On the Relationship Between Fertility and Public Education in Different Stages of Development*

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Abstract

This paper examines the relationship between public education expenditures and fertility rates across countries. While conventional wisdom holds that increasing the share of output devoted to public education increases educational attainment and lowers fertility, we find that for a set of developing countries, the former prediction holds while the latter does not. In fact, increases in the share of output devoted to public education tend to increase fertility in developing economies. This non-monotonicity may result from one or a combination of factors, some of which have been previously noted in the literature. However, we do not attempt to pin down the causal factors. We present a theoretical model that is sufficiently general to accommodate a number of complementary explanations. The construct allows us to investigate the behavior of a dynamic general equilibrium economy with endogenous fertility when the latter is affected by education differently across economies of different income levels. The empirical conclusions are subject to a battery of sensitivity analysis tests including a version that, guided by the theory, jointly estimates the parameters of fertility and education equations.

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1. Introduction

This paper examines the link between public education expenditures and fertility outcomes. According to conventional wisdom, increasing educational effort (particularly female education) will lower fertility rates. Indeed, the unconditional correlation between public education expenditures as a share of Gross Domestic Product (GDP) and fertility rates across 88 countries provides preliminary albeit crude support for the allegation.[1] Figure 1a illustrates a scatter plot of the data points and the estimated unconditional relationship. The slope coefficient is negative (with a point estimate of -47.74 and t-statistic of -8.22), although the fit is clearly imprecise as would be expected from a one variable explanation of fertility rates.

However, a different story emerges if one breaks the sample into high-income and low-income countries. Figure 1b depicts the fertility-education expenditures share relationship for the 33 "rich" countries whose initial income level exceeded the mean for the sample, while Figure 1c shows the same for the remaining 55 "poor" countries. The negative relationship between the education expenditures ratio and fertility remains for the "rich" countries (yielding a slope estimate of -27.42 with a t-statistic of -4.28), and with the exception of a few high-fertility countries, the estimated correlation is a fairly good fit considering the absence of any other conditioning variables. However, the "poor" countries, as a group, exhibit no systematic tendency for higher public education expenditure shares to be associated with lower fertility rates. In fact, the estimated correlation is positive, although it is numerically small and statistically insignificant (the slope estimate is 0.58 with a t-statistic of 0.08). Therefore, this exploratory excursion suggests that there should be a more rigorous examination of the impact of public education provision on fertility across countries in different stages of development. This paper accepts that task.[2]

The first tack is to examine whether the unconditional correlations hold up under closer scrutiny (as a conditional relationship). Section 2 presents results using the cross-section, time-series (five year averages) data for the 88 countries mentioned above. Our empirical implementation uses cross-country data because the preliminary evidence suggests that increases in the public education expenditures share affect fertility differently in economies with different income levels. An investigation of these implications could not be accomplished with micro-level data within any one country or between countries of similar development status. We find that, after accounting for country-specific fixed effects, time-specific effects and other determinants of aggregate fertility rates (female and male educational attainment, infant mortality and income per adult), the public education

[1]From here on, when we write the public education expenditure share, we mean as a share of GDP.

[2]We do not argue that governments of low-income economies should decrease expenditures on education. On the contrary, the results reported below show that there is insufficient spending on education. That is, most less-developed countries have not yet achieved the education level where market productivity effects dominate.

expenditure share explains a significant portion of fertility variations across countries and over time. Moreover, increases in the public education expenditure share yield declines in fertility in rich countries and *increases* in fertility in developing countries.

There have been other allusions to this positive relationship between education and fertility at low education or income levels. For example, the *World Development Report*, 1984 states "It is true that, in poorer countries, women with a few years of primary schooling have slightly higher fertility than do women with no education at all, especially in rural areas" (p. 109). The report briefly speculates that "some education may be associated with a lower rate of sterility, and it often leads to a decline in breast-feeding not offset by greater use of contraceptives." The lower sterility rate is likely associated with the increased awareness of health and sanitation issues that some exposure to education engenders. Also, several demographic studies have noticed the possible positive correlation between education and fertility at low education levels. Cochrane (1983) presents a review of these studies. However, by and large, the possibility of non-monotonicity in the fertility-education nexus has been overlooked by the economics profession.[3] Furthermore, there does not exist a theoretical under-pinning for the empirical relationship within a general equilibrium framework.[4]

What could cause an increase in education expenditures to increase fertility in less-developed economies? The World Bank Report (1984) and Schultz (1981) suggest that health improvements may be the causal factor. Dasgupta (1995) points to a possible decline in sexual post-partum taboos as female education rises, particularly in parts of Africa. Trussel, et al. (1992) find that breast-feeding declines as education rises in developing countries (breast-feeding triggers natural contraceptive tendencies). Goldin (1995) shows that female labor force participation initially *decreases* with increases in income. She attributes the probable cause of the decline to the existence of norms and stigmas that discourage female participation in market activity outside of the domicile during a time when labor effort is shifting from traditional to industrial markets. At higher income levels, norms begin to change and/or the types of available work shift (e.g., from factory to clerical) and female labor force participation begins to increase. The initial decline in labor force participation may be accompanied by a fertility increase.[5]

[3] An exception is Dasgupta (1995) who notices the "curious" relationship in passing. Also, Barro (1995) estimates a fertility equation that generates positive coefficient on primary education. There is also a recognition of a possible increase in fertility in some recent work on the demographic transition (e.g., Galor and Weil 1996, 2000).

[4] Schultz (1981), in a partial equilibrium setting, argues that "the supply [of children] schedule may be upward sloping [with respect to education], perhaps because more educated mothers are healthier and have greater fecundity, and their offspring have enhanced survival prospects" (pp. 127-128). He then proceeds to make a case for an empirically estimable inverse "V" curve. Our paper contains elements of this argument within the context of public policy toward education. There is also an attempt to theoretically account for the fertility transition in Galor and Weil (1996, 2000).

