Education and Fertility: Evidence from sub-Saharan Africa*

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Abstract

This study investigates the effects of different levels of education on fertility in 48 sub-Saharan African countries between 1970 and 2010. The results, based on panel data analysis with fixed effects and instrumental variables, show that lower education levels do not have a significant effect on people's fertility decisions. However, the results from the higher education levels suggest otherwise. There is evidence of a child quantity-quality trade-off which indicates a region that is transitioning from the Malthusian stagnation to a modern growth regime.

Keywords: education, fertility, sub-Saharan Africa

JEL Classification: O55, J13, I25

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1 Introduction

In today's society education is viewed as an important process of economic development. Not only is education linked to improved productivity, but significant empirical attention has also been given to the contributory role that the rise in demand for education plays in lowering fertility rates (Becker, Cinnirella & Woessmann 2010; Doepke 2004; Galor 2005, 2012).

Several explanations in literature have been reviewed as triggering the decline in fertility rates. Firstly, the Barro-Becker theory (1988, 1989) which focuses on opportunity costs involved with rising income per capita which may induce parents to substitute the quantity of children for higher quality[1]. Secondly, the unified growth theory which emphasises the role of technology in encouraging investments in child education (Galor 2005)[2]. Thirdly, the decrease in the gender gap which raises the cost of children (Galor & Weil 1996)[3]. Fourthly, the change in traditions regarding the old-age security hypothesis which views the younger generation as a measure of security for the older generation (Galor 2012; Reher 2011)[4]. Lastly, the declining mortality rates which reduces the need to have more children to replace those that may not survive (Conley *et al.* 2007; Dreze & Murthi 2001; Murtin 2013).

This study contributes to the existing literature by examining the post-independence transition

[1] Becker and Barro (1988, 1989) find that when the opportunity costs of raising children are high, either via increased wage rates or tax on children, they lower fertility in a model of intergenerational altruism. (See also Becker, Murphy & Tamura 1990).

[2] According to the unified growth theory, the process of development is divided into three distinct periods, the Malthusian epoch which is characterised by relatively constant income per capita and population growth, negligible technological progress and low returns on investment in education. As a result the relationship between income per capita and population growth is positive. The second period is the Post-Malthusian regime. As technological rates increase, the demand for skilled labour also increases which in turn raises the returns on human capital accumulation encouraging the population to invest in the education of their children and have less children, a process known today as the child quantity-quality trade-off. This demographic transition allows income to keep rising and helps to move the economy into the third sustained growth regime characterised by low fertility rates, low population growth rates, high skilled labour, high income per capita and high productivity (Galor 2005, 2012; Galor & Weil 1999, 2000; Galor & Moav 2002).

[3] Galor & Weil (1996) determine that the reduction in the gender gap has resulted in lower fertility rates. As demand for women's participation in the labour force increases, so do the wages for women which raise the cost of children relatively more than they raise household income, leading to decisions to have fewer children. (See also Schultz 2008; Van der Vleuten & Kok 2014).

[4] The introduction of capital markets, the establishment of national pension schemes and nursing homes negated the traditional views of having many children for old age security (Galor 2012; Reher 2011).

of sub-Saharan economies using the unified growth theory. The theory has been cited as inducing the child quantity-quality trade-off which eventually resulted in the demographic transition from high to low fertility rates. Most developed economies of today are characterised by high human capital accumulation, low fertility rates and high levels of productivity.

However, the differences in the timing of the fertility declines have also given rise to the differences in the take-offs of the demographic transitions, and this has led to the varying levels of economic development which we find between developed and developing economies today (Cervellati & Sunde 2013; Doepke 2004; Galor 2005; Galor & Mountford 2008; Reher 2011).

Figure 1 illustrates the fertility differences within sub-Saharan Africa. The more developed economies in the region, such as Botswana, Mauritius, Seychelles and South Africa, have earlier take-offs in fertility declines than the poorer economies such as Democratic Republic of Congo, Eritrea, Niger and Rwanda.

Figure 1: Fertility rates across countries (Source: World Development Indicators)

This delay in the decline of fertility rates makes our paper relevant in investigating the triggers for the take-off, specifically if there is evidence of a trade-off between education and fertility in sub-Saharan Africa as postulated by the unified growth theory, and what the implications of this trade-off may be towards economic development in the region.

We therefore investigate whether the effects of different levels of education, along with other associated variables suggested by literature, such as infant mortality and income per worker, induce a decline in the fertility rates of 48 sub-Saharan African countries between 1970 and 2010.

We further extend the analysis by including an education variable that represents the gender gap in schooling. In their analysis Galor & Weil (1996) discuss the negative effects on fertility from a reduction in the labour force gender gap. In our view, the reduction in the gender gap starts at schooling level as it illustrates changes in norms, particularly in the education of sons before daughters. As more female children are afforded similar education opportunities as male children, not only do their career opportunities increase which can lead to a reduction in the labour gender gap and raise the opportunity cost of having children (Galloway, Lee & Hammel 1998; Galor & Weil 1996), but they also gain knowledge on health and contraceptives earlier on which further reduces fertility (Dreze & Murthi 2001). To the best of our knowledge, none of the literature reviewed uses a similar gender gap variable.

Using panel data analysis with fixed effects and fixed effects with instrumental variables (FE-IV) to control for heterogeneity and endogeneity, we find that lower education levels do not have a significant effect on people's fertility decisions. However, the results from the secondary education levels show a consistent negative relationship with fertility, suggesting that higher levels of education are significant in lowering fertility in the region. This result is evidence of economies that are entering their own demographic transitions and moving from a Malthusian stagnation to modern economic growth, albeit more than a century after Western Europe (Galor 2005). Surprisingly, the reduction in the gender gap does not play a significant role in the decline of fertility rates. The result may indicate a region that is still holding on to traditional views for son preferences to daughters (Dreze & Murthi 2001).

Figure 2 shows a comparison of global regions' fertility rates and education levels in which we see the overall delay in sub-Saharan Africa's rates. The fertility rates in the region only start decreasing after 1980. This decline may be attributed to the improvements in post-independence child health care which increased survival of infants (Van der Vleuten & Kok 2014). Most of the regions, including other developing ones such as South Asia and Latin America, are already exhibiting declining fertility rates by the 1970s. The fertility rates for these regions also decline over the period to between 2 and 3 children per women, while sub-Saharan Africa to date is still double that (Conley *et al.* 2007). Interestingly, for the developing regions especially South Asia and sub-Saharan Africa, the different education rates are increasing significantly as fertility declines, compared to the developed regions (Europe and North America) whose education levels are already high initially. The graphs appear to indicate that education is a possible trigger for declining fertility rates in sub-Saharan Africa.

