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Abstract

This paper asks what explains the reduction in the college attainment gender gap in the U.S. over the last decades. The fraction of males attending college relative to females has decreased from 1.57 in the mid seventies to 1.19 at the beginning of the nineties. We use a model where parents make decisions on daughters and sons' education taking into account the effect of education on earnings, marriage opportunities, fertility and home production. The main finding is that observed changes in earnings and fertility can account for a fair amount of the decrease in the sex college attainment ratio, however observed changes in marital status and marital sorting imply a decrease in college attainment of women.

JEL Classification: J24, J16, I20

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1 Introduction

This paper asks what explains the reduction in the college attainment gender gap in the U.S. over the last decades. The fraction of males attending college relative to females has decreased from 1.57 in the mid seventies to 1.19 at the beginning of the nineties. We measure the contribution of earnings changes, marital status and marital sorting and fertility changes observed in the data to explain observed changes in the education distribution by sex.

We report the main facts on the potential explanations we explore. First, we observe that relative earnings of those with college education has increased as it has happened with married women's earnings relative to men. Second, we observe that the sharper decline that college education induced on women's fertility relative to men has decreased. Third, we observe that the fraction of single men and women has increased. Finally, marital opportunities have changed, mainly due to changes in the education distribution of women: as the fraction of dropout women has decreased men face a higher probability of getting married with a high or college educated women.

We build on Ríos-Rull and Sánchez-Marcos (2002) that shows that a simple model based on returns to investment (in terms of earnings and marriage), curvature in the utility function and no differences in the educational attainment opportunities between the sexes is not able to account for the sex college attainment ratio (SCAR). They explore several alternative theories that can rise the returns to college for men relative to women and they find that two alternative theories can account for the data: one that imputes a higher cost of education for females (from now on *Benchmark I*) and one that takes into account that college education induces a sharper decline in fertility for females than for males (from now on *Benchmark II*).

We find that earnings and fertility changes can account for a big reduction in the SCAR. However, observed changes in marital status and marital sorting would imply a decrease of women's college attainment. The main findings are as follows:

1. Earnings changes reduce the SCAR under *Benchmark I*, from 1.57 to 1.31, and *Benchmark II,* from 1.57 to 0.93. The increase in college earnings relative to non college increases the returns to investment in education of both daughters and sons. However, parents' concern with single motherhood makes them to invest massively in daughters' education, as the marginal utility from the additional consumption that education

provides is much higher than for sons.

2. Relative changes in the average number of children by education and sex can account for a large change in the education distribution. As the sharp decrease of fertility related to education observed during the mid seventies is removed, the incentives to invest in women's education increases so much that the model predict that men do not get college education, while the fraction of women attending college is 22%. The main reason for such behavior is, again, parents' concern with the poverty of their daughters in case of divorce.

3. Observed changes in marital status, mainly marriage delay, imply a higher SCAR under both *Benchmarks*. Under *Benchmark I* the explanation for such result is that the fraction of life that women spend as single mothers is now shorter. Under *Benchmark II*, a second mechanism is also operating, the increase of single men across dropouts increases the incentives to invest in their education as that increases the probability of getting married and enjoying children.

4. Changes in marital sorting induce slight changes in the education distribution under *Benchmark I*. However, they increase the college attainment of men under *Benchmark II*. The reason for this latter result is that the probability of a dropout man to get married with a dropout woman (the one with the highest fertility) and enjoying a large offspring is much lower now, obviously this effect does not operate in *Benchmark I* as it abstracts from fertility issues.

5. Finally, when all of the observed changes are introduced in each of the *Benchmarks* the results are as follows. First, the SCAR decreases to 1.36 under *Benchmark I*, so explaining 54% of the observed reduction in the SCAR. Part of the effect of the earnings changes is overcame by marital status changes. Second, the SCAR decreases to 0.10 under *Benchmark II* due to the additional impact of fertility changes, clearly it overpredicts the reduction observed in the data. We can think on this exercise as a way of discriminating between the two alternative theories that according to Ríos-Rull and Sánchez-Marcos (2002) were able to explain the SCAR during the mid seventies in the U.S.: that theory that provides closer predictions to the observed education distribution changes, given the observed changes in those we think are the main determinants of education decisions.

As far as we know, there is no other papers in the literature accomplishing a quantitative exercise as the one we present in this paper. However, related papers are Goldin (1995) and Goldin (2002). Goldin (1995) argues that indirect returns to education through the marriage market provided an incentive for women to invest in college education. In fact, Ríos-Rull and Sánchez-Marcos (2002) show that marital sorting provides enough incentive for women to attend college as much as men, in spite of the low returns in terms of own life-cycle earnings. Goldin (2002) argues that the diffusion of the birth control pill among young single women from 1960s had two main implications: (*i*) a direct positive effect on women´s career investment by almost eliminating the chance of becoming pregnant and thus the cost of having sex and (*ii*) it creates a social multiplier effect by encouraging the delay of marriage generally and thus increasing a career woman´s likelihood of finding an appropriate mate after professional school. She argues that these changes increased the fraction of women completing college education.

