Evidence on the Demographic Transition

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Abstract

This paper finds that fertility responds to productivity differently depending upon the economy’s stage of development. At low levels of development, productivity increases will increase fertility while at the more advanced stages of development, productivity increases lower fertility. During the process there may be important interaction effects between productivity and education demand. Increases in secondary education demand generate fertility declines regardless of the stage of development.

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1 Introduction

Malthus and Ricardo proposed a dismal outlook for standards of living in pre-industrial economies. Before the mid-nineteenth century high-fertility, low-productivity economies tended to respond to increases in income with proportional increases in population. This classical Malthusian population dynamic, driven by fixed factors of production, ensured stagnant living standards. Obviously, every currently “rich” economy experienced a reversal of that fertility dynamic. As income growth accelerated in industrializing economies, fertility rates dropped precipitously during a transitional phase and the current phase, characterized by sustained increases in per capita income, began. Following the above pattern, the fertility path for the early developers was not monotonic. Fertility rose before it fell, generating an inverted-U time path. \(^1\) Recently, models of very-long-run growth or unified growth seek to characterize, within one framework, the distinct phases of the growth process from low productivity and high fertility (classical Malthusian dynamics) and the transition to modern sustained-growth dynamics. The demographic transition is a key force driving the transition from the classical Malthusian dynamics into the sustained growth regime.

This paper provides empirical evidence on the fertility dynamics in modern-day economies where the specification and interpretation are motivated by these recent theoretical models of the demographic transition. In a sample of 95 countries with data in 5-year averages from 1960-64,..., 1995-99, there are observations from economies that have not yet experienced a demographic transition, observations from economies that are in the midst of the transition and observations from economies that are in the post-demographic transition phase. Therefore, the data provide observations of fertility dynamics in different phases of the growth process. The goals of this study are threefold: (i) to determine if the inverted-U fertility path is relevant for modern developers, (ii) to determine whether fertility dynamics (the relationship between fertility and other variables) differs across the various stages of development, in contrast to studies that seek to determine the long-run relationship between fertility and other variables, and (iii) to determine whether the fertility path depends on interactions between other variables. These goals are motivated by the theoretical literature summarized below. Moreover, an instrumental

\(^1\)See Dyson and Murphy (1985) and Galor (2005) for a detailed discussion of historical fertility patterns.
variables and general methods of moments estimator is employed to diminish the endogeneity bias that normally plagues cross-country econometric analyses.

The recent models of the demographic transition feature endogenously evolving productivity and a critical point where fertility dynamics change. Galor and Weil (2000) and Galor (2005) outline a human capital-based model of the demographic transition where the acceleration of productivity growth rates raise the return to human capital investment and triggers the substitution into child-quality and out of child-quantity. The model produces three distinct dynamical systems through which the economy transits endogenously as it proceeds through the development process. In Jones (2001) analytical model, fertility traces an inverted-U path as a function of the productivity level. Higher productivity lowers the relative price of subsistence consumption and generates a dominant income effect on fertility in the early stages of development. As productivity increases further, the income effect becomes increasingly weak relative to the to substitution effect and households substitute out of children and into consumption. In general, the theoretical models generate two well-defined dynamic regions, one where productivity and fertility are positively related and another where productivity and fertility are negatively related. The dynamics in Galor and Weil (2000), produce three distinct dynamical systems, specifically characterizing the system between the Malthusian regime and the modern growth regime. Therefore, the empirical implementation below will investigate the empirical evidence for multiple regimes with respect to fertility dynamics.

The key features of the models described above were motivated by the experience of the early developers. However, if that fertility dynamic is unique to early developers rather than a universal phenomenon, then the emphasis on that particular dynamic is mis-placed. Moreover, the evidence from

early developers consists solely of unconditional fertility plots. The different
timing of education increases in early developers relative to modern devel-
opers motivates the third objective of this study. In the former, education
rises after industrialization creates a demand for skilled labor while in mod-
ern economies education often increases before industrialization reaches a
critical mass.

While this paper draws on the ideas of the models of the very-long-run
growth process, the empirical investigation does not provide a structural
framework from which to judge one model of the long–run growth process
relative to the others. This study takes the fertility dynamics common to
these models and asks if this dynamic is relevant for modern day developers.
The econometric models include independent variables that these models sug-
gest are important factors for the fertility process: education levels (parental
human capital), education demand, productivity and productivity growth.
Furthermore, unique data and econometric approaches of the study include:
(i) the use of a fertility measure (the net reproductive rate) that accounts for
the impact of changing mortality on fertility patterns, (ii) its use of product-
itivity as an explanatory variable for fertility and (iii) the use of instrumental
variables to minimize the endogeneity bias.

The analysis examines four specifications, each of which has a slightly dif-
f erent take on the form of the non-linearity. In the first specification fertility
is hypothesized to be a quadratic function of productivity. This specification
asks if fertility responds non-linearly to productivity changes while changes
in other variables affect fertility monotonically. The second specification ex-
amines whether the non-monotonic fertility path is a result of interactions
between education and productivity levels. The third specification estimates
a threshold model where the structural break estimate allows all the slope
coefficients to differ between two regimes. Finally, I investigate the possibil-
ity of three distinct regimes as described in Galor and Weil (2000) and Galor
(2005) by sorting the economies into one of three pre-defined fertility regimes
based on their fertility levels at the beginning of the period: pre-demographic
transition (high fertility), transition economies and post-demographic transi-
tion (low fertility) economies. The regression equations allows all variables to
affect fertility differently depending on the economy’s stage of development.
This specification is valid only if the null hypothesis of three distinct regimes
is true. Otherwise, the estimates will be biased.

The results below will show the following: (1) Fertility follows an inverted-
U path as response to productivity increases. The critical values for a shift
in the dynamics from a positive to a negative fertility response may depend upon the level of productivity and/or the demand for education. In other words, economies in different phases of the growth process have different fertility dynamics. In particular, increases in productivity increase fertility in the early stages of development while in later stages of development productivity increases lower fertility. (2) Secondary enrollment rates appear to have a robust and nearly universal negative effect on fertility while primary enrollment rates tend to assert a positive effect on fertility.

Section 2 below presents some background, introduces the data and offers graphical depictions of the unconditional pattern of fertility. The visual evidence alone strongly suggests an inverted-U fertility pattern in modern pre-transition economies as well as different dynamics in different stages of the growth process. Section 3 details the econometric results by specification, while Section 4 concludes the paper.

2 Specification and Data

Most empirical studies of fertility and growth have utilized data averaged over long time spans (often the entire availability of the data). These studies tend to find negative relationships between fertility and other measures of economic development. In a slight departure from the norm, Barro and Sala-i-Martin (1995) using cross-country observations in 1965 and in 1985 and a two-equation SUR system with fertility and life expectancy as the two dependent variables, found a significant quadratic specification for income in the fertility equation. In fact, Barro and Sala-i-Martin’s results hint to some of the findings in this paper. Their quadratic income relationship is an inverted-U relationship. (However, they use only two observations over time, they do not explore other possible interactions or thresholds, nor do they use instrumental variables.) They interpret the income relationship as the Malthusian mechanism operating in the low-income countries. They also find that the male primary education enrollment rate and the female secondary and higher education enrollment rate are positively related to fertility while the female primary education enrollment rate and the male secondary and higher education enrollment rate are negatively related to fertility. With the exception of the Barro and Sala-i-Martin (1995) long-run regressions, the empirical fertility and growth literature has been relatively silent on the possible non-monotonic fertility path as an economy experiences a demographic
transition.\(^3\) Moreover, there are too few studies that attempt to tackle the endogeneity obstacles blocking causal inferences.

