Can Infant Mortality, Female Education, Urbanization and Income Explain Fertility Decline in Developing Countries?

Abstract

Motivated by the wide spread fertility transition phenomenon in developing countries following the end of World War II, and the four stand out hypotheses on demographic transitions in the literatures that concern the relationship between fertility and infant mortality, female education, urbanization and income, this paper is a serious attempt on checking the demographic theories against the developing world's reality. By collecting a panel of data for 92 developing countries and 51 years (1960-2010) and utilizing estimation techniques such as Pooled OLS, Panel fixed effect with Instrumental Variables and system GMM, this paper has found evidences supporting a positive direct effect of infant mortality as well as direct negative effects of urbanization, income and female education on women's fertility decisions in developing countries. Among all four direct effects, female education seems to have the strongest impact on fertility.

JEL classification: J11; I12; N30; O11

Keywords: Fertility, Infant Mortality, Urbanization, Female Education, Urbanization, Income

1. Introduction

The demographic transition, observed in the form of fertility decline, has been largely present in the developed world, (i.e. North America, Western Europe and the Oceania) from the late 19th century to the dawn of the 20th century (see e.g. Galor (2012), Guinnane(2011)). The fertility figures in the developing world however haven't experienced a significant decline until after World War 2, when science, technology and living standard began to rise in the developing countries. Since the mid-20th century demographers and economists in the developed world began to investigate the causes of fertility decline, proposing a series of "demographic transition theories". These are a wave of direct challenges to the traditional neo-classical view on fertility and population, which are represented by Solow and Malthus, who treated population as exogenous to the economy. The reason for these growing interests in demographic change is due to the realization of the important relationship between fertility and growth.

The current interest in the broad area of demographic behaviour and long-run growth reflects several intellectual influences, such as Robert E. Lucas' now-famous lectures on growth (Lucas (2002)). Early efforts in this area usually embed the microeconomic model of fertility decisions due to Gary Becker in a framework that allows feedbacks from the economy to fertility decisions. These models have either a single equilibrium, or possibly multiple equilibria without explicit focus on how an economy would transition from one to another. (see e.g. Becker et al. (1990)). A more recent body of research focuses explicitly on how economies transition from a “Malthusian” economy of high fertility and little growth in per capita incomes to one in which fertility is much lower and per-capita incomes grow rapidly. This “unified growth theory” due to Oded Galor, David Weil and others , integrates a microeconomic model of the demand for children with feedbacks from a model of growth and as such accounts in a coherent way for a central issue in our understanding of long-run growth. (see e.g. Galor (2005)).

The important implications from the above studies suggest that fertility is most likely endogenous, and often times, it’s an important channel through which many other potential growth determinants can take effect on economic development. So explaining fertility change becomes an ever important agenda for modern economists.

The current state of development of demographic transition theories can be summarized as a few hypotheses: (1) The rise in the level of income per capita: Becker (1960) argues that the decline in fertility was a by-product of the rise in income and the associated rise in the opportunity cost of raising children. He suggests that the rise in income induced a fertility decline because the positive income effect on fertility was dominated by a negative substitution effect brought about by the rising opportunity of raising children. (2) The decline in infant and child mortality that preceded the reduction in fertility and population growth in most advanced economies, with the notable exceptions of France and the United States, has been viewed as a plausible explanation for the onset of the decline in population growth during the demographic transition. (see e.g. Murtin (2012), Galor (2010)). (3) The rise in human capital: Galor and Weil (1999, 2000) and Galor and Moav (2002) argue that the acceleration in the rate of technological progress during the second phase of the industrial revolution increased the demand for human capital and induced parents to invest more heavily in the human capital of their offspring. (4) The increase in the direct cost of raising children: argued in the context of Becker (1981)’s Q-Q model (trade-off between the quality and quantity of children), this view considers urbanization an important factor to increase the direct cost of raising children and increase the parents favour in children’s quality rather than quantity.

So far, most of the above stated theories are used to explain the demographic transitions happened in the late 19th early 20th century among many developed countries, various empirical evidences supporting each of these theories have been found, including those investigating the long term causes of fertility decline (see e.g. Murtin (2012),Herzer et al. (2011)). But I haven't found any studies focus on explaining the on-going demographic transition in many developing countries. Do we need new theories to explain the developing world's version of transition? Or are current theories proposed for developed world already satisfactory and applicable to the developing countries as well? To answer these questions, this paper is a serious attempt on checking the demographic theories against the developing world's reality.

By collecting a panel of data for 92 developing countries and utilizing estimation techniques such as Pooled OLS and Panel fixed effect with Instrumental Variables for each of the four endogenous variables concerned, this paper has found evidences supporting all four leading theories on demographic transitions in the developing countries. In particular, infant mortality has a direct positive effect on fertility, while female education, urbanization and income impact fertility negatively. We also perform robustness checks of core results by including alternative measures of fertility, urbanization and female education and utilizing alternative estimation techniques such as the system GMM. Our study then contributes differently to the demographic transition literatures in that: (1) we focus exclusively on developing countries. (2) we check all four leading hypotheses on fertility transitions unlike many empirical literatures that only focus on one or two. (3)we utilize traditional instrumental variable approach to account for endogeneity, since there's growing concerns on the validity of system GMM/DOLS approaches that utilize internal lags of endogenous variables as instruments.

The rest of paper is structured as follows: section 2 reviews recent theories and empirical evidences on fertility transition in both developed and developing countries, section 3 describes the data and shows core results from pooled OLS and IV regressions, section 4 performs two types of robustness checks as mentioned above and section 5 concludes.

2. Causes of Fertility Transition – Theories and Empirical Evidences

The literatures investigating the causes of demographic transitions are many. Most of them focus on the following four potential determinants of fertility change:

2.1 Wealth and Income

The rise in income per capita prior to the decline in fertility has led some researchers to argue that the reduction in fertility was triggered by the rise in income in the process of industrialization. Perhaps the most representative papers in this line of work are Becker (1960) and Becker and Lewis (1973), which argue that rising income causes fertility to decline mainly because the negative substitution effect on fertility due to rising opportunity cost of raising children overshadows the positive income effect on fertility.

To illustrate the idea it's perhaps beneficial to look at a simple dynastic model presented by Herzer, Strulik and Vollmer (2012). In their micro-based model, a household's utility is represented by parents' consumptions at young and old age, and from the number of extra surviving children they produce ($u = \log(c_1 + \alpha) + \beta\pi_2 \log(c_2) + \gamma \log(\pi_1 n - \bar{n})$). Here β is the time discount rate, π_2 the survival probability from young adulthood to old age, γ is the weight of children in utility, the parameter α captures (subsistence) goods produced at home. c_1 and c_2 each represents consumption at young and old age. $\pi_1 n - \bar{n}$ is the extra fertility, as $\bar{n}$ represents the number of children that is regarded as "a basic need" due to the assumption that there exists a hierarchy of needs according to which children can less easily be substituted across time than consumption goods.

This household utility is then subjected to a budget constraint: $(1 - bn)y = c_1 + c_2$, where b is the time spent on child rearing, and it is assumed that the household is endowed with a total of 1 unit of time, y is the hourly wage. Solving the first order condition with respect to c_1, c_2 and n yields the following solution for optimal fertility:

$$n^* = \frac{\alpha\gamma\pi_1 + (\gamma\pi_1 + b\bar{n} + \beta b\bar{n}\pi_2)y}{(1 + \gamma + \beta\pi_2)b\pi_1 y}$$

And this implies the following relationship between optimal fertility n^* and income y:

$$\frac{\partial n^*}{\partial y} = -\frac{\alpha\gamma}{(1 + \gamma + \beta\pi_2)by^2} < 0$$

The above model predicts a negative relationship between fertility and income. This claim is also supported by another line of work that emphasizes on the trade-off between quantity and quality of children.

Becker and Lewis (1973) postulated that the income elasticity with respect to investment in children's education was greater than that with respect to the number of children, and hence the rise in income led to a decline in fertility along with an increase in the investment in each child. This is essentially the hypothesis for the now widely cited Q-Q model, which emphasizes on the possible trade-off between the number of children and their quality. The direct prediction from the Q-Q model assert that when household income rises, parents have incentives to have less children because they favour children's quality over quantity.

The Q-Q model received some criticism such as those from Guinnane (2011), which argues that the model is flawed in two aspects: first, the literatures that talk about the model provide no clear definition of "quality" of children, a large literature takes a child's education as a proxy for its quality, which seems reasonable but also ad-hoc. Second, Becker's model assumes that quality is the same for all children within a family, thus parents cannot react to changes in the price of quality by, for example, educating some of their children but not all. Guinnane goes on to argue that this is most likely not the case as we observe in most societies that boys usually receive more education than girls. Despite all the flaws identified, Becker et al (2009) use toughening of compulsory schooling laws in Prussia in the late 1840s to study the fertility effects of a reduction in the price of child quality and find a negative correlation between enrolment rates and family sizes. Bleakley and Lange (2009) examine a program that largely eradicated intestinal worms among children in the early 20th century Southern United States and argue that this intervention reduced the cost of child quality by making children better able to learn in school. They too confirm the Q-Q model's predictions.

