The Fertility Transition: Panel Evidence from sub-Saharan Africa

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Abstract

We investigate the effects of different socioeconomic indicators on fertility rates in 48 sub-Saharan African countries between 1970 and 2012. The results, based on panel analysis with fixed effects and instrumental variables, show that initially income per capita and infant mortality explain a significant part of the fertility decline in the region. However, the introduction of technology as an instrument augments the effect of education in reducing fertility. The results also provide significant evidence for fertility declines through increased female education. These results support empirical evidence of the unified growth theory which emphasises the role of technology in raising the demand for education and bringing about a demographic transition during the Post-Malthusian period.

Keywords: fertility, sub-Saharan Africa

JEL Classification: I25, J13, O55

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1 Introduction

In this paper, we investigate the theoretical linkage between various socioeconomic indicators and fertility declines in sub-Saharan Africa. We deviate from previous empirical works that typically test a specific hypothesis for this region, such as education (Ainsworth *et al.* 1996, Bittencourt 2014). In so doing, these works do not place as much focus on the role of the other determinants, such as income or infant mortality, and as such may understate the contribution of these determinants to the fertility transition in sub-Saharan Africa.

We test the various theories put forward in literature as contributing to fertility declines in industrialised economies in order to identify the determinants which have contributed to the region's fertility transition. We complement this empirical exercise by also investigating the effective channel through which technology has contributed to reducing fertility rates. For example, literature cites that one of the main catalysts for raising demand in education or sustaining rising incomes per capita is industrialisation which comes with technological progress, and this increased development in education and income induces declines in fertility rates (Galor 2005, Galor & Weil 2000). By conducting this empirical analysis we are able to place sub-Saharan Africa within a particular theoretical framework and developmental stage.

In today's society a demographic transition from high to low fertility rates is viewed as an important modernisation process of economic development. However, the differences in the timing of the fertility declines have given rise to the differences in the take-offs of the demographic transitions, and this has led to the varying levels of economic development between developed and developing economies (Galor 2005). Most developed economies are characterised by high human capital accumulation, low fertility rates and high levels of productivity. We find that these developed economies, such as Western Europe, also industrialised earlier and as a result experienced their demographic transitions earlier compared to developing regions, such as sub-Saharan Africa, which are still in the process of industrialising.

One of the main motivations for this study is the statistical data which shows a significant delay in the fertility decline for sub-Saharan Africa. Figure 1 shows the fertility rates within sub-Saharan Africa and between different regions in the world. Although there is evidence of an onset of fertility declines across the African region, the graph also shows that these fertility declines are stalling in mid-transition. The relatively developed economies such as Botswana, Mauritius, Seychelles and South Africa, indicate earlier take-offs than the poorer economies such as Chad, the Democratic Republic of Congo (DRC), Mali and Niger. The differences in take-offs may also suggest differences in industrialisation processes between economies in sub-Saharan Africa.

These slow fertility declines in the various African countries have contributed to an overall delay in the take-off of the region's demographic transition as compared to the other regions in the world. The fertility rates in the sub-Saharan African region start decreasing significantly after 1990, while other developing regions such as South Asia and Latin America, already exhibit declining rates by the late 1960s. All the regions, except sub-Saharan Africa, are converging at two to three children per woman.

