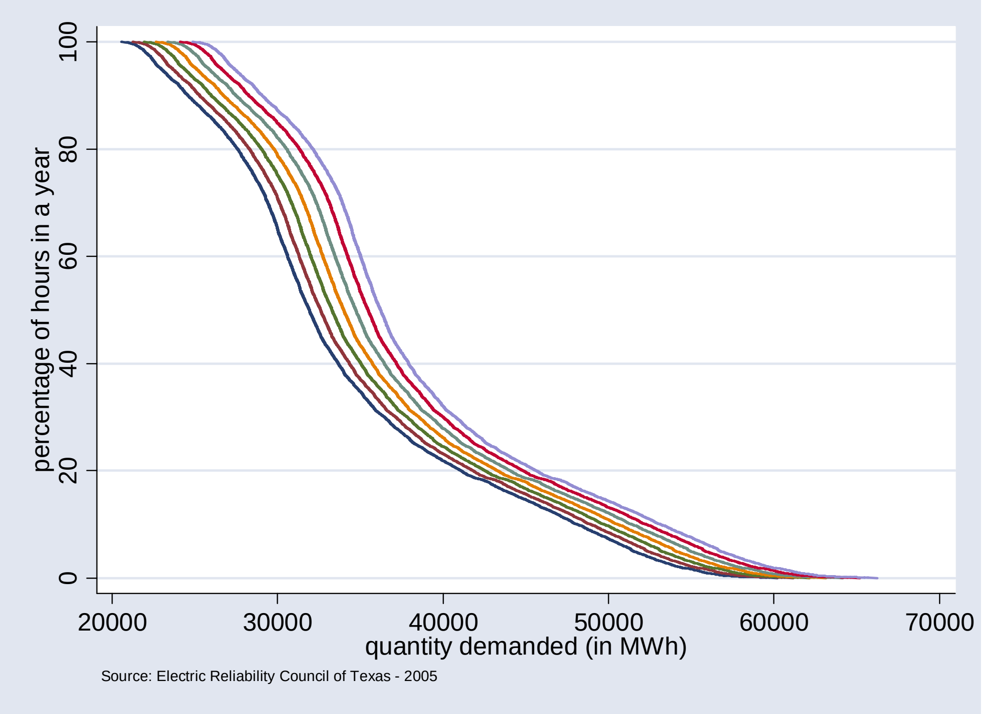
[15] Since among the units out of service there are new and old units, it was assumed that the probability of break down is not related to the unit's age. In other words, once built, a new unit has the same probability of a break down as an old unit.

[16] Energy prices were not mentioned in the report as one of the variables in the load forecast equation. I assumed that the price charged to consumers in the flat rate service will remain constant for all years.

[17] The forecasted load is 1.6% higher than the previous year load (forecasted or realized) plus a constant term. The constant term decreases progressively as the peak load is approached, in a way that the total forecasted load is 2.1% higher than the previous year load.



Source: Electric Reliability Council of Texas - 2005

Fig. 29. 2005's load and forecasted loads from 2006 until 2011

to be operating. Note that there is no restriction about the year the investment will take place. The solution to the maximization problem should specify the optimal investment in each technology for each year. Despite all the eventual difficulties associated with this infinite intertemporal maximization problem, the solution would still require much longer series of expected future fuel prices and load than the ones available.

This paper does not present the the optimal investment profile. Instead, for each year, it presents the investment profile[18] that maximizes the social surplus in the corresponding year. The procedure is repeated for all years for which data is available. Presumably, those investment profiles is an indicator of the optimal investment. For instance, suppose that the optimal investment in coal units for the years 2006, 2007, 2008, 2009, 2010 and 2011 are 100, 105, 95, 100, 105 and 110 MW, respectively. It implies that if new coal units with total capacity of 95 MW start operating in 2006 they will provide positive social surplus for at least the following five years. If no drastic changes in the parameters of the model are expected for the next years, 95 MW is probably a lowerbound indicator of the optimal investment in coal units.

In the first stage the algorithm calculates the investment in combustion turbine units that maximizes the social surplus in a given year under the assumption that there are no other technology available to receive positive investment. In the second stage some of those units are replaced by combined-cycle gas units if the replacement improves the social surplus in the corresponding year. Finally, in the third stage, some combined-cycle gas units are replaced by coal units. Finding that the investment in a given technology that maximizes the social surplus is zero, means that the technology

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[18] The investment profile of a given year does not specify how much money should be invested in each technology in that year but how many units of each technology should be operating in January 1^{st} of that year.

does not belong to the set of technologies qualified to receive positive investment. In this case, the technology should be removed from the set and, the procedure reapplied.

For four possible values of the elasticity demand and for each year from 2006 until 2011, Table XVII presents the investment in coal, combined-cycle gas turbine, and combustion turbine units that maximizes the social surplus in the corresponding year. For all elasticities and years considered, positive investment in combined-cycle gas turbine or combustion turbine units generates a social loss. Only investment in coal units can generate a positive social surplus.

It is possible that a certain investment in coal units provides positive social surplus for all years from 2006 until 2011 although, it is not optimal to build those units in any of those years. It can happen for two reasons. First, because the present value of social loss in later years is larger than the positive social surplus generated by the units. Second, it is possible that the present value of the social surplus can be maximized delaying all or part of the investment. A more strong implication can be inferred if a new unit of a given technology provides a social loss for all years from 2006 until 2011. That is the case of combined-cycle gas turbine and combustion turbine technologies. If at a given date, a unit of a given technology provides a negative surplus in the first year of its operation it implies that it is not optimal to invest in this technology at that date. Even if in the discounted future benefit is greater than the cost of building this unit at that date, the social surplus is maximized postponing the investment.

In conclusion, the results presented in Table XVII imply that it is not optimal to invest in combined-cycle gas turbine or combustion turbine units during the years considered.

Even in the case that there are no other technology available, investment in combustion turbine units can only generate a social loss. Obviously this technology

Table XVII. Investment profile that maximizes social surplus in the corresponding year and respective social surplus

year	coal (in MWh)	combined cycle (in MWh)	combustion turbine (in MWh)	social surplus per consumer in the corresponding year (in dollars)	social surplus in the corresponding year (in thousands of dollars)
Elasticity = -0.025					
2006	14,720	0	0	133.93	2,678,631
2007	15,532	0	0	137.72	2,754,316
2008	14,542	0	0	113.06	2,261,274
2009	14,011	0	0	93.72	1,874,414
2010	12,731	0	0	63.04	1,260,757
2011	12,327	0	0	43.26	865,225
Elasticity = -0.15					
2006	19,636	0	0	192.57	3,851,322
2007	20,558	0	0	195.78	3,915,623
2008	19,772	0	0	163.52	3,270,373
2009	19,525	0	0	138.12	2,762,433
2010	18,254	0	0	97.98	1,959,611
2011	17,936	0	0	70.32	1,406,461
Elasticity = -0.3					
2006	27,173	0	0	268.64	5,372,882
2007	28,172	0	0	271.04	5,420,770
2008	27,408	0	0	229.42	4,588,319
2009	27,285	0	0	197.06	3,941,107
2010	25,936	0	0	145.83	2,916,668
2011	25,597	0	0	109.64	2,192,742
Elasticity = -0.5					
2006	39,065	0	0	379.71	7,594,231
2007	40,152	0	0	380.89	7,617,804
2008	39,622	0	0	327.96	6,559,220
2009	39,696	0	0	287.80	5,756,021
2010	38,038	0	0	222.93	4,458,697
2011	37,870	0	0	177.00	3,539,981

does not belong to the set of technology qualified to receive positive investment. In the next step, combustion turbine is eliminated from the set and the procedure is reapplied. Once again, the optimal investment in combined-cycle gas units is zero and the only technology remaining in the set of technologies qualified to receive positive investment is the technology that uses coal as an input. Independent of the realized investment in coal units the optimal investment in combined-cycle gas turbine or combustion turbine units is zero. Even if new investment in coal units are not allowed, the optimal investment in other technologies remains zero. The absence of investment would imply that the changes in the parameters of the model, like demand increases, should be accommodated by changes in prices.

The fact that it is not optimal to invest in combined-cycle gas turbine or combustion turbine does not imply that the technologies does not belong to the optimal long run composition. It is possible that the system has exactly the optimal level of units for the technologies or an overinvestment happened in the past. A more optimistic scenario about the future prices of gas at the time of the investment decision might have contributed to an eventual overinvestment. Consequently, the substantial investment in combined-cycle gas turbine units in the last years[19] can be evaluated as an overinvestment under current expectations about future fuel prices.

For each elasticity and year, the investment in coal units presented in Table XVII is the investment that maximizes the social surplus in the corresponding year. If additional coal units with total capacity of 12 thousand MW start operating in 2006 they will provide positive social surplus for at least the following five years, even under the assumption of a extremely low demand elasticity of -0.025.

The elasticities -0.025 and -0.15 are intended to capture the consumers' short

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[19] See Figure 27

run reaction to RTP. In the long run, a greater response is expected from consumers. The elasticities -0.3 and -0.5 are intent to capture the long run impact of RTP. Considering the elasticities -0.025 and -0.15, the investment in coal units that would generate positive surplus for all considered years are about 12 and 17 thousand MW, respectively. For the elasticities -0.3 and -0.5 a positive social surplus is obtained for all years considered if the investment in coal units are approximately 25 and 37 thousand MW, respectively. For all years and elasticities considered, Texans can obtain a positive social surplus investing in at least 12 thousand MW.