The paper is organized as follows. Section 2 explains dimensions of the data that are relevant for our analysis. Section 3 explains the model and Section 4 explains the *Benchmark* economies that are used to measure the effect of observed changes in the determinants of education. Section 5 shows the implications of such changes for the education distribution. Finally, Section 6 concludes.

2 Data

We use the Panel Survey of Income Dynamics Public Release II to build the statistics reported to carry on the paper, mainly cross sectional data from 1976 and 1990. This Section is organized as follows. First, we report evidence on changes in education. Second, we show main changes in some dimensions of the data potentially relevant to the education decision making: earnings, fertility, marital status and marital sorting.

2.1 College attainment

First of all we show the education distribution by sex in two different periods, at the mid seventies (1976) and at the beginning of the nineties (1990). We look at the youngest cohorts of adults. Table 1 shows that the fraction of men with four or more years of college has gone from 31.0 in the mid seventies to 40.9 in 1990, whereas for women the same figure went from 19.7 to 34.3. So in 1976 the relative probability of men to complete college education was

1.57 of that of women, in 1990 it was only 1.19.

Table 1: **Education Distribution (25-35 years old, in %)**

	Males		Females	
	1976	1990	1976	1990
Four or more years of College	31.0	40.9	19.7	34.3
High School or some College	54.9	57.8	63.0	63.2
Elemental	14.1	1.3	17.3	2.5

Figure 1 in the Appendix shows the evolution of the fraction of men and women between 25 and 29 years old with four or more years of college according to the data of the Current Population Survey from 1940 to 2000. The SCAR was smaller at the beginning of the period than in the following years. This could be due to the fact that only people belonging to very rich families was completing education and there was no sex differences. In fact, as we show later, the college attainment gender gap is much smaller in families where parents have college education. However, when college education starts to spread across the population, the increase of college graduated is clearly biased against women. This gender difference in education persist until the mid seventies. Nowadays the fraction of women and men with college education is almost the same.

We report below facts on other issues that we consider are relevant to explain observed changes in the education distribution.

2.2 Earnings

In Table 2 we report data on life-cycle earnings for men and women by education and marital status for 1976 and in Table 3 we show the same numbers for 1990. The way in which these numbers are calculated is explained in the Appendix. Obviously, the evolution of earnings is the result of changes both in wages and employment rates. Two main well known changes are worth to mention. On one hand, the increase in the skill premia, see for example Krussell, Ríos-Rull and Violante (2000). This increases the incentives to complete college education for both men and women. On the other hand, the increase of married women´s employment during the seventies and the eighties, see for example McGrattan and Rogerson (1998). The potential effect of the second change is not clear as it depends on its relative importance across the education groups and on marriage market outcomes.

Table 2: **Individual life-cycle earnings, 1976**

	Males		Females	
	Single	Married	Single	Married
Four years of College	0.68	1.00	0.53	0.26
High or some college	0.50	0.65	0.33	0.13
Elemental	0.30	0.48	0.11	0.10

Total life-cycle earnings of married college males are normalized to 1.0

Table 3: **Individual life-cycle earnings, 1990**

	Males		Females	
	Single	Married	Single	Married
Four years of College	0.73	1.0	0.59	0.41
High or some college	0.49	0.56	0.28	0.19
Elemental	0.25	0.25	0.05	0.10

Total life-cycle earnings of married college males are normalized to 1.0

2.3 Fertility

We show differences in fertility across education and sex. All numbers are normalized by the average fertility of a dropout woman. We use the 1993 Individuals File from the PSID, that have additional information on births to individuals. Table 4 shows the numbers for those that were 25-35 years old in 1976.

The main feature of the data is that fertility is decreasing with education and specially for women.

Table 5 shows numbers for 1990. The negative relationship between education and fertility is less striking. Furthermore, we should take into account that we are not observing total

Table 4: **Fertility by Sex and Education, 1976**

	College	High School	Dropout
Females	0.57	0.72	1.00
Males	0.61	0.71	0.73

fertility of women between 25-35 in 1990, because in 1993 they are between 28-38 so they still have some fertile periods. However, given that first maternity age is negatively correlated with education, we are overestimating differences of fertility across educational groups. It follows from the data that fertility differences across educational groups are smaller in 1990 than in 1976, at least for women.