Since the theoretical literature normally speaks to desired number of surviving children per household, the dependent fertility variable in all specifications is the net reproductive rate (NRR).\(^4\) NRR is “the average number of daughters a hypothetical cohort of women would have at the end of their reproductive period if they were subject during their whole lives to the fertility rates and the mortality rates of a given period. It is expressed as number of daughters per woman.”\(^5\) The more often used total fertility rate does not make adjustments for mortality. Therefore, decreases in the total fertility rate may occur either because mortality has declined and fewer births are needed to achieve a desired number of surviving offspring or because the number of desired surviving offspring has declined. It is the latter concept that is normally implicit in the theoretical models.

The regressors will include one of three measures for productivity, a measure for parental human capital, two measures for education demand, productivity growth and the pupil to teacher ratio in primary schools. The data are a pooled cross-section time-series sample with 95 countries and eight time-series observations per country. Each time-series observation is an average over one five year interval spanning the period 1960-64 to 1995-99.\(^6\) Therefore, the data include information about changes within countries as well as information about differences between countries.

The productivity measures are GDP per worker, total factor productivity as calculated using the Solow residual methodology without any quality adjustment for labor (TFP) and total factor productivity with a human capital component (Augmented TFP).\(^7\)

There are two types of education variables in the fertility equation: (i)
measure of average education levels and (ii) enrollment rates (primary and secondary). The former variable measures the average total years of schooling for the population over 15 years of age at the beginning of the 5-year period. Therefore, this measure reflects the education level of potential parents at the beginning of the five-year period before their fertility decision for that period is realized. While this variable may not be strictly exogenous, it is pre-determined to the period’s fertility decision. (In fact, statistical tests never find this variable endogenous.) The variable is meant to capture the impact of parental human capital on fertility. Increases in parental human capital can generate both positive and negative influences on fertility. The positive effects act through non-price channels that improve health and fecundity often emphasized in the demography literature.\(^8\) Education may also remove sexual taboos and increase the incidence of postpartum coitus. (See Dasgupta (1995).) Finally, education may help to break down social stereotyping and encourage female participation in the labor-force. However, if the change in norms lags behind education changes then initially female labor force participation might decline and fertility rise.\(^9\) In fact, it seems to be widely accepted among demographers that the positive supply side incentives of higher education dominated the negative demand side implications in many countries, particularly in Africa, during the 1970s and 1980s. There has been some evidence of a positive effect of education on fertility documented in the demography literature. Cochrane (1993) offers a survey of these results. With a few exceptions, this fertility dynamic has been largely overlooked in empirical studies by macroeconomists. On the other hand, in-

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\(^8\)See, for example, World Bank Development Report (1984) and Schultz (1981). The latter study argues that “the supply [of children] schedule may be upward sloping [with respect to education], perhaps because more educated mothers are healthier and have a greater fecundity, and their offspring have enhanced survival prospects” (pp. 127-128). Additionally, Trussel, et al. (1992) find that breast-feeding declines as education rises in developing countries (breast-feeding produces a natural contraceptive).

\(^9\)Goldin (1995) shows that female labor force participation initially decreases with increases in income. She offers two, not mutually exclusive, explanations. First, an increase in income could generate an initial income effect allowing female specialization at home and male specialization in the market. The second possibility is that initially income increases are associated with movements toward market production and away from home production. However, initially norms prevent female participation in the market and so female labor force participation declines. Notice that the impact of increases in income on female labor force participation could also be part of the explanation for rising fertility as income increases since the decline in female labor force participation might enable higher fertility.
creases in parental human capital can also increase the opportunity cost of parents’ time and lower fertility by raising the time cost of child-rearing (e.g. Becker, Murphy and Tamura (1990), Galor and Weil (1996)). Thus, parental human capital can generate fertility movements independent of productivity changes.

The enrollment variables capture the current demand for education. While certainly a very important component of the demand for education will be driven by productivity increases, there may also be an increase in the demand for education driven by non-productivity channels, particularly, by changes in the cost of school attendance (including travel time, book and uniform costs, level of subsidies, etc.). See Pritchett (2001) for a discussion of education increases without productivity increases. In summary, while a very important channel (perhaps the most important channel) through which education demand influences fertility is through the induced demand for education arising from productivity changes, education demand can influence fertility decisions independent of productivity movements.

Also note that it is possible for increases in productivity to alter fertility decisions independent of their influence on the demand for education. For example, in Jones’ (2001) model does there is no educational choice variable. Instead, productivity increases generate both an income and a substitution, where the latter is the substitution of children for consumption. Therefore, both productivity and education should be included in the estimation to avoid omitted variable bias, even at the cost of multicollinearity.

Productivity growth is included as an regressor because in Galor and Weil (2000) and Galor (2005), it is the acceleration in productivity growth that generates the incentive for households to substitute child-quantity for child-quality. Finally, the pupil-teacher ratio in primary schools attempts to measure differences in education quality across countries and over time.

Figure 1 depicts the unconditional relationships between fertility (NRR) and the regressors. Each point on the figure is one five year observation for one country and all variables (except productivity growth) are logged. Even in the unconditional plots, one can discern an inverted-U fertility dynamic.

There is a high degree of correlation between productivity, education levels and secondary enrollment rates and this will make it difficult to tease out of the data the relative causal contributions of each of these variables in

\footnote{Only the plots of TFP and Augmented TFP against fertility have been omitted since those plots are essentially the same as the plot of output per worker in relation to fertility.}
generating fertility movements. However, the main purpose of this paper is not to conduct a structural test of competing theories of the demographic transition, but to determine if the fertility dynamics of modern economies are consistent with models of very-long run growth. As will be shown in the next section, despite the correlation, the estimates indicate that enrollment in secondary education produces a strong negative influence on fertility. That is, even when productivity and education levels are included in regressions along with secondary enrollment rates, the independent influence of the latter variable is strong enough to yield a statistically significant negative effect on fertility. Moreover, the results will show a non-linear relationship between productivity and fertility, conditioned on the strong negative impact of secondary enrollments.

Because the education variables and the productivity variables maybe endogenously determined with fertility, instrumental variable GMM estimation is used to minimize the endogeneity bias. The instruments used in this study are the number of telephones per adult, the number of newspapers per adult, the number of radios per adult and the ratio of quasi money to GDP. The first three variables are social indicators that do not directly affect the fertility decision but are correlated with productivity and education variables. The use of the ratio of quasi-money to GDP is motivated by the literature that links financial development to economic development. None of these variables are direct causal factors with respect to fertility decisions, but they are correlated with productivity and education. Table A1 in the Data Appendix shows the covariance matrix between the instruments and the endogenous regressors.

11 An alternative and innovative approach to avoid endogeneity bias was used by Schultz (1985) who, with mid-nineteenth century Swedish time-series data, used an exogenous change in the terms of trade for livestock and dairy products (production that employed primarily female labor) to isolate an exogenous change in female income relative to male income. For details on other studies, see Hotz, Klerman and Willis (1997) for a survey of empirical research of fertility determinants in developed economies.