[5] Another possibility is that the positive relationship between the education expenditure ratio and fertility in developing countries is driven by reverse causation. That is, as fertility rises, governments devote a larger share of national income toward education. However, we discarded

We present a theoretical framework in Section 3 to explore how these sorts of explanations fit into a general equilibrium model of growth and development with an endogenous fertility choice. To accommodate any of the explanations put forth above, we postulate that education increases productivity both in the market and at home where the home activity is bearing children. The increase in productivity of child bearing can be a result of increased health awareness, the decline in taboos, or even from a stigma associated with female labor force participation. However, we also stipulate that education can influence home productivity only up to a point. After a critical amount of education is achieved, further increases in education influence only market productivity.

Therefore, the reaction of fertility to increases in the public education expenditure share to output depends upon the contribution of education to raising home productivity relative to its positive effect on market productivity. In developing countries, the home productivity effect of education is operative and can therefore lead to fertility increases. On the other hand, developed countries may experience fertility declines and unbounded output growth as the education expenditures share rises because the home productivity effect of more education has already been exhausted.[6]

The final phase of the investigation revisits the empirical results. The model presented in section 3, as with many models of endogenous fertility, has both an endogenous fertility and education choice. Section 4 presents a simultaneous equation model that also presumes fertility and education are jointly determined. After allowing for the simultaneity of the education and fertility decision, the results presented in section 2 remain in tact. Less-developed countries respond to a higher public education expenditure share with higher fertility while developed countries respond with lower fertility. Overall, the results indicate that in this sample, the market productivity effects of educational advances do not outweigh the home productivity (fertility enhancing) effects for the majority of less-developed countries .[7]

2. Base-line Empirical Model

In this section we use the panel data sets assembled by Barro and Lee (1993) and (1996) to estimate how fertility is related to changes in the share of output devoted to public

that notion for several reasons. First, the differential response between rich and poor countries was not readily explained by the reverse causation argument. Second, the reverse causation argument relies on the ratio public education expenditures to GDP rising with fertility. While it is sensible to argue that increases in fertility lead to increases in the level of public spending on education, over longer periods of time, the higher fertility also increases the level of GDP. Yet, the positive relationship in developing countries holds for long-time averages as well (Figures 1a-c). Since, in long-time averages, the reverse causality explanation would increase both education expenses and GDP, one would not expect to see this if the entire explanation were due to reverse causality.

[6] We will use the term human capital to refer to the human capital employed in market production rather than home production.

[7] The presentation below is agnostic to the welfare effects of high fertility. The research simply aims to illustrate that the relationship between government spending on education and fertility may not be negative for a substantial sub-set of economies.

education. Panel data have an obvious advantage over strictly cross-sectional data in increasing the number of observations, but more importantly, the panel data also allow us to take into account country specific effects on fertility. Since child-bearing can be heavily influenced by cultural norms, societal beliefs and other unobserved country-specific effects, the ability to at least partially account for those factors is especially helpful.[8] The panel consists of 88 countries and spans the years from 1960 to 1984.[9] Each time-series observation is a five year average, thereby yielding five points for every country. The use of five-year averages helps to smooth variations due to business cycle phenomenon and facilitates the discovery of underlying secular relationships.

In estimating the fertility relationship, we use national total fertility rates which are derived from age-specific birth rates and represent how many children a woman would bear in her lifetime if she experienced the current age-specific birth rates.[10] This measure is intended to minimize the effects on fertility due to changes in the age structure of the population and the percentage of women in the total population. Other more simple measures of fertility, such as crude or net birth rates, would be subject to those demographic variations. The independent variables include (1) the ratio of public education expenditures to GDP, (2) real Gross Domestic Product per equivalent adult, (3) the infant mortality rate, (4) average years of female and male education (primary, secondary, higher or total) and (5) time dummies for the last four of the five 5-year time periods.[11]

Clearly, the first independent variable is the major focus of the empirical investigation. The income variable is scaled by the adult population, rather than the entire population to avoid simultaneity with the dependent variable and is included to capture the net impact of the wealth and substitution effects of higher adult incomes. The substitution effect acts through the opportunity cost of having children given that child-rearing is time-consuming. The wealth effect acts by pushing out the budget constraint and allowing the household to consume more of all goods, including children. The infant mortality rate affects fertility because some children will not live past the age of five and it is presumed that parents care about the number of children that reach adulthood.

Government spending on education may affect fertility decisions partly through ed-

[8] Note that many studies between fertility and education have been conducted within one country. Certainly this tack holds country specific effects constant. However, our goal is to examine the differential effects of government spending on education in high- and low-income countries. Therefore we need cross-country data and by utilizing these data in a panel form we can control for country specific effects.

[9] We began with Barro-Lee's (1993) sample of 98 countries. Ten countries had insufficient time-series data to include in the sample. Also, note that their (1993) data end in 1985 and thus provide the end-constraint on the estimation period. Finally, since we are using the five year averages, the last five year period spans 1980-1984.

[10] These are live births and are not adjusted for child deaths during infancy.