The optimal investment in coal units depends on several variables. First the expected increase in demand over the years raises the benefit of investing in coal units. The expected decrease in gas prices[20] reduces the marginal cost of the gas units currently operating making the investment in inframarginal units, like coal units, less attractive. The expected increase in coal prices reduces the gain of replacing more expensive units currently operating units for coal units. Entry of new units can reduce the optimal investment in coal units. Exit of units can increase it. Those variables affect the optimal investment in different directions. Moreover, some of those variables does not follow a smooth or continuous pattern. Entries and exits, for instance, represents one time change.

Despite of all the expected changes in the variables that determines the investment in coal units from 2006 until 2011[21], once a elasticity is selected, the investment in coal units that maximizes the social surplus in a given year does not change drastically from one year to another. So, if no huge changes in the variables that determine the investment in coal units is expected for the years following 2011, it is possible that

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[20] See Figure 21.

[21] Specially the changes in the future fuel prices. See Figure 21.

the figures presented in Table XVII represent a reasonable indicator of the optimal investment in coal units at the present date.

Charging the RTP from consumers would improve the social surplus for two reasons. First, it maximizes the social surplus given the current capacity installed. Second, assuming that electricity suppliers are price takers, the RTP system would induce the realization of the optimal investment. The social surplus in Table XVII intend represent an estimative of the second impact. For each investment profile in Table XVII, the last two columns present the associated social surplus and social surplus per consumer obtained in the corresponding year. For the elasticities -0.3 and -0.5, efficiency gains range from approximately 2,192 to 7,617 million dollars per year. For the same elasticities, implementation of the investment profile in Table XVII would generate a surplus between 109 and 380 dollars per consumer a year[22]. Assuming the elasticity of -0.3 the social surplus ranges from about 2,192 to 5,420 million a year depending on the year. For the elasticity of -0.5 it ranges from about 3,539 to 7,617 million.

Table XVIII presents the proposed investments after 2005. Comparison of the results in Table XVII, suggests that some underinvestment may be occurring in the ERCOT system; also, a tendency to invest in coal and other baseload units as the investment profile in Table XVII would imply.

Figure 30 presents the demand curves for elasticity of -0.3 and the marginal cost curve in January of 2006 before and after the optimal investment is realized. The horizontal lines in Figure 30 represent the marginal cost in January of 2006 for the three technologies qualified to receive positive investments.

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[22] According to ERCOT annual report there are approximately 20 million consumers in the ERCOT market.

Table XVIII. Total capacity (in MW) of proposed and new units after 2005

Proposed

	2006	2007	2010	2011	2050	Total
Steam & Lignite (coal)	-	-	1,720	600	-	2,320
Steam & Coal	-	-	550	-	-	550
Wind	298	160	-	-	-	458
others	24	-	-	-	-	24
Total	**322**	**160**	**2,270**	**600**	**0**	**3,352**

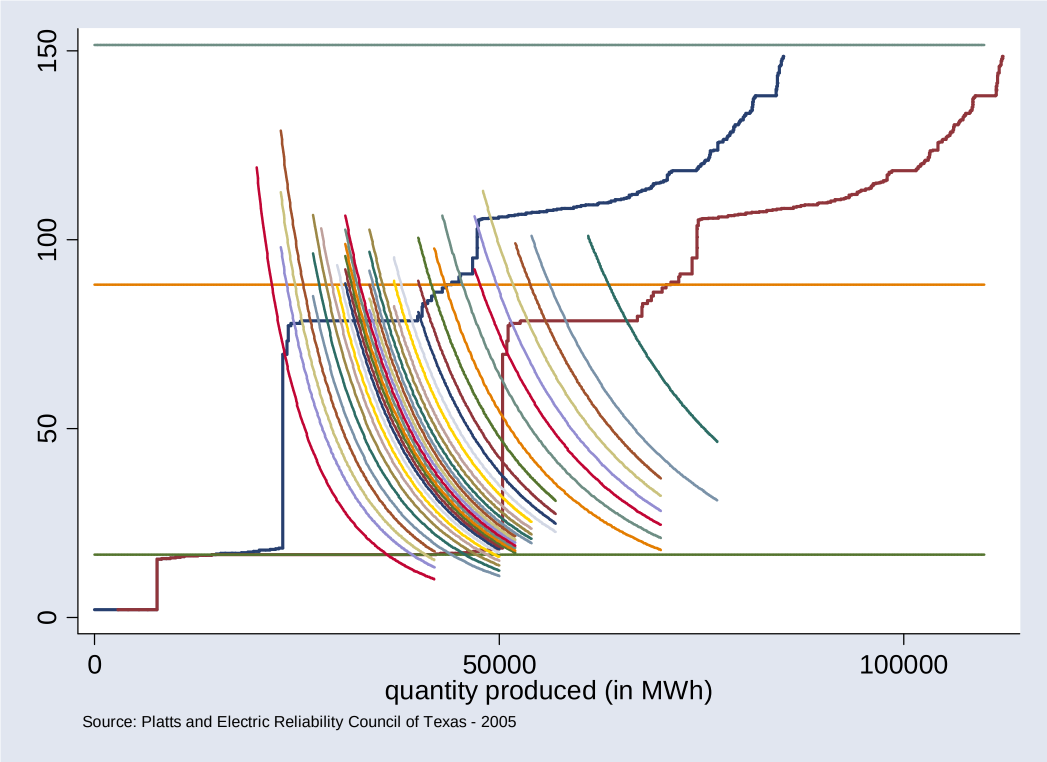
Early development

	2006	2007	2010	2011	2050	Total
Steam & Coal	-	-	750	-	800	1,550
Steam & PetCoke	-	-	-	-	300	300
Gas Turb & Natural Gas	100	-	-	-	-	100
others	-	-	-	-	20	20
Total	**100**	**0**	**750**	**0**	**1,120**	**1,970**

New units under construction

	2006	2007	2010	2011	2050	Total
Combined Cycle & Natural Gas	820	-	-	-	-	820
Steam & Natural Gas	50	-	-	-	-	50
others	-	2	-	-	-	2
Total	**870**	**2**	**0**	**0**	**0**	**872**

Source: PLATTS - 2005



Source: Platts and Electric Reliability Council of Texas - 2005

Fig. 30. System's marginal cost curve in January of 2006, system's marginal cost curve after investing the optimal amount and some estimated demand curves. The demand curves were estimated assuming elasticity of -0.3

F. Carbon emission market

According to The Wall Street Journal[23], "Power plants produce 39% of U.S. carbon-dioxide [a green house gas] emissions, and four-fifths of that amount comes from coal-fired plants. Texas is responsible for 10% of the nation's total, more than any other state".

Electricity generators cause a negative externality emitting carbon-dioxide. In a competitive market, the optimal outcome can be achieved by charging the Pigouvian Tax from generators. In equilibrium, the Pigouvian Tax is equal to the social cost of having an extra marginal amount of CO_2 in the atmosphere. Since there is no objective way to identify the social cost in this case, this section presents an exercise that attempts to provide a rough indicator of the sensibility of the results presented in Table XVII to the establishment of a carbon emission market.

The marginal cost of a gas or coal unit, already installed or considered for investment, is calculated according to the equation

$$\begin{gathered}\text{MgC} = \text{original MgC} + \\ \text{[carbon emission factor (in tonne/Btu)] x [heat rate (in Btu/MW)]} \\ \text{x [carbon allowance's price (in dollar/tonne)].}\end{gathered}$$

Data for 2004's carbon emission factors are provided in the Energy Information Administration webpage[24]. For natural gas, the factor is 116.97 pounds of CO_2 per million btus. The relevant factors for coal units are 205.45, 212.58 and, 215.53 pounds of CO_2 per million btus for bituminous, sub-bituminous and lignite, respectively.

As an exercise, I assume two possible price levels for carbon allowances. The

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[23] "As Emission Restrictions Loom, Texas Utility Bets Big on Coal" by Rebecca Smith; July, 21^{st} of 2006.

[24] See http://www.eia.doe.gov/cneaf/electricity/epa/epata1p3.html. Released in November, 2005.

first price level is set equal to the average future price of carbon allowances in the EU market from 2006 until 2011. That is, 18.29 €/tonne of CO_2[25] or 23.44 US$/tonne of CO_2[26]. The second price level is equal to the first price level multiplied by two, i.e., 46.88 US$/tonne of CO_2.

Tables XIX and XX present the investment profiles that maximizes the social surplus in each corresponding year assuming the carbon allowances price of 23.44 and 46.88 US$/tonne of CO_2, respectively. Obviously, it is not optimal to invest in combined cycle or combustion turbine units. The results presented in the previous section, Table XVII, imply that it is not optimal to invest in gas units even if investment in coal units is not possible. An upward shift of the marginal cost curve and increase in the marginal cost of gas units can only reduce the social surplus associated to an investment in those units. Therefore, the optimal investment in gas units can not be positive after the introduction of carbon emission costs.

The investment in coal units that maximizes social surplus drops significantly with the introduction of carbon emission costs. The corresponding social surpluses drop even more.

For any demand curve, the social surplus of an extra coal unit is given by the area between the marginal cost curves before and after adding the extra unit to the system that lies below the demand curve. Consideration of carbon emission costs causes an upward shift of the marginal cost curve. First, imagine a parallel upward

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[25] In September, 6th of 2006, the annual future prices posted on the energy exchange website http://www.eex.de/index.php were 16.59, 17.08, 18.13, 18.63, 19.32 and, 19.97 €/tonne of CO_2 for all years from 2006 until 2011. Those prices are similar to the ones available in a leading platform for carbon emissions trading, http://www.ecxeurope.com. Since the future volumes are not available, I calculated a simple mean for all years.