However, recently, growing empirical literatures assert just the opposite view on the role of income in fertility transition. For examples, the evidence from Murtin (2012) based on a panel of countries during 1870-2000 shows that income per worker was positively related with fertility rates after controlling for mortality rates and education. Murphy (2009) finds, based on panel data from France during 1876 – 1896, that income per capita had a positive effect on fertility rates during France's demographic transition after controlling for education, the gender literacy gap and mortality rates. Moreover, in a quantitative analysis of the demographic transition in England, Fernandez-Villaverde (2001) suggests that in contrast to Becker's theory, the force associated with a rise in income would have led to an increase in fertility rates rather than to the observed decline.

With even harsher criticism, Galor (2012) deems Becker's theory "counterfactual" and claim income may have very little effect on fertility decisions in the first place. He points out the fact that the decline in fertility occurred in the same decade across Western European countries that differed significantly in their income per capita. "In 1870, on the eve of the demographic transition, England and the Netherlands were the riches countries in Western Europe, enjoying GDP per capita of $3190 and $2760 respectively, in contrast, Germany and France, which experienced the onset of a decline in fertility in the same decade as England and the Netherlands, had in 1870 a significant smaller GDP per capita of $1840 and $1880 respectively. Moreover, Sweden and Norway's GDP per capita were only about 40% of that of England in 1870, and Finland's GDP per capita were merely a third of the level in England. Nevertheless, the onset of the fertility decline in these poorer economies occurred in the same decade as in England."

It is therefore in this context, we are particularly interested in this long proposed yet heavily debated determinant of fertility. Whether or not it may be a key factor affecting the recently observed demographic transition in developing countries is definitely worth investigating. Income in most developing countries surge after the Second World War. In the same period, demographic transition began to occur in most countries. However, the general stylized fact is that income growth experienced a lot of fluctuations while the fertility declines in those countries in the same period are much smoother, suggesting these two variables may not be nicely correlated, and the relationship between the two, if any, may be complicated.

2.2 Infant Mortality

Another classic explanation offered for historical fertility transition is the decline in mortality rates. The central idea, called "demographic transition theory" famously represented by demographer Frank Notestein (1945) asserts that couples in high infant mortality societies have a lot of births because that is necessary to ensure a surviving brood. An infant mortality decline would induce couples to have fewer children because they would not need to have so many to achieve a given number of survivors. The underlying assumption is that there exists a precautionary demand for children among parents who are risk averse with respect to the number of surviving offspring. Thus they tend to hold a buffer stock of children in a high-mortality environment. To see this, continuing onto Herzer, Strulik and Vollmer's model, taking the derivative of optimal fertility n^* with respect to infant survival rate π_1 yields the following negative relationship between fertility and infant survivability, hence a positive relationship between fertility and infant mortality:

$$\frac{\partial n^*}{\partial \pi_1} = -\frac{\bar{n}(1+\beta\pi_2)}{(1+\gamma+\beta\pi_2)\pi_1^2} < 0$$

This theory becomes particularly interesting when looking at the experience of developing countries after World War II, where public-health interventions created dramatic reductions in infant and child mortality in a relatively short period compared with Europe in the 19th century. World Bank (2010) notes that in developing countries child mortality declined by about 25%, from 101 per 1,000 in 1990 to 73 in 2008, meanwhile measles immunization rate has climbed in all developing countries, for e.g. in Mozambique immunization coverage increased from 58% in 1996 to 77% in 2002.

The current state of empirical literature has a very mixed view on this matter. Among those that support the theory, for examples, Eckstein et al. (1999) use long-run Swedish data from 1751-1990 to fit a five-period overlapping generation model, which takes child mortality and income as (exogenous) determinants of fertility. They identify a negative impact of income on fertility and child mortality as the most important factor explaining the fertility decline. Interestingly, they also find that child mortality is not sufficient to explain the secular fall of net fertility. Angeles (2010) tries to resolve endogeneity problems and to identify causality by using the difference-GMM estimator and finds that a fall in mortality induces a significant reduction in fertility while the impact of GDP per capita on fertility is statistically insignificant. Lorentzen et al. (2008) find a positive association between fertility and mortality and (indirectly) a negative association between fertility and economic growth.

Schultz (1997) finds that income per adult is negatively associated with mortality and positively with fertility.

More prominent are the views that are against the theory. First off, In the context of developed countries, the stylized facts don't seem to support the theory. As pointed out by Guinnane(2011), "fertility in the United States declined for decades before any noticeable decline in mortality. The TFRs reported by Haines (2000, Table 8.2) decline from the early 19th century, there is however no sustained fall in the infant mortality rate, on the other hand, until the 1890s, French experience was similar, with a fertility transition preceding mortality declines."

There're two fundamental theoretical flaws in the Notestein's version of mortality theory on fertility according to Guinnane (2011). First, the theory treats infant mortality as being exogenous, while it's more plausible to assume that parents can assert some influence on their children's mortality risks by providing some degree of health care, such as breast feeding and protection from danger such as hearth fires. Guinnane and Brown(2002) finds that while mortality has a strong, positive effect on fertility in an OLS model, in the counterpart IV model the effect is zero. Secondly, even a fully exogenous reduction in infant mortality should reduce the price of having children, thus, making parents favour the quantity of children over quality, if the strong substitution of the Q-Q model is at work, then decline in mortality should induce a shift out of quality and into numbers of children, hence, actually raise fertility.

Growing empirical literatures are confirming the claims against the "demographic transition theory" in terms of mortality decline. For examples, Doepke (2005) uses the mortality and fertility data from England during 1861-1951, finds that in the absence of changes in other factors, the decline in child mortality during this time should have resulted in a rise in net fertility rates, i.e. the number of surviving children. This conflicts the original theory that says mortality decline should have no effect on the number of surviving children. Fernandez-Villaverde (2001)'s quantitative analysis confirms the insignificance of declining mortality for determining the decline in fertility. Murphy (2009) finds that, based on panel data from France during 1876-1896, mortality rates had no effect on fertility during France's demographic transition, accounting for education, income and the gender literacy gap.

Despite all the mixed views, infant mortality could be potentially even more important to the demographic transition in developing countries than the developed world, since most of the European experiences were based on a long-term gradual improvement of healthcare conditions, but in the context of developing country, where most of the transition happened after World War II, the speed of improvement is much faster. This is mainly caused by the fact that after World War II, medical science and technology had major break throughs in key areas such as immunization, anti-biotics, and maternal cares, dramatically reducing infant mortality in a much faster rate for developing countries than back in 19th century for now advanced economies. We therefore decide to include infant mortality in our main regressions.

*2.3 **The Rise in Human Capital: Female Education***

The gradual rise in demand for human capital during the second phase of industrialization and its close association with the timing of the demographic transition has led researchers to argue that the increasing role of human capital in the production process induced households to increase their investment in the human capital of their offspring, leading to the onset of the fertility decline. This line of work, like the argument of income, is also based on the Q-Q model. Human capital has potentially a negative effect on fertility through probably two channels.

On one hand, if the demand in children’s human capital rises, it’s because parents value children’s quality more than their quantity, which means the negative substitution effect from the Q-Q model dominates the positive income effect caused by rise in income. For example, Galor and Weil (1999, 2000) and Galor and Moav (2002) argue that the acceleration in the rate of technological progress during the second phase of the industrialization increased the demand for human capital and induced parents to invest more heavily in the human capital of their offspring.

On the other hand, if the actual level of parents’ human capital rises, it exhibits a rising level of opportunity cost associated with raising children, making parents shift away from quantity to quality of children, effectively reducing fertility desired. (see e.g. Becker (1960), Mincer (1963), Willis (1973)). This is particularly important for women, as they are the ones that’s responsible for rearing children at home in most traditional societies. So if the child bearing age women are more educated, they have a better chance in finding not only jobs, but high paying jobs, which subsequently raises the income foregone due to raising children at home. Also, under positive assortative mating, a woman's education casually connected to her mate's education (Behrman and Rosenzweig (2002)), so that the effect of education on household permanent income is augmented through a multiplier effect. Last, education may improve an individual's knowledge of, and ability to process information regarding fertility options and healthy pregnancy behaviors (Grossman (1972)).

To see the above theoretical claims in detail, it's perhaps best to see a slightly modified simple dynastic model presented by Murtin (2012) concerning the Q-Q trade off. We however add another parameter: mother's education into this model to address the important role of mother's education in her children's human capital investments. Being different from Herzer et al. (2012)'s specification, households now obtain utilities from consumption c, fertility n and educating their own children (child quality h). So the central problem is to maximize household's utility by choosing optimal level of consumption, fertility and child quality, subject to a budget constraint comprising consumption, cost of raising children and cost of educating children:

$$Max_{cnh}\, V = u(c) + \beta u(snh)$$

$$s.t. \quad c + \phi sn + \tau esn = y$$

Where s is the child survival rate, ϕ is the marginal cost associated with raising children, and τ is the marginal cost associated with educating children. y is total income. The most important assumption in this model however is that mother's education can influence children's education, so that children's quality (or human capital h) is an increasing function of mother's education e: $h = (1+e)^{\eta}, \eta < 1$. In other words, highly educated mothers tend to want their children to be highly educated as well, albeit at a less extent, hence, the decreasing returns of child education from mother's education, indicated by the parameter η. In the case where mother has no education, each child is then endowed with 1 unit of human capital. The first order condition then yields:

$$\frac{\frac{\partial V}{\partial n}}{\frac{\partial V}{\partial e}} = \frac{1+e}{\eta n} = \frac{\phi + \tau e}{\tau n}$$

After some algebra:

$$e^{*} = -\frac{1}{1-\eta} + \frac{\eta}{1-\eta}\left(\frac{\phi}{\tau}\right)$$

Clearly, from the above equation we can infer that there's a positive relationship between the optimal (utility maximizing) level of maternal education and the relative cost of raising children to educating children, i.e. the trade-off between quantity and quality of children. In other words, highly educated mothers tend to favour quality of children over quantity of children, therefore tend to invest more in their children's education instead of reproducing more, hence, have lower total fertility rate.