12 The instruments are deflated by the number of adults rather than by the population to avoid any feedback between fertility and instruments. The data are available in per capita form, but were transformed to per adult form by counting the percentage of the population over 14 as the adult population. The conversion was made so that fertility changes within the period will not affect the instrument within the same period. The first two variables are used in Easterly (1999).

13 See, for example, King and Levine (1993). Levine (1997) surveys the finance and development nexus.
For each regression equation, each regressor is tested individually for endogeneity. Those variables for which the null hypothesis of exogeneity cannot be rejected are then treated as exogenous. Furthermore, for each regression equation, each instrument is tested individually for validity. If the (joint) null hypothesis of the orthogonality of the tested (and non-tested) instruments can not be rejected, the instrument remains in the instrument set. In all specifications the secondary enrollment rate tested as endogenous and in some cases, the productivity measure tested as endogenous. However, the primary enrollment rate, average years of education and the productivity growth rate never tested as endogenous. Since the secondary enrollment rate is likely to capture the decision to stay in school or to have children, it seems reasonable that this variable should test as endogenous. Also, it is likely the best indicator of current education demand across countries. The primary enrollment rate, on the other hand is probably does not pick up much of the decision to stay in school or to have children. Since average years of education is pre-determined, it is also reasonable that this variable might reasonably be orthogonal to the error process.

In the section below, the possibility of a non-linear fertility dynamic is investigated in three ways. First, fertility is hypothesized to follow an inverted-U pattern related to the level of development. Therefore, productivity levels are entered quadratically while the other variables are entered linearly. In this specification only fertility’s response to productivity changes over the development process and the turning point is estimated as the peak of the inverted-U. The second specification, allows for non-linearity through interaction effects. Specifically, the specification allows for fertility dynamics with respect to productivity to depend upon the demand for education and the dynamics with respect to demand for education to depend upon the productivity level. This specification is motivated by the experience of early developers relative to modern developers. For the early developers, educa-

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14 The test is evaluated using the C-statistic - the difference between the Sargan-Hansen statistic generated by the regression treating the variable as endogenous and and Sargan-Hansen statistic generated by the regression treating the variable as exogenous.

15 Again, the test is evaluated using the C-statistic - the difference between the Sargan-Hansen statistic generated by the regression estimates using the instrument in question and and Sargan-Hansen statistic generated by the regression not using the instrument in question.

16 As will be discussed later, the primary enrollment rate is most likely capturing some of the non-price influences on fertility that occur as education increases at low initial levels of education.
tion did not increase in the initial stage of the industrial revolution because
the increased demand for labor was predominantly a demand for unskilled
labor. As the industrial revolution progressed, the increase in education was
generated by an increase in the demand for skilled labor and was associ-
ated with increasing economic growth rates. That is, education increases
were driven by industry’s demand for educated labor. In many modern day
developing economies, education has increased without the concomitant in-
crease in demand for skilled labor and without the associated acceleration in
growth rates. In modern developing economies demand for schooling may
be influenced by governmental or humanitarian efforts to increase education
rather than by industry’s demand for skilled labor. This observation prompts
the interaction specification which will seek to determine if a critical joint
level of productivity and eduction demand must be achieved to trigger a de-
ographic transition? The third specification estimates a threshold model
where fertility’s response to all regressors can vary between two regimes.
The data determine the point in the development process where the fertility
dynamics shift. The threshold model is ideal for estimating regime shift; however, the methodology developed for IV/GMM estimation by Caner and
Hansen (2004) allows for the estimation of only one threshold (two regimes).
If Galor and Weil’s (2000) model correctly characterizes growth dynamics,
there are three distinct regimes. To investigate this the final specification
divides the sample into three subsamples: a pre-transition (high fertility)
sample, a post-Malthusian (transition) sample and a modern growth (low
fertility) sample. I then estimate a specification that allows the fertility dy-
namics to differ across these three regimes. The specification is valid only if
the null hypothesis of three distinct regimes is correct. Thus, the different
specifications consider alternative (although not mutually exclusive) sources
of the linearity: (i) arising solely from productivity movements, (ii) generated
by interaction effects and (iii) due to a structural break affecting fertility’s
response to all variables.

Since the central theme of this study is to determine whether the fertility
path over demographic transition is non-monotonic before proceeding I used
Ramsey’s regression specification error test, to examine whether a linear
version of the regression equation suffices to capture the dynamics. If linearity

\footnote{17For a discussion of fertility and related variables in the early developers, see Galor (2005). For analyses of the impact of education in modern-day developers, see Pritchett (2001) and Krueger and Lindahl (2001).}
is sufficient, then non-monotonicity can be ruled out. Using the IV/GMM estimator, the basic fertility equation is estimated as a log linear function of the education variables, the productivity variables and the pupil teacher ratio. The residuals from this linear specification were squared and cubed and the higher order residual terms were inserted into the linear fertility equation. The coefficient estimates on cubed residuals when included in the fertility equation were statistically significant, indicating the presence of non-linearity. While the specification test does not offer much guidance as to the functional form of the non-linearity, it leaves open the possibility of non-linearity in the fertility dynamics.

3 Results

3.1 Quadratic Specification

Prior to presenting the econometric results, it is interesting to note that there is a visible unconditional inverted-U fertility path for some less-developed economies. Figure 2a plots the country-specific total fertility rate and net reproductive rate for the sub-sample of countries that I have designated as “pre-transition” countries - those countries that have initially high total fertility rates (at least 6.0) and whose fertility rates remain high for at least 10-15 years. Of the 95 countries in the sample, 31 fall into the pre-transition/high-fertility category. Some of these countries begin to transition during the sample while others do not. The motivation for this categorization is that the upper leg of the inverted-U occurs, of course, before the downward leg. So, if an inverted-U is present in the data, the upper leg will occur only in the countries that have not yet begun the fertility transition. Also keep in mind that some of the high fertility countries may have experienced an unconditional fertility rise before the sample period so that even if an inverted-U is a universal unconditional phenomenon, the available data may show only the downward leg. About 13 of these high-fertility countries have unconditional

\[18\] All variables except productivity growth are logged.

\[19\] The sample was divided by applying the criterion to the total fertility rate since previous literature has focused on “high” and “low” fertility based on total fertility rates. The econometric results that are based upon the fertility regime categorization were also done using an alternative categorization based on the net reproductive rate. The conclusions are very similar and more details are given in the next section. Table A2 in the Data Appendix shows which countries fall into which fertility regime.
fertility paths displaying an obvious upward trend preceding a fertility decline or plateau when measured with the total fertility rate. Moreover, when the net reproductive rate is used to measure fertility, almost all countries in this sample experience an initial fertility rise.