[26] The Wall Street Journal exchange rate in the edition of September, 6th of 2006 was 1.282 US$/€.

Table XIX. Investment profile that maximizes social surplus in the corresponding year and respective social surplus assuming the price of carbon allowance of 23.44 US$/tonne of CO_2

year	coal (in MWh)	combined cycle (in MWh)	combustion turbine (in MWh)	social surplus per consumer in the corresponding year (in dollars)	social surplus in the corresponding year (in thousands of dollars)
Elasticity = -0.025					
2006	12,147	0	0	77.66	1,553,106
2007	12,797	0	0	77.21	1,544,113
2008	11,651	0	0	52.44	1,048,725
2009	10,819	0	0	32.53	650,676
2010	7,296	0	0	8.45	168,967
2011	0	0	0	0.00	0
Elasticity = -0.15					
2006	14,521	0	0	97.31	1,946,169
2007	15,251	0	0	96.11	1,922,221
2008	14,190	0	0	67.15	1,342,932
2009	13,405	0	0	43.47	869,465
2010	9,860	0	0	13.75	275,014
2011	1,383	0	0	0.16	3,220
Elasticity = -0.3					
2006	17,803	0	0	122.12	2,442,456
2007	18,594	0	0	119.85	2,396,936
2008	17,567	0	0	85.80	1,716,019
2009	16,758	0	0	57.81	1,156,113
2010	13,173	0	0	21.56	431,224
2011	4,891	0	0	2.08	41,653
Elasticity = -0.5					
2006	22,736	0	0	156.99	3,139,807
2007	23,673	0	0	153.30	3,065,927
2008	22,530	0	0	112.60	2,251,927
2009	21,669	0	0	79.42	1,588,400
2010	17,993	0	0	35.25	705,098
2011	9,895	0	0	9.24	184,846

Table XX. Investment profile that maximizes social surplus in the corresponding year and respective social surplus assuming the price of carbon allowance of 46.88 US$/tonne of CO_2

year	coal (in MWh)	combined cycle (in MWh)	combustion turbine (in MWh)	social surplus per consumer in the corresponding year (in dollars)	social surplus in the corresponding year (in thousands of dollars)
Elasticity = -0.025					
2006	9,149	0	0	30.33	606,678
2007	9,491	0	0	26.28	525,632
2008	5,913	0	0	5.55	110,967
2009	0	0	0	0.00	0
2010	0	0	0	0.00	0
2011	0	0	0	0.00	0
Elasticity = -0.15					
2006	10,022	0	0	33.22	664,429
2007	10,329	0	0	28.50	570,088
2008	6,534	0	0	6.46	129,105
2009	0	0	0	0.00	0
2010	0	0	0	0.00	0
2011	0	0	0	0.00	0
Elasticity = -0.3					
2006	11,130	0	0	36.82	736,382
2007	11,483	0	0	31.26	625,126
2008	7,345	0	0	7.55	151,011
2009	0	0	0	0.00	0
2010	0	0	0	0.00	0
2011	0	0	0	0.00	0
Elasticity = -0.5					
2006	12,744	0	0	41.83	836,517
2007	13,115	0	0	35.16	703,110
2008	8,525	0	0	9.06	181,172
2009	0	0	0	0.00	0
2010	0	0	0	0.00	0
2011	0	0	0	0.00	0

shift. Considering or not carbon emission costs, the area between the marginal cost curves before and after the addition of one coal unit to the system is the same but, for each demand curve, the area between the marginal cost curves that lies below the demand curve is smaller for the upward-shifted marginal cost curve. Therefore, introduction of carbon emission costs reduces the social surplus of an extra coal unit and, consequently, decreased the investment that maximizes social surplus. The impact is even greater because the upward shift in the marginal cost curve is not parallel. The marginal cost of coal units increased more than the marginal cost of gas units after the introduction of carbon emission costs.

In average, over the years, the low segment of the marginal cost curve is shifting upward because of the increase in coal's price and; the higher segments are shifting downward because of the decrease in gas's price. Everything else kept constant, this continuous increase in the low segment and decrease of the high segments of the marginal cost curve will reduce the social surplus associated to extra coal units. Consequently, the investment that maximizes the social surplus decreases over the years.

The factors that contributed to make the estimated investment slightly smaller for later years in Table XVII, have their impact magnified for higher carbon allowances costs, causing a substantial dispersion between the investment that maximizes the social surplus over the years considered. In particular, for the higher price of carbon allowances, 46.88 US$/tonne of CO_2, the investment that maximizes social surplus drops to zero in the last three years considered in the estimations. This result is not surprising. Note from Figure 30 that for most demand curves, the social surplus of adding the first extra coal unit to the system is mainly determined by the first tall rectangle between the marginal cost curves before and after adding the extra unit. Besides, the social surplus of adding the first coal unit to the system is extremely similar to the social surplus of adding the second coal unit to the system. In fact, the social surplus of extra coal units does not change much until the system's marginal cost curve start crossing the demand curves around the point in which they are highly concentrated. At this point, for an increasing number of demand curves, the first tall rectangle between the two marginal cost curves, before and after the addition of one extra coal unit, no longer lies below the demand curve. Until the system reaches the point in which the demand curves are highly concentrated, the social surplus associated to the first extra coal units is similar to the social surplus of the second extra unit and, so on. Therefore, if it is welfare enhancing to invest in one extra coal unit, it is welfare enhancing to invest in several units. That is also the reason of the sudden drop in the investment that maximizes the social surplus from 2010 to 2011 for the lower price of carbon allowances and elasticity -0.025.

For the carbon allowance price of 23.44 US\$/tonne of CO_2, the investment in coal units that generate positive social surplus for all years considered, in MW, are zero, 1,383, 4,891 and 9,895 for the elasticities 0.025, 0.15, 0.3 and 0.5, respectively. For the carbon allowance price of 46.88 US\$/tonne of CO_2, no positive investment in coal units generates positive social surplus for all years considered is zero.

Consideration of carbon emission costs introduced a greater variability of the results to changes in the parameters of the model. If the parameters experience changes of the same magnitude for the years following 2011, the investment profile that maximizes social surplus in subsequent years can be very different from the investment profile obtained for the years from 2006 until 2011. The sensibility of the results to changes in the parameters of the model, compromise attempts to predict the optimal investment based on the results from 2006 until 2011. Nevertheless, one can argue that the increase in the expected price of coal and the stabilization of the expected price of gas after 2011 (see Figure 21) will contribute to reduce the investment that maximizes social surplus for a few years following 2011.

G. Conclusion

The paper presents investment profiles in electricity generation that provides positive social surplus for every year from 2006 to 2011. During the covered period it is not optimal to invest in combined cycle or combustion turbine units. The investment in coal units that generate positive social surplus for all years considered ranges from about 12 to 37 thousand MW depending on the assumption about demand elasticity. The associated efficiency gains lie between, approximately, 43 and 177 dollars per consumer a year. Once the social costs associated to carbon emission are considered, the investment in coal units that maximizes social surplus drops substantially. For the carbon allowance price of two times the level in Europe, the optimal investment in coal units is zero. Consideration of carbon emission costs does not transform cycle or combustion turbine technologies in attractive technologies for investment.

One limitation of the paper is that the starting up cost, the cost that each unit faces when it is turned on, is assumed to be zero. Another limitation is that demand and costs are assumed to be known with certainly.

Only three technologies qualified to receive positive investment are considered. According to Borenstein [8], they represent three technology types: baseload, mid-merit, and peak. Under this interpretation, the results presented represent the estimated investments that generates positive social surplus for three classes of technology. The most informative estimation would specify the optimal investment range for all technologies qualified to receive positive investment. However, such detailed result demands an estimation of the annual capital cost for all technologies qualified to receive positive investment.

Significant investment in coal units would most likely change the future prices of fuels and, consequently, the optimal investment. Instead of modeling price of fuels as a function of the investment, it was assumed that the future prices of fuel would remain constant for all investment levels.

The cost of achieving the optimal outcome is assumed to be zero. It is possible that the benefit of implementing the optimal investment does not pay its cost. A perfectly competitive market implies charging the Real Time Price (RTP) from all consumers. The society cost of adopting the RTP includes the cost of measuring consumption in short time intervals, the consumer's costs of constantly checking prices and, the disutility generated by the introduction of uncertainty about future prices. If this cost is significant, maximization of the social welfare may point to some variation of the time-of-use (TOU)[27]approach that, although, does not generate the efficient investment, is cheaper to implement.

An interesting topic for future work would be to measure the performance in terms of efficiency of the alternative TOU rates. To estimate the magnitude of the gap between expected and optimal investment under alternatives TOU rates; and the welfare loss implied by this gap. In other words, what share of the social welfare that the optimal investment would yield can be captured by adopting specific TOU rates. If RTP is an unattainable solution or costly to implement, maximization of the social welfare in the long run demands knowledge about the relative performance of alternative price approaches in terms of optimal investment.

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[27] The TOU rates consist of the pre-established rates that differ depending on the season of the year, day of the week, and time of the day. There are many possible rates for different TOU periods. Even imposing revenue neutrality, one is still left with several rates. Borenstein [9] suggests some TOU rates that satisfy some extra conditions like no cross-subsidies among consumers.

CHAPTER V

CONCLUSION

This dissertation contains three essays. The first and second essays extend the research on intergenerational mobility in Brazil to three generations within the same family.