For empirical evidences concerning the channel that emphasizes on the improvement of children's human capital, a direct test of the effect on fertility of the rise in the return on human capital has been conducted by Bleakley and Lange (2009) in the context of the eradication of hookworm disease in the American South. They note that the eradication of the disease can be viewed as a positive shock to the return to child quality since it raises the return on human capital investment, had a very low fatality rate and negligible prevalence among adults. The finding is largely that the rise in the return to child quality (rise in children's human capital) had a significant adverse effect on fertility.

More prominent are the evidences focus on the contemporaneous effect, i.e. parents' education and their fertility decisions. For examples, Becker et al. (2009) find that education stimulated a decline in fertility in Prussia during the 19th century. Murphy (2009) finds, based on a panel data from France during 1876-1896, that the level of education attainment had an adverse effect on fertility rates during France's demographic transition. McCrary and Royer (2011) uses age-at-school-entry policies to identify the effect of female education on fertility and infant health. They focus on sharp contrasts in schooling, fertility, and infant health between women born just before and after the school entry date. School entry policies affect female education and the quality of a woman's mate and have generally small, but possibly heterogeneous effects on fertility and infant health. They then go on to argue that school entry policies manipulate primarily the education of young women at risk of dropping out of school. De Paoli (2010) uses a representative sample of Ecuadorian young women's households and found that schooling is positively related to women's labor market participation rate and negatively to early motherhood.

In the context of developing countries, after World War II, there's been a massive improvement in educational attainment for fertile aged women. For most developing countries in our sample, the growth rate is 200-300% across 50 years. Much like the decline in infant mortality, the improvement for education in the developing countries also recorded a much faster growth rate compared with their European counterparts experience in the late 19th century. It is for these reasons that we include female's education as another candidate for the tests of determinants of demographic transition in the developing countries.

2.4 Increase In the Direct Cost of Raising Children: Urbanization

According to Becker's Q-Q model, two types of costs are essential for the trade-off between quantity and quality of children. One is the opportunity cost of raising children, as mentioned in the previous section, this is motivated by the fact that parents especially female parents these days have improved their human capital accumulation, therefore are more qualified for higher paying jobs, this directly raises the income forgone due to the need to care for kids at home for these parents, hence, the rising opportunity cost of raising children. The other cost we haven't touched much so far is the direct cost of raising children.

One logical possibility to explain the fertility transition due to rising direct cost is that the direct costs of child-bearing changed in ways that induced couples to have smaller families. However, as pointed out by Guinnane (2011), most direct costs of child-bearing did not change, over the relevant period for the European demographic transition, in ways that would produce the observed fertility decline. "Most households in this period devoted the bulk of their expenditure to food, clothing, and housing. The real price of clothing dropped dramatically following the technological innovations of the industrial revolution, many of which were in textiles. Food prices varied over time and place, and protective tariffs on agricultural goods could raise the price of food in one country well above its counterpart in others. But in general, food prices declined, which at a crude level would imply a reduction" in the direct of costs of raising children.

Despite all the negative figures for food prices, there certainly is some consensus among the literatures regrading significant increases in direct costs of raising children in the context of rising housing prices in the developed world during the fertility transition period (usually occurred in the industrial revolution age in western Europe), and that coincides with the rapid process of urbanization. For examples, Haines (2000) points out that only 6% of the US population lived in an urban place in 1800, the figure is 40% in 1900. Woods (1996) points out that England was already very urban in 1801 (34%), but by 1911, 79% of the English population lived in an urban center. Urbanization in Germany was especially rapid in the late 19th century. Germans living in places with fewer than 2000 people fell from 64% to 40% of the population between 1871 and 1910. (Wehler (1995)). Guinnane (2011) also acknowledged that "in urban areas, housing prices exceeded those in rural areas during the transition period, in the meantime, urban fertility was lower than rural fertility in the 19th century. Once the fertility transition began, fertility usually fell first in urban areas, with rural areas then catching up."

To illustrate these ideas, Zhang (2002) has built a comprehensive dynastic model with three overlapping generations, where a middle-aged agent obtain utilities from his own middle-age consumption $c_{1,t}$, own old-age consumption $c_{2,t+1}$, his parent's old-age consumption $c_{2,t}$, the number of children n_t, and the potential income/earnings of each child, e_{t+1}, and the utility function that takes on the Cobb-Douglas form looks the following:

$$U_t = \left(c_{1,t}^{\phi} c_{2,t+1}^{1-\phi}\right)^{\sigma} c_{2,t}^{\epsilon} \left(e_{t+1}^{\delta} n_t^{1-\delta}\right)^{1-\sigma-\epsilon}, \qquad 0 < \sigma, \phi, \epsilon, \delta < 1, \qquad 1 - \delta - \epsilon > 0$$

The production functions for urban and rural workers respectively are:

$$f_u(k_t, l_t h_t) = k_t^{\theta} \left[\sum_{\Omega_{u,t} \subset I_{u,t}} (l_t h_t) \right]^{1-\theta}, k_t \geq \underline{k}$$

$$f_r(k_t, l_t h_t) = k_t^{\theta} \left[\sum_{\Omega_{r,t} \subset I_{r,t}} (l_t h_t) \right]^{1-\theta}$$

Where k_t is physical capital, h_t is human capital, l_t is labor input.

Children's human capital h_{t+1} depends on education investment q_t and parents' human capital h_t : $h_{t+1} = A_i q_t^{\beta_i} h_t^{1-\beta_i}, i = r, u,\ 0 < A_r < A_u\ ,\ 0 < \beta_r < \beta_u < 1$

The budget constraints for urban workers across generations are:

$$c_{1,t} = (1 - vn_t)w_t h_t - n_t q_t - s_t$$

$$c_{2,t+1} = (1 + r_{t+1})s_t$$

Where v is time spent on raising children, so that $(1 - vn_t)$ is time left for working, assuming each agent has a total of endowment of 1 unit of time. w and r are real wage and interest rate respectively. s_t is savings for old-age consumption.

The budget constraints for rural migrant workers across generations are:

$$c_{1,t} = (1 - vn_t)w_t h_t - \alpha(1 + r_t) - n_t q_t - s_t$$

$$c_{2,t+1} = (1 + r_{t+1})s_t$$

Where α is a "location-specific" moving cost to a rural agent should he/she decides to migrate from rural area to the urban cities.

Upon solving the household's utility maximization problem, by choosing optimal fertility, consumption, child quality (education investment) and parental human capital, in the equilibrium, the average fertility rate across rural and urban regions takes on the following form:

$$n_{a,t} = \frac{\left(L_{u,t} - L_{m,(t-1)}\right)n_u}{L_t} + \frac{L_{m,t-1}n_{m,t}}{L_t} + \frac{L_{rm,t}n_{rm}}{L_t} + \frac{L_{rr,t}n_r}{L_t}$$

Where L_m denotes the labor force that migrated from rural area to urban cities, and L_{rr} represents the rural labor force after urbanization (migration), L_{rm} is the rural labor when expecting children to migrate. n_{rm} is the rural fertility when expecting children to migrate, n_m is the fertility of a migrant. From this equation it's then clear that since $n_u < n_r$, the average fertility $n_{a,t}$ falls as the fraction of population in urban areas increases, i.e. the value of $L_{u,t} - L_{m,t-1}$decreases.

Other studies concerning the direct costs of children focus on more specific issues, for examples, Easterlin (1976) argues that the fertility decline in rural America is caused by rising costs of farmland as an area was settled. The assumption is that farmer parents wanted to establish each child on a farm similar to their own. As the price of local farmland rises, parents either have to send their children further west, where land was cheaper, or have fewer children. Parents preferred to have fewer children and be able to settle them locally as an old-age social security insurance to their own. Guinnane (2011) mentioned the possibility of the effect of child labor on fertility. He noted that in the early days of industrial revolution, the use of child labor was quite a norm. For example, Nardinelli (1990) notes that by the 1830s large minorities of English children were working, in most English counties, at least one-quarter of children aged 10-14 were reported in the workforce. Some parts of the textile sector depended heavily on children. One parliamentary inquiry reported that in cotton textiles, half of all workers were under 18, and 6.8% were under 10. However this trend has been reversed by mid-19th century. Government imposed age restrictions and other measures that dramatically reduced the earnings possibilities of children, especially in industry. (see e.g. the British “Factory Acts” of 1833 and the Prussian 1839 Act). Guinnane goes on to argue that the use of child labor offset some of the direct costs of raising children for the parents, as children can self-support to some degree, therefore the elimination of child labor in the late 19th century effectively increased the direct costs associated with child rearing , and we did witness the European demographic transition took place at the same period of time. However, Wehler (1996) emphasizes that the German restrictions did not successfully limit the role of children in production at home, which remained important throughout the 19th century. Moehling (1999) also warns that the anti-child labor acts and legislations were enacted when industry no longer opposed them, “either it had become very easy to substitute capital and other sorts of labor for child labor, or the workforce had already changed in ways that the new laws were not a binding constraint when passed.” So if child-labor restrictions were introduced when they were mostly irrelevant, then they could not be a strong causal force in the fertility transition.