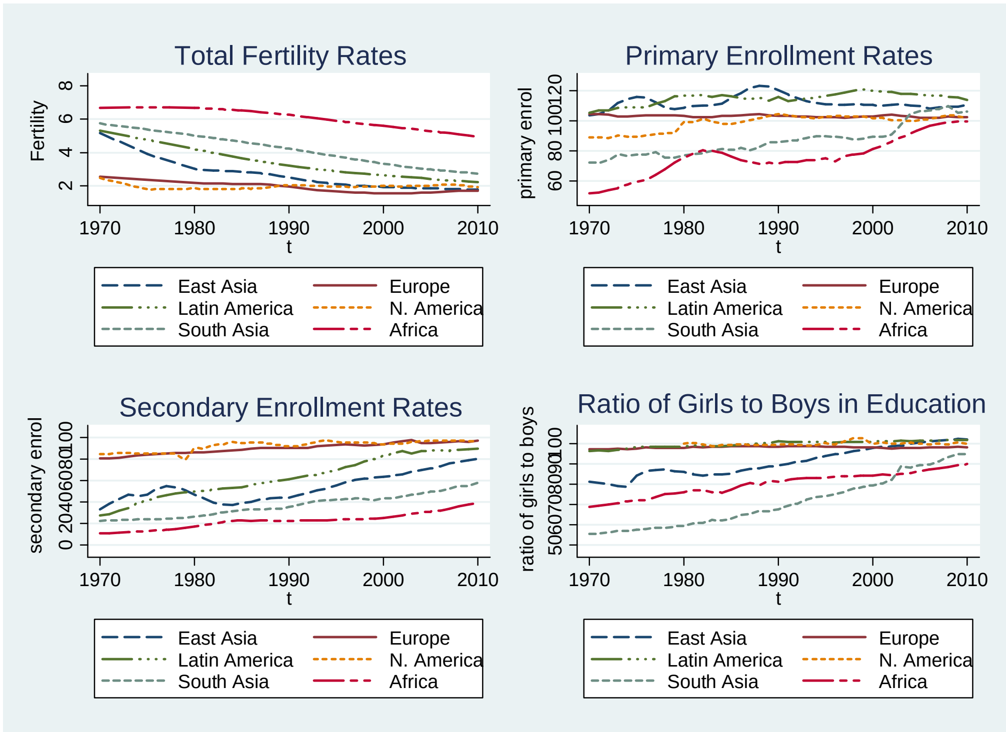

Figure 2: Total Fertility Rates and Education (Source: World Development Indicators)

2 Empirical Analysis

2.1 Data

We use a sample of 48 countries covering 41 years from 1970 to 2010. We are limited to this time period because education data for the sample is recorded from 1970 onwards. However we are confident that the period captures the various transitions described in the unified growth theory as most of the countries gained their independence during this period and subsequently began to implement growth promoting policies aimed at improving education, health, trade, institutions *etc.* Given that several European countries were already exhibiting a quantity-quality trade-off in the 19th century (Becker *et al.* 2010; Galloway *et al.* 1998; Klemp & Weisdorf 2012), inclusion of countries from other regions may not give a true reflection of the effects of education on fertility in sub-Saharan Africa.

The dependent variable (*fertility*) is the total fertility rate which measures the number of births per woman and is obtained from the World Development Indicators (WDIs).

We use three different variables for education levels. Primary education (*primary enrol*) is measured by the gross primary enrollment rate as a percentage of the population. The secondary education variable (*secondary enrol*) is the gross secondary enrollment rate as a percentage of the population. The third education variable (*girl-boy educ*), measured in percentages, is the ratio of girls to boys in primary and secondary education which captures the gender gap in schooling, as previously stated. All three variables are obtained from the WDIs.

An increase in the primary and secondary enrollment rates indicates a rise in the current demand for education. A negative coefficient for the education variables suggests a trade-off between education and fertility. A higher ratio of girls to boys denotes an increase in the percentage number of girls being educated in relation to boys which reduces the gender gap. We therefore interpret a negative coefficient as an increase in the number of girls in schooling in relation to boys (i.e. reduction in gender gap) reduces fertility.

This trade-off signifies a child quantity-quality preference as people realise the benefits of schooling and start investing more in the education of their children. According to the unified growth theory this quantity-quality trade-off played a significant role in the onset of the demographic transitions in Western Europe and its spread to regions outside Europe (Becker *et al.* 2010; Bittencourt 2014; Doepke 2004; Galor 2012).

To avoid omitted variable bias we introduce some control variables based on the various literature (Becker & Barro 1988; Becker *et al.* 1990; Cervellati & Sunde 2013; Conley *et al.* 2007; Galor 2005). These controls include infant mortality and income per worker. The mortality variable (*mortality*) is the infant mortality rate per 1,000 live births taken from the WDIs. We expect a positive relationship between mortality and fertility rates. As fewer children die due to improved health knowledge and infrastructure, fertility rates should decline (Cervellati & Sunde 2013; Conley *et al.* 2007; Reher 2011).

Income per worker (*gdp)* is taken from the Penn World Tables 7.1 and is converted using the purchasing power parity at 2005 constant prices. We expect a negative relationship between income and fertility rates which suggests that as income increases, the opportunity cost of raising children increases resulting in people choosing to have fewer children (Becker & Barro 1988; Becker *et al.* 1990; Galor & Weil 1996; Schultz 2008). All variables are logged.

2.2 Descriptive Statistics

We offer a brief look at the statistics and correlations in Table 1. According to Van der Vleuten & Kok (2014), the fertility rates in the region have remained high until recently and this is shown by the average fertility rate in the region which measures at 5.9 children per woman. Interestingly, when we look at the data in detail, we find that the richer economies, such as Botswana, Mauritius, Seychelles (recorded highest income per worker at $62,338.66) and South Africa, are also characterised by lower fertility rates (Mauritius at 1.47 children per woman), lower mortality rates (Seychelles 11.5 children per 1,000 births) and higher education attainment rates (both Mauritius and Seychelles are among the countries recording the highest secondary and primary enrollment rates during the period under review).

The opposite holds true for the poorer countries. The Democratic Republic of Congo (DRC), Eritrea, Niger and Rwanda are some of the poorer economies (DRC recorded the lowest income per worker at $481.95) in the region. They are characterised by high fertility rates (Rwanda at 8.3 children per woman), high mortality rates (Malawi recorded the highest at 199.50) and low education attainment rates (Eritrea and Niger recorded some of the lowest primary enrollment rates during the period under review).

Table 1: Descriptive Statistics & Correlation Matrix

Variables	Obs	Mean	Std. Dev.	Min	Max	Sources
Fertility	1945	5.89	1.23	1.47	8.29	World Bank
Primary enrol	1612	80.27	32.95	7.86	207.82	World Bank
Secondary enrol	1244	25.28	22.35	1.06	122.20	World Bank
Girl-boy educ	1113	79.19	20.32	29.42	146.83	World Bank
Mortality	1924	94.27	35.35	11.50	199.50	World Bank
Gdp	1916	5226.45	7343.16	481.95	62338.66	Penn World Tables
	Fertility	Primary enrol	Secondary enrol	Girl-boy educ	Mortality	Gdp
Fertility	1.000					
Primary enrol	-0.494*	1.000				
Secondary enrol	-0.797*	0.576*	1.000			
Girl-boy educ	-0.568*	0.676*	0.530*	1.000		
Mortality	0.699*	-0.555*	-0.728*	-0.661*	1.000	
Gdp	-0.492*	0.332*	0.660*	0.341*	-0.478*	1.000

The negative correlation between the education variables and fertility implies a trade-off in education and fertility. The remaining controls are statistically in line with expectations. Infant mortality is positively correlated with fertility suggesting that as fewer children die, fertility also starts to decline. Income per worker is negatively correlated with fertility suggesting that as countries become more developed, fertility rates start to decline. Among the determinants of fertility, secondary education and infant mortality are the most correlated with the dependent variable.