Table 5: **Fertility by Sex and Education, 1990**

	College	High School	Dropout
Females	0.63	0.90	1.00
Males	0.56	0.66	0.85

All numbers normalized to children of a dropout female. PSID Data: total number of children of those that were 26-55 in 1968.

2.4 Marital status and sorting

Table 6 reports data of the fraction of single women by education in 1976 and 1990

Table 6: **Females' Marital Status Distribution (25-35 years old)**

	Single 1976	Single 1990
College	23.1	35.1
High	20.5	42.3
Elemental	22.8	39.2

The main change observed from 1976 to 1990 is the increase of single women for all educational levels. This can be reflecting a delay in the marriage decision, a reduction of the marriage rate or an increase of the divorce rate. In all cases implying that women spend a higher fraction of their lives alone. For women aged 25-65 numbers in Table 6 are 22.0, 26.0 and 21.0 in 1976 and 22.0, 32.0 and 19.0 in 1990. We also report in Table 7 the divorce rates for 1976 and 1990 in the US, it has increased slightly for high and college educated and it has decreased for dropouts. So we conclude from here that a big fraction of the increase of single women should be due to a delay of marriage decision, as it is pointed out by Goldin (2000).

Table 7: **Divorce Rates by Education (25-35 years old)**

	Divorce Rate 1976	Divorce Rate 1990
College	0.016	0.019
High	0.026	0.029
Elemental	0.057	0.033

Tables 8 and 9 report data on marital sorting by education for females. The common feature to both periods is that education seems to be crucial to determine the probability distribution of women´s husband.

Table 8: **Females' Marital Sorting (25-35 years old), 1976**

	College	High	Drop
College	81.0	19.0	0.0
High	23.0	63.0	14.0
Elemental	1.0	42.0	57.0

Table 9: **Females' Marital Sorting (25-35 years old), 1990**

	College	High	Drop
College	80.0	20.0	0.0
High	13.0	84.0	3.0
Elemental	0.0	69.0	31.0

Concerning changes from 1976 to 1990 we observe a reduction in the probability of a college women getting a college husband (this is induced by the fact that in 1990 the ratio college men to college women is lower). High educated women also decrease the chances of getting a college husband, however they have a higher probability of getting a high educated husband instead of a dropout one. So marital sorting is increased due to the change in the education distribution. The relative returns of college education with respect to high education is reduced for women.

Consistency requires that the two transition matrices across marital status yield that the number of males in education group $\hat{e}$ married to females in education group $\tilde{e}$ is equal to the number of females in education group $\tilde{e}$ married to males in education group $\hat{e}$. Unfortunately, this is not likely to be the case because of sampling error in the data, and because the distribution of education in the data is not stationary (so estimates of marriage transitions need not be consistent). To deal with this issue, we take the educational distribution for males and females from the data as well as the transitions for females. We then adjust when required the transition of males so that the consistency requirement is satisfied. The fraction of single male and the marital sorting for male that are implied are shown in Tables 10, 11 and 11. For men aged 25-65 these numbers are 15.0, 13.0 and 24.0 in 1976 and 33.0, 23.0 and 53.0, respectively, in 1990. So the implied changes for men are huge compared to the ones observed for women.

Table 10: **Males' Marital Status Distribution (25-35 years old)**

	Single 1976	Single 1990
College	26.8	58.2
High	21.4	37.7
Elemental	27.0	60.7

Table 11: **Males' Marital Sorting (25-35 years old), 1976**

	College	High	Drop
College	53.0	47.0	0.0
High	8.0	79.0	13.0
Elemental	0.0	49.0	51.0

Table 12: **Males' Marital Sorting (25-35 years old), 1990**

	College	High	Drop
College	80.0	20.0	0.0
High	11.0	85.0	4.0
Elemental	0.0	69.0	31.0

We observe an increase in the probability of a college educated male to get a college educated female, just because the change in the female´s education distribution, and a decrease for the high educated men of the probability to get a dropout wife. Again, an increase in marital sorting is reflected in these numbers.

3 Model

We use a similar framework to Ríos-Rull and Sánchez-Marcos (2002). The model consists of overlapping generations of agents that differ in gender $g \in \{f, m\}$. Agents may marry, and if they do, they have children (that is the only way of having children). Parents invest resources in the education of their children to improve both their earnings and the odds of marrying a highly educated person. Parents like their children equally, where college attainment is equally expensive for males and for females, and where household earnings are equally shared by the two adult members.