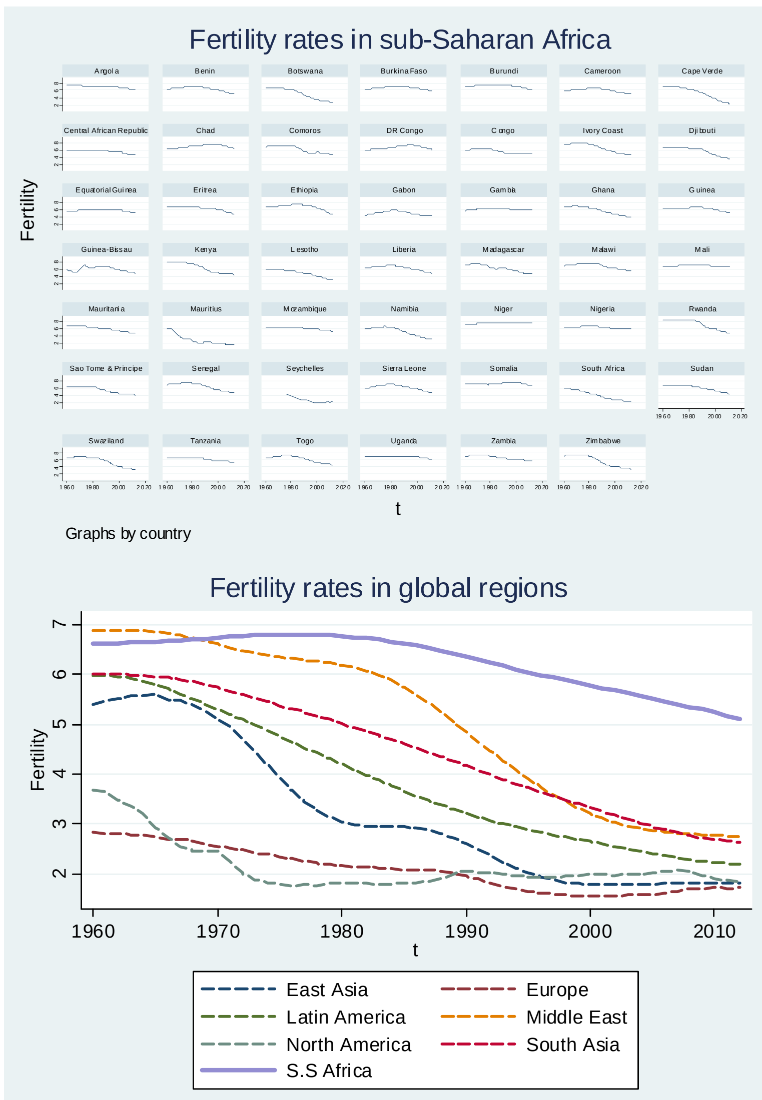

Figure 1: Fertility rates in sub-Saharan Africa and different global regions, 1960-2012 (Source: World Development Indicators)

Several mechanisms in literature have been proposed as triggering the decline in fertility rates. Firstly, the Barro-Becker wealth theory (1988, 1989) which focuses on opportunity costs involved with rising income per capita which may induce parents to reduce the quantity of children. Secondly, the unified growth theory which emphasises the effect of education in reducing fertility (Becker, Cinnirella & Woesmann 2010, Galor 2005). Thirdly, the health theory on declining infant mortality rates which reduce the need to have more children to replace those that do not survive (Conley, McCord & Sachs 2007, Murtin 2013). Fourthly, the decrease in the gender gap in wages which raises the cost of children (Galor & Weil 1996). Lastly, 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)[1].

As a first contribution we examine the post-independence fertility transition in 48 sub-Saharan African countries between 1970 and 2012. Using macro-analysis from country level data, we investigate the effects of different education levels, income per capita and infant mortality on fertility rates.

A second contribution is the introduction of technological progress through instrumental variables. In Western Europe the Industrial Revolution is associated with technological progress which is cited as increasing investments in education and inducing fertility declines (Galor 2005, Galor & Weil 2000). 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. Given that sub-Saharan Africa is in the process of industrialising and at the same time there is evidence of fertility declines, including technology in the empirical analysis is relevant, firstly in determining if technological progress is acting as a catalyst that creates incentives that discourage fertility in sub-Saharan Africa, and secondly in determining the most effective channel through which technological progress works in reducing fertility rates. Interestingly technological progress plays a significant role not only in increasing demand for education, but also in increasing income per capita, reducing infant mortality rates and reducing the gender gap in wages.

According to the unified growth theory, technological advancement in the industrialisation process has contributed significantly to incentives for increased demand for education. Within this theory, the process of development is divided into three distinct periods, the Malthusian

[1] The establishment of national pension schemes and nursing homes in developed economies negated the traditional views of having many children for old age security (Reher 2011).

period 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 and any increases in income are offset by the increase in population size in the absence of technology. The second period is the Post-Malthusian period. As technological rates increase, the returns on education increase, such as better quality of labour and increased opportunities for employment, encouraging people to invest in the education of their children and have less children, a process known as the child quantity-quality trade-off. This transition allows income to keep rising and helps to move the economy into the third sustained growth period characterised by low fertility rates, high human capital accumulation and high incomes per capita. It is this same trade-off that 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, Doepke 2004, Galor 2012, Galor & Moav 2002).

A complementary channel for the technological progress is through income per capita. Rising income per capita initially has a pure income effect which is to raise demand for children, but this effect is gradually offset by the technological progress which increases returns on labour, such as higher wages, and induces a substitution effect for quality over quantity of children (Becker, Murphy & Tamura 1990, Galor & Weil 2000). The acceleration in technological progress is also linked to the sustained increase in income per capita between the transition from Post-Malthusian period to the sustained growth period.