Using the three-generations data set to estimate the main equation yielded by a modified version of Becker-Tomes model, I find that family background explains 34.9% of the variation in earnings among young males living with their parents. If it were possible to eliminate the differences in investment in the children's human capital, the variation in earnings would fall by no more than 21.1%. Additionally, if there were no differences in endowments among children, the variation in earnings would fall by no less than 26%.

I examine the evolution of the intergenerational elasticity across generations. I find that the intergenerational elasticity between grandfather and grandsons is about the same as the elasticity between father and grandsons. This result may be driven by the high intergenerational elasticity between grandfather and fathers (0.89) and by the skipping generation effect. Estimation results suggest that grandfathers may have a direct impact on their grandsons' earnings through a channel other than the fathers. In other words, the grandfathers with high earnings have a direct positive impact on their grandsons' earnings.

This study extends the research on intergenerational mobility in Brazil by examining the relationship between fertility and mobility. Controlling for fathers' percentile in the earnings distribution, each additional sibling has a negative impact on the sons' percentile. Remains for future work to investigate the sources of this negative impact and, how the magnitude of the impact relates to the fathers' percentile and number of siblings.

This study extends the research on intergenerational mobility in Brazil by examining the implications of marriage on mobility. The estimated elasticity in earnings between fathers and sons is about the same as the elasticity between fathers-in-law and sons-in-law. Remains for future work to determine if these results express that individuals marry in the same economic class or if father-in-law is an important determinant of the sons-in-law's earnings.

The third essay presents a method to estimate the optimal investment in each technology available to generate electricity. I apply this method to estimate an indicator of the optimal investment in electricity generation in Texas and associated efficiency gains. The estimation considers the expected entry and exit of generation plants, future fuel prices, different demand elasticities, expected demand and carbon allowance prices. The method and the estimations assume no uncertainty. Remains for future work to include uncertainty about demand and costs.

REFERENCES

[1] R. P. Barros, R. Henriques, R. Mendoną, A Estabilidade inaceitável: desigualdade e pobreza no Brasil, Discussion paper 800, IPEA, Rio de Janeiro, 2001.

[2] G. S. Becker, N. Tomes, An equilibrium theory of the distribution of income and intergenerational mobility, Journal of Political Economy, 87 (1979) 1153-1189.

[3] G. S. Becker, N. Tomes, Human capital and the rise and fall of families, in: Human capital: a theoretical and empirical analysis with special reference to education, third ed., University of Chicago Press, Chicago, 1993.

[4] J. R. Behrman, A. Gaviria, M. Szekely, Intergenerational mobility in Latin America, Inter-American Development Bank, working paper 452, Washington, 2001.

[5] Y. Ben-Porath, The production of human capital and the life cycle of earnings, The Journal of Political Economy, 75 (1967) 352-365.

[6] T. J. Biblarz, V. L. Bengtson, A. Bucur, Social mobility across three generations, Journal of Marriage and the Family, 58 (1996) 188-200.

[7] S. Borenstein, J. B. Bushnell, F. A. Wolak, Measuring market inefficiencies in California's restructed wholesale electricity market, American Economic Review, 92 (2002) 1376-1405.

[8] S. Borenstein, The long-run efficiency of real-time electricity pricing, Energy Journal, 26 (2005) 93-117.

[9] S. Borenstein, Wealth transfers from implementing real-time retail electricity pricing, CSEM Working Paper CSEMWP-147r, University of California Energy Institute, University of California, Berkeley, 2005.

[10] S. D. Braithwait, M. O'Sheasy, RTP customer demand response – empirical evidence on how much can you expect, in: A. Faruqui, K. Eakin (Eds.), Electricity Pricing in Transition, Kluwer Academic Plublishers, Boston, 2002.

[11] J. Bushnell, E. T. Mansur, C. Saravia, Vertical arrangements, market structure, and competition: an analysis of restructured U.S. electricity markets, American Economic Review, 98 (2008) 237-266.

[12] M. Corak, Do poor children become poor adults? Lesson from a cross country comparison of general earnings mobility, IZA Discussion Paper No.1993, Institute for the Study of Labor, Bonn, 2006.

[13] C. E. Dunn, The intergenerational transmission of lifetime earnings: evidence from Brazil, The B.E. Journal of Economic Analysis & Policy, 7 (2007) 1-40.

[14] ERCOT, Report on existing and potential electric system constraints and needs, Electric Reliability Council of Texas, October 2005.

[15] J. Erola, P. Moisio, Social mobility over three generations in Finland, European Sociological Review, 23 (2007) 169-183.

[16] M. K. Fabrizio, N. L. Rose, C. Wolfram, Do Markets reduce cost? Assessing the impact of regulatory restructuring on U.S. electric generation efficiency, American Economic Review, 97 (2007) 1250-1277.

[17] S. G. Ferreira, F. A. Veloso, Mobilidade intergeneracional de educação no Brasil, Pesquisa e Planejamento Econômico, 33 (2003) 481-513.

[18] S. G. Ferreira, F. A. Veloso, Intergenerational mobility of wages in Brazil, Brazilian Review of Econometrics. 26 (2006) 181-211.

[19] N. D. Grawe, Lifecycle bias in estimates of intergenerational earnings persistence, Labour Economics, 13 (2006) 551-570.

[20] W. H. Greene, Econometric Analysis, fifth ed., Upper Saddle River, Prentice Hall, New Jersey, 2003.

[21] S. Haider, G. Solon, Life-cycle variation in the association between current and lifetime earnings, American Economic Review, 96 (2006) 1308-1320.

[22] J. W. Hardin, The robust variance estimator for two-stage models, Stata Journal, 2 (2002) 253-266.

[23] J. J. Heckman, Sample selection bias as a specification error, Econometrica, 47 (1979) 153-161.

[24] A. R. Hole, Calculating Murphy-Topel variance estimates in Stata: a simplified procedure, National Primary Care Research and Development Centre, Centre for Health Economics, University of York, York, 2006.

[25] A. Hortacsu, S. Puller, Understanding strategic bidding in multi-Unit auctions: a case study of the Texas electricity spot market, RAND Journal of Economics, 39 (2008) 86-114.

[26] J. Ishii, Technology adoption and regulatory regimes: gas turbine electricity generators from 1980 to 2001, CSEM Working Paper CSEMWP-128, University of California Energy Institute, University of California, Berkeley, 2004.

[27] P. Joskow, J. Tirole, Reliability and competitive electricity market, Rand Journal of Economics, 38 (2007) 60-84.

[28] B. Jovanovic, Job Matching and the Theory of Turnover. The Journal of Political Economy, 87 (1979) 972-990.

[29] A. Mayer, Intergenerational relationships over the lifecycle and the determination of wages, Journal of Applied Economics, forthcoming.

[30] K. M. Murphy, Welch, Finis, Empirical age-earnings profiles, Journal of Labor Economics, 8 (1990) 202-229.

[31] R. H. Patrick, F. A. Wolak, Estimating the customer-level demand for electricity under real-time market prices, NBER working paper 8213, National Bureau of Economic Research, Cambridge, 2001.

[32] H. E. Peters, Patterns of intergenerational mobility in income and earnings, The Review of Economics and Statistics, 74 (1992) 456-466.

[33] S. Puller, Pricing and firm conduct in California's deregulated electricity market, Review of Economics and Statistics, 89 (2007) 75-87.

[34] G. Solon, Intergenerational mobility in the labor market, in: O. Ashenfelter, D. Card (Eds.), Handbook of Labor Economics, Princeton University, Princeton, 1999.

[35] G. Solon, Cross-Country Differences in Intergenerational Earnings Mobility, The Journal of Economic Perspectives, 16 (2002) 59-66.

[36] J. R. Warren, R. M. Hauser, Social stratification across three generations: new evidence from the Wisconsin Longitudinal Study, American Sociological Review, 62 (1997) 561-572.

[37] C. D. Wolfram, Measuring duopoly power in the British electricity spot market, American Economic Review, 89 (1999) 805-826.

APPENDIX A

MATHEMATICAL DERIVATIONS FROM CHAPTER II

The child at time t=0 will be a parent at time t=1 and will solve the same maximization problem, with the proper adjustments for time index. At t=1, the optimal choice of I_2 will depend on I_1. Let $I_2^*(I_1)$ be the parent's best response function at t=1. For every investment made in the parent when he/she was a child at t=0, $I_2^*(I_1)$ gives the optimal investment the parent should make in the child at t=1. Given that I_2 is a function of I_1, a more convenient way of writing the equation 2.8 would be

$$\max_{\{I_1\}}\{(1-\beta)\ln((1+r)I_0+A_0-I_1)+\beta\ln((1+r)I_1+a_1-I_2^{*e_0}(I_1))\} \tag{A.1}$$

At t=0, parent solves the maximization problem for t=1

$$\max_{\{I_2\}}\{(1-\beta)\ln((1+r)I_1+a_1-I_2)+\beta\ln((1+r)I_2+a_2^{e_0}-I_3^*(I_2))\} \tag{A.2}$$

At t=0, parent solves the maximization problem for t=2

$$\max_{\{I_3\}}\{(1-\beta)\ln((1+r)I_2+a_2^{e_0}-I_3)+\beta\ln((1+r)I_3+a_3^{e_0}-I_4^*(I_3))\} \tag{A.3}$$