Therefore, the first econometric specification posits that fertility rates are a quadratic function of productivity. Table 1a presents the results that indicate there is strong support for an inverted-U fertility path driven by productivity levels. The point estimates imply a range of output per worker between $8000 and $10,800 for the peak effect of productivity on fertility\textsuperscript{20} When output per worker is the measure of productivity, the point estimates indicate that the inverted-U peaks at around $10,800. When TFP is used as the productivity measure, the median value of output per worker within plus or minus one-tenth of a log point around the value of TFP at the peak of the inverted-U is approximately $8000.\textsuperscript{21} When augmented TFP is used as the productivity measure, the median value of output per worker within plus or minus one-tenth of a log point around the value of augmented TFP at the peak of the inverted-U is approximately $8900.\textsuperscript{22}

To illustrate the range of observations over which the quadratic estimates imply a positive effect of productivity on fertility, the first vertical line on the plot of fertility in relation to output per worker in Figure 1 is drawn at a value of output per worker of $9400 - the midpoint between $8000 and $10,800. About 40\% of the observations have values for output per worker less than $8000 while just under 50\% of the observations have values for output per worker less than $10800. Thus, for much of the sample, increasing productivity will create the partial effect of increasing fertility.

Another robust result in this set of equations is that secondary enrollment rates are always negative and highly statistically significant. When productivity is represented with either of the TFP measures, the magnitude of the coefficient estimate on secondary enrollment is lower relative to the magnitude in the equation that uses output per worker as a productivity measure,

\textsuperscript{20} All values for output per worker are in 1996 dollars as reported in the Penn World Tables version 6.1.

\textsuperscript{21} The point estimates imply that the inverted-U peaks at a value of 5.9 for the log of TFP. For the 48 observations whose value of the log of TFP are between 5.8 and 6.0, the median value of output per worker is approximately $8000.

\textsuperscript{22} The point estimates imply that the inverted-U peaks at a value of 6.2 for the log of TFP. For the 32 observations whose value of the log of TFP are between 6.1 and 6.3, the median value of output per worker is approximately $8900.
however the difference is not statistically significant. The results also show a positive effect on fertility from the demand for primary education. Both the positive impact of primary enrollment on fertility and the negative impact of secondary enrollment on fertility will be echoed in the results that follow.

The above equations were re-estimated for the sub-sample of countries that excludes economies that have already experienced the demographic transition: those 28 economies who begin the sample with low fertility (total fertility rate less than 4.0) and whose fertility remained below that level during the sample period. These are denoted the post-demographic transition economies. If the quadratic relationship is driven by increasing fertility in the pre-transition phase and declining in fertility during the transition, but with a different set of dynamics in the modern growth phase, then the quadratic relationship should remain stable between the full sample and the stated sub-sample. Table 1b shows results for this sub-sample and the implied peak in the quadratic for each equation is very similar to the peaks given by the full sample. For the equation using output per worker, the peak is exactly the same. For the equation using TFP, the median output per worker for observations plus or minus .1 log points from the peak estimate is $8700 while that for the equation using augmented TFP is $9000.

The similarity in estimated peaks implies that the omitted observations contribute little to the estimates for the quadratic nature of the dynamic. By implication, the inverted-U dynamics are driven mostly by those economies that have not yet experienced a complete demographic transition.

In all cases the coefficient estimates on productivity growth are negative and the coefficient estimates for the pupil teacher ratio are positive, but none are statistically significant.

### 3.2 Productivity-education interactions specification

In this specification fertility movements depend on a critical interaction between productivity levels and education demand. As previously discussed, this idea is motivated by the observation that in modern-day developers, demand for education may increase for reasons other than an increase in demand arising from market forces. Therefore, there may not be a critical level of productivity or education alone that would trigger a demographic transition, but that the critical value of one variable is dependent upon the level of another variable.

There are several potential mechanisms that could produce an interaction
effect between productivity and education demand. For example, it may be that education demand’s depressing effect on fertility requires the return to education to be sufficiently high and the latter is linked to the level of productivity. That is, perhaps sufficient market opportunities must exist to sell skilled labor if the quality/quantity or time-cost mechanism is to be effective. Alternatively, there may be some threshold level of returns to education beyond which the positive income effect of higher productivity is dominated by the negative substitution effect.

Table 2 shows the results of regressions with an interaction term between productivity levels and demand for secondary education. The coefficient estimate on secondary enrollment is positive while the interaction term coefficient is negative. This implies a critical productivity level after which secondary enrollment rates decrease fertility and before which the impact of secondary enrollment is positive. However, the critical value implied by the point estimates is below or approximately the same as the smallest value in the sample for all three productivity measures. Therefore, as in the quadratic specification, secondary enrollment rates have a universal negative impact on fertility. Also, primary enrollment rates have a positive influence on fertility, although not statistically significantly so at the 95% confidence level when the productivity is measured with augmented TFP.

The results with respect to productivity are similar to those found in the quadratic specification. For each measure of productivity, the coefficient estimate on the productivity variable alone is positive and highly statistically significant. The coefficient estimate on the interaction term is negative and also highly statistically significant. Therefore, increases in productivity will increase fertility at low levels of education demand and decrease fertility after a critical rate of education demand is achieved. Moreover, the negative effect of productivity on fertility increases with the level of education demand. The critical values of secondary enrollment are approximately 39%, 43% and 34% for output per worker, TFP and augmented TFP respectively. Approximately 34%, 38%, and 29% of the observations fall below the critical value for each of the productivity measures, again, respectively. The plot of fertility against secondary enrollment rates in Figure 1 includes a vertical line drawn at a secondary enrollment rate of 40% to give an approximate view of

23The critical values are 5.44, 3.96, and 4.5 for the log of output per worker, log of TFP and the log of augmented TFP, respectively. The respective minimum values in the sample are 6.43, 4.24 and 4.35. There are two values of the log of augmented TFP below the critical value of 4.5, they are 4.35 and 4.41.
the range of observations that fall above and below the critical value.

In summary, this specification mirrors many of the results of the quadratic specification: the negative influence of secondary enrollment rates, the positive effect of primary enrollment enrollment rates and the inverted-U fertility path generated by productivity levels. The difference between specifications is that in the interactions specification the change in dynamics is achieved when secondary enrollment rates reach a critical level (approximately 40%) whereas in the quadratic specification the change in dynamics occurs at a critical level of productivity (approximately $9400 of output per worker).

### 3.3 Threshold specification

This section presents results from a specification that allows fertility dynamics with respect to all the variables to differ between regimes. Using Caner and Hansen’s (2004) methodology for estimating the threshold of a regime change in the presence of endogenous variables (i.e. using an IV/GMM estimator), I search for a data-determined structural break. The analytical models suggest that the structural break should occur at some crucial point in the development process when productivity levels reach a critical level. The methodology posits that the relationships between fertility and the regressors is linear, but that the linear relationship shifts after a critical level of productivity is achieved. The threshold variable must be an exogenous variable, therefore the estimation results presented below use the instrument telephone main lines per adult as the threshold variable. Among the instrumental variables, telephone main lines per adult is the most highly correlated with the productivity measures (its correlation coefficient with respect to output per worker, total factor productivity and augmented total factor productivity is .90, .79 and .89, respectively). Moreover, statistical tests confirm that this variable is exogenous for each of the threshold regression equations. Figure 3 shows the unconditional plot between the threshold variable and the three productivity measures.

To judge the statistical significance of the estimated break point as recommended in Hansen (2000), Figure 4 graphs the LR statistic for the possibility of a structural break over each potential value of the threshold variable. The estimated threshold occurs at the trough of this plot. If the plot resembles a sharp V-shape with steep sides, the threshold estimate is fairly precise. The horizontal line delineates the critical value at the 95% confidence level. For all points of the plot below this line, one cannot reject, at the 95% confidence
level, the hypothesis that those values denote structural break points. As the graphs indicate, the trough (the structural break point) is well defined and statistically significant.