We decide to include only urbanization as a measure of direct costs of raising children in our study. The reasons are two folds: first, our main research objects are developing countries, and the observed transition period is post-1960. By this time, most of the developing countries have already established laws to prohibit child labor. Secondly, the farmland prices argument is too specific for the American experience which is largely irrelevant in the context of most developing countries. Land endowments vary across many developing nations, and there's no observations for universal farmland price decrease in those countries. Finally, the argument for urbanization is highly relevant for developing countries in the post-World War II era, as many developing countries began the process of their own version of industrialization and dramatically established new cities and factories, reduced the share of GDP in the agricultural sector. For example, in the 1960s more than 95% of the Chinese residents live in the country area, today, half of its residents are urban dwellers. (see WDI, World Bank).

3. Core Results

3.1 Data and Descriptive Statistics

Table 1 provides descriptive statistics for the key variables of interests. We collect a panel of data for 92 developing countries across the globe with 60 years (1960-2010) of consecutive data on fertility, female education, urbanization and income. Data availability for female human capital is the main drive for our selection countries. When considering the endogeneity issue for all four main explanatory variables, for some regressions the observations are reduced because of data availability for some instrumental variables. In these cases, the length of time series for these variables is reduced to 20 years (1991-2010) and the number of countries is reduced to 83.

Table 1: Summary Statistics for Main Variables

	Mean	Std. Dev (overall)	Min (overall)	Max (overall)	Observations	No. of Countries	Year
Total Fertility ($fertility_{i,t}$)	4.99	1.81	1.229	9.22	4692	92	51
Crude Birth Rate($Birth_{i,t}$)	35.48	11.31	8.092	57.84	4692	92	51
Infant Mortality($infmort_{i,t}$)	78.63	47.18	4.00	242.1	4692	92	51
Female Education($femedu_{i,t}$)	4.20	2.76	0.009	11.04	4692	92	51
Female Primary Completion ($complete_{i,t}$)	62.89	31.30	0.71	138.77	4692	92	51
Female Primary	70.33	24.72	4.84	99.90	4692	92	51

Enrolment ($enroll_{i,t}$)							
Urbanization ($urban_{i,t}$)	37.33	20.46	2.00	94.7	4692	92	51
Population Agglomeration ($popagglo_{i,t}$)	16.85	10.50	1.21	59.23	4233	83	51
Population in Largest Cities ($popcity_{i,t}$)	39.86	21.71	2.52	375.30	4692	92	51
Log GDP per worker	6.49	1.23	3.56	10.23	4692	92	51
Development Aid ($devaid_{i,t}$)	43.45	85.96	-114.29	1287.66	4233	83	51
Share of Employment in Service ($servicemp_{i,t}$)	44.79	17.54	5.60	85.00	1660	83	20
Population Density Within 100km of Coast ($LT100_{i,t}$)	154.28	203.04	0.628	1323.42	1660	83	20
Precipitation ($Precip_{i,t}$)	1170.7	847.95	32.2	3725.5	4233	83	51

3.1.1 Fertility (Dependent Variable)

Fertility is measured in two ways. In the main regression we use total fertility rate ($fertility_{i,t}$), which is the average number of children that would be born to a woman over her lifetime if she were to either experience the exact current age-specific fertility rates through her lifetime or to survive from birth through the end of her reproductive life, it is obtained by summing the single-year age-specific rates at a given time. The data are compiled by the “Gapminder” organization from various sources such as the UN data. Total fertility rate is often considered a better candidate for the measure of fertility rate than the crude birth rate since it is not affected by the age distribution of the population. (see e.g. Herzer et al. (2012).

For the purpose of robustness checks with alternative measures of fertility, we also use crude birth rate ($birth_{i,t}$), in the form of number of births per 1,000 people per year. The data is obtained from World Bank’s World Development Index (WDI) database. Albeit a less desirable measure of fertility, it is also used by some economists because of its better availability. (see e.g. Murtin (2012), Herzer et al. (2012)).

3.1.2 Explanatory Variables: (Infant Mortality, Urbanization, Female Education, Income)

Infant mortality ($infmort_{i,t}$) is measured as the number of infants (0 to 12 months old) death per 1,000 live births. The data is obtained from World Bank's WDI.

Urbanization is measured in three ways. In the main regressions, we use the most common measure: the percentage of urban population in total population ($urban_{i,t}$), obtained from World Bank's WDI. However, there's some criticism against this type of measure as two obvious problems are likely to arise: (1) the data may not be immediately comparable across countries, as some countries' statistics on the urban population are based on administrative boundaries (i.e., cities in a political sense), while in others they are based on territorial units delimited in terms of ecological criteria. (2) The degree of urbanization is defined as the proportion of the total population of the total population who reside in urban units. These units may be cities, urban areas or metropolitan areas, in any case, for practical purposes, the small points of population concentration typically do not enter into urban statistics. (see e.g. Gibbs (1966)).

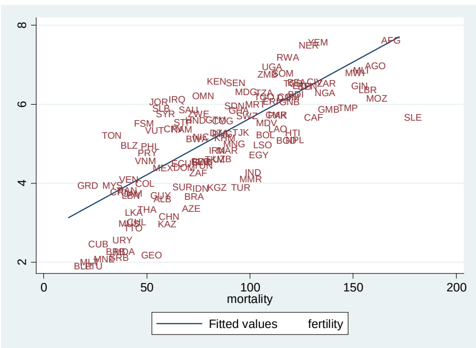
To address the natural sketchy part of the traditional urbanization measure, we also use two other urbanization measures for robustness checks: the percentage of population lives in urban agglomerations ($popagglo_{i,t}$) in total population, and the percentage of population live in the largest cities in urban population ($popcity_{i,t}$). Urban agglomerations specifies the type of urban centre that is focused on for measuring urban population, so it's a much more specific measure of the degree of urbanization than the traditional measure. Population that lives in the largest cities also focus on the most urbanized part of the population, however a higher reading on this indicator indicates a lower urbanization level, because it suggests a majority part of the urban population is confined in the biggest cities, and not spread out across the region. For e.g. In the 1980s China, only 16% of the Chinese population live in the urban area, however, the majority of such population live in big cities such as Beijing and Shanghai, in other words, the level of development of urban centers in China was low back then, resulting an extremely high big-city population to total urban population ratio.

Female education is also measured in three ways. In the main regressions we use the most popular measure: educational attainment measured by the average years of schooling for females aged from 15 to 50 ($femedu_{i,t}$). This age group represents the common fertile ages for women. The data are obtained from Barro and Lee's schooling dataset from World Bank. This type of measure is acknowledged by many economists, the earliest of those can be traced to Psacharopoulos and Arriagada (1986).

For robustness checks, we also utilize the average primary school completion ($complete_{i,t}$) and enrolment ($enroll_{i,t}$) rates for females in the fertile age (i.e. 15-50) obtained from World Bank's WDI. Enrolment rates as a measure of human capital is proposed mainly by Barro(1991) and Barro and Lee (2001), albeit the obvious drawbacks that a student's effectiveness can only be recognized after participating in production activities. It is for this reason we decide to also include the completion rate of primary school students as a measure to reflect the outcome part of human education. The decision to use only primary enrolment and completion rates comes from the fact that in most developing countries, secondary and tertiary education are not prevalent, and that the main focus of human capital development is on the primary education front in these countries.

Finally, we follow Murtin (2012) to use Log GDP per working-age adult to measure income level as it more accurately measures parental income which is of interest. The data is from Penn World Table (PWT) 7.1.

Figure 1 to 4 shows cross-section relationship between fertility and infant mortality, female education, urbanization respectively, clear indicating an obvious positive relationship between the first pair and a negative relationship between the latter three pairs.