Figure 3 depicts the geographical distribution of fertility and gross primary enrollment rates in the region for 1989 and 2009. The distribution confirms that the relatively mature economies, such as Botswana, Mauritius and South Africa show higher levels of education and lower fertility rates compared to the poorer economies, such as Niger and Rwanda. Data coverage also improves over the years in the region, especially primary enrollment rates, which helps with more accurate analysis of the economies.

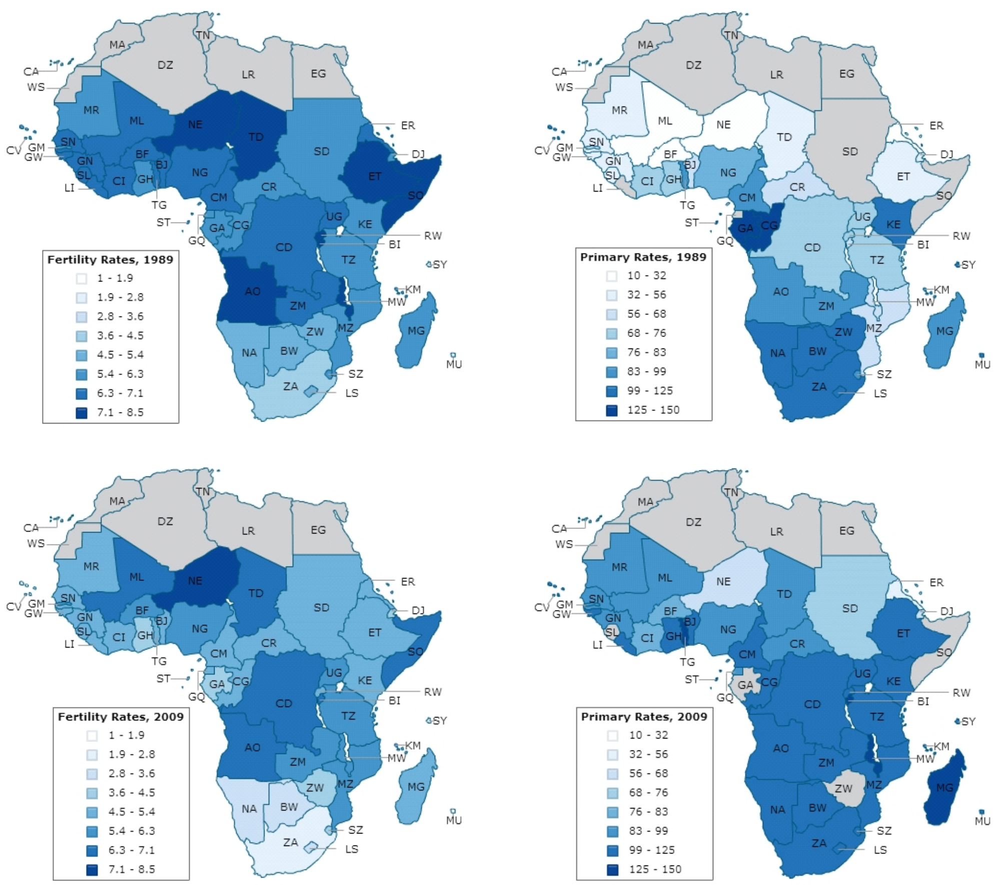

Figure 3: Fertility and Primary Enrollment Rates in sub-Saharan Africa (Source: World Development Indicators)

Figure 4 illustrates a similar negative relationship between education and the different education variables. This characteristic is in line with the quantity-quality trade-off theory which indicates the onset of demographic transitions within the region.

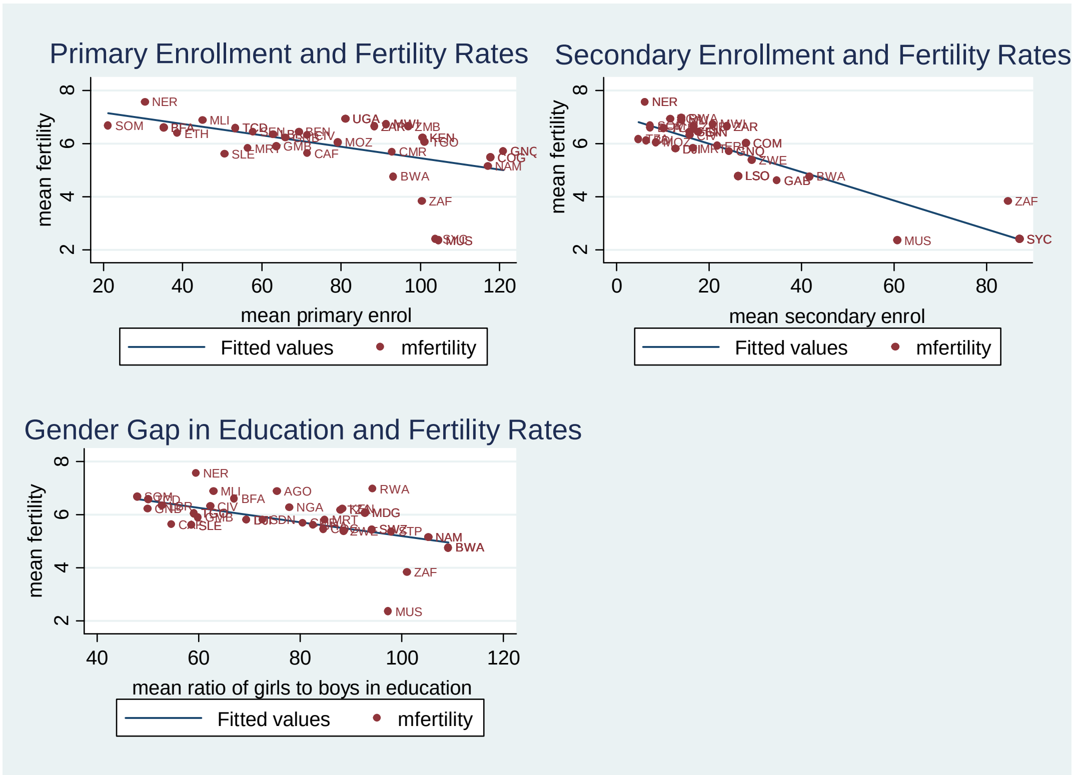

Figure 4: Education and Fertility Rates (Source: World Development Indicators)

3 Methodology

We estimate the following equation using panel data techniques:

$$fertility_{it} = \alpha_i + \beta_1 educ_{it} + \beta_i \mathbf{X}_{it} + \mu_{it}$$

where $fertility$ represents the dependent variable, $educ$ represents the three education explanatory variables entered in separate models and $\mathbf{X}$ is a vector of control variables. The panel data approach allows us to control for heterogeneity, as well as test for more behavioural models than purely cross section or time series. This helps us to get a more informative analysis of the region.

We estimate a baseline pooled OLS (POLS) model which assumes homogeneity among the countries, that is they share common intercepts and slopes. However, countries like South Africa and Nigeria will not necessarily exhibit similar characteristics in trade policies, political barriers, geographic location or access to technology. The fixed effects α_i capture the heterogeneity present in the model by taking these differences into account and incorporating individual specific effects, allowing for more efficient estimates.

Since reverse causality may be present in the model[5], we test each regressor for endogeneity using the Wu-Hausman F-test and the Durbin-Wu-Hausman chi-square test. We reject the null hypothesis for exogenous regressors for secondary enrollment and infant mortality rates. Primary enrollment rates and the gender gap education variable are weakly endogenous. We reject the null hypothesis when we enter them individually in the regressions, but fail to reject exogeneity when control variables are included. We therefore treat them as endogenous variables. We also fail to reject the null hypothesis for exogenous regressors for income per worker.