To simplify the structure while having agents live many periods, and hence to allow us to interpret periods as years, agents age exponentially, and go through three stages: childhood, adulthood and retirement. In childhood and retirement agents do not make any decision. Adults agents age with probability ψ. While children, agents are attached to their mother. If a mother retires her children become adults. If a mother does not retire, her children may or may not grow into adulthood, an event that occurs with probability ϕ. This modelization ensures that childhood and adulthood have the appropriate lengths. Parameters ψ and ϕ are set at calibration stage.

Besides age and gender, adult agents may also differ in educational attainment, $e \in \{c, h, d\}$, or college graduate, high school graduate and high school dropout. Education is a permanent characteristic of agents, i.e., agents start adulthood with an education level that remains constant throughout their remaining life. We use t to denote the type or permanent fixtures of an agent (the pair gender and education) $t = \{g, e\}$. Sex and education determine individual earnings $\varepsilon_{g,e}$.

In addition to the permanent attributes of individual agents, there are two additional characteristics that matter and that will be the agents individual state variables. They pertain to their marital status and family size. Individuals can be single or married. If married, the educational attainment of the spouse matters. Henceforth, we denote by $z \in \{0, c, h, d\}$ the marital status of an individual, where $z = 0$ denotes single. We assume that marital status evolves exogenously as a Markov process with transition matrix $\Gamma^{g,e}_{z,z'}$. This assumption is only possible under steady states. In particular, the matching probabilities have to be consistent with the distribution of available singles. We will come back later to this point. In the meantime we take $\Gamma_{z,z'}$ as a constant which is what matters from an individual point of view. Because we assume periods to be short, we assume that changing partners requires a spell of singleness. This makes $\Gamma^{g,e}_{z,z'}$ to be zero everywhere except the first column and the first row and the diagonal.

We denote the number of children by $n \in \{0, 2\}$. Children can grow old, in which case they emancipate, and the number of children in their mother's household reverts from 2 to 0. Upon divorce the children remain attached to their mother who has to remain single for at least one period before a possible remarriage in which case, the groom treats the bride's children as if they were his own. We summarize the individual state by $s = \{z, n\}$. We denote with $\Gamma^{g,e}_{s,s'}$ the joint Markov process of individual states.

Households choose consumption, c, and resources invested in their children, that may differ by the child's sex, y^f and y^m. Consumption is shared equally among all family members (we drop this assumption later on), and the amount of consumption enjoyed by each person equals the value of the household's total consumption expenditures adjusted by family size through standard household equivalence scales. To save on notation we make this adjustment by indexing the utility function by the household's type.

Investments in children increase the probability of educational attainment according to functions $\gamma_e(y^g)$. Note that this notation implies that we are assuming that educational attainment is not gender dependent. Conditional on their educational attainment, exogenous distribution $\mu(t, s)$, determines how the transient characteristics of the person get determined in the first period of individual adult life.

At any point in time, there is a distribution of agents according to both their permanent and transient attributes, which we denote by $x(t,s)$, and we normalize to $\sum_{s,e} x(f,e,s) = 1$.

3.1 The adult agents' decisions

The only decisions that households make are how much to consume, how much to invest in the boy and how much to invest in the girl. Therefore, households without children do not have any choice to make and they limit themselves to consume their income. Those with children do have decisions to make.

The decision of a single female of any education with children, i.e, an agent of type $\{t,s\} = \{g,e,0,2\}$. We denote the value function of an agent as $V(t,s)$. The problem of a single mother is given by

$$V(f,e,0,2) = \max_{c,y^f,y^m} \quad u\left(c,s\right)$$
$$+\,\beta\left(1-\psi\right)\left[\phi\sum_{z'}\sum_{n'}\ \Gamma^{f,e}_{0,z'}\ V(f,e,z',n') + (1-\phi)\sum_{z'}\ \Gamma^{f,e}_{0,z'}\ V(f,e,z',2)\right] +$$
$$+\,\beta\ \left[\phi(1-\psi)+\psi\right]\ \sum_{g'}\sum_{e'}\sum_{s'}\ \gamma_{e'}(y^{g'})\ \ \mu(g',e',s')\ \ V(g',e',s'). \tag{1}$$

subject to:

$$c + y^f + y^m = \varepsilon_{f,e} \tag{2}$$

The terms in the first row of this expression refer to current utility and the value in case that the person does not age, which happens with probability $(1-\psi)$. With probability ϕ the children emancipate and with probability $(1-\phi)$ they stay at home. The terms in the second row refer to the utility achieved through the children upon their emancipation. Note that this occurs when the mother ages (probability ψ), and with probability ϕ when the mother does not age (probability $(1-\psi)$. The utility of children is the sum of the utility of each weighted by the probability distribution that determines their type which is affected by how their education turns out to be via the child specific investments and the investment function γ_e, and via the distribution of marital status conditional on the own education μ.