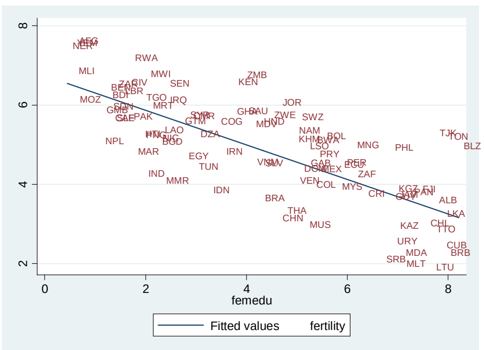
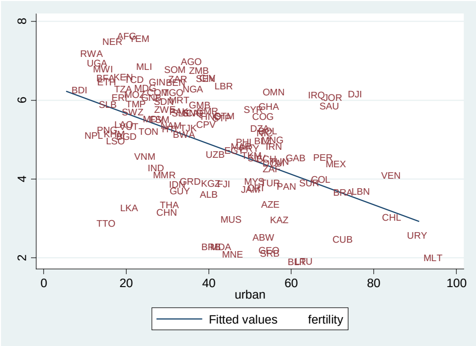


Figure 1: Fertility and Infant Mortality

Figure 2: Fertility and Female Education



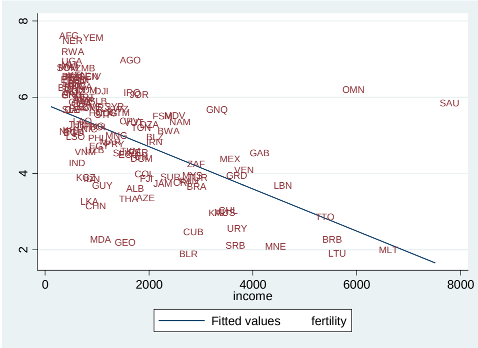


Figure 3: Fertility and Urbanization

Figure 4: Fertility and GDP Per Capita (in levels)

3.1.3 Instrumental Variables and Identification Strategy

We use net official development assistance and official aid received ($devaid_{i,t}$), immunization of measles among children aged 0-24 months ($immune_{i,t}$), and access to safe drinking water ($cleanwater_{i,t}$) as instruments for infant mortality. Share of employment in service sector ($servicemp_{i,t}$) and the measurement of degree of democracy from the Polity IV project ($polity_{i,t}$) are used as instruments for female education. Urbanization is instrumented by population density for regions that are within 100km to the coastline ($LT100$). Income is instrumented by average precipitation level ($Precip_{i,t}$**).** Precipitation data are obtained from Mitchel et al. (2004) for pre-2000 periods and NASA's rainfall data GPCP 2.2 for post-2000 periods. $LT100$ data are from Columbia University's PLACE III project. Data for other variables except for Polity are obtained from World Bank's WDI.

There has been general consensus among economists that development aid, whether in the form of monetary payment or development assistance can significantly reduce infant mortality. For e.g. Mishra and Newhouse (2007) used data from 118 countries between 1973 and 2004, and found that doubling per capita aid is associated with a 2% reduction in infant mortality rate, which then implies that increasing per capita aid money by US$ 1.60 per year is associated with 1.5 fewer infant death per thousand births. Other examples include Rajan and Subramanian (2005), Younger (1992), Bauer (1982), Sachs (2005) and Clemens et al. (2004). Even among those who dispute the effectiveness of foreign aid on development and economic growth such as Ovaska (2003) acknowledged the positive effect of aid in reducing infant mortality. On the other hand, generally there's no consensus that aid and fertility are directly related, only a few research papers such as Bahar (2009) pointed out that there may exist a positive relationship between aid and fertility, however these results contradict with the fact that increases in aid should lower fertility rate via its direct effect on infant mortality rather than increasing it, hence, don't affect the validity of development aid as an instrumental variable for infant mortality rate in our research.

Immunization coverage is another important factor for the reduction of infant mortality rates observed in many developing countries in the post-war era, as point out by Shimouchi et al. (1994) who used logistic regression analysis of data from 97 developing countries and found that immunization coverage is one of the main predictors of the infant mortality rate. It represents one of the health intervention components which can be used as a proxy indicator of the availability of PHC service in developing countries. Other evidences on this matter are also available from Berggren et al. (1983) for rural Haiti, Jain (1985) for rural India and Cantrelle et al. (1986) for Senegal. All the above evidences testify infant mortality as a suitable channel through which immunization coverage might affect fertility, hence, the validity of immunization as an instrument for infant mortality in our fertility regressions.

Access to safe drinking water has long been argued as a major determinant of infant mortality levels by many economists. For e.g. Meeker (1972) inferred the impact of water supply improvements on mortality in American cities from the reduction in typhoid fever death rates following the filtration of their public water supplies. Condran (1987) studied the effect of water supply in Philadelphia in the period 1890-1920, and found that typhoid fever declined following the introduction of water filtration during that period. More recent evidences include Esrey and Habicht (1986), who investigated whether the availability of piped water and the presence of toilets provided different protection to infants of literate mothers compared with those of illiterate ones and found that the difference in water quality could benefit the illiterate mothers, so that providing good-quality water would close the gap and result in an antagonistic interaction with literacy. Gamper-Rabindran et al. (2008) also found similar evidences for Brazil by using a quantile treatment effects with panel data. Due to data availability, only 20 years of observations are available for $immune_{i,t}$ and $cleanwater_{i,t}$.

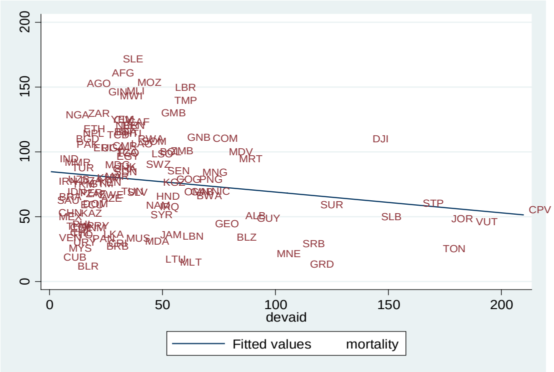
One of the pre-condition for urbanization is the existence of surplus food. Thus, many geographic variables such as tropics and distance to equator could be potential good instruments for urbanization, but unfortunately they are meaningless in a panel regression as these variables are time-invariant. Fortunately, apart from the existence of surplus food, lower transport cost and ease of exchange of ideas are also important determinants of urbanization level. As pointed out by Gallup et al. (1999), "coastal areas are conducive for urban growth and thus countries with access to ocean are more likely to reap the benefit of agglomeration economies. Easy access to coasts enhances the extent of market (both internal and external) and thereby increases the opportunity of specialization." Transport cost has historically played important role in the diffusion of technology, ideas and new products. Coastal areas with lower transportation cost compared to land-locked countries are likely to be more exposed to newer products, ideas and technical advancements. In this context, we instrument urbanization by $LT100$ which certainly varies over time.

Recently, Growing literatures utilize Rainfall and other climate variable such as temperature to instrument GDP. (see e.g. Miguel et al. (2004), Burke and Leigh (2010)). This is particular true for estimations that involve mainly developing countries, as agriculture represents a larger portion of the economic activities in these countries, and are sensitive to climate conditions due to the primitive farming technique utilized. For e.g. Bruckner and Ciccone (2011) use rainfall variation to examine the effect of economic shocks on democratic institutions in Africa. Chaney (2010) combines rainfall and flood data to estimate the effect of economic shocks on political stability in Egypt. Bohlken and Sergenti (2010) replicate Miguel et al.'s study for India, using rainfall fluctuation to predict state-level GDP and its effect on rioting. Since precipitation is fully exogenous (i.e. determined purely by nature), it is also an ideal instrumental variable for income in our study.

In current state of the literatures, education is often instrumented with either family background variables such as social status of the parents or natural experiment variables such as changes or differences in compulsory schooling laws (see e.g. Angrist and Krueger (1991), Webbink (2005), Hoogerheide et al, (2007)). However these two types of variables are too specific for general dynamic panel studies with 92 developing countries, hence, the studies cited above often concentrate on case studies or regional analysis within a single country. At this point, we turn to a recently established hypothesis on the size of the service sector and female employment presented by Rendall (2010). The central idea is that women have always self-selected into occupations with low physical requirements, with a large share of these occupations concentrated in the service sector, thus increasing the impact of service sector change on female employment, hence, their incentives to get educated for the job, since the service sector jobs often times require more intellectual capacity over physical strength. Rendall in his model concluded that "economies that do not facilitate the movement of women into the labor market, by imposing high taxes, causes service production to remain at home. This reduces technological innovation, pushing an economy into a self-reinforcing loop, where a small service sector feeds back into low total hours worked by women (and men), further depressing the service sector". To utilize this hypothesis of service sector on female employment and education, we instrument female education with share of employment in the service sector. The idea is that a larger share of employment in the service sector represents a larger size of the service sector, increases employment opportunities for females, hence, increase their incentives to get educated as these job opportunities in the service sector often demand higher human capital.

On the other hand, the correlation between education and democracy has long been argued as a significant relationship by many economists (see e.g. Dewey (1903), Chomsky et al. (1994), Torres (1998)). What we are interested in this relationship is however the linkage between democracy and women's basic rights such as education rights. Donno and Russett (2004) builds on Fish (2002)'s work on Islam and authoritarianism and examine the link between authoritarianism and women's empowerment in the Islam society. They not only acknowledge Fish's work which concludes that countries with an Islamic religious tradition are substantially more autocratic and more oppressive of women's rights, but also found that it is democracy, the form of institutions that matter more for women's rights such as education rights rather than a particular type of religion such as Islam. These results motivate us to use the measure of degree of democracy ($Polity_{i,t}$) from the Polity IV project as instrument for female education, since there's no obvious casual relationships between democracy and fertility asserted by the literatures.

Figure 5 and 6 below plot the casual relationship between infant mortality and development aid per capita, and between female education and polity (democracy), indicating that development aid and polity are suitable instruments for the two key endogenous variables in interest.