We use fixed effects with instrumental variables (FE-IV) to minimise both heterogeneity and endogeneity issues. The IV method allows consistent estimation in large samples where the endogenous variables are correlated with the error terms. In other words, the instrumental variables used influence the level of fertility through their impact on education and mortality.

We instrument the education variables with globalisation (*globalisation*) and infant mortality with immunisation against measles (*measles*). Finding external instruments always proves a difficult task in empirical analysis, however in our view, these instruments represent exogenous shocks to sub-Saharan countries during the post-independence period.

The instrument for education accounts for the latest external wave of globalisation taking place in the world including sub-Saharan Africa. The globalisation instrument is taken from a dataset compiled by Dreher (2006) and updated by Dreher, Gaston and Martens (2008). It is made up of economic, social and political globalisation which represents the openness of a country through international flows of goods, capital, technology, people, information and ideas. According to Andersen and Dalgaard (2011) greater international interaction between people from different nations facilitates the spread of ideas thus stimulating aggregate productivity.

Sub-Saharan Africa is a relatively open region, but being a globalised country does not necessarily lead to lower fertility as indicated in Figure 5. According to the globalisation index,

[5]For instance, Becker *et al.* (2010) find that causation between fertility and education runs both ways. Higher fertility may also discourage investments in human capital. Alternatively, higher stocks of capital may reduce the demand for children because that raises the cost of the time spent on child care (Becker *et al.* 1990). Furthermore, Klemp & Weisdorf (2012) show that having more children in a family reduces their chances of becoming literate and skilled in 18^{th}-19^{th} century England. Conley *et al.* (2007) highlight the question of causal directionality between child mortality and fertility rates. They argue that increased child mortality may be due to increased fertility which increases strain on household resources, decreases parental care and supervision with the addition of more children. As reported by Dreze & Murthi (2001), high fertility may raise child mortality for biological (age of giving birth) or behavioural reasons (cultural preferences for sons instead of daughters), while high child mortality may raise fertility rates by inducing parents to replace the lost children.

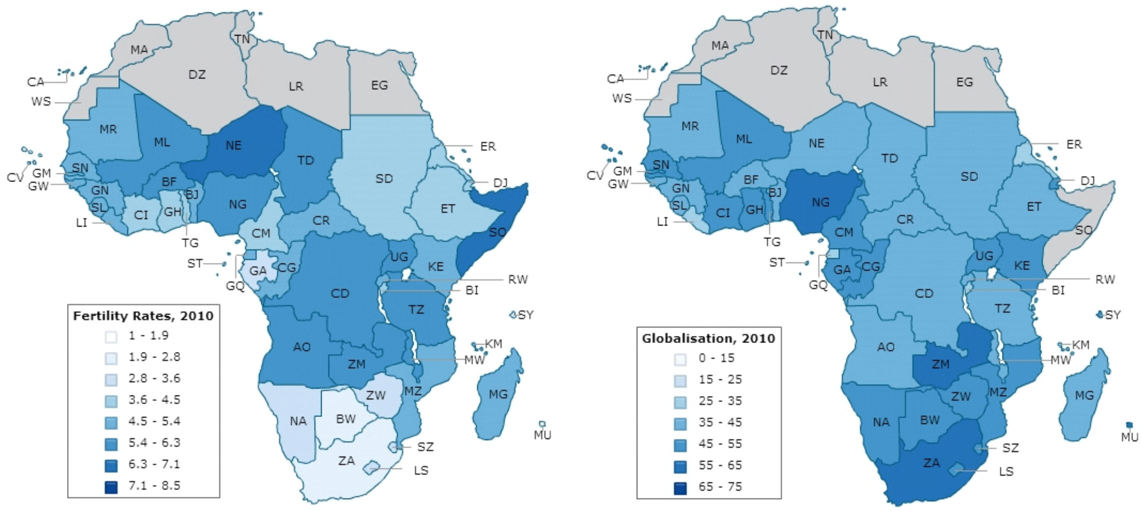

Figure 1: **Figure 5:** Globalisation and Fertility Rates (Source: Dreher et al. 2008; World Development Indicators)

countries such as Mali, Nigeria and Zambia are fairly open, ranging between 55 and 65, but high fertility rates of between 5 to 7 children per woman persist. On the other hand, Burundi, Ethiopia and Togo have low globalisation indices but are characterised with relatively lower fertility rates. A more plausible channel is that the external wave of globalisation improved education by introducing better technologies in the region which required some level of schooling, for example the use of contraceptives or medication.

Analysis by Galor and Mountford (2008) finds that gains from trade in developed economies are used to improve the specialisation of industrial skill-intensive goods which induces a rise in demand for skilled labour and leads to a gradual investment in the quality of the population. On the other hand, they also find that gains from trade in developing countries is concentrated in non-industrial unskilled-intensive goods, such as agricultural produce, which may lower incentive to invest in education and encourage further increase in population. Research undertaken by Avelino, Brown & Hunter (2005) also finds a positive association between trade openness and education.

The instrument for mortality is the immunisation against measles (% of children ages 12-23 months) and is obtained from the WDIs[6]. Vaccinations are an exogenous shock to the region as

[6] Other instruments used in literature for infant mortality include adult male mortality (Galloway *et al.* 1998),

they were introduced by external organisations such as the World Health Organisation (WHO) and the United Nations (United Nations Expanded Program on Immunization, Soares 2007) to prevent child mortality in developing economies. Immunisations against measles is one such external program. As part of their campaign to achieving the fourth Millennium Development Goal to reduce child mortality, WHO partnered with the United Nations and several other international organisations for a routine measles vaccination coverage program which coincides with the period under review. Evidence in Figure 6 also shows that fertility rates were already declining by the time the measles vaccinations coverage was implemented. We therefore expect the introduction of measles vaccinations to assist in reducing infant mortality in the region as intended by the external health programs. Any effect on fertility rates is incidental.

Literature advances that declines in infant mortality rates are largely driven by improvements in public health, education and adoption of technologies (Soares 2007; Reher 2011; Van der Vleuten & Kok 2014; Schultz 2008). In their earlier work, Murthi, Guio and Dreze (1995) find that access to public health services reduces child mortality but has no significant effect on fertility. According to Conley *et al.* (2007) exogenous changes to child mortality through immunisations, improved nutrition, the advent of public health or safe drinking water were seen to be the basic driver to reduced fertility rates.