We can write problem (1) more compactly as

$$V(t,s) = \max_{c,y^f,y^m} u\,(c,s)+\beta\,(1-\psi)\sum_{s'}\ \Gamma^t_{s,s'}\ V(t,s')+\beta\ \left[\phi(1-\psi)+\psi\right]\sum_{g'} E\left\{V(t',s')|y^g\right\} \quad (3)$$

The value for a single agent without children, be it a man or a woman is

$$V(t,s) = \ \ u\,(\epsilon_t,s)+\beta\,(1-\psi)\sum_{s'}\ \ \Gamma^t_{s,s'}\ V(t,s'), \qquad\qquad s=\{0,0\}. \qquad (4)$$

The married couple decision problem is pretty the same as the single woman decision problem except form the fact that married couples total resources are given by $\varepsilon_{f,e}+\varepsilon_{m,z}$. The reason is that in the model the two adults in the household see eye to eye with respect to the allocation of current resources. This is due to the assumption that the only way to carry resources into the future is via investment in the children (this investment only pays out if children emancipate) and to the fact that they have the same consumption and the same attitude towards children. These assumptions allow us to abstract from issues of bargaining within the household, and to solve the problem of one of the adults to obtain the households choices.

The law of motion of the adult population and the definition of the competitive equilibrium for this economy can be found in Ríos-Rull and Sánchez-Marcos (2002).

3.2 Functional forms, demographics and earnings

The model is restricted by means of U.S. demographic and economic features such as the earnings-educational distribution and the marriage patterns across education groups.

A period is equivalent to a year because this simplifies the comparison between data and model statistics. Adulthood starts at age 25. The reason for this late start is that they want to ensure that for all practical purposes, education is completed once agents are adults. Agents retire at age 65. These two choices restrict the two aging parameters ψ and ϕ.[2] The marital status transition probabilities, $\Gamma^{g,e}_{z,z'}$ are obtained directly from the data.

[2]While the aging of adults can be fixed independently of all other parameters, that of young agents cannot. The reason is that young agents sometimes age at the same time as their parents and some time alone. This means that the age distribution of adults at first birth matters for the aging of children unless we correct it, which is what we do to ensure that
all children's expected age at becoming adults is 25 years.

Earnings by education, gender and marital status are taken directly from the data the distribution of earnings by education, gender and marital status. We assume that there are no life cycle features in the earnings profiles. Therefore, we take the earnings of the different groups as being those reported in Table **??**.

An important feature of the model is that the average number of children that a person leaves behind depends on the average fraction of time that this person has children,[3] and this varies by sex and educational groups. This introduces a spurious reward to education, in particular when using preferences with more curvature than log where the larger the number of children, the worse off parents are. In the baseline model preferences are normalized by the expected number of children so that fertility does not affect education.

Differences in fertility are still present since the number of children affects effective consumption of their parents. This mechanism just normalizes the expected utility from the progenies but not the costs.

There are three functional forms that have to specified. Those that pertain to the utility function and to the probabilities of college and high school attainment given parental investments. For the temporary utility function, they choose a standard CRRA function with parameter σ, and a discount rate of β. With respect to educational attainment, they assume that the probability of attending college given expenditure y is given by $\gamma_c(y) = 1 - \exp(-\alpha_1 \;\; y^{\alpha_2})$. They use two parameters in this function because they want to be able to match both the level and the derivative. If an individual does not attend college, the probability of attending high school is also increasing in parents expenditures, so $\gamma_h(y) = [1 - \gamma_c(y)][1 - \exp(-\alpha_3 \;\; y^{\alpha_2})]$. To determine how expenditures in consumption translate into consumption enjoyed by each household member, they use the household equivalence scales of the OECD, where the first adult counts as 1, the second as 0.7 and each child as 0.5. These choices of functional forms leave 5 parameters to be determined, $\{\sigma, \beta, \alpha_1, \alpha_2, \alpha_3\}$.

4 Benchmark economies

Ríos-Rull and Sánchez-Marcos (2002) show that a simple model based on returns to investment (in terms of earnings and marriage), curvature in the utility function and no differences in the educational attainment opportunities between the sexes is not able to account for the

[3]The actual mechanism through which this happens is the age of first marriage.

sex college attainment ratio (SCAR). They show that the failure of the simple model is due to the curvature of the utility function, to the fact that women live as single mothers for some periods of their lives, to the fact that there is substantial assortative mating, and to the fact that agents have dynastic preferences. They found two different theories that are able to explain the college attainment gender gap observed in the mid seventies in the U.S..