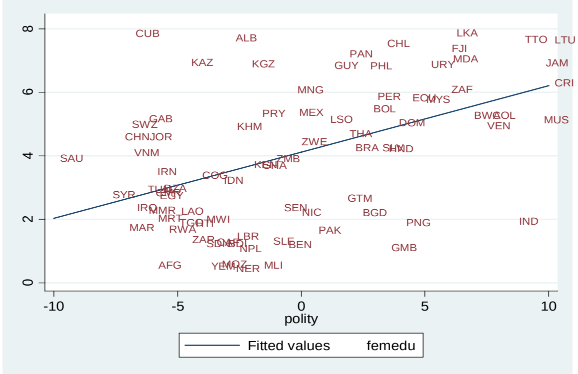


Figure 5: Infant Mortality and Development Aid

Figure 6: Female Education and Polity (Democracy)

3.2 OLS and IV results

3.2.1 OLS Results

This section attempts to utilize both the pooled OLS and fixed effect OLS to estimate equations (1) and (2) respectively so that we can test the four main hypotheses on fertility transitions in developing countries which were presented in section Two:

$$fertility_{i,t} = \alpha_0 + \alpha_1 infmort_{i,t} + \alpha_2 femedu_{i,t} + \alpha_3 urban_{i,t} + \alpha_4 Log(GDP)_{i,t} + b_t + u_{i,t} \quad (1)$$

$$fertility_{i,t} = \alpha_0 + \alpha_1 infmort_{i,t} + \alpha_2 femedu_{i,t} + \alpha_3 urban_{i,t} + \alpha_4 Log(GDP)_{i,t} + \delta_i + b_t + u_{i,t} \quad (2)$$

Where b_t are the time dummies, δ_i is the country-specific fixed effect, and $u_{i,t}$ is an error term with $E(u_{i,t}) = 0$ for all i and t.

Table 2 and 3 present results from pooled OLS (i.e. dropping the country-specific effect, δ_i) and fixed effect (i.e. including both the time and country-specific fixed effects) regressions respectively. Column (1) through (4) in both tables present the four individual effects while column (5) to (7) look at the combined effect without considering endogeneity for any of the four explanatory variables.

It's quite evident from these results that we support all four hypotheses on fertility transitions predicted by the theoretical models presented in section Two. A 1% increase in infant mortality rate in particular will increase total fertility rate by 0.26 as an individual effect under pooled OLS, and 0.12 when taking other three factors into account. The individual effect is weaker under the fixed effect model at 0.06, but still considerably large as it practically means that if infant mortality goes up by 18%, women will consider about having another child. These results are also statistically significant as shown by the t-values in brackets which are generated by robust standard errors.

Female education, urbanization and income are seen to reduce fertility rate considerably. A 1-year increase in schooling reduces total fertility rate by 0.27-0.43 depends on model specifications. A 1% increase in urban population is seen to reduce children conceived by a woman by 0.005 in the pooled model and 0.009 in the fixed effect model. Income measured by log GDP per worker also has a significant negative effect on fertility. Among these four sources of fertility reduction, female education seems to be the dominant one. For all four explanatory variables, the coefficients drop from simple to multiple variable regressions under the pooled model, but the degree of change is the smallest for female education.

As discussed in section 3.1.3, all four explanatory variables are proved to be endogenous in the literatures and we have found suitable instrumental variables to extract exogenous variations from each of the four endogenous explanatory variables.

3.2.2 IV Results

We run two-stage least-squares regressions with heteroskedasticity-consistent standard errors and fixed effect for the panel model concerned. The second stage form is identical to equation (2) from the fixed effect regressions. The first stage varies as illustrated in section 3.1, because we specify different instruments for each endogenous variable and specifically they take on the following forms:

$$infmort_{i,t} = \alpha_5 devaid_{i,t} + \alpha_6 immune_{i,t} + \alpha_7 clearwater_{i,t} + v_{1_{i,t}} \quad (3)$$

$$femedu_{i,t} = \alpha_8 polity_{i,t} + \alpha_9 serviceemp_{i,t} + v_{2_{i,t}} \quad (4)$$

$$urban_{i,t} = \alpha_{10} LT100 + v_{3_{i,t}} \quad (5)$$

$$Log(GDP)_{i,t} = \alpha_{11} precip_{i,t} + v_{4_{i,t}} \quad (6)$$

Where $v_{1_{i,t}}, v_{2_{i,t}}, v_{3_{i,t}}, v_{4_{i,t}}$ are the corresponding error terms in each of the first-stage specification respectively.

Because of the technical difficulty to find common instruments for all four endogenous variables, which is due to the fact that there’s no one to one correspondence between endogenous variables and its instrumental variables when running a 2sls regression with more than one endogenous variable (i.e. all exogenous variables must be used as instruments for each endogenous variable), equations (3) to (6) were estimated separately by the 2sls when only one endogenous variable was included in the second stage regression. For e.g., equation(3) is estimated when only the endogenous variable $infmort_{i,t}$ is included in the second stage equation.

We do however report coefficients from a 2sls regression with multiple endogenous regressors and specified instruments in column (8), table 3, by doing the 2sls manually: first, we estimate equations (3) to (6) separately by OLS with fixed effects, obtain predicted values for each of the four endogenous variables, and then regress fertility on all four sets of predicted values, finally we follow Sanchez (2005) to correct for standard errors. This method is essentially the 2sls approach in case of a single endogenous variable model, however with multiple endogenous regressors, it produces biased coefficients as the nature of simultaneous systems dictates that for efficiency purposes, all exogenous variables must be included as instruments for each endogenous variable. Column (8) is included for merely comparison purposes as we struggle to find common instruments for all endogenous variables.

Column (1) to (7) give clear evidences that the four hypotheses on fertility transitions are valid even after accounting for endegeneity. These results are also robust to the choice of instruments. As can be seen from column (1) to (3), infant mortality has a positive impact on total fertility rate regardless the choice of the three instruments. The negative impact of female education on fertility rate is also evident regardless if we choose polity or service employment rate as instruments as shown by column (4) and (5). Column (6) and (7) confirm the negative impact of urbanization and income on fertility respectively.

Because of data availability for instrumental variables, the number of countries involved in regressions is reduced from 92 to 83, results between tables 2 and 3 and table 4 are not absolutely comparable. However what we are more interested in is not to identify the source of the endogeneity (i.e. measurement errors and etc) problem, but rather to test the hypotheses on fertility transition. This explains why we decide to utilize the maximum sized balanced panel possible under each estimation technique. That said, the coefficients from table 4 do not appear to be radically different from those in table 2 and 3.

All coefficients on key explanatory variables are statistically significant, except for income in column (8). The first stage results suggest the instruments chosen are valid as the coefficients on all instruments are significant, and in case of more than one instrument used, the p-values from the Sargan-Hansen test of over-identification suggest they are not over-identified and the F statistics from first stage suggest they are jointly significant. Both the first and second stage R^2 also suggests each regression model is sufficiently informative.

From table 2 to 4, it's quite evident that total fertility rate is affected positively by infant mortality, and negatively by female human capital, urbanization and income level. However our results so far are backed by only one type of measure of fertility, female human capital and urbanization. Also due to the difficulty to find common instruments, estimating the four effects in a single regression yields biased results (see column (8)). In the next section, we strive to perform a set of robustness checks to address these concerns.

4. Robustness Checks

We perform two types of robustness checks. First, we check if our core results from IV regressions as shown in table 4 are robust to alternative measures of fertility, female human capital and urbanization levels. Second, we check if our core results are robust to different estimation techniques such as system GMM as an alternative to the IV approach. Under each type of check, we utilize the largest balanced panel possible so that for checks of robustness to alternative measures of variables, the IV approach is used and the sample size is reduced to 83 due to data availability for IVs, while in the checks for alternative estimation technique, full sample is used as the system GMM utilize internal lags of endogenous variables as instruments. (See e.g. Blundell-Bond (1998))

Table 2: Determinants of Demographic Transition in Developing Countries: OLS Pooled

Dependent Variable: $fertility_{i,t}$							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$infmort_{i,t}$	**0.026*** (60.67)**				**0.012*** (18.65)**	**0.012*** (16.09)**	**0.012*** (15.90)**
$femedu_{i,t}$		**-0.430*** (-63.45)**			**-0.272*** (-29.68)**	**-0.274*** (-27.92)**	**-0.276*** (-28.03)**
$urban_{i,t}$			**-0.036*** (-41.61)**		**-0.005*** (-5.60)**		**-0.003*** (-3.25)**

$Log(GDP_{i,t})$ (per worker)				**-0.824*** (-44.66)**		**-0.087*** (-3.76)**	**-0.041* (-1.81)**
Observations	4692	4692	4692	4692	4692	4692	4692
No. of Countries	92	92	92	92	92	92	92
R^2	0.61	0.65	0.44	0.55	0.70	0.73	0.73
Time Dummies	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Fixed Effects	**No**	**No**	**No**	**No**	**No**	**No**	**No**

Note: The regressions are estimated using Pooled OLS, with t-values produced by robust standard errors in parentheses with 4692 observations and 92 developing countries. All OLS regressions include time dummies (50 of them) to control time fixed effect. Data for all variables are collected for a period of 51 years (1960-2010). The constants are not reported. $infmort_{i,t}$ shows infant mortality rates within a country. $fertility_{i,t}$ is total fertility rate. $femedu_{i,t}$ denote female educational attainment in a country. $urban_{i,t}$ is the urban population to total population ratio. $Log(GDP_{i,t})$ is the log of GDP per capita in a country. Significance at the 1%, 5% and 10% levels are denoted respectively by ***, ** and *.