The estimated structural break (where the LR statistic reaches its minimum) occurs at a value of -2.905 for the log of telephone main lines per adult when productivity is measured with output per worker or augmented TFP and -2.77 when productivity is measured with TFP. The threshold level corresponds to a level of output per worker of approximately $13,700. Interestingly, if I restrict the threshold estimation to exclude the post-transition economies, the estimated threshold also occurs at a value of -2.905 for the log of telephone main lines per adult for all productivity measures. This echoes the findings from the quadratic specification where the estimated peak was virtually identical when the post-transition economies were excluded from the sample. The second vertical line on the plot of fertility against output per worker in Figure 1 is drawn at $13,700. This threshold level is larger than estimated peak effect in the quadratic specification, but the threshold estimate takes into account the possibility of all coefficients changing from one regime to the other while the quadratic specification allows only the dynamics with respect to productivity to change.

Table 3 presents the estimates of fertility’s relationship to the other variables in the low productivity regime (where value for the telephone main lines per adult is below the threshold value) and in the high productivity regime (where value for the telephone main lines per adult is above the threshold value). The point estimates indicate that not only does fertility’s response to productivity differ across regimes, but there is also a pronounced difference in fertility’s response to the education variables. However, the coefficient estimates are only statistically significantly different between regimes for productivity (for all productivity measures) and parental education (except when productivity is measured with TFP). Productivity increases generate higher fertility in low-productivity economies and lower fertility in high productivity economies. Once, again the data produce an inverted-U fertility dynamic with respect to productivity movements. Moreover, there is no other variable other than productivity that is statistically significantly posi-

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24 The median value of output per worker within plus or minus 0.1 log points of the -2.905 threshold is $13,688, the mean is $14,225 and there are 20 observation in this range. At the threshold value of -2.77, the median value of output per worker within plus or minus 0.1 log points threshold is $13,789, the mean is $15,346 and there are 15 observation in this range.
tive in low productivity economies and statistically significantly negative in high-productivity economies.

Parental human capital, on the other hand, tends to lower fertility in low productivity economies and increase fertility in high-productivity economies - generating a U-shaped fertility response. However, the impact of parental human capital is never statistically significant when productivity is measured with TFP and is only statistically significant for the high-productivity economies when productivity is measured with output per worker. While it should be expected that parental human capital could have an ambiguous impact on fertility (as a result of the positive and negative effects discussed in the previous section), the expectation would be for the positive effects to be strongest in the low productivity economies. Yet, the data disagree. Apparently, for any given productivity level, those high productivity economies with higher parental education will tend to have higher fertility. Also notice that the results from the quadratic and the interactions specification also yield positive (but insignificant) coefficients on the parental education variable. On the other hand, the coefficients on the primary enrollment rate is statistically significantly positive in the low productivity regimes. Recall that the coefficients on primary enrollment rates were positive in both the quadratic and interactions specification as well. It is likely that the positive impact on fertility of increasing education (the non-price channels discussed earlier) occur at lower levels of education. Therefore, the primary enrollment rates may be capturing these positive influences rather than the parental human capital variable. Again, using the observations within plus or minus .1 log points of the threshold estimate, the median value of education years is approximately 4.5 when the structural break occurs. This value is depicted on the relevant plot in Figure 1.

Finally, secondary enrollment rates are statistically significantly negative in both the low-productivity and the high-productivity regimes. Moreover, the point estimates indicate that negative impact of secondary enrollment is higher in the high productivity economies relative to the low productivity economies. This result is consistent with the interactions specification results - that the negative impact of secondary enrollment increases with productivity levels. However, the difference in magnitude between the point estimates is not statistically significant. Once again, using the observations within plus or minus .1 log points of the threshold estimate, the median value of secondary enrollment is approximately 55% when the structural break occurs. This value is depicted on the relevant plot in Figure 1.
In summary, the threshold estimates indicate a structural break in the fertility dynamics that occur when output per worker is approximately $13,700, the average years of education is about 4.5 and when secondary enrollment rates are approximately 55%. Prior to the structural break increases in productivity and primary enrollment rates result in higher fertility, while increases in secondary enrollment rates and parental education decrease fertility. After the regime shift, increases in productivity and secondary enrollment rates reduce fertility while increases in parental education tend to raise fertility.

### 3.4 Pre-defined fertility regimes specification

It is possible that the fertility dynamics are characterized by a single threshold and two regimes as estimated above or, as discussed in Galor and Weil (2000) and Galor (2005), by three distinct regimes: Malthusian (pre-transition), post-Malthusian (transition), and modern growth (post-demographic transition). Unfortunately, the econometric theory for estimating a threshold in the presence of endogenous variables has not been extended to estimating multiple thresholds. Therefore, I will investigate the possibility of three regimes by estimating an equation that allows the slope coefficients to differ across three regimes that are pre-defined by visual inspection of their fertility paths. The three pre-defined regimes (pre-demographic transition, transition and post-demographic transition) are defined by their fertility levels during the sample period. In the previous sections I discussed the sample of 31 pre-transition economies and the 28 economies post-transition economies. The remaining 36 economies are transition economies: economies whose fertility is high (total fertility rate above 6.0) at the beginning of the sample, but declines during most of the sample period and whose total fertility rate is below 4.0 at the end of the sample period. Figures 2b and 2c plot the total fertility rate and the net reproductive rate for the transition and post-transition sub-samples. The Data Appendix indicates which countries fall into each sub-sample and Figure 5 plots unconditional scatter plots showing fertility’s relationship to productivity, productivity growth, years of education, secondary enrollment and primary enrollment in each of the pre-defined fertility regimes. Each observation is one five-year observation for one country. This distinction by

\footnote{For brevity’s sake, fertility’s relationship to TFP and to Augmented TFP are omitted. These relationships are very similar to that of output per worker.}
visual inspection is meant to be instructive, rather than definitive since the categorization into the three pre-defined fertility regimes is, in some sense, *ad hoc*. Yet, the scatter plots suggest a marked degree of dissimilarity between the sub-groups in the relationship between fertility and the other variables. Moreover, observed fertility dynamics are quite easy to distinguish. It is nearly universally accepted and observed that over the demographic transition, fertility begins at a high level, falls quickly and then remains low. There are no fertility reversals. If each regime is governed by a different data generating process, then one can estimate the dynamics separately for each regime. The danger inherent in conducting this investigation is that if there are not truly distinct dynamics across regimes, then dividing the sample based on the dependent variable will create attenuation bias.

Notice (from Figure 5) that in the pre-transition sub-sample, there are no discernible negative relationships between any of the variables and fertility rates. It is within the transition sub-sample that the negative relationship between fertility and some of the other variables is visually obvious. Within the post-transition sub-sample one can detect a more modest negative relationship between fertility and productivity. It is difficult to discern an unconditional relationship between fertility and productivity growth and the education variables are tightly distributed around relatively high levels of attainment and enrollment. The difference in unconditional correlations between sub-samples can also be seen in the correlation coefficients of Table A1 in the Data Appendix. These visual inspections offer some support for distinct dynamic processes within each fertility regime.