The first theory relies on the fact that women have an extra cost of getting educated than men. The amount of time daughters can devote to home production activities is decreasing in family´s resources devoted to daughters' education because getting educated requires both parents' income and children' time (boys are not able to make home production). This assumption add a new ingredient to the baseline model explained above. Then, home production function is decreasing on y_f and is characterized by two new parameters, δ_1 and δ_2[4]. Table 13 shows the calibration of the model to some dimensions of the data. The performance of the model in terms of non calibrated statistics (SCAR by father´s education and intergenerational persistence of education) is quite acceptable and it is shown in Table 14.

Table 13: **Benchmark I: Female more expensive to educate**

Variables	Targets	Model
Fraction of College Males	31.0	31.0
Fraction of High School Males	49.0	49.0
Fraction of College Females	19.7	19.7
Household Production / Consumption (in %)	8.0	8.0
College Attainment Ratio father drop	2.13	2.13
$Prob$(coll | fath coll) / $Prob$(coll | fath high)	1.77	1.77
Education Expenditures/ Consumption (in %)	5.0	5.0
Parameters		
α_1		8.68
α_2		0.86
α_3		31.13
δ_1		-2.33
δ_2		-0.30
σ		2.15
α^{hd}		6.37

[4]Home production function is $\delta_1 \exp(-y_f^{\delta_2})$. This implies that household consumption is equal to $c + \delta_1 \exp(-y_f^{\delta_2})$.

Table 14: **Benchmark I, Other Statistics**

	Model	Data
$Prob$(coll | fath coll) / $Prob$(coll | fath drop)	2.52	3.27
$Prob$(coll | moth coll) / $Prob$(coll | moth high)	1.70	1.17
$Prob$(coll | moth coll) / $Prob$(coll | moth drop)	2.74	2.72
College Attainment Ratio | father coll	1.40	1.21
College Attainment Ratio | father high	1.63	1.50

The second theory that is able to explain the data is the one that assumes that individuals care for the number of descendents they have. In such scenario, parents decide to invest less on daughters than on sons because fertility is decreasing in education specially for women. In this *Benchmark* it is necessary to give life some value, and this is done by adding parameter $\bar{U}$ to the utility per period. The calibration is detailed in Table 15. There are some deviations of parameters in Table 15 with respect to those in Ríos-Rull and Sánchez-Marcos (2002) that are due to differences in fertility assumed in each case. The numbers for fertility we use here are more accrual because they are total fertility numbers of women between 25-35 in 1976, whereas in their case they use fertility numbers of all women in 1976. Again, we show in Table 16 the performance of the model in terms of non-calibrated statistics, that is quite good. The model is able to reproduce the variability of the SCAR across education groups.

Table 15: **Benchmark II: Individuals derive utility from the number of descendants**

Variables	Targets	Model
Fraction of College Males	31.0	29.4
Fraction of High School Males	49.0	49.0
Fraction of College Females	19.7	20.0
$Prob$(coll | fath coll) / $Prob$(coll | fath high)	1.77	1.77
Education Expenditures/ Consumption (in %)	14.0	14.0
Parameters		
α_1		6.33
α_2		0.98
α_3		14.03
$\overline{U}$		11.18
α^{hd}		2.87

Table 16: **Benchmark II, Other Statistics**

	Model	Data
$Prob$(coll | fath coll) / $Prob$(coll | fath drop)	2.34	3.27
$Prob$(coll | moth coll) / $Prob$(coll | moth drop)	3.01	2.72
College Attainment Ratio | father coll	1.23	1.21
College Attainment Ratio | father high	1.50	1.50
College Attainment Ratio | father drop	1.80	2.13

We base on these two theories to measure the implications of observed changes in the data on education distribution by sex.

5 Changes in the determinants of education

In this Section we present the predictions of the baseline models when we introduce observed changes in the determinants of education decisions. Specifically, changes in earnings, marital sorting, marital status and fertility that we showed above.

5.1 Changes in earnings

We look at changes in the relative earnings individuals get along their lives. The main implications of the changes under *Benchmark I* are in Table 17. The SCAR decreases from 1.57 in the mid seventies to 1.31 in the nineties. The implications of the change under *Benchmark II* are in Table 18. In this case, the new SCAR is 0.93, meaning that the fraction of college graduated women is higher than the fraction of men.

Table 17: **Changes in earnings under** *Benchmark I*

Variables	Data 90s	Model 90s	Model 70s
Fraction of College Males	40.9	37.6	31.0
Fraction of College Females	34.3	28.7	19.7

The same qualitative conclusion is achieve under both *Benchmarks* economies: relative changes of earnings across sex and education are able to explain, at least, a fraction of the decrease in the SCAR observed over the last twenty years. So, observed increases in female´s relative earnings are enough to offset home production by daughters in the first case, and the

Table 18: **Changes in earnings under *Benchmark II***

Variables	Data 90s	Model 90s	Model 70s
Fraction of College Males	40.9	38.1	29.4
Fraction of College Females	34.3	41.6	20.0

lower number of descendants associated with college education in the second case. However, the quantitative implications are different, *Benchmark II* accounts for a larger decrease of the SCAR.