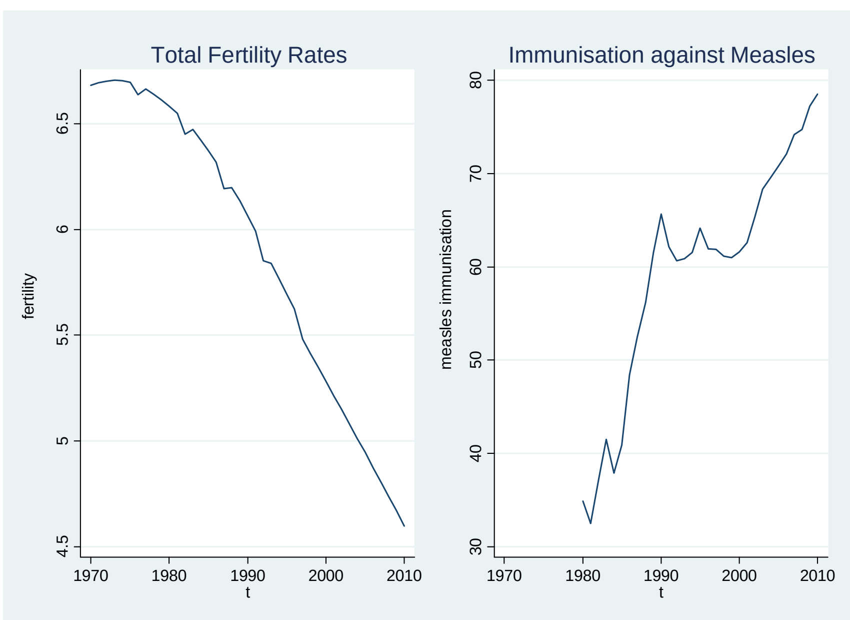

Figure 6: Fertility Rates and Measles Immunisation (Source: World Development Indicators)

lagged mortality (Murtin 2013); malaria ecology and percentage of population at risk of malaria (Conley *et al.* 2007).

4 Results

4.1 Basic Results

We report our findings in Table 2 for both the pooled OLS and the fixed effects models. These results are the baseline regressions which include the variables stated by literature as encouraging the quantity-quality trade-off (Galor 2005). The results indicate a negative and significant relationship between secondary education and fertility rates, while the primary and gender gap education variables become positive and insignificant once we account for the heterogeneity in our panel and include control variables[7].

A 10% increase in secondary enrollment rates diminishes fertility by about 0.5% to 2% suggesting that investing in higher education has more effect in reducing fertility than primary level or the ratio of girls to boys in schooling.

Our results are in line with Bittencourt (2014), Lehr (2009) and Murtin (2013). Empirical analysis by Bittencourt (2014) finds a negative and significant relationship between secondary enrollment rates and fertility within the Southern African Development Community (SADC) region. Similarly, Lehr (2009) also finds that secondary enrollment rates are negatively related with fertility across both high and low-productivity economies, whereas primary education is positively related to fertility, more so in low-productivity economies that have not yet experienced the demographic transition. On the other hand, Murtin (2013) finds a negative and significant relationship between fertility and all three levels of education (primary, secondary and tertiary schooling), while Becker *et al.* (2010) find that primary school enrollments already had a negative impact on fertility in 19^{th} century Prussia.

Results are generally negative and significant for primary education and the gender gap education variable. However the inclusion of fixed effects and control variables appears to undermine these results. Analysis by Ainsworth *et al.* (1996) shows that the last years of primary female schooling affect fertility negatively in about half of the fourteen sub-Saharan African countries under review, while secondary education is associated with significantly lower fertility across all the

[7]The positive primary education effects may act through channels that improve health, fecundity and changes in social norms of women (Lehr 2009). Educated women may have better basic knowledge on health and thus have greater fecundity. According to Ainsworth *et al.* (1996), a possible reason for the positive relationship may be that girls who complete only a few years of schooling are those who become pregnant and thus do not receive the full benefit of higher education, or those that are forced by family to get married early as they will bring in income through the customary bridal price.

countries in their sample. The negative effect of the gender gap works through several channels in reducing fertility. Increasing female education may raise a woman's age at marriage (Ainsworth *et al.* 1996; Galor & Weil 1996), and it may encourage women to invest in the education of their children (Ainsworth *et al.* 1996). Increased education also raises women's knowledge of contraceptive methods (Dreze & Murthi 2001), and it may increase the wage that women can earn in the labour market which raises the opportunity cost of having children (Becker & Barro 1988; Becker *et al.* 1990; Galloway *et al.* 1998; Galor and Weil 1996).

Infant mortality is positively and significantly related to fertility rates (Cervellati & Sunde 2013; Conley *et al.* 2007; Murtin 2013). Survival of infants was low in the past due to adverse health conditions during childbirth, and women may have therefore spent a considerable amount of time replacing those that did not survive. However, with better education in health and hygiene for mothers, and improvements in health facilities, mortality rates have gradually started to decrease reducing the need to have many children (Reher 2011). Evidence by Conley *et al.* (2007) indicates that the infant mortality may be the most important factor in explaining declining fertility rates globally. Moreover, Cervellati and Sunde (2013) suggest that differences in infant mortality may explain a substantial part of the observed differences in the timing of the demographic transition across countries[8].

The results for income per worker are negative and sometimes significant. According to the unified growth theory, the increase in technological progress, not only allows income per worker to keep rising, but also raises the demand for skilled labour. This effect encourages people to invest in quality rather than quantity which reduces fertility (Galor & Weil 1999). The negative income results are also in line with the Barro-Becker (1988, 1989) hypothesis. Rising income per worker, through increased labour opportunities for women, may increase the opportunity costs of raising children, thus lowering fertility (Galloway *et al.* 1998; Galor & Weil 1996).

[8] The decline in infant mortality in Western Europe during the 1800s was associated at first with increasing fertility rates (Galor 2012). However empirical evidence by Doepke (2005) and Murphy (2010) shows that infant mortality rates were already declining before fertility rates in England and France during the 19^{th} century.

Table 2: Pooled OLS and Fixed Effects

	1	2	3	4	5	6	7	8	9	10	11	12
FERTILITY	POLS	POLS	POLS	POLS	POLS	POLS	FE	FE	FE	FE	FE	FE
Primary enrol	-0.224***			-0.017**			-0.212***			0.019		
	(0.010)			(0.007)			(0.029)			(0.032)		
Secondary enrol		-0.217***			-0.048***			-0.182***			-0.060*	
		(0.010)			(0.007)			(0.027)			(0.031)	
Girl-boy educ			-0.568***			-0.031			-0.435***			0.073
			(0.030)			(0.022)			(0.089)			(0.073)
Mortality				0.435***	0.401***	0.434***				0.531***	0.404***	0.548***
				(0.014)	(0.018)	(0.018)				(0.051)	(0.065)	(0.053)
Gdp				-0.039***	-0.032***	-0.055***				0.028	-0.00008	-0.021
				(0.005)	(0.006)	(0.007)				(0.040)	(0.046)	(0.045)
Observations	1,590	1,223	1,093	1,540	1,183	1,059	1,590	1,223	1,093	1,540	1,183	1,059
F test	501.61***	492.72***	351.02***	618.55***	526.44***	487.48***	52.85***	44.37***	23.98***	52.52***	44.34***	53.02***
R-squared	0.184	0.445	0.271	0.672	0.691	0.696	0.167	0.405	0.158	0.548	0.556	0.598
Number of i							47	47	48	47	47	48
Country FE							YES	YES	YES	YES	YES	YES

Coefficients reported. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Given that reverse causality may be present in the model, we also use fixed effects with instrumental variables for the potentially endogenous variables and report the results in Table 3. The identifying instruments are statistically significant in the first stage regressions[9], as well as the F-tests for joint significance which minimises the issues of weak instruments. We also test for overidentification of instruments and reject the null hypothesis for the Sargan test, concluding that the equation is exactly identified.

Globalisation is positively and significantly related to education. Results by Rodrik (1998) find that open countries have bigger governments implying increased public expenditure towards education, health, housing, *etc.*[10]. The immunisation against measles reduces infant mortality and is statistically significant. This is in line with expectations given the introduction of measles vaccinations from international organisations within the region (Soares 2007).