[11] The education measures for total years of schooling for women over the age of 15 comes from Barro and Lee (1996) while the other measures (with the exception of income per equivalent adult) comes from Barro and Lee (1993). The former data set covers more countries and extends the time range; however, it does not include total government spending on education as one of its variables. Income per equivalent adult was obtained directly from the Penn World Table version 5.6 assembled by Robert Summers and Alan Heston and described in Summers and Heston (1991).

ucational attainment.[12] Therefore, placing female education in the regression equation presents two concerns: (1) its inclusion will bias the coefficient estimate on government education expenditures toward zero and (2) it may be simultaneously determined with fertility and, therefore, present an endogeneity problem. However, there are other factors driving educational attainment such as employment opportunities, urbanization and government regulation that argue in favor of keeping the education variables in the empirical specification. In light of the above considerations we proceed with the empirical study by first estimating the impact of government spending on fertility conditional on female education. By so doing, if we find statistically significant results, we have done so under conditions which were not favorable to that conclusion. In another section to follow, we also investigate the robustness of the results in face of a simultaneity bias by estimating a simultaneous equation system that allows for the joint determination of fertility and education decisions.

We utilize measures of average years of education for primary, secondary and higher education, and average total years of education for females over 15 years of age. Since no particular version of these measures stands out as the obvious choice, we estimate each fertility equation four times, each time using one of the four different education measures. As discussed below, the results are not overly sensitive to the specific choice of the education variable.

Note that there will obviously be heterogeneity in both educational quality and private education expenditures across countries, and to the extent that these differences are not captured by the included variables, their impact will be part of the error term. However, we do not believe that these factors will alter our conclusions with respect to the relationship between the public education expenditure share and fertility in the less-developed economies. To see this, consider two poor countries with the same public education expenditure share, but one has higher quality education and/or more private education investment. Now suppose both of these countries raise their share of government spending on education. The country that has higher private education spending and/or higher educational quality is more likely to have surpassed the threshold that would encourage an increase in fertility. Therefore, the existence of these cross-country differences would bias the coefficient estimate on the public education expenditure share toward zero in the less-developed sample. This leads us to conclude that our findings of a positive coefficient on the public education expenditure shares is robust to those cross-country differences. Also, conditioning the estimates on education levels helps to eliminate some of these cross-country differences since countries with similar government spending ratios but higher quality and/or private investment are likely to also have higher education levels. Finally, note that the public education expenditure share may help to measure quality of public education and it is partially through the quality channel that the proposed link may operate.

Proceeding with the estimation, we divide the sample of 88 countries into two sub-

[12]It could also change the quality of education and influence fertility through that channel by raising the market return to education or by providing more thorough health education.

samples, which we label "developed" and "less-developed" countries. Countries are assigned to a particular category based upon their initial (1960-64 average) income levels per adult. Specifically, we split the sample into those countries whose initial income levels exceed the mean and those whose income levels are below the mean. This procedure yields 56 low-income countries and 32 medium- to high-income countries. While this selection criteria is admittedly arbitrary its choice diminishes the chances of falsely accepting our null hypothesis of differential fertility influences across samples. Specifically, we have included in our sample of less-developed countries not only the poorest of economies, but also some countries who may have reached and passed the threshold over the sample period. We have also examined the robustness of our results with respect to sample selection by re-estimating the results using sub-samples based on the uppermost and lowermost quartiles of income distribution as well as by dividing the sample into high and low education countries. The outcomes using these alternative specifications is discussed below, but in general, the results remain intact.

The panel structure of the data allows us to account for unobserved country specific effects on fertility. Our prior is that the fixed effects model is the most appropriate because it seems probable that the unobserved effects might be correlated with the regressors, implying that the random effects specification would be undesirable. However, for the sake of robustness, we also estimate a random effects specification. The results are not significantly affected by the choice.[13]

2.1. Results

Tables 1 presents the estimation results for the fixed effects specification.[14] The different versions of the model (i.e., different columns in the table) arise from the use of a different measures for educational attainment within each sub-sample. Columns (a) - (d) display results for average years of primary, secondary, higher and total years of education, respectively. In the sample of developed countries, increases in the public education expenditure share are associated with declines in fertility rates and the estimated coefficients are statistically significant at the 5% level or better in every case. On the other hand, in the sample of less-developed countries, the estimated coefficients on the public education expenditure share are positive. All versions in the less-developed sample, with the exception of the equation using average higher education years, yield statistically significant coefficient estimates at close to the 5% level or better. Yet, while the estimated coefficients are positive, the magnitude of the coefficients is rather small.

[13]It seems natural to suspect that the relationship between fertility and other variables is non-linear since there is an upper bound on national fertility and this might be approached non-linearly. Therefore, we estimate the model in log-log form. If the variables are not logged, the results are similar, but statistical signficance in poor sample declines.

[14]We tested for statistical significance of the fixed effects and found that one could not eliminate the panel aspect of the data in favor of a pooled regression. Finally, we ran a battery of tests for heteroscedasticity using modified Breusch-Pagan tests. When the errors showed signs of heteroscedasticity, the method of weighted least squares was used.

To interpret the findings, we focus on the coefficient estimates from the version using total years of education, columns (d), when it is convenient to use a numerical example. These results indicate that if a less-developed country with an education expenditure share of 1.2% of GDP (the lowest time-average in the sample) increased the education expenditure share to 4% of GDP (a 233% increase), its fertility rate would rise by 13%.[15] The magnitude of the negative effect in the developed country sample is larger. If a country in that sample increased its education expenditure share from 4% of GDP to the developed country average of 4.6% of GDP (a 15% increase), its fertility rate would fall by 3.5%.

Comparing other coefficient estimates between the developed and less-developed countries, it is interesting to note that while the sub-samples are generated by income differences, there may still be important income effects within each sample. In all cases, the coefficient estimates are negative and often statistically significant. Interestingly, the coefficient estimates in the developed sample are two to three times as large as the estimates from the less-developed country sample. By far, the most important factor in lowering fertility in developing countries is a lower infant mortality rate. The second most important factor in less-developed countries is female education. Raising total years of female education from one to three years (a 200% increase), would lower fertility by 26.8%. A curious result in the developed country sample is the statistically significant positive sign on female education and the statistically significant negative coefficient estimate on male education.