5.2 Changes in the fraction of single females

In this Section we measure the effect on education decisions of changes in marital status distribution[5]. As we said before, an increase in the number of periods that women live unmarried is observed over the last decades. Tables 19 and 20 show the implications under the two *Benchmarks* economies. Under *Benchmark I* we find that the increase of the fraction of single females implies an increase in the SCAR. As children are attached to the mother upon divorce, single motherhood make women very poor and, because the utility function is concave, parents have an extra incentive to invest in daughters education to avoid their poverty, even if the returns in terms of earnings are very low. As the number of periods women spend single before the first marriage increased, the expected number of periods that women face as single mothers is lower and at the end of the life-cycle. Furthermore, divorce rate for dropouts is much lower in 1990. These two reasons make the incentives to invest in women´s education decrease in 1990.

When we assume *Benchmark II* qualitative results go in the same direction, however, they are quantitatively larger, implying that women are not attending college at all. The reason to expect a decrease in women's college attainment is the same as in *Benchmark I*. However, in this case the increase in the fraction of single men across dropouts relative to other educational levels, creates an additional incentive to invest in son's education, because men enjoy offspring only during marriage. This effect can only play a role in *Benchmark II*.

There are other effects working. A delay in marriage decision implies that individuals

[5] As the average age of maternity is increased we need to make some adjustments in parameter ϕ to keep constant the number of periods that children spend in parents' households.

Table 19: **Changes in marital status distribution under** *Benchmark I*

Variables	Data 90s	Model 90s	Model 70s
Fraction of College Males	40.9	28.4	31.0
Fraction of College Females	34.3	15.3	19.7

Table 20: **Changes in marital status distribution under *Benchmark II***

Variables	Data 90s	Model 90s	Model 70s
Fraction of College Males	40.9	27.6	29.4
Fraction of College Females	34.3	0.0	20.0

derive utility from their descendents later in life, so then, differences in fertility should be less important for the education decision under *Benchmark II*, and they should reduce the disincentive to invest in women's education. However, effects explained above seem to dominate.

5.3 Changes in marital sorting

We isolate here the effect on education decisions of changes in marital sorting that were reported above. Table 21 shows the results under *Benchmark I.* As it is observed, education distribution by sex remains unchanged. So changes in returns to education by sex through the marriage market are such that the relative incentives to invest in men versus women remain the same.

However, if we assume *Benchmark II* the implications are different. Table 22 shows that the fraction of women completing college education decreases as we impose marital sorting of the nineties. The increased returns to education due to better marriage chances, specially for males, induce a decrease of female´s college attainment only when parents care about descendents. This is due to the fact that one of the implications of men's marital sorting in 1990 is that the probability for a dropout male to get married with a dropout female (the one with the highest fertility) is much lower and then the potential benefit of lower education for males (a large offspring) decreases.

Table 21: **Changes in marital sorting under** *Benchmark I*

Variables	Data 90s	Model 90s	Model 70s
Fraction of College Males	40.9	31.4	31.0
Fraction of College Females	34.3	19.0	19.7

Table 22: **Changes in marital sorting under *Benchmark II***

Variables	Data 90s	Model 90s	Model 70s
Fraction of College Males	40.9	30.0	29.4
Fraction of College Females	34.3	2.9	20.0

5.4 Changes in fertility

Table 23 shows the effect of changes in fertility. This can only be accomplished assuming *Benchmark II*, because, as it was explained above, in *Benchmark I* the effect on utility of differences in fertility is eliminated. Differences in fertility across education groups are much lower in 1990 than in 1976. This means that keeping the other inputs and parameters constant (included $\bar{U}$, that measure the value of life) the incentive to do not invest in women' education disappears, and the effect of single mothers' poverty dominates the decision, making the returns to college education for women much higher than those for men. So the reduction in differences in fertility across education could be a reason explaining the reduction of the SCAR.

Table 23: **Changes in fertility under** *Benchmark II*

Variables	Data 90s	Model 90s	Model 70s
Fraction of College Males	40.9	0.0	29.4
Fraction of College Females	34.3	22.0	20.0

5.5 All Changes

Tables 24 and 25 show the statistics implied by *Benchmark I* and *II* when we impose all observed changes in the data. The SCAR predicted in *Benchmark I* is 1.36, lower than the one for the 1970s. In *Benchmark II*, however, it is much lower, 0.10, as we could expect given the results above.