Primary enrollment and the gender gap education coefficients are negative and significant when entered alone, but insignificant when control variables are included. Secondary education remains negative and significant. The economic effect is also now larger than that of our fixed effects regressions. A 10% increase in secondary education lowers fertility by about 2.7% to 4.9%, results which are similar to Lehr (2009).

Infant mortality loses explanatory power with the introduction of instruments. However, the income per worker is now positive and significant suggesting a dominant income effect at play in

[9] We also use lagged endogenous variables as instruments. The results remain in line with the ones reported in the paper. Results are available on request.

[10] Kaufman and Segura-Ubiergo (2001), on the other hand, find that the negative effect of globalisation works mainly in the area of social security expenses, while health and education are less affected.

the region. Results by Dreze and Murthi (2001) suggest that income effects depend on whether children are perceived as an economic burden or productive asset. In developed countries, they are seen as a consumption good leading to a focus on the cost of children and the quantity-quality trade-off as income rises. In developing countries, children are more likely to be regarded as productive assets because they are a source of labour power and old-age security. Hence developing regions, such as sub-Saharan Africa, are inclined to have more children with rising incomes. Evidence from a transitioning Western Europe in the 19^{th} century supports our findings which suggest that the sub-Saharan African region may be in a Post-Malthusian stage where rising income initially raises fertility[11]. Galor and Weil (1999) also state that rising income may increase fertility by encouraging marriages.

Table 3: Fixed Effects with Instrumental Variables

	1	2	3	4	5	6
FERTILITY	FE-IV	FE-IV	FE-IV	FE-IV	FE-IV	FE-IV
Primary enrol	-0.632***			-1.996		
	(0.029)			(1.969)		
Secondary enrol		-0.269***			-0.489***	
		(0.010)			(0.127)	
Girl-boy educ			-1.245***			0.664
			(0.065)			(0.582)
Mortality				-1.397	-0.166	1.157***
				(2.143)	(0.251)	(0.328)
Gdp				-0.236	0.056**	0.165*
				(0.347)	(0.024)	(0.089)
Observations	1,528	1,173	1,052	1,089	809	751
F test	479.46***	759.89***	371.58***	21.86***	153.94***	137.34***
R squared	0.186	0.282	0.334	0.028	0.118	0.035
Number of i	46	46	47	46	46	47
Country FE	YES	YES	YES	YES	YES	YES
First Stage Regressions						
Globalisation	0.852***	2.010***	0.440***	0.636***	1.239***	0.302***
	(0.031)	(0.052)	(0.016)	(0.036)	(0.063)	(0.021)
Measles				-0.092***	-0.100***	-0.062***
				(0.010)	(0.013)	(0.012)
F test weak instruments	753.32***	1475.51***	723.09***	195.61***	255.20***	163.00***
F test weak instruments				487.62***	360.31***	336.19***

Coefficients reported. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

[11] Murtin (2009) and Murphy (2010) present results for OECD countries and France that find that income per capita and fertility rates were positively related during the 19^{th} century.

4.2 Robustness Tests

We undertake several robustness checks to verify the validity of the results obtained for the education variables.

4.2.1 Inclusion of Time Variations

We incorporate lagged independent variables to capture possible time delays of the variables in affecting fertility rates. The results in Table 4 are generally robust and in line with our previous results. Secondary education remains significant in lowering fertility in the region by 0.5% to 4.8%. The magnitudes of the coefficients also do not vary much with the previous results. Primary education and the gender gap coefficients remain weak determinants of fertility. The control variables are not significantly different from the contemporaneous results and the instruments remain valid. An increase in past infant deaths increases current fertility rates either because people decide to have more children to replace those that did not survive in the previous period (Conley *et al.* 2007; Dreze & Murthi 2001), or there is a delay in people's perceptions of the decreased risks of infant mortality (Montgomery 2000).

Table 4: Results with lagged regressors

	1	2	3	4	5	6	7	8	9
FERTILITY	POLS	POLS	POLS	FE	FE	FE	FE-IV	FE-IV	FE-IV
Primary enrol $_{t-1}$	-0.018**			0.017			-1.302		
	(0.007)			(0.031)			(0.940)		
Secondary enrol $_{t-1}$		-0.051***			-0.067**			-0.483***	
		(0.007)			(0.032)			(0.119)	
Girl-boy educ $_{t-1}$			-0.040*			0.066			0.858
			(0.022)			(0.074)			(0.791)
Mortality $_{t-1}$	0.449***	0.414***	0.446***	0.551***	0.419***	0.572***	-0.609	-0.081	1.312***
	(0.014)	(0.017)	(0.018)	(0.051)	(0.063)	(0.054)	(1.021)	(0.227)	(0.449)
Gdp $_{t-1}$	-0.038***	-0.029***	-0.053***	0.029	0.003	-0.019	-0.092	0.056**	0.184
	(0.006)	(0.006)	(0.007)	(0.042)	(0.047)	(0.047)	(0.148)	(0.023)	(0.114)
Observations	1,508	1,163	1,036	1,508	1,163	1,036	1,057	789	728
F test	672.94***	573.92***	528.98***	56.40***	52.55***	53.51***	48.12***	167.77***	115.05***
R-squared	0.685	0.704	0.708	0.560	0.573	0.608	0.001	0.207	0.496
Number of i				47	47	48	46	46	47
Country FE				YES	YES	YES	YES	YES	YES
First Stage Regressions									
Globalisation $_{t-1}$							0.624***	1.157***	0.297***
							(0.036)	(0.063)	(0.021)
Measles $_{t-1}$							-0.095***	-0.106***	-0.066***
							(0.010)	(0.012)	(0.012)
F test weak instruments							177.76***	220.52***	151.21***
F test weak instruments							457.01***	338.91***	310.15***

Coefficients reported. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

4.2.2 Inclusion of other control variables

Another robustness check we employ is to include a squared term for income per worker and conflict as added control variables. Given that sub-Saharan African countries are still transitioning from developing to developed economies, we check for possible nonmonotonicity in the model (Lehr 2009; Murtin 2013). According to the unified growth theory, there is an initial positive Malthusian income effect on fertility as wealth increases, but over time this effect is replaced by a substitution effect as parents start to invest in child education with higher income which in turn decreases fertility (Galor & Weil 1999; Murtin 2013).

Evidence by Vandenbroucke (2014) finds that conflict may cause a negative shock to the household by increasing the probability of a woman remaining alone and reducing income through the death of the husband, or the period that he is away from home. This may negatively impact on fertility during the war. For instance, Caldwell (2004) provides evidence that fertility declined in several European countries during various episodes of social and political unrest. However, Vandenbroucke (2014) also finds that fertility rebounded postwar induced by a catch-up effect from households that could still have children. Since conflict has been persistent in sub-Saharan Africa over the years, we expect that fertility may have been adversely affected during times of unrest, but there may also be a temporary increase in birth rates during times of stability.

The conflict variable is obtained from the Armed Conflict and Intervention datasets (2013) compiled by the Center for Systemic Peace and it captures the magnitude of conflict involving the country between 1970 and 2010.