Table 2 displays the estimates from a random effects model (where the unobserved country specific effects are specified as part of the error structure). In the less-developed sample, the magnitude of the coefficient on the public education expenditure share rises and the magnitude of the coefficient on female education falls (in absolute value), relative to the fixed effects specification. Also, the coefficient on the public education expenditure share loses its statistical significance in the developed sample. However, as mentioned above, it is unlikely that unobservable country specific influences on fertility are not correlated with the regressors.

To ensure that the results shown in Table 1 were not driven by mis-specification, we also re-estimated the results under the following alternative specifications: (i) dividing the sample by income categories and by education, (ii) using average female enrollment rates rather than average total years of schooling, and (iii) allowing lagged income per equivalent adult to proxy for its contemporaneous value.

In one alternative sample division we culled countries in the top and bottom quartiles of the income distribution and labeled the first group "rich" and the second group "poor". Since the rich distribution is practically identical to the developed country sample above, all of the results for that group remain unchanged. For the poor group, the positive

[15] Estimating the model over the full sample with total years of education to measure educational attainment and entering the public education expenditure share quadratically indicates that the positive effect of public education on fertility peaks at about 4% of GDP. The coefficents on the linear and quadratic terms of the education share are 8.28 and -204.48, respectively and both are significant at the 1% level.

statistically significant relationship between the public education expenditure share and fertility remain but the magnitude of the coefficient falls. In the second alternative split we divided the countries by their education levels rather than income levels. In theory, the two samples should be very similar because of the high theoretical correspondence between human capital and income per capita. However, we initially chose to split the sample by income levels because it is often asserted that the existing education data do not adequately proxy for human capital. For that reason our preferred sample split is by income level; however, to check for robustness, we re-estimated the model dividing the countries into those whose initial average years of total female education lie above the full sample mean ("high education" sub-sample) and those whose average years of total female education fall below the sample mean ("low education" sub-sample). In this alternative, the low education sample results are similar to the poor sample above. The high education sample produced a small negative coefficient on the public education expenditure share that is statistically insignificant.

We also estimated the model using enrollment ratios for female education measures in lieu of the stock measures of years of education attained. The stock measure better matches in timing with the fertility variable, and is therefore our preferred measure, but we recognize that enrollment rates may influence fertility through the education/schooling choice. Conditioning the coefficient estimates on the public education expenditure share with female enrollment rates, yields coefficients on the former variable that are nearly identical (and statistically significant) to those calculated in the income generated sub-samples (our base-line model).[16]

Finally, we wanted to address the issue of the possible endogeneity of income in the model. We chose to include income per adult in the model rather than income per capita to minimize the possible endogeneity problem with this variable. That is, if fertility increases, this will, by definition lower output per capita but not output per adult. However, it is also possible for current fertility to lower current work effort and, therefore, fertility may be endogenous with respect to current output. Therefore, we also re-estimated the model using lagged output as an instrument for current output to diminish the possibility of endogeneity. In the less-developed sample, the magnitude of the coefficient on the public education expenditure share does not change and its statistical significance increases, while the coefficient estimates on the education variables decline in magnitude and lose their statistical significance. In the developed country sample, the magnitude of all coefficient estimates declines and the coefficients on both output and the public education expenditure share become statistically insignificant.

In summary, the finding of a positive correlation between the public educations expenditure share and fertility in less-developed countries survives a battery of sensitivity analysis. This contrasts with the negative correlation between the same variables in de-

[16]Interestingly, when both female primary and secondary enrollment rates are entered into the same regression equation in the less-developed country sample, the coefficient estimate on the primary enrollment rate is positive while that for the secondary enrollment rate is negative. This is not true in the developed country sample. Again, this offers evidence that initial increases in primary education have a positive effect on fertility.

veloped countries. The following section presents an over-lapping generations model with endogenous fertility and education choices. The model predicts that countries with low initial levels of human capital will settle into a steady-state with high fertility and low education while high initial human capital countries will experience unbounded output and human capital growth and a low fertility rate. Moreover, the low human capital countries will increase fertility when the public education expenditure share rises while high human capital countries will lower fertility. The features that drive this result are a (1) human capital technology that has increasing returns to scale in its inputs (average aggregate human capital and public education expenditures) and (2) fertility behavior that is increasing in public education expenditures while the latter remain below a critical value.

3. The Model

Our theoretical predictions are drawn from a three period over-lapping generations model with an endogenous fertility choice. More specifically, at each period of time, $t \in \mathbb{N}$, a new generation appears (is born). $N(t)$ members of this generation survive and spend the first period of life as children (making no economic decisions). In the second period of life, agents are young adults and start with a minimum level of productive skills, h_{min}, which they were born with or acquired during childhood. They are also endowed with one unit of time, which they allocate between human capital accumulation (schooling or training) and child-rearing.

We follow the standard "demand" model of fertility choice in assuming that agents enjoy parenthood; however, since time is scarce, agents face a trade-off between raising children and augmenting their own skill level. We adopt this formulation to capture in the sharpest and simplest way the deferment of marriage and child-bearing that characterizes the average individual pursuing secondary and higher education. (Table 3 presents cross-country data on women's fertility rate, average age at first marriage, years of schooling and secondary and tertiary education enrolment.)[17] For convenience, we also assume that individuals do not consume in the first two periods of life, although the case where they consume a fixed amount of output (endowed from their parents) can readily be introduced.