Table 24: **All Changes under** *Benchmark I*

Variables	Data 90s	Model 90s	Model 70s
Fraction of College Males	40.9	33.7	31.0
Fraction of College Females	34.3	24.7	19.7

Table 25: **All changes under *Benchmark II***

Variables	Data 90s	Model 90s	Model 70s
Fraction of College Males	40.9	2.7	29.4
Fraction of College Females	34.3	28.5	20.0

Then both theories predict that some of the observed changes in the inputs of the model, that we think are the main determinants of education decision, provide a plausible explanation for the decrease of the SCAR.

6 Conclusions

We conclude from our analysis that observed changes in earnings are able to explain a considerable reduction in the SCAR. We can also conclude that the reduction in fertility differences across educational groups induce parents to invest more in daughters' education. The effect of changes in marital sorting and marital status have the opposite effect on women´s college attainment. However, under *Benchmark I* these effects are more than offset by changes in relative earnings across education and sex. Under *Benchmark II*, those effects are offset, not only by the effect of changes in earnings, but also by the effect of changes in fertility. In this latter case implied changes for the education distribution are huge, the relative incentives to invest in women´s education versus men are much higher, making males' college attainment too low.

The results obtained here could be though as a way for selecting between the two potential theories of the SCAR until the mid seventies according to Ríos-Rull and Sánchez-Marcos (2002): that theory that provides closer predictions to the observed education distribution changes, given the observed changes in those we think are the main determinants of education decisions. The more suitable theory in that sense would be the one that relies on the fact that women have an extra cost of getting educated than men: the amount of time daughters can devote to home production activities is decreasing in family´s resources devoted to daughters' education.

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8 Appendix

8.1 College attainment gender gap

8.2 The measure of life-cycle earnings

8.2.1 Individual life-cycle earnings

We obtain a measure of life-cycle earnings by sex, education and marital status. We use data from the Panel Survey of Income Dynamics 1976 and 1990, in which information of wages and hours worked refers to the previous year. The measure of potential life-cycle earnings we built is computed considering people in and out of the labor market. For people out of the labor market we estimate a wage per hour according to their characteristics. To impute wages we use the wage equation below. This equation includes as regressors, age, experience, educational level and Mills Ratio. Heckman (1979) shows that the inclusion of this last regressor lets estimate the rest of the coefficients in the wage equation consistently, avoiding the problems related to sample selection typical in estimation of wage equations. For each sex we estimate the following regression:

$$\ln w_j = \beta_0 + \sum_{i=1}^{7} \beta_i \, x_{i,j} + \varepsilon_j$$

where $x_{1,j}$ is a dummy variable that takes the value 1 if the individual has 4 or more years of college and zero otherwise, $x_{2,j}$ is a dummy variable for having finished high school but not graduated from college, $x_{3,j}$ is age, $x_{4,j}$ is age square, $x_{5,j}$ is labor experience, $x_{6,j}$ is labor experience squared and $x_{7,j}$ is the Mills ratio, obtained through the estimation of a Probit model on the employment decision.

After imputing wages to people that are out of labor market we obtain average wage per hour, $\overline{w}$, and average annual hours worked, $\overline{h}$, for seven groups of age $\{25-29, 30-34, \cdots, 60-64\}$. We build a measure of life-cycle labor earnings at the beginning of the adult life by sex, $g = \{f, m\}$, education, $e = \{c, h, e\}$, and marital status, $d = \{\text{single, married}\}$, that result from the discounted sum of labor earnings along the life-cycle. We use an interest rate of $r = 4\%$ to discount earnings:

$$\varepsilon_{g,e,d} = \sum_{t=1}^{7} \overline{w}_{g,e,d}(t)\overline{h}_{g,e,d}(t) \left(\frac{1}{1+r}\right)^{(t-1)*5} \left(\frac{1-\left(\frac{1}{1+r}\right)^4}{1-\left(\frac{1}{1+r}\right)}\right),$$

We are assuming that there are no cohort effects.

8.2.2 Household life-cycle earnings

In building this measure we assume that married individuals equally share their earnings with their spouses. Let $z \in \{0, c, h, d\}$ be the marital status of the individual: single, married with a college spouse, married with a high school graduated spouse or married with a high school dropout. Given the distribution of the population by marital status in age group 25-65, $\mu(z)$, we can build a measure of the expected earnings of an individual of sex g and education e, $\hat{\varepsilon}_{g,e}$. Then,

$$\hat{\varepsilon}_{g,e} = \sum_{z} \mu(z) \left[\left(\frac{\varepsilon_{g,e,z} + \varepsilon_{\overline{g},z,e}}{2} \right) I_{z>0} + \varepsilon_{g,e,z} I_{z=0} \right]$$