In general, at t=0 parent will solve the maximization problem for any time $t \in \mathbb{N}$,

$$\max_{\{I_{t+2}\}}\{(1-\beta)\ln((1+r)I_{t+1}+a_{t+1}^{e_0}-I_{t+2})+\beta\ln((1+r)I_{t+2}+a_{t+2}^{e_0}-I_{t+3}^*(I_{t+2}))\} \tag{A.4}$$

The first order condition of this problem is

$$\frac{(1-\beta)}{(1+r)I_{t+1}+a_{t+1}^{e_0}-I_{t+2}}=\frac{\beta(1+r-I_{t+3}^{*'}(I_{t+2}))}{(1+r)I_{t+2}+a_{t+2}^{e_0}-I_{t+3}^*(I_{t+2})}$$

For every $t \in \mathbb{N}$, the same maximization problem will be solved. So, for all t, the solution should be the same. Consider the following guess for the solution of the above equation, $I_{j+2} = bI_{j+1} + c$ for all $j \in \mathbb{N}$. In particular, $I_{t+2} = bI_{t+1} + c$ and $I_{t+3} = bI_{t+2} + c$. Substitute the former two equations in the above equation to obtain

$$\frac{(1-\beta)}{(1+r)I_{t+1} + a^{e_0}_{t+1} - bI_{t+1} - c} = \frac{\beta(1+r-b)}{(1+r)(bI_{t+1}+c) + a^{e_0}_{t+2} - bI_{t+2} - c}$$

Solve for I_{t+2} as a function of I_{t+1} to find

$$\begin{aligned} I_{t+2} \quad &= \quad \frac{[(1-\beta)(1+r)b - \beta(1+r-b)^2]}{(1-\beta)b} I_{t+1} + \\ &\quad \frac{(1-\beta)rc + (1-\beta)a^{e_0}_{t+2} - \beta(1+r-b)(a^{e_0}_{t+1} - c)}{(1-\beta)b} \end{aligned}$$

According to the guess, the coefficient on I_{t+1} should be equal to b and the second term on the right hand side should be equal to c,

$$b = \frac{[(1-\beta)(1+r)b - \beta(1+r-b)^2]}{(1-\beta)b}$$

$$c = \frac{(1-\beta)rc + (1-\beta)a^{e_0}_{t+2} - \beta(1+r-b)(a^{e_0}_{t+1} - c)}{(1-\beta)b}$$

Solve for b and c, to find two set of solutions,

$$\begin{array}{lll} b = 1+r & \text{and} & c = a^{e_0}_{t+2} \\ b = \beta(1+\text{r}) & \text{and} & c = \frac{\beta(1+r)}{r} a^{e_0}_{t+1} - \frac{1}{r} a^{e_0}_{t+2}. \end{array}$$

So, the guess is correct.

The first set of solutions is not an interesting case because it would imply that average endowed parents with average market luck and average endowed children invest all their earnings in their children.

$I_{t+2} = bI_{t+1} + c$ for the second set of solution is

$$I_{t+2} = \beta(1+r)I_{t+1} + \frac{\beta(1+r)}{r} a^{e_0}_{t+1} - \frac{1}{r} a^{e_0}_{t+2}$$

For t=0,

$$I_2 = \beta(1+r)I_1 + \frac{\beta(1+r)}{r}a_1 - \frac{1}{r}a_2^{e_0}$$

Substitute $a_2^{e_0}$ by $\delta a_1 + \theta a_0$ in the above equation to find

$$I_2 = \beta(1+r)I_1 - \frac{\delta - \beta(1+r)}{r}a_1 - \frac{\theta}{r}a_0$$

At t=0, parent maximizes equation (A.1). Substitute the above equation in equation (A.1) to obtain

$$\max_{\{I_1\}}\{(1-\beta)\ln((1+r)I_0 + A_0 - I_1) + \beta\ln((1+r)(1-\beta)I_1 + \frac{\delta + r - \beta(1+r)}{r}a_1) + \frac{\theta}{r}a_0\}$$

The first order condition of this problem is

$$\frac{(1-\beta)}{(1+r)I_0 + A_0 - I_1} = \frac{\beta(1+r)(1-\beta)}{(1+r)(1-\beta)I_1 + \frac{\delta+r-\beta(1+r)}{r}a_1 + \frac{\theta}{r}a_0}$$

Solve for I_1 to find

$$I_1 = \beta((1+r)I_0 + A_0) + \frac{\beta(1+r) - \delta - r}{r(1+r)}a_1 + \frac{\theta}{r(1+r)}a_0$$

Equivalently,

$$I_1 = \beta y_0 + \frac{\beta(1+r) - \delta - r}{r(1+r)}a_1 + \frac{\theta}{r(1+r)}a_0$$

Table XXI. Estimation of equation (iv) allowing for non-linearities

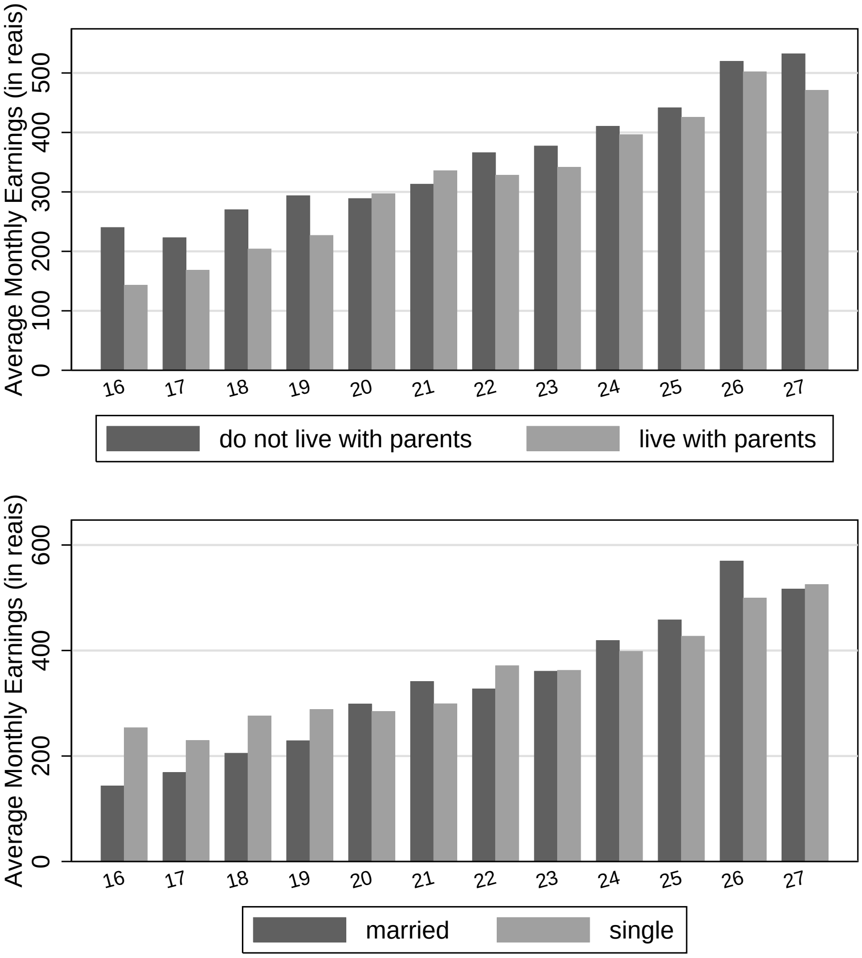
(a) OLS
(b) Heckman Two Step Estimation
(c) Heckman Maximum Likelihood Estimation

	(a)	(b)	(c)
Dependent Variable: Grandson's Earnings			
Grandfather's Earnings	1.802***	1.834***	1.836***
	(0.254)	(0.191)	(0.255)
Grandfather's Earnings Squared	–0.137***	–0.139***	–0.140***
	(0.021)	(0.016)	(0.021)
Father's Earnings	0.235***	0.235***	0.235***
	(0.015)	(0.011)	(0.015)
Son's Years of Education	0.059***	0.060***	0.060***
	(0.003)	(0.003)	(0.003)
Father's Years of Education	–0.007**	–0.006**	–0.006*
	(0.003)	(0.003)	(0.003)
Constant	–0.919	–1.047*	–1.051
	(0.762)	(0.574)	(0.765)
Older Cohort	0.313***	0.273***	0.274***
	(0.019)	(0.020)	(0.020)
Selection Equation			
Married		–2.570***	–2.553***
		(0.042)	(0.035)
Age		–0.157***	–0.156***
		(0.007)	(0.004)
Enrolled in School		0.144***	0.177***
		(0.054)	(0.031)
Father's Earnings (Imputed)		0.190***	0.175***
		(0.027)	(0.018)
Constant		3.474***	3.527***
		(0.184)	(0.111)
R^2	0.395		
LR Test of Indep. Equations			21.667
N. of Observations Uncensored		5,125	5,125
N. of Observations	5,125	10,176	10,176

Source: PNAD.

Note: Standard errors in parentheses. Cluster: family (except for the two step regression). Omitted age: 16-21 years old.

* significant at 10%, ** significant at 5%, *** significant at 1%.