The results reported in Table 5 are in line with our previous findings. Secondary education remains negative and significant across the estimators, while the primary and ratio of girls to boys' levels of education have weak explanatory powers. Infant mortality is positively related with fertility in most regressions, as is income per worker. But this relationship changes when we include the squared variable of income per worker. There is a non-linear relationship which suggests as income continues to rise, households eventually substitute larger family sizes with smaller ones thus lowering fertility rates. The results are in line with Lehr (2009) and Murtin (2013) who both find that at low levels of development, fertility increases with rising income, while at advanced stages of development, fertility decreases with rising income. The results also give credence to the unified growth theory that suggests that rising income initially raises demand for children but is gradually offset by the technological progress and rise in demand for human capital accumulation (Galor & Weil 1999, 2000).

The conflict variable turns out to be a poor determinant for fertility in the analysis[12].

[12] The weak explanatory power for conflict persists even when lagged.

Table 5: Results with other control variables

	1	2	3	4	5	6	7	8	9
FERTILITY	POLS	POLS	POLS	FE	FE	FE	FE-IV	FE-IV	FE-IV
Primary enrol	-0.017**			-0.003			-3.471		
	(0.007)			(0.034)			(5.550)		
Secondary enrol		-0.052***			-0.063**			-0.522***	
		(0.007)			(0.030)			(0.129)	
Girl-boy educ			-0.002			0.034			0.907
			(0.022)			(0.079)			(0.701)
Mortality	0.426***	0.384***	0.434***	0.492***	0.368***	0.509***	-3.218	-0.265	1.304***
	(0.015)	(0.019)	(0.018)	(0.057)	(0.068)	(0.060)	(6.360)	(0.260)	(0.408)
Gdp	0.670***	0.721***	0.621***	0.621	0.822*	0.605	6.453	0.728***	-0.081
	(0.079)	(0.094)	(0.103)	(0.464)	(0.434)	(0.433)	(9.356)	(0.204)	(0.438)
Gdp^2	-0.043***	-0.046***	-0.041***	-0.036	-0.050*	-0.039	-0.425	-0.041***	0.016
	(0.005)	(0.006)	(0.006)	(0.028)	(0.026)	(0.027)	(0.630)	(0.013)	(0.032)
Conflict	0.011	0.029	0.038	-0.000	0.030	-0.033	0.385	0.055	-0.180**
	(0.018)	(0.021)	(0.024)	(0.064)	(0.068)	(0.050)	(0.773)	(0.059)	(0.075)
Observations	1,491	1,150	1,036	1,491	1,150	1,036	1,061	790	735
F test	385.24***	350.70***	315.37***	28.76***	36.14***	33.66***	4.45***	87.85***	66.90***
R-squared	0.685	0.708	0.703	0.552	0.574	0.610	0.001	0.035	0.339
Number of i				45	45	46	44	44	45
Country FE				YES	YES	YES	YES	YES	YES
First Stage Regressions									
Globalisation							0.653***	0.084***	0.304***
							(0.036)	(0.030)	(0.021)
Measles							-0.090***	-0.100***	-0.065***
							(0.011)	(0.013)	(0.012)
F test weak instruments							129.67***	151.62***	97.53***
F test weak instruments							294.30***	222.40***	207.55***

Coefficients reported. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

4.2.3 Exclusion of outliers

We also exclude Mauritius, Seychelles and South Africa as they appear to be outliers in the data and may bring in some bias. The results in Table 6 however are not significantly different to those reported for the full sample of countries. Secondary enrollment rates remain robust in reducing fertility rates as compared to the other education variables and there is relatively small variation in the magnitudes of the coefficients.

Table 6: Results excluding outlier countries

	1	2	3	4	5	6	7	8	9
FERTILITY	POLS	POLS	POLS	FE	FE	FE	FE-IV	FE-IV	FE-IV
Primary enrol	-0.045***			0.017			-1.866		
	(0.007)			(0.035)			(2.567)		
Secondary enrol		-0.063***			-0.067**			-0.445***	
		(0.006)			(0.033)			(0.139)	
Girl-boy educ			-0.097***			0.074			0.249
			(0.020)			(0.080)			(0.479)
Mortality	0.323***	0.278***	0.313***	0.517***	0.374***	0.553***	-1.325	-0.099	0.915***
	(0.014)	(0.016)	(0.019)	(0.061)	(0.073)	(0.065)	(2.863)	(0.278)	(0.277)
Gdp	-0.024***	-0.015***	-0.041***	0.026	0.006	-0.022	-0.152	0.070***	0.082
	(0.005)	(0.006)	(0.006)	(0.042)	(0.048)	(0.047)	(0.354)	(0.022)	(0.064)
Observations	1,464	1,124	1,002	1,464	1,124	1,002	1,032	762	706
F-test	386.67***	318.03***	285.97***	39.54***	31.23***	37.50***	22.30***	158.44***	178.43***
R-squared	0.509	0.539	0.537	0.519	0.524	0.563	0.015	0.204	0.311
Number of i				44	44	45	43	43	44
Country FE				YES	YES	YES	YES	YES	YES
First Stage Regressions									
Globalisation							0.668***	1.278***	0.324***
							(0.038)	(0.067)	(0.022)
Measles							-0.081***	-0.086***	-0.051***
							(0.011)	(0.013)	(0.012)
F test weak instruments							196.27***	235.44***	162.73***
F test weak instruments							459.13***	333.89***	316.37***

Coefficients reported. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

5 Additional Analysis

5.1 Male and Female Education

In Table 7, we decompose the secondary enrollment rate into male and female to determine which is driving the results. We use the logged gross female and male secondary enrollment rates taken from the WDIs. We find that the male secondary enrollment rates are more robust in reducing fertility rates compared to the female secondary enrollment rates. Although Dreze & Murthi (2001) do not find a significant association between male literacy and fertility rates, they do not dispute that male education is also an important determinant for fertility decline. They argue that even though women are the primary caregivers, in cases where the fertility decisions are dominated by males, the level of male education has a greater impact on the fertility levels.

Table 7: Male and Female Secondary Education

FERTILITY	1 POLS	2 POLS	3 FE	4 FE	5 FE-IV	6 FE-IV
Female secondary enrol	-0.041***		-0.039		-1.061	
	(0.007)		(0.027)		(0.778)	
Male secondary enrol		-0.042***		-0.062*		-0.711***
		(0.007)		(0.036)		(0.275)
Mortality	0.394***	0.417***	0.424***	0.413***	-1.916	-0.400
	(0.020)	(0.017)	(0.067)	(0.066)	(1.990)	(0.465)
Gdp	-0.041***	-0.041***	-0.027	-0.020	-0.123	0.082***
	(0.007)	(0.007)	(0.052)	(0.049)	(0.159)	(0.030)
Observations	1,028	1,028	1,028	1,028	726	726
F test	508.37***	514.80***	45.13***	47.57***	23.85***	85.67***
R-squared	0.704	0.702	0.569	0.575	0.008	0.034
Country FE			YES	YES	YES	YES
Number of i			47	47	46	46
First Stage Regressions						
Globalisation					1.464***	1.031***
					(0.074)	(0.065)
Measles					-0.109***	-0.109***
					(0.015)	(0.015)
F test weak instruments					305.60***	189.10***
F test weak instruments					313.74***	313.74***

Coefficients reported. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

5.2 Dynamic Specification

We introduce the lagged dependent variable to account for the persistence of social behaviour. Current fertility rates may be determined by imitation of parental behaviour or social class behaviour in the past (Murtin 2013) i.e. people may decide to have fewer children because their parents had fewer children or because that is the norm within their social class.