Table3: Determinants of Demographic Transition in Developing Countries: Panel Fixed Effect

Dependent Variable: $fertility_{i,t}$							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$infmort_{i,t}$	**0.006*** (10.22)**				**0.011*** (16.24)**	**0.011*** (16.64)**	**0.012*** (17.24)**
$femedu_{i,t}$		**-0.352*** (-24.80)**			**-0.430*** (-29.19)**	**-0.433*** (-28.21)**	**-0.457*** (-28.68)**
$urban_{i,t}$			**-0.007*** (-4.19)**		**-0.009*** (-4.95)**		**-0.010*** (-5.34)**
$Log(GDP_{i,t})$ (per worker)				**-0.278*** (-13.11)**		**-0.087*** (-3.65)**	**-0.098*** (-4.14)**
Observations	4692	4692	4692	4692	4692	4692	4692
No. of Countries	92	92	92	92	92	92	92
R^2 (overall)	0.44	0.64	0.36	0.47	0.68	0.71	0.73
Time Dummies	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Fixed Effects	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Note: The regressions are estimated using panel fixed effect regressions, with z-values produced by robust standard errors in parentheses with 4692 observations and 92 developing countries. All country fixed effect regressions include time dummies (50 of them) to control time fixed effect. Data for all variables are collected for a period of 51 years (1960-2010). The constants are not reported. $infmort_{i,t}$ shows infant mortality rates within a country. $fertility_{i,t}$ is total fertility rate. $femedu_{i,t}$ denote female educational attainment in a country. $urban_{i,t}$ is the urban population to total population ratio. $Log(GDP_{i,t})$ is the log of GDP per capita in a country. Significance at the 1%, 5% and 10% levels are denoted respectively by ***, ** and *.

Table 4: Determinants of Demographic Transition in Developing Countries: Instrumental Variables

Dependent Variable: $fertility_{i,t}$								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Second Stage Regressions								
$infmort_{i,t}$	**0.030*** (25.84)**	**0.057*** (56.69)**	**0.056*** (59.93)**					**0.032*** (6.35)**
$femedu_{i,t}$				**-0.710*** (-31.45)**	**-0.867*** (-47.17)**			**-0.435*** (-12.04)**
$urban_{i,t}$						**-0.177*** (-26.85)**		**-2.531*** (-8.78)**
$Log(GDP_{i,t})$ (per worker)							**-1.073*** (-4.77)**	-0.048 (-0.02)
Observations	4233	1660	1660	1660	4233	1660	4233	1660
No. of Countries	83	83	83	83	83	83	83	83
R^2 **(overall)**	0.57	0.65	0.65	0.39	0.65	0.37	0.43	0.18
Fixed Effects	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Panel B: First Stage Information								
Instrumented	$infmort_{i,t}$	$infmort_{i,t}$	$infmort_{i,t}$	$femedu_{i,t}$	$femedu_{i,t}$	$urban_{i,t}$	$Log(GDP_{i,t})$	***All Dep Var***
$devaid_{i,t}$	**-0.173*** (-23.85)**	**-0.015*** (-4.38)**						**-0.121*** (-16.18)**
$immune_{i,t}$		**-0.512*** (-53.54)**	**-0.377*** (-32.91)**					
$cleanwater_{i,t}$			**-0.414*** (-24.85)**					
$servicemp_{i,t}$				**0.075*** (21.83)**	**0.067*** (18.23)**			
$polity_{i,t}$					**0.122*** (25.25)**			**0.172*** (31.35)**
$LT100_{i,t}$						**0.059*** (20.58)**		**0.056*** (21.05)**
$Precip_{i,t}$							**-0.0003*** (-4.62)**	**-0.0003*** (-5.72)**
Sargan-Hansen Test (P-value)	n/a	0.126	0.357	n/a	0.798	n/a	n/a	n/a
F**-statistics (P-values)**	568.70 (0.000)	1459.27 (0.000)	1977.89 (0.000)	476.34 (0.000)	637.71 (0.000)	632.20 (0.000)	21.34 (0.000)	n/a
R^2**(overall)**	0.14	0.39	0.55	0.23	0.19	0.11	0.12	n/a

Note: The regressions are estimated using panel fixed effect and 2sls regressions, with z-values produced by robust standard errors in parentheses with 4233 observations and 83 developing countries for regressions using development aid per capita ($devaid_{i,t}$), Polity ($polity_{i,t}$) and precipitation ($precip_{i,t}$) as instrumental variables, and 1660 observations and 83 developing countries for regressions using measles immunization (% of children aged 12-23 months) ($immune_{i,t}$), Access to safe drinking water ($cleanwater_{i,t}$), share of employment in the service sector ($serviceemp\_(i,t)$) and population density for regions that are within 100km to the coastline ($LT100$). Variables with 4233 observations have 51 years of data available (1960-2010). Variables with 1660 observations have only 20 years of data available. (1991-2010). The constants are not reported. $infmort_{i,t}$ shows infant mortality rates within a country. $fertility_{i,t}$ is total fertility rate. $femedu_{i,t}$ denote female educational attainment in a country. $urbanization_{i,t}$ is the urban population to total population ratio. $Log(GDP_{i,t})$ is the log of GDP per capita in a country. Multi-endogenous explanatory variable regression in column (8) is conducted by obtaining predicted values of explanatory variables from first stage regressions. Significance at the 1%, 5% and 10% levels are denoted respectively by ***, ** and *.

4.1 Robustness to Alternative Measures of Fertility, Female Education and Urbanization

Table 5 presents the results from replacing total fertility rate with crude birth rate, replacing female educational attainment (schooling years) with primary enrolment and completion rates, and replacing percentage of urban population with percentage of people living in largest cities and urban agglomerations.

From column (1) and (2), we see that female primary enrolment and completion rates as two alternative measures of female human capital in developing countries also confirm the female education story on fertility. Column (3) and (4) confirm the robustness of the negative effect of urbanization on fertility. On one hand, when the majority of **urban** population are concentrated in a few largest cities as measured by $popcity_{i,t}$, it really says that the urban lifestyle is not wide spread out, and that the degree of development of suburban areas which can accommodate more non-rural population is low, hence, the urbanization level is low. Not surprisingly, we found a significant positive effect of $popcity$ on fertility. On the other hand, urban agglomeration includes not only the largest cities but also suburbs or the extension of traditional large cities. Hence, the indicator $popagglo_{i,t}$ which measures the share of total population living in urban agglomerations has a higher value when the degree of urbanization is high. The negative and statistically significant coefficient on this variable also confirms the urbanization story on fertility decline.

Column (5) to (8) report statistically significant coefficients on all four explanatory variables in their original measures when adopting crude birth rate as the alternative measure of fertility. These results largely concur the same findings from table 4, as female education also shows the dominant negative effect on fertility, but the income effect seems to be stronger now with effect from infant mortality slightly weaker. Development aid and polity are chosen as instruments for infant mortality and female education in all regressions for robustness checks. The reason is that the data quality for these instruments is better than other candidates shown in table 4. We do however find consistent results as well by including vaccination, access to safe drinking water and share of employment in the service sector as instruments.

4.2 Robustness to Alternative Estimation Technique

The natural confinement of using IVs to estimate a multi-endogenous variable model due to the hardship to find common IVs for four distinctive endogenous variables prompt us to use the Blundell-Bond (1998) System GMM estimation technique to check the robustness of our previous IV results. The system GMM approach estimates a dynamic panel model and utilizes own lags of endogenous variables as instrumental variables to account for endogeneity. Since we no longer need to find external instruments for our four endogenous variables, our maximum sample size is now restored to 92 as seen in table 2 and 3. To avoid the problem of too many instruments which will have adverse effects on the estimates and instigate over-identification issues, we follow Roodman(2009b) to collapse the instrument matrix. In general, we estimate equation (7):

$$fertility_{i,t} = \alpha_0 + \alpha_{12} fertility_{i,t-1} + \alpha_1 infmort_{i,t} + \alpha_2 femedu_{i,t} + \alpha_3 urban_{i,t} + \alpha_4 Log(GDP)_{i,t} + b_t + u_{i,t} \quad (7)$$

Where the country-specific effect δ_i is left out in the equation, since the system GMM approach is designed to estimate model that may contain country fixed effect in the errors. (Roodman (2009a)).

The two-step robust system GMM estimator shown in table 6 confirms the four hypotheses on fertility transition individually, but cast some doubts on the combined effect. When regressing fertility on infant mortality, female education and urbanization together, in column (5) urbanization becomes insignificant. When leaving out infant mortality, female education becomes insignificant in column (6). When including everything in column (7), female education and urbanization become insignificant. These negative results are understandable as our four explanatory variables are not wholly independent of one another. For e.g. urbanization and income growth are closed related, (see e.g. Bloom et al (2008)), female education also has some correlations with either growth or urbanization as the latter two stimulate the female labor market and subsequently create incentives for females to get education. Murtin (2012) also finds that female education and income are also good determinants of infant mortality. It is therefore not surprising that we run into multicollinearity problem, which affects calculations regarding individual predictors as the coefficient estimates may change erratically in response to small changes in the model or the data. Nevertheless, multicollinearity does not reduce the predictive power or reliability of the model as a whole. (Greene (2011)).