Source : 1996 PNAD

Fig. 31. Average earnings of sons by living arrangements, marital status and age

APPENDIX B

APPENDIX FROM CHAPTER III

Table XXII. Racial distribution of fathers and sons by year (percentages)

1976			
	Father's Race		
Son's Race	White or Asian	Black or Indian	Mixed
White or Asian	87.95	1.35	10.70
Black or Indian	14.17	73.68	12.14
Mixed	17.71	7.70	74.59
Number of Observations: 3,628			
1990			
	Father's Race		
Son's Race	White or Asian	Black or Indian	Mixed
White or Asian	88.49	0.56	10.95
Black or Indian	4.27	85.85	9.88
Mixed	12.92	3.49	83.58
Number of Observations: 13,017			
1992			
	Father's Race		
Son's Race	White or Asian	Black or Indian	Mixed
White or Asian	86.01	0.68	13.31
Black or Indian	5.53	81.90	12.57
Mixed	14.07	4.61	81.32
Number of Observations: 13,195			

Table XXII. Continued

1993			
	Father's Race		
Son's Race	White or Asian	Black or Indian	Mixed
White or Asian	85.82	0.70	13.48
Black or Indian	4.74	82.98	12.28
Mixed	14.73	4.39	80.89
Number of Observations: 13,707			
1995			
	Father's Race		
Son's Race	White or Asian	Black or Indian	Mixed
White or Asian	87.21	0.48	12.31
Black or Indian	4.06	84.63	11.31
Mixed	14.41	3.98	81.61
Number of Observations: 14,492			
1996			
	Father's Race		
Son's Race	White or Asian	Black or Indian	Mixed
White or Asian	87.06	1.06	11.88
Black or Indian	6.42	81.53	12.05
Mixed	14.66	5.25	80.10
Number of Observations: 14,434			

Source: PNAD.

Note: Only sons aged 13 to 17 are considered in order to calculate the percentages.

Other checks

Adding noise to the fathers' earnings

Because the fathers' earnings are estimated, the variance of the distribution of the fathers' earnings is probably lower for the estimated earnings than for the true earnings. The greater dispersion of the distribution of the sons' earnings in September of 1996 compared to the estimated fathers' earnings may cause an upward bias in the estimate of the intergenerational elasticity. To address the problem, I now add noise to the estimated fathers' earnings. First, I collect the error terms of males in the same experience range of the fathers in the first step regression. Second, I separate the error terms in groups according to the male's years of schooling. Third, for each group, I build a new sample randomly selecting error terms with replacement from the original sample. Last, I allocate those error terms to the fathers according to the fathers' years of schooling.

The estimate of the intergenerational elasticity is presented in Table XXIV. There are some main differences between the results in Tables XI and XXIV. First, the estimate of γ in Table XXIV, 0.429, is much lower than in Table XI, 0.847. It is also lower across cohorts, race, region, and in rural and urban areas. The estimate of γ is now lower if the fathers' earnings are below the median, significantly lower for blacks and individuals of mixed race than other race groups and significantly lower in the south.

Dealing with zero earnings

In all estimations, I drop from the data the sons with zero earnings in September of 1996 because zero can not be a proxy for their lifetime earnings. Similarly, I assume the father was temporarily unemployment if he was not working at the time his son was aged 15. Therefore, I do not consider the father's employment status when

Table XXIII. State of birth versus state of residence for males aged 13 to 17 in 1976 (in percentages)

	State Where Is Living at The Age of 15																								
State Where Was Born	RO	AC	AM	RR	PA	AP	MA	PI	CE	RN	PB	PE	AL	SE	BA	MG	ES	RJ	SP	PR	SC	RS	MT	GO	DF
Rondônia (RO)	92.79	2.27	4.55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.39
Acre (AC)	3.48	88.65	5.22	0	1.76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.88
Amazonas (AM)	0.36	2.14	89.85	0	3.54	0	0	0	0	0	0	0	0	0	0	0	0	3.81	0	0	0	0	0	0	0.3
Roraima (RR)	0	0	21.78	66.28	0	0	0	0	0	0	0	0	0	0	0	0	0	9.23	0	0	0	0	0	0	2.71
Pará (PA)	0	0	0.79	0	97.83	0.26	0	0	0	0	0	0	0	0	0	0	0	0.46	0	0	0	0	0	0.53	0.13
Amapá (AP)	0	0	0	0	7.78	92.22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maranhão (MA)	0	0	0	0	0.23	0	95.28	1	0.43	0	0	0.29	0	0	0.29	0.22	0	0.3	1.13	0	0	0	0.06	0.17	0.6
Piauí (PI)	0	0	0	0	1.02	0	4.82	87.17	1.7	0	0	0.86	0	0	0	0.42	0	0	0.63	0	0	0	0	0.79	2.6
Ceará (CE)	0.23	0	0	0	0.3	0	1.05	0.38	92.78	0.19	0.28	0.66	0	0.09	0.29	0.13	0	0.91	1.27	0.47	0	0	0.08	0.19	0.69
Rio Grande do Norte (RN)	0.2	0	0	0	0	0	0	0	0.5	93.95	0.26	0.75	0	0	0	0	0	1.78	1.42	0	0	0	0	0.2	0.94
Paraíba (PB)	0	0.29	0	0	0.07	0	0	0	1.27	0.91	83.93	2.92	0	0	0	0	0	6.2	2.83	0.18	0	0	0.07	0.15	1.18
Pernambuco (PE)	0	0	0	0	0	0	0	0	0.5	0.25	1.1	88.49	3.04	0	0.85	0	0	1.31	3.76	0.17	0	0	0.03	0.17	0.33
Alagoas (AL)	0	0	0	0	0	0	0	0	0.25	0.26	0.26	1.8	83.6	0.76	0.77	0	0	1.07	8.53	2.52	0	0	0.1	0	0.08
Sergipe (SE)	0	0	0	0	0	0	0	0	0	0	0	0	0	91.65	2.55	0.36	0	1.09	3.97	0	0	0	0.21	0	0.17
Bahia (BA)	0	0	0	0	0	0	0	0.11	0	0	0	0.68	0	0.06	91.02	1.2	0.04	0.95	4.03	0.95	0	0	0.07	0.36	0.53
Minas Gerais (MG)	0	0	0.04	0	0.06	0	0.18	0	0.03	0	0	0.04	0	0	0.53	87.7	0.8	1.68	5.34	1.43	0	0	0.33	0.89	0.95
Espírito Santo (ES)	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.17	81.6	9.09	1.87	4.37	0	0	0.34	0	0.32
Rio de Janeiro (RJ)	0	0	0	0	0.07	0	0.12	0	0	0.06	0.06	0.31	0.12	0.06	0.3	0.72	0.09	95.39	1.43	0.06	0.12	0.12	0	0	0.96
São Paulo (SP)	0.07	0	0	0	0.01	0	0	0	0.11	0	0.09	0.42	0.14	0.08	0.08	0.54	0	0.53	94.65	2.47	0	0.06	0.42	0.18	0.15
Paraná (PR)	0.06	0	0	0	0.06	0	0	0	0.07	0	0.07	0.07	0	0	0.29	0.52	0.05	0.2	10.5	86.17	0.36	0.21	1.13	0.14	0.08
Santa Catarina (SC)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.21	0	0	0.64	9.42	88.47	1.12	0.06	0	0.08
Rio Grande do Sul (RS)	0	0	0	0	0	0	0	0	0	0.06	0	0	0	0	0	0	0	0.13	0.75	4.48	2.12	92.28	0.07	0.02	0.09
Mato Grosso (MT)	0.19	0	0	0	0	0	0	0	0	0	0	0	0	0.48	0	1.37	0	2	6.32	0.95	0	0	87.28	0.96	0.44
Goiás (GO)	0.2	0	0	0	0.71	0	0.51	0	0.26	0	0	0	0	0	0	3.18	0	0	0.85	0	0	0	1.02	88.57	4.72
Brasília (DF)	0	0	0	0	0	0	0	0	1.85	0	0	0	0	0	0	0	0	3.95	2.07	1.84	0	1.84	0	8.19	80.27

Table XXIV. OLS estimation of the intergenerational elasticity in earnings after adding noise to the fathers' earnings

(A)

	(a)	(b)	(c)
Dependent Variable: Son's Earnings			
Fathers' Earnings with Noise	0.479***	0.292***	0.299***
	(0.006)	(0.020)	(0.008)
Father's Earnings*Son Aged 25-34		0.121***	
		(0.022)	
Father's Earnings*Son Aged 35-44		0.221***	
		(0.022)	
Father's Earnings*Son Aged 45-54		0.278***	
		(0.024)	
Father's Earnings*Son Aged 55-64		0.256***	
		(0.027)	
Father's Earnings*Father's Earn. Below the Median			–0.058***
			(0.014)
Fathers Earnings Below the Median			–0.320***
			(0.076)
Constant	2.544***	3.640***	3.912***
	(0.237)	(0.262)	(0.231)
N. of Observations	36,705	36,705	36,705

Source: PNAD.

Note: Standard errors in parentheses. Omitted cohort in column (b): sons aged between 16 and 24. In all Columns, coefficients of indicator variables for every age of the sons are not presented.

* significant at 10%, ** significant at 5%, *** significant at 1%.