Finally, in the last period of life, old adults supply labor inelastically (the time endowment is again normalized to one) and enjoy consumption of a single good. Naturally, the higher is the individual's human capital acquired in the previous period, the more consumption they will command this period. The lifetime preferences of an individual born at time $t-1$ are given by the simple utility function:

$$U_{t-1} = \phi ln(n_t) + (1-\phi) ln(c_{t+1}), \qquad \phi \in (0, 1/2), \tag{3.1}$$

[17] Cigno (1991) also discusses the evidence supporting later child-bearing for high-education females. Furthermore, evidence from developing countries suggest that increases in primary education are associated with an increase in the age of cohabitation. See Appleton (1996) and the references therein.

where n_t represents the number of children and c_{t+1} denotes consumption in the last period of life.

Young individuals at time t accumulate human capital according to the following learning technology, which is similar to the technology adopted by Glomm and Ravikumar (1992):[18]

$$h_t = h_{min} + E_t^{\alpha} H_{t-1}^{\gamma} e_t, \qquad \alpha \in (0,1),\ \alpha+\gamma > 1 \tag{3.2}$$

where E_t, H_{t-1}, and e_t denote, respectively, public provision of education services per old person (or as explained below per tax-payer), the average level of human capital of the previous generation ($H_{t-1} = \sum_{i=1}^{N_{t-2}} \frac{h_{it-1}}{N_{t-2}}$) and time devoted to education by the young adult.[19] The fact that $\alpha+\gamma > 1$ is important for dynamic properties of the model. It can be justified in a variety of ways (see, for example, Romer (1986), Boldrin (1992b), and Azariadis (1996, especially Sections 4.1, 4.4, and 4.5)). Finally, note that human capital accumulation is linear in e_t purely for convenience; it allows us to obtain a closed-form solution of the model.

The empirical results presented above indicate that fertility responds to increases in the public education expenditures share positively in less-developed countries and negatively in developed countries. As discussed in the introduction, the positive reaction of fertility may be a result of increased health World Bank (1984) and Schultz (1981)], decreased breast-feeding [Trussel, et. al. (1992) and Appleton (1996)], the diminution of taboos [Dasgupta (1995)], or the persistence of norms against female participation in market activity [Goldin (1995)].[20] The empirical results do not distinguish between these different mechanisms nor will the mechanism below. We simply view the increase in education at low levels of human capital as creating higher home productivity (where the major activity is assumed to be child-bearing). The increase in home productivity may be a result of any one or combination of the above factors. We suspect that different channels may be more prominent than others in specific regions or countries, but this does not deny the main conclusion that at low levels of human capital, increasing education tends to increase home productivity as well as market productivity. Because the positive effect

[18]We use uppercase letters to denote variables which are outside the control of each agent and lowercase letters to denote individual specific variables.

[19]In an earlier version of the paper we included education expenditures per person in school, $E_t \frac{N_{t-2}}{N_{t-1}}$, in the human capital accumulation equation. Here, we adopt the current formulation because it simplifies the algebra considerably, without changing the main results of the paper (since individual agents take education expenditures and the population size as given). An even more general formulation is the one where $E_t \frac{N_{t-2}}{(N_{t-1})^{\varepsilon}}$, $\varepsilon \in [0,1]$, enters in (3.2).

[20]For example, Trussel, et. al. (1992) find a nearly universal decline in breast-feeding with increases in education for those countries that participated in the World Fertility Surveys or the Deomographic Health Surveys. Appleton (1996) estimates that a woman with complete secondary education will reduce the duration of breastfeeding by eight months relative to a woman with no schooling. Also, Dasgupta (1995) states that "[i]n Sub-Saharan Africa, where polygyny is widely practiced, post-partum female sexual abstinence can last up to three years after birth." The views of the World Development Report (1984) and Goldin (1995) were summarized in the introduction.

of public education expenditures on fertility seems to be exhausted (or at least much less important) in developed countries, we presume that public education expenditures increase home productivity only at low levels of expenditures and human capital. On the other hand, increases in public education expenditures increase market productivity at all levels of expenditures and human capital.[21]

Thus, we presume the existence of a threshold level of public education expenditures, $\overline{E}$, after which increases in E will no longer be accompanied by increases in the number of children per household. The positive effects on fertility are fully exploited at lower levels of expenditures and fertility is governed by the following formulation:

$$n_t = \begin{cases} E_t^{\beta}(1-e_t) & if\ E_t < \overline{E} \\ \\ \overline{E}^{\beta}(1-e_t) & otherwise \end{cases} \quad , \qquad \beta \in (0,1). \tag{3.3}$$

Finally, the consumption good is produced with a constant returns to scale production technology:

$$y_{t+1} = Ah_t, \tag{3.4}$$

where $A > 0$ is a positive constant.

The government finances its spending with a proportional income tax on the working generation (old adults).[22] Thus, $E_t = \tau W_t h_{t-1}$, where τ, $\tau \in (0,1)$, is a constant tax rate and W_t represents the wage rate in period t.

Agents maximize their lifetime utility (equation(3.1)) subject to the learning technology (equation (3.2)), the "technology" for child-rearing,

$$n_t = [(1-j)E_t + j\bar{E}]^{\beta}(1-e_t), \tag{3.5}$$

and the private budget constraint,

$$c_{t+1} = (1-\tau)W_{t+1}h_t, \tag{3.6}$$

where $j = 0$ if $E_t < \overline{E}$ and $j = 1$ otherwise.

Firms maximize their profits subject to the production technology (equation (3.4)) by choosing labor in effective units (h_t) employed.