This specification also allows us to use the system-gmm which is commonly used in empirical literature to estimate dynamic models (Blundell & Bond 1998; Lehr 2009; Murtin 2013). System-gmm uses deeper lagged levels of the endogenous variable as instruments for the first-differenced model, as well as additional moment conditions in first differenced form of the endogenous variable for the model in levels. To reduce the possibility of instrument proliferation which may overfit endogenous variables and fail to expunge their endogeneity, we specify the number of lags and collapse the instruments (Roodman 2009). System-gmm also takes care of serial correlation and persistence which are more than likely to be present in the lagged dependent variable. We include

Table 8: Dynamic Results

	1	2	3	4	5	6	7	8	9	10	11	12
FERTILITY	POLS	POLS	POLS	FE	FE	FE	FE-IV	FE-IV	FE-IV	Sys-Gmm	Sys-Gmm	Sys-Gmm
Primary enrol	-0.003***			-0.007***			0.131			-0.025*		
	(0.001)			(0.002)			(0.091)			(0.014)		
Secondary enrol		-0.004***			-0.009***			0.035			-0.018***	
		(0.001)			(0.002)			(0.022)			(0.006)	
Girl-boy educ			-0.010***			-0.016**			-0.178			0.010
			(0.002)			(0.006)			(0.127)			(0.041)
Mortality	0.012***	0.012***	0.011***	0.011**	0.003	0.007	0.206*	0.084**	-0.125	0.015	0.017	0.019
	(0.001)	(0.001)	(0.002)	(0.005)	(0.007)	(0.007)	(0.123)	(0.033)	(0.115)	(0.020)	(0.043)	(0.027)
Gdp	0.001**	0.002***	0.002***	0.001	0.003	0.002	0.031	0.004	-0.025	0.013*	0.013	0.000
	(0.000)	(0.000)	(0.001)	(0.003)	(0.003)	(0.003)	(0.019)	(0.003)	(0.022)	(0.008)	(0.016)	(0.010)
Fertility $_{t-1}$	1.005***	1.002***	1.007***	1.007***	1.001***	1.010***	0.945***	1.012***	1.065***	1.057***	1.032***	1.016***
	(0.002)	(0.003)	(0.003)	(0.005)	(0.005)	(0.007)	(0.033)	(0.016)	(0.057)	(0.036)	(0.025)	(0.042)
Observations	1,523	1,169	1,046	1,523	1,169	1,046	1,085	806	748	1,523	1,169	1,046
F test	79558.55***		70366.70***	15312.90***	17911.63***	9509.50***	4843.14***	15031.12***	8022.40***	34359.10***	106094.51***	2028.32***
R-squared	0.998	0.999	0.999	0.996	0.996	0.996	0.947	0.987	0.978			
No. of instruments										53	53	53
AR(2) p-value										0.215	0.139	0.144
Hansen J-test p-value										0.276	1.000	0.999
Number of i				47	47	48	46	46	47	47	47	48
Country FE				YES	YES	YES	YES	YES	YES	YES	YES	YES
Year FE										YES	YES	YES
First Stage Regressions												
Globalisation							0.690***	0.807***	0.357***			
							(0.046)	(0.078)	(0.027)			
Measles							-0.086***	-0.096***	-0.051***			
							(0.010)	(0.013)	(0.011)			
F test weak instruments							147.28***	229.45***	125.88***			
F test weak instruments							379.18***	280.52***	286.52***			

Coefficients reported. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

the two-step robust procedure which uses the Windmeijer's (2005) finite-sample correction for downward-biased standard errors and makes it a more efficient estimator than the onestep robust estimation.

Results remain generally in line with previous ones, though the inclusion of the lagged dependent variable appears to be affecting the explanatory power of variables when we incorporate fixed effects and instruments together (Achen 2001). We fail to reject the null hypothesis for the Hansen J-test for overidentifying instruments and the Arellano-Bond test for no second-order serial correlation.

5.3 Different Dependent Variable

As a final analysis we employ a different dependent variable, the logged crude birth rates per 1,000 people from the WDIs (Murtin 2013). The findings in Table 9 show that secondary education lowers birth rates, more so when we control for both fixed effects and endogeneity.

Table 9: Birth Rates

	1	2	3	4	5	6	7	8	9
BIRTH RATE	POLS	POLS	POLS	FE	FE	FE	FE-IV	FE-IV	FE-IV
Primary enrol	-0.010			0.022			-0.770		
	(0.006)			(0.020)			(0.697)		
Secondary enrol		-0.031***			-0.021			-0.291***	
		(0.005)			(0.023)			(0.086)	
Girl-boy educ			-0.039**			0.116**			0.456
			(0.018)			(0.050)			(0.408)
Mortality	0.336***	0.322***	0.332***	0.379***	0.333***	0.421***	-0.359	-0.079	0.743***
	(0.012)	(0.014)	(0.016)	(0.030)	(0.045)	(0.032)	(0.758)	(0.170)	(0.230)
Gdp	-0.041***	-0.034***	-0.051***	0.004	-0.018	-0.022	-0.111	-0.011	0.069
	(0.004)	(0.004)	(0.005)	(0.027)	(0.032)	(0.030)	(0.129)	(0.017)	(0.064)
Observations	1,558	1,200	1,075	1,558	1,200	1,075	1,101	821	762
F test	661.71***	552.12***	503.86***	79.58***	52.46***	76.95***	50.99***	136.11***	153.38***
R-squared	0.718	0.742	0.745	0.564	0.576	0.635	0.021	0.152	0.257
Number of i				47	47	48	46	46	47
Country FE				YES	YES	YES	YES	YES	YES
First Stage Regressions									
Globalisation							0.637***	1.231***	0.303***
							(0.036)	(0.063)	(0.021)
Measles							-0.095***	-0.104***	-0.065***
							(0.010)	(0.013)	(0.012)
F test weak instruments							197.91***	258.17***	164.86***
F test weak instruments							491.65***	364.09***	338.68***

Coefficients reported. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

6 Conclusion

Overall, the results suggest that higher levels of education significantly lower fertility in sub-Saharan Africa. Given the literature, the findings favour the predictions made by the unified growth theory that growth in educational attainment will bring about a decline in fertility and hence a demographic transition (Murtin 2013). The results are also consistent with the unified growth theory in which the quantity-quality trade-off is already present in the stages leading to the modern growth regime.

We also confirm evidence in support of infant mortality rates raising fertility rates, as well as the non-linear effect of income per worker on fertility rates (Galor & Weil 1999, 2000; Lehr 2009; Murtin 2013). The Malthusian income effect is offset by the Post-Malthusian substitution effect for more education to complement the rising technology.

The implications of the results suggest that the region may be exhibiting the characteristics of economies transitioning out of the Malthusian stagnation with higher levels of education contributing significantly to the decline in fertility rates. According to Galor & Moav (2002), the acceleration in technological progress in 19^{th} century Europe stimulated the accumulation of human capital and resulted in a demographic transition in which fertility rates declined rapidly. Therefore, as sub-Saharan Africa continues to develop we expect the demand for a more skilled and educated population to increase which may induce further investments in child education and lower fertility, enabling the region to enter into a complete demographic transition and an era of sustained economic growth. Despite the region's slow start, Africa may just still be on time (Pinkovskiy & Sala-i-Martin 2014; Young 2012).

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