From table 4, 5 and 6 we can conclude that the four individual direct effects on fertility transition based on the four main hypotheses are valid and confirmed by both the IV and system GMM estimations, albeit the combined effect is hard to test because of the correlation between the explanatory variables.

5. Conclusion

In sum, this paper is motivated by the recent wide spread fertility transition phenomenon in developing countries following the end of World War II, and the four stand out hypotheses on demographic transition in the literatures which concern the relationship between fertility and each of the four explanatory variables: infant mortality, female education, urbanization and income. By estimating panel models that utilize OLS, IV and system GMM approaches, this paper has found evidences that support the following:

First, the fertility decline in developing countries in the post-war era measured by both the gradual decline in total fertility rate and crude birth rate is at least partially caused by the decline in infant mortality and rise in female education, urbanization level and the income level. We certainly find a direct relationship between fertility and each of the four explanatory variables individually even after accounting for endogeneity by using instruments for each of the four endogenous explanatory variables. These results are robust to not only alternative measures of fertility, urbanization and female human capital, but also an alternative estimation technique: system GMM.

Second, the effect of female education on fertility transition in developing countries seem to be the strongest among the four effects tested, this confirm the view from the unified growth theory as well as findings from Murtin (2012).

Finally, attempting to test the entire model that includes all four explanatory variables is proven to be difficult. Albeit the four hypotheses are valid and each individual explanatory variable directly affects fertility, they are however also inter-related, causing multicollinearity in the multiple regressions and disrupt the accuracy of coefficients readings.

Table 5: Robustness Checks: Alternative Measures of Fertility, Female Education and Urbanization, IV estimation

Dependent Variable: $fertility_{i,t}$					$birth_{i,t}$			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Second Stage Regressions								
$infmort_{i,t}$					**0.170*** (28.03)**			
$femedu_{i,t}$						**-4.61*** (-47.36)**		
$enroll_{i,t}$	**-0.171*** (-23.36)**							
$complete_{i,t}$		**-0.095*** (-31.85)**						
$urban_{i,t}$							**-1.125*** (-27.72)**	
$popcity_{i,t}$			**1.003*** (3.23)**					
$popagglo_{i,t}$				**-0.447*** (-18.04)**				
$Log(GDP_{i,t})$ (per worker)								**-5.485*** (-4.50)**
Observations	4233	4233	1660	1660	4233	4233	1660	4233
No. of Countries	83	83	83	83	83	83	83	83
R^2 **(overall)**	0.42	0.52	0.12	0.18	0.59	0.67	0.35	0.43
Fixed Effects	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Panel B: First Stage Information								
Instrumented	$enroll_{i,t}$	$complete_{i,t}$	$popcity_{i,t}$	$popagglo_{i,t}$	$infmort_{i,t}$	$femedu_{i,t}$	$urban_{i,t}$	$Log(GDP_{i,t})$
$devaid_{i,t}$					**-0.173*** (-23.85)**			
$polity_{i,t}$	**0.608*** (19.83)**	**1.061*** (25.48)**				**0.123*** (25.25)**		
$LT100_{i,t}$			**-0.011*** (-3.18)**	**0.024*** (17.87)**			**0.056*** (21.03)**	
$Precip_{i,t}$								**-0.0003*** (-4.62)**
F**-statistics (P-values)**	393.33 (0.000)	649.36 (0.000)	10.13 (0.001)	319.29 (0.000)	568.68 (0.000)	637.71 (0.000)	442.07 (0.000)	21.34 (0.000)
R^2**(overall)**	0.13	0.15	0.09	0.23	0.11	0.19	0.20	0.12

Note: The regressions are estimated using panel fixed effect and 2sls regressions, with z-values produced by robust standard errors in parentheses with 4233 observations and 83 developing countries for regressions using development aid per capita ($devaid_{i,t}$), Polity ($polity_{i,t}$) and precipitation ($precip_{i,t}$) as instrumental variables, and 1660 observations and 83 developing countries for regressions using population density for regions that are within 100km to the coastline ($LT100$). Variables with 4233 observations have 51 years of data available (1960-2010). Variables with 1660 observations have only 20 years of data available. (1991-2010). The constants are not reported. $infmort_{i,t}$ shows infant mortality rates within a country. $fertility_{i,t}$ is total fertility rate. $femedu_{i,t}$ denote female educational attainment in a country.$birth_{i,t}$ is the crude birth rate. $urbanization_{i,t}$ is the urban population to total population ratio. $Log(GDP_{i,t})$ is the log of GDP per capita in a country. $enroll_{i,t}$ is primary school enrolment for female students (% of relevant age group), $complete_{i,t}$ is primary school completion rate for female students, $popcity_{i,t}$ is population lives in largest cities (% of urban population), $popagglo_{i,t}$ is population lives in urban agglomeration (% of total population). Significance at the 1%, 5% and 10% levels are denoted respectively by ***, ** and *.

Table 6: Robustness Checks: Alternative Estimation Technique, System GMM (Two Step, Robust)

Dependent Variable: $fertility_{i,t}$							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$fertility_{i,t-1}$	0.937*** (114.46)	0.974*** (80.19)	0.984*** (119.08)	0.993*** (184.33)	1.006*** (63.45)	0.982*** (48.57)	0.945*** (84.99)
$infmort_{i,t}$	**0.003*** (9.20)**				**0.005*** (8.39)**		**0.004*** (6.80)**
$femedu_{i,t}$		**-0.029*** (-3.61)**			**-0.061*** (-4.92)**	0.004 (0.25)	0.007 (1.05)
$urban_{i,t}$			**-0.006*** (-4.91)**		0.003 (1.47)	**-0.008*** (-3.96)**	-0.0006 (-0.82)
$Log(GDP_{i,t})$ **(per worker)**				-**0.042** (-6.22)**		**0.021** (2.02)**	**0.033*** (2.93)**
Observations	4692	4692	4692	4692	4692	4692	4692
No. of Countries	92	92	92	92	92	92	92
No. of Instruments	82	82	82	82	82	82	85
Time Dummies	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
AR(1) (p-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)
AR(2) (p-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
AR(3) (p-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
AR(4) (p-value)	(0.000)	(0.001)	(0.216)	(0.270)	(0.000)	(0.036)	(0.000)
AR(5) (p-value)	(0.598)	(0.813)	(0.195)	(0.325)	(0.128)	(0.663)	(0.468)
Hansen Test of Over-identification	89.03 (0.229)	89.81 (0.191)	120.66 (0.210)	121.91 (0.188)	86.36 (0.218)	87.00 (0.204)	84.98 (0.303)
Diff-in-Hansen Test (p-value)	(0.202)	(0.156)	(0.182)	(0.198)	(0.156)	(0.132)	0.247

Note: The regressions are estimated using two-step system-GMM , with z-values produced by robust standard errors in parentheses with 92 countries and 4692 observations. The constants are not reported. For regressions done in column (1) (2) (3) and (4), the first 15 lags of each endogenous variables are used as instrumental variables to ensure the number of instrumental variables is less than the number of countries. For regressions done in column (5) (6) and (7), the first 5 lags of each endogenous variables are used as instrumental variables to ensure the number of instrumental variables are less than the number of countries. In all regressions instrument matrix are collapsed. Year dummies are included in all regressions. . $infmort_{i,t}$ shows infant mortality rates within a country. $fertility_{i,t}$ is total fertility rate. $femedu_{i,t}$ denote female educational attainment in a country. $urbanization_{i,t}$ is the urban population to total population ratio. $Log(GDP_{i,t})$ is the log of GDP per capita in a country.The values reported for AR(1) to AR(5) are the p-values for first through fifth order autocorrelated disturbances in the first difference equations. Hansen test of over-identification of instruments is provided with the null hypothesis being “robust, but can be weakened by many instruments”. Differences in Hansen test is provided to check the exogeneity of instruments. The null hypothesis is that the instruments are exogenous.. Significance at 10%, 5% and 1% are denoted by *, **,***.

The above results certainly have some policy implications. For developing countries that attempt to migrate from a high mortality high fertility society with low income to a low mortality low fertility with high income society, investment in improving infant mortality, female education and urban infrastructure constructions (which boosts urbanization levels) are vital. Focusing on development in so many key areas is time consuming and challenging for developing countries as resources such as capital are capital. But money can be saved by initially focusing on key areas among the four such as female education and urban infrastructure improvement, as female education has the strongest effect on fertility decline, and can also subsequently improve health indicators such as infant mortality, further accelerate the transition along the way. On the other hand, good urban planning such as infrastructure improvement can stimulate income growth also further accelerate the demographic transition.

Overall, the bottom line is that, for countries that are still in the developing stage, all four traditional determinants of fertility transition seem to matter and could be very important if the developing world wants to converge into the western developed style society with similar demographic structures.

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