A competitive equilibrium for our economy consists of a set of sequences $\{e_t\}_{t=1}^{\infty}$, $\{n_t\}_{t=1}^{\infty}$, $\{h_t\}_{t=1}^{\infty}$, $\{c_{t+1}\}_{t=1}^{\infty}$, $\{E_t\}_{t=1}^{\infty}$, $\{N_t\}_{t=1}^{\infty}$, $\{W_t\}_{t=1}^{\infty}$, such that given $H_0 > h_{min} > 0$ and $N_1, N_0 > 0$, (i) each person's lifetime utility is maximized given H_{t-1}, E_t, W_t, (ii) firms maximize profits, (iii) the labor market clears, (iv) the government budget constraint is balanced every period, (v) $N_t = N_{t-1}n_t \ \ \forall t \geq 0$ and (vi) $H_t = h_t \ \ \forall \ \ t$.

[21] It will be discussed below that $\bar{E}$ will be linked to a critical level of human capital, $\bar{h}$. For levels of human capital below $\bar{h}$, the economy will converge to a low output (no growth) steady-state, while for levels of human capital above $\bar{h}$, the economy will converge to a steady-state growth path.

[22] The analysis would be unchanged if the government financed expenditures with a consumption tax.

The first-order necessary conditions with respect to n_t, e_t, h_t, and c_{t+1}, for the agent's problem are:

$$\frac{\phi}{n_t} = \lambda_{2t}, \tag{3.7}$$

$$\lambda_{1t} E_t^{\alpha} H_{t-1}^{\gamma} = \lambda_{2t} \left[(1-j)E_t + j\bar{E}\right]^{\beta}, \tag{3.8}$$

$$\lambda_{1t} = \lambda_{3t+1}(1-\tau)W_{t+1}, \tag{3.9}$$

$$\frac{1-\phi}{c_{t+1}} = \lambda_{3t+1}, \tag{3.10}$$

where λ_{1t}, λ_{2t} and λ_{3t}, $t = 1, 2, ...$, are the Lagrangian multipliers associated with equations (3.2), (3.5) and (3.6) respectively. These conditions equate the marginal product of its activity to its marginal cost.

The firm's maximization problem, on the other hand, yields $W_t = A \;\; \forall\, t \geq 1$. Also, the resource constraint for this economy, obtained by combining (3.6) with the government constraint, is

$$E_t + c_t = Ah_{t-1}.$$

Using the first-order conditions, the resource constraint and the equilibrium condition $H_{t-1} = h_{t-1}$, one can get:

$$e_t = 1 - \frac{\phi}{1-\phi}\frac{h_t}{\tau^{\alpha} A^{\alpha} h_{t-1}^{\alpha+\gamma}} = 1 - \frac{\phi}{1-\phi}\frac{h_t}{h_t - (1-\phi)h_{\min}}. \tag{3.11}$$

Furthermore, equations (3.2) and (3.5) can be rewritten as

$$h_t = (1-\phi)\left\{h_{min} + \tau^{\alpha} A^{\alpha} h_{t-1}^{\alpha+\gamma}\right\}, \tag{3.12}$$

$$n_t = [(1-j)\tau A h_{t-1} + j\bar{E}]^{\beta}(1-e_t). \tag{3.13}$$

Equation (3.12), together with the initial condition ($H_0 \geq h_{min} > 0$), describes the evolution of human capital. Given the dynamic path of h, (3.11) and (3.13) determine the evolution of e and n. Note that (3.12) implies that, for a wide range of parameters values, there is a poverty trap (see Figure 2).[23] Economies that start with an initial level of human capital between $h_{\min}$ and $\overline{h}$ converge to the human capital level h^*. On other hand, economies that start with an initial level of human capital above (the unstable steady-state level) $\overline{h}$ experience persistent growth.

[23]Boldrin (1992a) analyzes in detail the dynamic implications of external effects in a standard overlapping generations model with physical capital. He finds that a poverty trap always arises whenever persistent growth is possible.

3.1. Less-developed economies

Consider first the case of less-developed economies, that is, economies that are initially endowed with a low of human capital. For these economies we assume that $j = 0$. The stationary levels of human capital, fertility rate, and education effort, h^*, n^* and e^*, are given by the following simultaneous equation system:

$$h^* - (1-\phi)A^\alpha \tau^\alpha (h^*)^{\alpha+\gamma} = (1-\phi)h_{min}, \tag{3.14}$$

$$e^* = 1 - \frac{\phi}{1-\phi}\frac{1}{\tau^\alpha A^\alpha (h^*)^{\alpha+\gamma-1}}. \tag{3.15}$$

$$n^* = (E^*)^\beta (1-e^*) = \frac{\phi}{1-\phi}A^{\beta-\alpha}\tau^{\beta-\alpha}(h^*)^{1+\beta-\alpha-\gamma}, \tag{3.16}$$

It follows that if the government of a less-developed economy were to increase the percentage of GDP devoted to public education (i.e., $\tau \equiv \frac{E}{y}$ increases), then its steady-state levels of human capital, output and education effort would rise.[24] However, the effect on fertility is ambiguous and is given by the following expression

$$\frac{dn^*}{d\tau} = \frac{\phi}{1-\phi}A^{\beta-\alpha}\tau^{\beta-\alpha-1}(h^*)^{\beta-\alpha-\gamma}\left[(\beta-\alpha)h + (1+\beta-\alpha-\gamma)\frac{dh^*}{d\tau}\right]. \tag{3.17}$$

The ambiguity arises from the two competing effects on fertility engendered by the increase in the public provision of education. On the one hand, at low levels of education, increases in government provided services will tend to raise home productivity and, therefore, augment fertility. However, on the other hand, the increase in education also adds to market productivity and thereby enhances the incentives for an individual to pursue more education (lower the time spent raising children $1 - e$) and a higher consumption level in the following period. Nevertheless, it follows from (3.17) that if public spending on education is equally or more effective in contributing to home rather than market activity and the external effect of human capital is small then fertility will unambiguously rise. Put differently, $\beta \geq \alpha$ and $1 \geq \gamma$ are sufficient conditions for $\frac{dn^*}{d\tau} > 0$.