Table 4 shows the results from regressions that allow the slope coefficients and the constant terms to differ between fertility regimes. In this specification, only the transition economies display statistically significant relationships between fertility and the regressors. Secondary enrollment rates, productivity levels (except when productivity is measure with augmented TFP) and productivity growth rates are negatively related to fertility while primary enrollment rates are positively related to fertility in the transition economies. In fact, this is only specification where productivity growth rates generate the statistically significant pressure on fertility described in Galor and Weil (2000) and Galor (2005). The primary enrollment, secondary enrollment and productivity growth estimates are statistically significantly different from their values for the pre-transition economies. However, they are not statistically significantly different from their counterpart estimates in the post-transition economies because the standard errors on the post-
transition estimates are relatively large. Also, in no instances are the coefficient estimates in the pre-transition economies significantly different from their counterpart estimates for the post-transition economies. Again, this is driven by the large standard errors on the post-transition estimates. 26

For an inverted-U dynamic driven by productivity, it would be expected that the coefficient on productivity for pre-transition economies would be positive and statistically significant. However, the coefficient estimates, regardless of productivity measure, are negative and insignificant. Moreover, the econometric results largely substantiate the scatter plot relationships in Figure 5: the strong negative correlation between parental education and secondary enrollment rates in the transition economies and weak relationships elsewhere.

The fertility regimes were constructed based on the behavior of the total fertility rate. An alternative grouping was also constructed based upon the net reproductive rate. There were six countries whose total fertility rates displayed a continual downward pattern (placing them in the transition grouping), but whose net reproductive rates rose in the beginning of the sample and then declined. The alternative grouping placed these countries in the pre-transition group rather than the transition group. The countries placed in the transition group initially, but moved to the pre-transition group under the alternative grouping are: Guatemala, Haiti, Indonesia, Iran, Nicaragua, and Zimbabwe. Table A5 in the Data Appendix display the results. The results using the alternative grouping based on net reproductive rates produces results very similar to the original grouping based on total fertility rates with the exception that secondary enrollment rates are not statistically significant, and productivity levels in transition economies are statistically significantly positive.

With the inverted-U relationship so robust in all other specifications, why not in the pre-defined fertility regime specification? Recall that the estimated break in fertility dynamics occurs at productivity levels of $9,400 or $13,700 (depending on the specification) and where secondary enrollment

26If one estimates this specification without different constant terms for each regime, the standard errors on most of the post-transition estimates declines and the coefficients on primary enrollment, secondary enrollment and years of education become statistically significant for the post-transition economies, they are also statistically significantly different from their pre-transition counterparts. However, the coefficients on productivity are never statistically significant in any of the regimes. Table A4 illustrates these results is in the Data Appendix.
rates reach around 40%. Within the transition sample, 40% of the observations have values for output per worker below $9,400 and 65% of the observations have values below $13,700. Also, approximately 40% of all transition observations have secondary enrollment rates below 40%. Therefore, if the true dynamics depend on reaching a critical level of productivity or a joint level of productivity and secondary enrollment, and the observations below that critical value have been split between two of pre-defined regimes, then the pre-defined fertility regime specification is mis-specified. Since the results over the other specifications are quite robust with respect to presence of an inverted-U and because the pre-defined fertility regimes are not statistically determined, I would conclude that this attempt to discern three separate regimes may be inappropriate. Nevertheless, the scatter plots in Figure 5 are intriguing and this specification does highlight a result missed by the other specifications, specifically that during the demographic transition, higher productivity growth rates may be a causal factor in generating the shift into child-quality and out of child-quantity as described by Galor and Weil (2000) and Galor (2005). These results also indicate that the positive impact of productivity on fertility lingers while economies enter into the demographic transition.

4 Conclusion

In summary, the results show that there is not one fertility dynamic common to all economies regardless of their phase of development. Instead, in the initial stage of the development process fertility responds positively to productivity and to increases in primary enrollment rates. In the subsequent stage of development fertility responds negatively to productivity and perhaps positively to parental human capital. The results with respect to productivity are consistent with the recent theoretical literature on the very-long run growth process. The results showing the positive impact of parental education in high productivity economies are somewhat surprising. The results with respect to the positive influence of primary enrollment rates are consistent with effects from non-price channels outlined by demographers. On the other hand, the negative relationship between education demand (secondary enrollment rates) and fertility seems common to all economies.

Therefore, the data and results from this study support the existence of at least two regimes with respect to fertility dynamics. The pre-defined
three fertility regime specification showed that only in a few instances were the coefficients in the transition sample statistically significant and also statistically significantly different from the other sub-samples. But the design of the pre-defined three-regime equations may make it difficult to accurately judge the presence of more than two regimes. Nonetheless, the differences between the pre-defined regimes is interesting. I believe that future research could help to further refine the investigation for multiple regime shifts.

A major point of this study is that much of the negative correlation derived from long-run relationships between fertility and other variables arises from differences in fertility levels between pre-transition and post-transition economies rather than a universally applicable dynamic. In general the data support a Malthusian dynamic early in the development process followed by a period where productivity increases and education demand eventually dominate to lower fertility.

The positive relationship between parental human capital and fertility also opens an avenue for future research. One possible explanation for this result is that there may be a second wealth effect at higher levels of development. The early Malthusian dynamics are driven by an initial wealth effect at low levels of development. As an economy becomes richer and parents more educated, perhaps less work effort (either in the marketplace or from home production) is needed from each household to obtain a desired level of consumption and this creates additional time for child-rearing. A related mechanism could be that at higher levels of human capital there are more market solutions for child-rearing (day-care, child-activities, market provided tutoring, etc.) that enable households to increase family size. But these are merely conjectures and more definite conclusions will depend on future research.
References


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## Table 1a - Estimates from Quadratic Productivity Specification

<table>
<thead>
<tr>
<th>Variable</th>
<th>Output per worker</th>
<th>TFP</th>
<th>Augmented TFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary enrollment</td>
<td>0.62 (0.17)*</td>
<td>0.52 (0.14)*</td>
<td>0.48 (0.16)*</td>
</tr>
<tr>
<td>Secondary enrollment</td>
<td>-0.82 (0.22)*</td>
<td>-0.53 (0.16)*</td>
<td>-0.55 (0.18)*</td>
</tr>
<tr>
<td>Average years of education</td>
<td>0.11 (0.10)</td>
<td>0.04 (0.08)</td>
<td>0.09 (0.07)</td>
</tr>
<tr>
<td>Productivity</td>
<td>2.23 (0.45)*</td>
<td>2.37 (0.48)*</td>
<td>1.74 (0.29)*</td>
</tr>
<tr>
<td>Productivity squared</td>
<td>-0.12 (0.02)*</td>
<td>-0.20 (0.04)*</td>
<td>-0.14 (0.02)*</td>
</tr>
<tr>
<td>Productivity growth</td>
<td>-0.09 (0.14)</td>
<td>-0.14 (0.14)</td>
<td>-0.07 (0.11)</td>
</tr>
<tr>
<td>Pupil teacher ratio</td>
<td>0.01 (0.09)</td>
<td>0.15 (0.08)</td>
<td>0.09 (0.07)</td>
</tr>
<tr>
<td>Constant</td>
<td>-9.85 (1.90)</td>
<td>-7.45 (1.34)</td>
<td>-5.40 (0.90)</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>567</td>
<td>566</td>
<td>561</td>
</tr>
<tr>
<td>P-value for Hansen J-stat</td>
<td>.37</td>
<td>.36</td>
<td>.31</td>
</tr>
</tbody>
</table>