Table XXIV. Continued

(B)

	(d)	(e)	(f)
Dependent Variable: Son's Earnings			
Fathers' Earnings with Noise	0.429***	0.405***	0.411***
	(0.007)	(0.009)	(0.006)
Father's Earnings*Black/Mixed	–0.048***		
	(0.011)		
Black/Mixed	–0.189***		
	(0.064)		
Father's Earnings*North		–0.072***	
		(0.024)	
Father's Earnings*Northeast		0.118***	
		(0.014)	
Father's Earnings*South		–0.042***	
		(0.015)	
Father's Earnings*Midwest		–0.031*	
		(0.018)	
Father's Earnings*Rural			–0.030**
			(0.015)
Rural			–0.574***
			(0.081)
Constant	3.129***	3.206***	3.081***
	(0.232)	(0.235)	(0.226)
N. of Observations	36,705	36,705	36,705

Source: PNAD.
Note: Standard errors in parentheses. Omitted region in column (b): Southeast. In all Columns, coefficients of indicator variables for every age of the sons are not presented. Coefficients of indicator variables for regions in column (b) are not presented.
* significant at 10%, ** significant at 5%, *** significant at 1%.

estimating a fathers' earnings. Now, I redo the estimations including the unemployed sons[1]. I replace their zero earnings by 1, so their log-earnings are equal to zero. To be consistent, I also replace the log-earnings of a father by zero if he was not working at the time the son was aged 15. Because the sample has many outliers–father and son pairs with one of them with positive earnings and the other with zero earnings–I use median estimation which is less sensitive to outliers than OLS estimation. The estimates are presented in Table XXV. There are three main differences between the results in Table 2 and A5. First, the estimate of γ, 0.4, is lower than the previous estimate, 0.847. The estimates of γ is also lower across cohorts, race, region, and in rural and urban areas. Second, the estimate of γ differs significantly across races. It is lower for blacks and individuals of mixed race than other race groups. Third, the estimate of γ is no longer significantly lower in the north than in the southeast.

Appropriate age interval of the sons

According to Haider and Solon (2005), the attenuation bias caused by using one-year-earnings as a proxy for lifetime earnings is small for sons in their early thirties and mid forties. Their result applies to males born in US between 1931 and 1933. I restrict the sample to males aged 31 to 45 to check if the estimates change. As shown in Table XXVI the results are similar except that the estimate of γ tends to be slightly higher for the restricted sample. Another difference is that the estimate of γ is significantly higher for blacks and individuals of mixed race than other race groups.

---

[1] A son is considered unemployed if he does not have an occupation, is not enrolled in school and was engaged in at least one activity related to job search in the reference week.

Table XXV. Estimation of the intergenerational elasticity in earnings including the observations with zero earnings of unemployed fathers and sons

(A)

(a) OLS
(b)-(f) Median Regressions

	(a)	(b)	(c)
Dependent Variable: Son's Earnings			
Father's Earnings	0.249***	0.402***	0.197***
	(0.01)	(0.00)	(0.02)
Father's Earnings*Son Aged 25-34			0.130***
			(0.02)
Father's Earnings*Son Aged 35-44			0.277***
			(0.02)
Father's Earnings*Son Aged 45-54			0.371***
			(0.02)
Father's Earnings*Son Aged 55-64			0.256***
			(0.03)
Adjusted R^2	0.068		
Pseudo R^2		0.056	0.059
N. of Observations	38,295	38,295	38,295

Source: PNAD.

Note: Standard errors in parenthesis. Omitted age: 16-24 years old. In all Columns, coefficients for constant and indicator variables for age are not presented.

* significant at 10%, ** significant at 5%, *** significant at 1%.

Table XXV. Continued

(B)

	(d)	(e)	(f)
Dependent Variable: Son's Earnings			
Father's Earnings	0.350***	0.240***	0.270***
	(0.01)	(0.01)	(0.01)
Father's Earnings*Black/Mixed	–0.183***		
	(0.01)		
Father's Earnings*North		–0.012	
		(0.02)	
Father's Earnings*Northest		0.235***	
		(0.01)	
Father's Earnings*South		0.016	
		(0.01)	
Father's Earnings*Midwest		–0.047***	
		(0.02)	
Father's Earnings*Rural			0.120***
			(0.02)
Pseudo R^2	0.087	0.087	0.105
N. of Observations	38,295	38,295	38,295

Source: PNAD.

Note: Standard errors in parenthesis. Omitted region: Southeast. In all columns, coefficients of indicator variables for every age of the sons are not presented. Coefficients of indicator variables for regions in column (e) are not presented. Coefficient of indicator variable for rural areas in column (f) is not presented.

* significant at 10%, ** significant at 5%, *** significant at 1%.

Table XXVI. OLS estimation of the intergenerational elasticity in earnings restricting the sample to sons aged 31 to 45

(A)

	(a)	(b)	(c)
Dependent Variable: Son's Earnings			
Father's Earnings	0.853***	0.806***	0.645***
	(0.024)	(0.023)	(0.018)
Father's Earnings*Son Aged 25-34		0.097***	
		(0.021)	
Father's Earnings*Father's Earn.			0.664***
Below the Median			(0.072)
Fathers Earnings Below the Median			–3.797***
			(0.390)
Constant	1.104***	1.378***	2.454***
	(0.156)	(0.152)	(0.117)
Adjusted R^2	0.287	0.288	0.302
N. of Observations	17,861	17,861	17,861

Source: PNAD.

Note: Murphy-Topel standard errors in parenthesis. Omitted cohort in column (b): sons aged between 31 and 37. Coefficients for indicator variables for every age of the sons are not presented.

* significant at 10%, ** significant at 5%, *** significant at 1%.

Table XXVI. Continued

(B)

	(d)	(e)	(f)
Dependent Variable: Son's Earnings			
Father's Earnings	0.756***	0.763***	0.726***
	(0.021)	(0.022)	(0.019)
Father's Earnings*Black/Mixed	0.063**		
	(0.026)		
Black/Mixed	–0.653***		
	(0.144)		
Father's Earnings*North		–0.113**	
		(0.045)	
Father's Earnings*Northeast		0.218***	
		(0.029)	
Father's Earnings*South		–0.046	
		(0.030)	
Father's Earnings*Midwest		–0.085**	
		(0.036)	
Father's Earnings*Rural			0.282***
			(0.038)
Rural			–2.197***
			(0.210)
Constant	1.793***	1.724***	1.958***
	(0.141)	(0.140)	(0.126)
Adjusted R^2	0.306	0.309	0.349
N. of Observations	17,861	17,861	17,861

Source: PNAD.

Note: Murphy-Topel standard errors in parenthesis. Omitted region in column (b): Southeast. In all columns, coefficients of indicator variables for every age of the sons are not presented. Coefficients of indicator variables for regions in column (b) are not presented.

* significant at 10%, ** significant at 5%, *** significant at 1%.

Fathers' earnings imputed ignoring differences in earnings across race and places of residence

I argue that ignoring the father's race and state of residence when imputing the father's earnings may cause a downward bias in the estimated intergenerational elasticity and lead to incorrect conclusions about the difference in mobility across races and regions. To avoid this problem, the first step regression includes controls for race and state when imputing the fathers' earnings. The disadvantage of controlling for race and state is that for many years the variable race is not available in the data set. For the sake of comparison, I now estimate the fathers' earnings without controls for race and place of residence. In this case, the used PNAD's are 1976-9, 1981-90, 1992-3, 1995 and 1996. The estimates of the intergenerational elasticity are presented in Table XXVII. The estimated intergenerational elasticity in earnings, about 0.78, is lower than the elasticity in Table XI, 0.847. It is also lower than in Table XI across cohorts, race, region, in rural and urban areas, for low-earnings and high-earnings groups. Another difference is that mobility among the sons living in the midwest is no longer significantly different from the southeast.

Dropping the sons living in rural areas in the north and the midwest

In the early years that the PNAD was conducted, the sample is not fully representative of the rural areas in the north and midwest. If the earnings in the areas not fully representative are lower than in the remaining areas, the estimated fathers' earnings in these regions may be upward biased. As shown in Table XXVIII, no systematic difference emerges after excluding the rural areas in the north and midwest from the sample. The estimates are similar except that the estimate of γ is significantly higher for blacks and individuals of mixed race than other race groups, for a 10% significance level.

Table XXVII. OLS estimation of the intergenerational elasticity in earnings – fathers' earnings imputed ignoring differences in earnings across race and state

(A)

	(a)	(b)	(c)
Dependent Variable: Son's Earnings			
Father's Earnings	0.777***	0.526***	0.633***
	(0.010)	(0.028)	(0.009)
Father's Earnings*Son Aged 25-34		0.162***	
		(0.030)	
Father's Earnings*Son Aged 35-44		0.290***	
		(0.031)	
Father's Earnings*Son Aged 45-54		0.377***	
		(0.033)	
Father's Earnings*Son Aged 55-64		0.359***	
		(0.039)	
Father's Earnings*Father's Earn. Below The Median			0.173*** (0.062)
Father's Earnings Below The Median			–1.191***
			(0.316)
Constant	1.092***	2.462***	2.021***
	(0.230)	(0.270)	(0.229)
Adjusted R^2	0.269	0.274	0.281
N. of Observations	36,705	36,705	36,705

Source: PNAD.

Note: Murphy-Topel standard errors in parenthesis. Omitted cohort in column (b): sons aged between 16 and 24. In all columns, coefficients for indicator variables for every age of the sons are not presented.

* significant at 10%, ** significant at 5%, *** significant at 1%.

Table XXVII. Continued

(B)

	(d)	(e)	(f)
Dependent Variable: Son's Earnings			
Father's Earnings	0.703***	0.679***	0.664***
	(0.010)	(0.012)	(0.009)
Father's Earnings*Black/Mixed	0.000		
	(0.015)		
Black/Mixed	–0.445***		
	(0.087)		
Father's Earnings*North		–0.103***	
		(0.030)	
Father's Earnings*Northeast		0.206***	
		(0.018)	
Father's Earnings*South		0.010	
		(0.019)	
Father's Earnings*Midwest		0.005	
		(0.023)	
Father's Earnings*Rural			0.101***
			(0.025)
Rural			–1.174***
			(0.135)
Constant	1.769***	1.878***	1.831***
	(0.224)	(0.226)	(0.220)
Adjusted R^2	0.311	0.324	0.326
N. of Observations	36,705	36,705	36,705

Source: PNAD.