3.2. Developed Economies

We next consider the case where an economy spends at least $\bar{E}$ on public education.[25] The evolution of h_t, e_t and n_t is described by (3.11), (3.12) and (3.13), where $j = 1$. In this case economies experience persistent growth. Furthermore, e_t and n_t converge asymptotically to $(1-2\phi)/(1-\phi)$ and $\bar{E}^\beta\phi/(1-\phi)$, respectively.

[24] We consider a change in τ from an arbitrary point. For a model of public education financed through income taxation, whose rate is determined by majority voting, see Boldrin (1992b).

[25] $\overline{E}$ is as assumed to be greater or equal to the level of public education expenditure that corresponds to $\overline{h}$, that is, $\overline{E} \geq \tau A\overline{h}$.

Notice that an increase in the percentage of GDP devoted to education (increase in τ) tends to increase the returns to education and therefore raises the entire paths of human capital and education effort. Moreover, the dynamic path of the number of children per household shifts down as the opportunity cost of child-rearing increases. That is, $dh_t/d\tau > 0$, $de_t/d\tau > 0$, and $dn_t/d\tau < 0$, $\forall\ t$.

Summarizing, in less-developed economies when the initial level of human capital is low, an increase in the public education expenditure share will tend to raise human capital and output and increase fertility if the home productivity effect is strong relative to the market productivity effect. That is, at low levels of education, there is a positive relationship between the public education expenditure share and fertility, contrary to some popular beliefs. On the other hand, the negative relationship between fertility and public education expenditure shares does hold in developed economies. The dichotomy results from the dual contribution of education to both market and home productivity. In the presence of fertility threshold effects, developed economies have initial education and human capital levels that are sufficiently high so that increases in government provided education do little to improve home productivity. Therefore, in developed economies only the effect on market productivity prevails and increases in public education expenditure shares raise the opportunity cost of child-bearing and lower fertility. While in less-developed economies, increases in government provided education will increase fertility if the effect on home productivity dominates. Indeed, we saw in the previous section that the empirical evidence bears out the threshold effect of government provided education and supports the dichotomous effect in developed versus less-developed economies. We now return to the empirical evidence and add a bit of structure that is guided, in part, by theory.

4. Simultaneous Equation Estimates

The above theoretical section illustrates a potential problem in the single-equation baseline regressions, namely, the possible endogeneity of the female education measures with respect to fertility rates. A woman's education and fertility decisions may occur within the same period of life and, therefore, the desire to pursue more education is very likely to result in postponed and reduced fertility. Thus, while the female education rates do proxy for time costs (in terms of wages) as well as other important influences on fertility, there may also be a simultaneity issue in the statistical estimation. The theory also predicts that changes in the public education expenditure share will increase education, again implying that education may not be strictly exogenous. Therefore, we also re-estimated the model as a simultaneous equation system with the two endogenous variables being fertility and female education measures.

The seemingly unrelated regression (SUR) technique is used to jointly estimate parameter values for this two equation system. The system is "identified" by (1) using the share of investment in income to proxy for the return to labor under the common assumption of a positive cross-product between labor and capital in the production function and (2) by assuming that the infant mortality rate only affects female education decisions through its impact on fertility. So, the fertility equation contains the same set of conditioning variables as in the base-line model, while the education equation includes the fertility rate, the public education expenditure share, output per equivalent adult, the investment share and years of male education as independent variables.

Tables 4 and 5 show the results for the less-developed and developed sub-samples, respectively, using the fixed effects specification. Focusing first on the less-developed sample, any simultaneity bias present in the base-line results (Table 1) seems not to have distorted the main findings with respect to the effect of the public education expenditure share on fertility. In most cases, the magnitude of the coefficient estimates are quite similar to the base-line model as are the standard errors. In the simultaneous equation system, female education has a stronger negative impact on fertility relative to the base-line results and are estimated a bit more precisely. The same can be said for the positive influence of male education on fertility, while the coefficients on output per adult are similar to the base-line model. Turning to the education equation, the model suggests that increases in public education expenditure share should increase educational attainment. The data bear out this prediction with the strongest impact of higher spending occurring in secondary and higher years of education. Also notice that the investment share is positive and statistically significant in all education equations except higher education (there is very little female higher educational attainment in the less-developed country sample.) This is consistent with the motivation for its placement in the education equation: to capture higher returns to education engendered by industrialization. In fact, in the less-developed sample, investment share is more strongly related to female educational attainment than is output per adult. Finally, as suspected, fertility is negatively related to female educational attainment. In summary, the above evidence suggests that the simultaneous equation system for the less-developed sample may have allowed for more precise estimates of the impact of education on fertility. However, the conclusions with respect to the impact of public education expenditures on fertility are unchanged.

The system estimation of the fertility equation for the developed country sample (Table 5) also yields coefficient signs and magnitudes for the public education expenditure ratio that are very similar to the base-line single equation results, although they are estimated a bit more precisely in the systems estimation. Output per adult has a much stronger negative impact on fertility relative to the base-line single equation model. And, as for the less-developed sample, the magnitudes (in absolute value) of the education variables rise and the standard errors fall. Yet, the signs still remain positive and negative, respectively, for female and male education. The education equation also shows that output per adult is strongly positively associated with female educational attainment and, unlike the less-developed sample, is much more important than the investment share for explaining female educational attainment. Surprisingly, fertility is positively related to female educational attainment in the developed country sample. So that, after conditioning on income per adult and public education expenditure shares, fertility and female education tend to be positively related. Of course, this is consistent with the positive coefficient estimate on female education in the fertility equation.