NOTES: The dependent variable is the log of the net reproductive rate. All independent variables (including the excluded instruments) are logged except the productivity growth rate. Standard errors are in parentheses and are adjusted using the Newey-West procedure. Secondary enrollment tested as endogenous and the instruments are newspapers in circulation per adult and the ratio of quasi-money to GDP. Telephone mainlines per adult is also used when output per worker measures productivity. The Hansen J-statistic tests the null hypothesis that the moment conditions are valid. An asterick indicates significance at the 95% confidence level or better.
## Table 1b - Estimates from Specification Where Productivity Enters Quadratically: Sample Excludes Post-Transition Economies

<table>
<thead>
<tr>
<th>Variable</th>
<th>Output per worker</th>
<th>TFP</th>
<th>Augmented TFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary enrollment</td>
<td>0.32 (.13)*</td>
<td>0.28</td>
<td>0.45 (.18)*</td>
</tr>
<tr>
<td>Secondary enrollment</td>
<td>-0.33 (.13)*</td>
<td>-0.22</td>
<td>-0.42 (.19)*</td>
</tr>
<tr>
<td>Average years of education</td>
<td>-0.06 (.06)</td>
<td>-0.09</td>
<td>-0.03 (.07)</td>
</tr>
<tr>
<td>Productivity</td>
<td>1.86 (.49)*</td>
<td>0.60</td>
<td>1.71 (.48)*</td>
</tr>
<tr>
<td>Productivity squared</td>
<td>-0.10 (.03)*</td>
<td>-0.05</td>
<td>-0.14 (.03)*</td>
</tr>
<tr>
<td>Productivity growth</td>
<td>-0.05 (.12)</td>
<td>-0.15</td>
<td>-0.15 (.11)</td>
</tr>
<tr>
<td>Pupil teacher ratio</td>
<td>0.04 (.08)</td>
<td>0.10</td>
<td>0.01 (.09)</td>
</tr>
<tr>
<td>Constant</td>
<td>-7.97 (2.09)*</td>
<td>-1.88</td>
<td>-5.18 (1.40)*</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>405</td>
<td>382</td>
<td>347</td>
</tr>
<tr>
<td>P-value for Hansen J-stat</td>
<td>.19</td>
<td>.37</td>
<td>.64</td>
</tr>
</tbody>
</table>

NOTES: The dependent variable is the log of the net reproductive rate. All independent variables (including the excluded instruments) are logged except the productivity growth rate. Standard errors are in parentheses and are adjusted using the Newey-West procedure. Secondary enrollment tested as endogenous and the instruments are newspapers in circulation per adult and the ratio of quasi-money to GDP. Telephone mainlines per adult is also used when output per worker measures productivity. The Hansen J-statistic tests the null hypothesis that the moment conditions are valid. An asterisk indicates significance at the 95% confidence level or better.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Output per worker</th>
<th>TFP</th>
<th>Augmented TFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary enrollment</td>
<td>0.41</td>
<td>0.41</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td>(0.13)*</td>
<td>(0.13)*</td>
<td>(0.14)</td>
</tr>
<tr>
<td>Secondary enrollment</td>
<td>1.27</td>
<td>1.27</td>
<td>1.35</td>
</tr>
<tr>
<td></td>
<td>(0.41)*</td>
<td>(0.41)*</td>
<td>(0.32)*</td>
</tr>
<tr>
<td>Average years of education</td>
<td>0.10</td>
<td>0.10</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>(0.06)</td>
<td>(0.06)</td>
<td>(0.05)</td>
</tr>
<tr>
<td>Productivity</td>
<td>1.20</td>
<td>1.20</td>
<td>1.06</td>
</tr>
<tr>
<td></td>
<td>(0.19)*</td>
<td>(0.19)*</td>
<td>(0.15)*</td>
</tr>
<tr>
<td>Productivity* Secondary enrollment</td>
<td>-0.32</td>
<td>-0.32</td>
<td>-0.30</td>
</tr>
<tr>
<td></td>
<td>(0.06)*</td>
<td>(0.06)*</td>
<td>(0.04)*</td>
</tr>
<tr>
<td>Productivity growth</td>
<td>-0.14</td>
<td>-0.14</td>
<td>-0.12</td>
</tr>
<tr>
<td></td>
<td>(0.13)</td>
<td>(0.13)</td>
<td>(0.10)</td>
</tr>
<tr>
<td>Pupil teacher ratio</td>
<td>0.04</td>
<td>0.04</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>(0.06)</td>
<td>(0.06)</td>
<td>(0.06)</td>
</tr>
<tr>
<td>Constant</td>
<td>-6.25</td>
<td>-6.25</td>
<td>-5.29</td>
</tr>
<tr>
<td></td>
<td>(0.88)</td>
<td>(0.87)</td>
<td>(0.66)</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>567</td>
<td>535</td>
<td>531</td>
</tr>
<tr>
<td>P-value for Hansen J-stat</td>
<td>0.17</td>
<td>.08</td>
<td>.28</td>
</tr>
</tbody>
</table>

NOTES: The dependent variable is the log of the net reproductive rate. All independent variables (including the excluded instruments) are logged except the productivity growth rate. Standard errors are in parentheses and are adjusted using the Newey-West procedure. In all regressions secondary enrollment alone and interacted with productivity tested as endogenous. When output per worker is the productivity measure, productivity is also endogenous. The instruments for all regressions are telephone mainlines per adult (tel), newspapers in circulation per adult (news), radios per adult (rad), the ratio of quasi-money to GDP (my) and the interaction terms: rad*news rad*tel rad*my tel*news and tel*my, with the exception that the equation using augmented TFP does not use my as an instrument. The Hansen J-statistic tests the null hypothesis that the moment conditions are valid. An asterick indicates significance at the 95% confidence level or better.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Productivity Level</th>
<th>Difference</th>
<th>TFP</th>
<th>Output per Worker</th>
<th>TFP</th>
<th>Augmented TFP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
<td>High-Low</td>
<td>Low</td>
<td>High</td>
<td>High-Low</td>
</tr>
<tr>
<td>Primary enrollment</td>
<td>0.35</td>
<td>0.12</td>
<td>-0.23</td>
<td>0.27</td>
<td>0.10</td>
<td>-0.17</td>
</tr>
<tr>
<td>Secondary enrollment</td>
<td>-0.37</td>
<td>-0.80</td>
<td>-0.43</td>
<td>-0.27</td>
<td>-0.69</td>
<td>-0.42</td>
</tr>
<tr>
<td>Average years of education</td>
<td>-0.05</td>
<td>0.31</td>
<td>0.37</td>
<td>-0.08</td>
<td>0.27</td>
<td>0.35</td>
</tr>
<tr>
<td>Productivity</td>
<td>0.14</td>
<td>-0.25</td>
<td>-0.40</td>
<td>0.23</td>
<td>-0.64</td>
<td>-0.87</td>
</tr>
<tr>
<td>Productivity growth</td>
<td>0.02</td>
<td>-0.17</td>
<td>-0.19</td>
<td>-0.11</td>
<td>-0.15</td>
<td>-0.04</td>
</tr>
<tr>
<td>Pupil teacher ratio</td>
<td>0.02</td>
<td>0.03</td>
<td>0.01</td>
<td>0.10</td>
<td>0.02</td>
<td>-0.08</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.84</td>
<td>4.91</td>
<td>5.75</td>
<td>-1.19</td>
<td>6.25</td>
<td>7.44</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>280</td>
<td>287</td>
<td>1.57*</td>
<td>275</td>
<td>260</td>
<td>2.28*</td>
</tr>
<tr>
<td>P-value for Hansen J-stat</td>
<td>.47</td>
<td>.92</td>
<td>.82</td>
<td>.40</td>
<td>.82</td>
<td>.51</td>
</tr>
</tbody>
</table>