Note: Murphy-Topel standard errors in parenthesis. Omitted region in column (b): Southeast. In all columns, coefficients of indicator variables for every age of the sons are not presented. Coefficients of indicator variables for regions in column (b) are not presented.

* significant at 10%, ** significant at 5%, *** significant at 1%.

Table XXVIII. OLS estimation of the intergenerational elasticity in earnings after dropping the rural residencies in the north and midwest

(A)

	(a)	(b)	(c)
Dependent Variable: Son's Earnings			
Father's Earnings	0.847***	0.595***	0.638***
	(0.019)	(0.027)	(0.013)
Father's Earnings*Son Aged 25-34		0.163***	
		(0.031)	
Father's Earnings*Son Aged 35-44		0.288***	
		(0.034)	
Father's Earnings*Son Aged 45-54		0.364***	
		(0.036)	
Father's Earnings*Son Aged 55-64		0.388***	
		(0.042)	
Father's Earnings*Father's Earn. Below the Median			0.603*** (0.050)
Fathers Earnings Below the Median			–3.473***
			(0.275)
Constant	0.655***	2.035***	2.022***
	(0.251)	(0.270)	(0.236)
Adjusted R^2	0.302	0.306	0.316
N. of Observations	35,540	35,540	35,540

Source: PNAD.

Note: Murphy-Topel standard errors in parenthesis. Omitted cohort in column (b): sons aged between 16 and 24. In all columns, coefficients for indicator variables for every age of the sons are not presented.

* significant at 10%, ** significant at 5%, *** significant at 1%.

Table XXVIII. Continued

(B)

	(d)	(e)	(f)
Dependent Variable: Son's Earnings			
Father's Earnings	0.756***	0.742***	0.727***
	(0.017)	(0.017)	(0.015)
Father's Earnings*Black/Mixed	0.034*		
	(0.018)		
Black/Mixed	–0.499***		
	(0.100)		
Father's Earnings*North		–0.162***	
		(0.032)	
Father's Earnings*Northeast		0.195***	
		(0.021)	
Father's Earnings*South		0.008	
		(0.021)	
Father's Earnings*Midwest		–0.145***	
		(0.027)	
Father's Earnings*Rural			0.196***
			(0.027)
Rural			–1.697***
			(0.149)
Constant	1.361***	1.375***	1.410***
	(0.243)	(0.242)	(0.233)
Adjusted R^2	0.320	0.327	0.356
N. of Observations	35,540	35,540	35,540

Source: PNAD.

Note: Murphy-Topel standard errors in parenthesis. Omitted region in column (b): Southeast. In all columns, coefficients of indicator variables for every age of the sons are not presented. Coefficients of indicator variables for regions in column (b) are not presented.

* significant at 10%, ** significant at 5%, *** significant at 1%.

Replication of Ferreira and Veloso (2006) results

The estimated intergenerational elasticity in earnings in this paper, 0.847, is higher than the one estimated by Ferreira and Veloso (2006), 0.58. The conclusions also differ with respect to mobility across race. They find that mobility is higher among blacks and individuals of mixed race than other race groups, while the results in this paper are inconclusive about differences in mobility across race. Depending on the estimation criteria, my estimate of γ for blacks and individuals of mixed races compared to other race groups is not significantly different (Tables XI and XXVII), significantly lower (Tables XXIV and XXV) or significantly higher (Table XXVI and XXVIII).

Differences in the sample and methods may explain the different results. First, Ferreira and Veloso restrict the sample to males between 25 and 65 years old. Second, they do not include race and state of residence in the specification used to impute fathers' earnings. Third, their sample consist of males working at least 40 hours a week and living in urban areas. Forth, their specification includes indicator variables for region, indicator variables for race, the son's age and the square of son's age. Fourth, they use sample weights in all regressions[2]. Last, they considered six occupational categories in the specification used to impute the fathers' earnings.

Table XXIX shows how the estimate of γ changes as I adopt the same criteria as Ferreira and Veloso. The first columns show the changes caused by each isolated difference in estimation criteria. Most of the difference in the estimates are explained by three differences in estimation criteria: (1) dropping from the sample the sons working between 15 and 39 hours a week or living in rural areas, (2) inclusion of indi-

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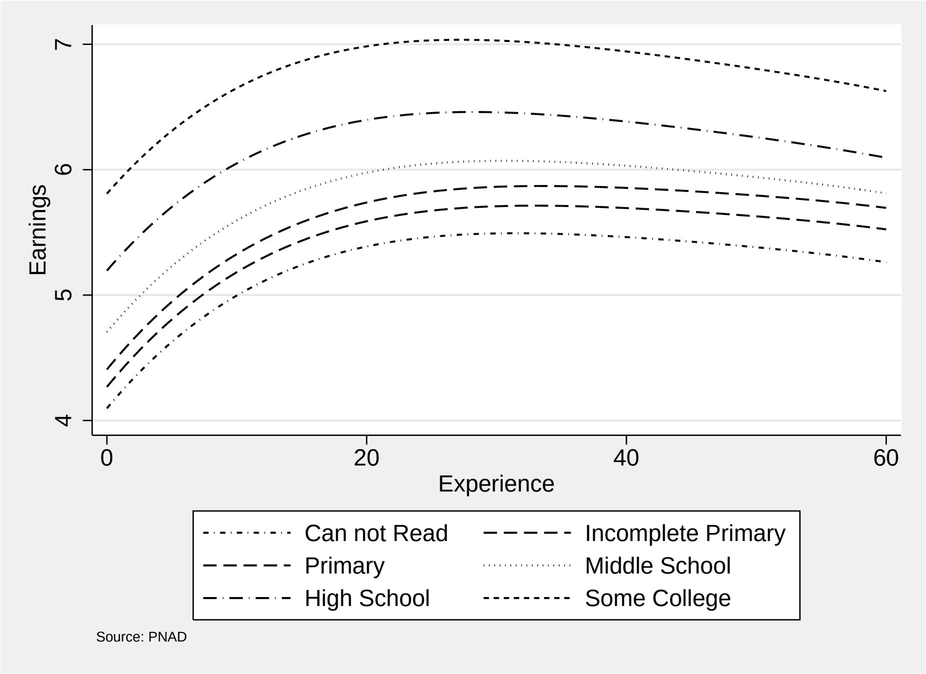
[2] Computation of the coefficients in a regression using sample weights is equivalent to computation of Generalized Least Square coefficients for a heteroscedasticity case. Since this is not the case here, sample weights should not be used in the regressions.



Source: PNAD

Fig. 32. Male earnings depending on years of experience by educational achievement

cator variables for race and region in the specification and (3) imputing the fathers' earnings ignoring the difference in earnings across race and state.

Column (f) replicates Ferreira and Veloso estimation criteria except for a few differences. First, I consider 46 six occupational categories in the specification used to estimate the fathers' earnings while they consider 6. Second, I use the PNAD's 1976-9, 1981-90, 1992-3, 1995 and 1996 to estimate the father's earnings while they use the PNAD's 1976, 1981, 1986, and 1990. Third, they use sample weights in the regressions. The estimate of γ in column (f), 0.594, is similar to Ferreira and Veloso estimate, 0.58. Replicating their estimation, I also find that mobility is higher among blacks and individuals of mixed race compared to other race groups.

Table XXIX. Replication of Ferreira and Veloso results

Sons Aged 25 to 64

(a) No Restriction Except for the Different Age Interval
(b) Fathers' Earnings Imputed Ignoring Differences in Earnings across Race and State
(c) Dropping from the Sample the Sons Working from 15 to 39 Hours a Week or Living in Rural Residencies
(d) Including Indicator Variables for Region and Race
(e) Replacing Indicator Variables for Cohorts by Son's Age and Son's Age Squared and Using Sample Weights
(f) Applying all Restriction from (a) to (e)

	(a)	(b)	(c)	(d)	(e)	(f)
OLS Estimation						
Dependent Variable: Son's Earnings						
Father's Earnings	0.866***	0.792***	0.743***	0.741***	0.896***	0.594***
	(0.020^{MT})	(0.010^{MT})	(0.014^{MT})	(0.016^{MT})	(0.000)	(0.000)
Adjusted R^2	0.292	0.262	0.264	0.323	0.298	0.305
Mobility across Races						
Father's Earnings	0.770***	0.713***	0.666***	0.744***	0.780***	0.606***
	(0.018)	(0.010)	(0.013)	(0.016)	(0.000)	(0.000)
Father's Earnings*Black/Mixed	0.041**	0.015	–0.017	–0.011	0.075***	–0.049***
	(0.019^{MT})	(0.016^{MT})	(0.020^{MT})	(0.018^{MT})	(0.001)	(0.001)
Adjusted R^2	0.311	0.304	0.288	0.323	0.320	0.305
N. of Obs.	33,987	33,987	24,519	33,987	16,341,128	11,600,081

Source: PNAD.

Note: Standard errors in parenthesis. The superscript MT stands for Murphy-Topel standard errors. Coefficients for constant, indicator variables for every age of the sons in columns (a), (b), (c) and (d), age and age squared of the sons in columns (e) and (f), indicator variable for race and region in columns (d) and (f) are not presented. When estimating mobility across race an indicator variable for race is included the specification.

* significant at 10%, ** significant at 5%, *** significant at 1%.

VITA

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