While our preferred specification is fixed effects, we also estimated the system using the random effects specification. (See Tables 6 and 7.) In the less developed sample, the public education expenditures ratio becomes more important and female education becomes less important in explaining fertility. In the education equation, almost all of the variation in female educational attainment is accounted for by variations in output per adult and male education. In the developed country sample, the coefficient estimates on the public education expenditure share remain negative and are statistically significant in the equations using higher and total years of education. The coefficient estimates on female and male education remain, respectively, positive and negative in the fertility equation and the coefficient estimate on fertility and in the education equation remains positive in three of the four versions.

5. Conclusion

Our work has shown that increases in the share of output devoted to public education do not monotonically lower fertility rates as conventional wisdom might suggest. We believe this occurs because education not only increases market productivity but also has far reaching effects on the evolution of norms, beliefs as well as implications for health and well-being. We have used the catch-all term "home productivity" to refer to the set of mechanisms that shifts female activity toward child-bearing as education rises from initially low levels. In less-developed economies, the home productivity effect outweighs the market productivity effect and increases in the public education expenditure share tend to increase fertility. In more developed economies, however, the market productivity effect dominates and increases in the public education expenditure share decrease fertility.

Of course, this does not imply that the optimal government action is to withdrawal support for education. On the contrary, the empirical results show that most less-developed economies have not yet reached levels of education where the fertility decreasing impact dominates. Clearly, education, no matter what its estimable impact on output and fertility may be, promotes literacy and other social cohesion skills that are desirable in their own right. In fact, our results suggest that macroeconomists should devote more effort toward understanding the channels through which education influences macroeconomic outcomes. It is our intention to focus on the changing norms and institutions that education may promote and to explore their implications for macroeconomic growth, fertility and development.

References

[1] Appleton, Simon. "How Does Female Education Affect Fertility? A Structural Model for the Cote d'Ivoire." *Oxford Bulletin of Economics and Statistics*, February 1996, 139-166.

[2] Azariadis, Costas. "The Economics of Poverty Traps. Part One: Complete Markets." *Journal of Economic Growth* December 1996, 449-486.

[3] Barro, Robert J. and Jong-Wha Lee. "International Comparisons of Educational Attainment." *Journal of Monetary Economics*, December 1993, 363-394.

[4] Barro, Robert J. and Jong-Wha Lee. "International Measures of Schooling Years and Schooling Quality." *American Economic Review*, May 1996, 218-223.

[5] Boldrin, Michele. "Dynamic Externalities, Multiple Equilibria, and Growth." *Journal of Economic Theory* May 1992, 198-218.

[6] Boldrin, Michele. "Public Education and Capital Accumulation." Discussion Paper 1017, Center for Mathematical Studies in Economics and Management Science. Northwestern University, 1992b.

[7] Cigno, Allesandro. *Economics of the Family*, Oxford University Press, New York, 1991.

[8] Cochrane, Susan H. "Effects of Education and Urbanization on Fertility." In *Determinants of Fertility in Developing Countries*, Vol. II, Eds. Rodolfo Bulatao and Ronald Lee. New York: Academic Press, 1983, 587-626.

[9] Dasgupta, Partha. "The Population Problem: Theory and Evidence." *Journal of Economic Literature*, December 1995, 1879-1902.

[10] Galor, Oded and David Weil. "The Gender Gap, Fertility and Growth." *American Economic Review*, June 1996, 374-387.

[11] Galor, Oded and David Weil. "Population, Technology and Growth: From Malthusian Stagnation to the Demographic Transition and Beyond." *American Economic Review*, September 2000, 806-828.

[12] Glomm, Gerhard and B. Ravikumar. "Public versus Private Investment in Human Capital: Endogenous Growth and Income Inequality." *Journal of Political Economy*, August 1992, 818-834. .

[13] Goldin, Claudia. "The U-Shaped Female Labor Force Function in Economic Development and Economic History." in Investment in Women's Human Capital, Ed. T. Paul Schultz. Chicago: The University of Chicago Press, 1995, 61-90.

[14] Romer, Paul M. "Increasing Returns and Long-Run Growth." *Journal of Political Economy*, October 1986, 1002-37.

[15] Schultz, T. Paul. *Economics of Population*, Reading, MA: Addison-Wesley, 1981.

[16] Summers, Robert and Alan Heston. "The Penn World Table (Mark 5): An Expanded Set of International Comparisons." *Quarterly Journal of Economics*, May 1991, 327-368.

[17] Trussell, James, Laurence Grummer-Strawn, German Rodriguez and Mark Vanlandingham. "Trends and Differentials in Breastfeeding Behaviour: Evidence from WFS and DHS." *Population Studies*, July 1992, 285-307.

Table 3: Cross-Country Data

Countries	TFR 1992	MA 1980-90	AYS 1992	FSER 1990	FTER 1990
Sub-Saharan African	6.1	19.0	1.0	15	1.1
Least Developed	6.5	18.7	0.9	12	0.9
OECD	1.8	25.3	11.0	85	47.0
Nordic	1.9	28.7	11.2	88	55.0

Source: UNDP, Human Development Report 1994 and 1995

Key: TFR: Total fertility rate
MA: Women's average age at first marriage
AYS: Average number of years of schooling received per woman aged 25 and over
FSER: Female secondary education enrollment ratio
FTER: Female tertiary education enrollment ratio

Number of Countries in Each Group:

Sub-Saharan Africa:	44
Least-Developed Countries:	45
OECD:	25
Nordic:	5