NOTES: The dependent variable is the log of the net reproductive rate. All independent variables (including the excluded instruments) are logged except the productivity growth rate. Standard errors are in parentheses and are adjusted using the Newey-West procedure. Secondary enrollment and productivity were treated as endogenous and the instruments are telephone mainlines per adult, newspapers in circulation per adult, radios per adult and the ratio of quasi-money to GDP. The Hansen J-statistic tests the null hypothesis that the moment conditions are valid. An asteriick indicates significance at the 95% confidence level or better.
**Table 4 - Estimates from Pre-determined Fertility Regimes**

<table>
<thead>
<tr>
<th>Productivity measure</th>
<th>Output per worker</th>
<th>TFP</th>
<th>Augmented TFP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Diff from Pre</td>
<td>Diff from Post-Pre</td>
<td>Diff from Pre</td>
</tr>
<tr>
<td>Pre*Primary Enroll</td>
<td>-0.22 (.21)</td>
<td>0.72 (.26)</td>
<td>-0.27 (.21)</td>
</tr>
<tr>
<td>Trans*Primary Enroll</td>
<td>0.50 (.16)</td>
<td>0.56 (0.18)</td>
<td>0.53 (0.19)</td>
</tr>
<tr>
<td>Post*Primary Enroll</td>
<td>0.48 (.50)</td>
<td>0.03 (.52)</td>
<td>0.35 (.37)</td>
</tr>
<tr>
<td>Pre*Secondary Enroll</td>
<td>0.23 (.23)</td>
<td>-0.60 (.25)</td>
<td>0.28 (.22)</td>
</tr>
<tr>
<td>Trans*Secondary Enroll</td>
<td>-0.37 (.11)</td>
<td>-0.39 (0.12)</td>
<td>-0.36 (0.13)</td>
</tr>
<tr>
<td>Post*Secondary Enroll</td>
<td>-1.84 (1.89)</td>
<td>1.47 (1.90)</td>
<td>-1.59 (1.75)</td>
</tr>
<tr>
<td>Pre*Yrs of Education</td>
<td>-0.04 (.05)</td>
<td>-0.20 (.10)</td>
<td>-0.05 (0.05)</td>
</tr>
<tr>
<td>Trans*Yrs of Education</td>
<td>-0.24 (.09)</td>
<td>-0.21 (0.11)</td>
<td>-0.14 (0.13)</td>
</tr>
<tr>
<td>Post*Yrs of Education</td>
<td>0.47 (.34)</td>
<td>-0.71 (.35)</td>
<td>0.43 (0.36)</td>
</tr>
<tr>
<td>Pre*Productivity</td>
<td>-0.04 (.09)</td>
<td>-0.02 (.10)</td>
<td>-0.11 (0.15)</td>
</tr>
<tr>
<td>Trans*Productivity</td>
<td>-0.06 (.05)</td>
<td>-0.11 (0.09)</td>
<td>-0.11 (0.09)</td>
</tr>
<tr>
<td>Post*Productivity</td>
<td>0.35 (.85)</td>
<td>-0.40 (.85)</td>
<td>0.20 (.10)</td>
</tr>
<tr>
<td>Pre*Prod Growth</td>
<td>0.19 (.12)</td>
<td>-0.53 (.18)</td>
<td>0.36 (0.18)</td>
</tr>
<tr>
<td>Trans*Prod Growth</td>
<td>-0.33 (.14)</td>
<td>-0.59 (0.15)</td>
<td>-0.32 (0.13)</td>
</tr>
<tr>
<td>Post*Prod Growth</td>
<td>0.45 (.53)</td>
<td>-0.79 (.55)</td>
<td>0.50 (.46)</td>
</tr>
<tr>
<td>Pre*Pup Teacher Ratio</td>
<td>0.08 (.12)</td>
<td>0.09 (.15)</td>
<td>0.10 (.12)</td>
</tr>
<tr>
<td>Trans*Pup Tcher Ratio</td>
<td>0.16 (.16)</td>
<td>0.16 (0.12)</td>
<td>0.15 (0.12)</td>
</tr>
<tr>
<td>Post*Pup Teacher Ratio</td>
<td>-0.04 (.24)</td>
<td>0.20 (.26)</td>
<td>-0.06 (0.29)</td>
</tr>
<tr>
<td>Number of Obs</td>
<td>567</td>
<td>535</td>
<td>531</td>
</tr>
<tr>
<td>P-value; Hansen J-stat</td>
<td>.29</td>
<td>.25</td>
<td>.77</td>
</tr>
</tbody>
</table>

**NOTES:** The dependent variable is the log of the net reproductive rate. All independent variables (and excluded instruments) are logged except the productivity growth rate. Standard errors are in parentheses and are adjusted using the Newey-West procedure. For all regressions, secondary enrollment and each productivity measure tested as endogenous and the instruments, interacted with fertility regime dummy variables, are telephone mainlines per adult, radios per adult, newspapers in circulation per adult and the ratio of quasi-money to GDP. The Hansen J-statistic tests the null hypothesis that the moment conditions are valid. An asterisk indicates significance at the 95% confidence level or better. "Pre*", "Trans*" and "Post*" indicate multiplication by a dummy variable for the pre-transition, transition, and post-transition regimes, respectively. All regressions included a separate constant term for each regime.
Figure 1: Unconditional fertility relationships

Note: Each dot is one five-year observation.
Figure 2a: Fertility rates in pre-transition economies

Note: The left axis displays the scale for the total fertility rate and the right axis displays the scale for the net reproductive rate.
Figure 2b: Fertility rates in transition economies

Note: The left axis displays the scale for the total fertility rate and the right axis displays the scale for the net reproductive rate.
Figure 2c: Fertility rates in post-transition economies

Note: The left axis displays the scale for the total fertility rate and the right axis displays the scale for the net reproductive rate.
Figure 3: Relationship between instrument and productivity measures

Note: Each dot is one five-year observation.
Figure 4: LR statistics from threshold estimations

Productivity measure: Output per worker

Productivity measure: TFP

Productivity measure: Augmented TFP

Note: The graphs plot the LR statistic for each possible value of the threshold. If the LR is less than the 95% critical value, fail to reject the null hypothesis that a particular value of the threshold is the true threshold.
Figure 5: Unconditional fertility relationships by pre-defined fertility regimes

Note: Each dot is one five-year observation.