The introduction of technological progress through preventative medicines and improved child health care has helped to reduce infant mortality rates which has reduced high fertility rates (Chowdhury 1988, Van der Vleuten & Kok 2014). In the absence of technological progress, high levels of infant mortality tended to raise fertility by either inducing parents to have more children than they desired in anticipation of losing some, or to replace those that did not survive (Bongaarts & Casterline 2012). 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 rates may explain a substantial part of the observed differences in the timing of the demographic transition across countries.

As a final contribution we extend the analysis by exploring the gender gap reduction theory through male and female education and male and female labour force participation rates. This theory also looks at the indirect role of technology in reducing fertility rates. In their analysis Galor & Weil (1996) highlight the role of technological progress in decreasing the comparative advantage of male labour and raising the demand for female labour thereby increasing the opportunity cost of fertility. Initially, men had a comparative advantage in physically intensive jobs, but with industrialisation demand for fine motor skills and mentally intensive tasks in which women have a better advantage has increased (Galor & Weil 1996, Goldin 1995). As demand for women's labour increases, so do the wages for women which raises the cost of having children relatively more than it raises wage rates, leading to a trade-off between quality and quantity of children.

The empirical evidence from this study lends credence to the unified growth framework with emphasis on the role of technology in increasing the demand for education resulting in lower fertility rates. There is inconclusive evidence on the role of technology through the wealth and health channels. We also find that the reduction in the education gender gap has more impact on decreasing fertility rates than the reduction in the labour force gender gap. The male labour participation rates induce higher fertility. However these positive effects from the male labour force participation rates are counteracted with the inclusion of the technology instrument indicating the influence of technological progress in decreasing the comparative advantage of male labour and reducing fertility rates.

This study shows evidence of a region that is in a Post-Malthusian period where a demographic transition is starting to take place as the economies become more industrialised. However, the study also indicates a region that is still characterised by a patriarchal system where women are expected to play a traditional role of raising children and this may be contributing to the stalling fertility declines leading to delays in the demographic transition.

2 Empirical Analysis

2.1 Data

We use a sample of 48 countries[2] from 1970 to 2012. 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).

[2] *Sample of countries:* Angola, Benin, Botswana, Burkina Faso, Burundi, Cameron, Cape Verde, Central African Republic, Chad, Comoros, Congo (Democratic Republic), Congo (Republic), Cote d'Ivoire, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea Bissau, Kenya, Liberia, Lesotho, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome & Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe.

We use three different variables for education levels. Primary education (*primary enrol*) is measured by the gross primary enrolment rate as a percentage of the population. The secondary education variable (*secondary enrol*) is the gross secondary enrolment rate as a percentage of the population. The third education variable (*tertiary enrol*) is the gross tertiary enrolment rate as a percentage of the population. All three variables are obtained from the WDIs.

A negative coefficient for the education variables suggests a trade-off between education and 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. Empirical analysis by Bittencourt (2014a, 2014b) finds a negative and significant relationship between secondary enrolment rates and fertility within the Southern African Development Community (SADC) region, as well as primary completion rates and fertility within the same region. Similarly, Lehr (2009) also finds that secondary enrolment 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 enrolments already had a negative impact on fertility in 19^{th} century Prussia.

We also include infant mortality and income per capita based on the other proposed mechanisms in literature that triggered fertility declines. The inclusion of these variables also minimises issues with omitted variable bias. The infant mortality rate per 1,000 live births (*infant mort*) is taken from the WDIs. We expect a positive relationship between infant mortality and fertility rates. As fewer children die, fertility rates start to decline (Cervellati & Sunde 2013).

Income per capita (*gdpcap)* at 2005 constant prices is also taken from the WDIs. 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 *et al.* 1990). All variables are logged[3].

[3]While fertility and infant mortality data are available across all countries and most years, there is missing data for the education variables and income per capita. Although we lose some observations in the regressions, they are not significant enough to bias the overall conclusions drawn from the results.

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 statistics in detail, we find that the richer economies, such as Botswana, Mauritius, Seychelles (with the highest recorded income per capita at $13,889.95) and South Africa, are also characterised by lower fertility rates (Mauritius at 1.43 children per woman), lower mortality rates (Seychelles 12.2 children per 1,000 births) and higher education enrolment rates (Seychelles recorded the highest secondary enrollment rates during the period under review).

The opposite holds true for the poorer countries. The DRC, Liberia, Niger and Rwanda are some of the poorer economies in the region (Liberia recorded the lowest income per capita at $50.04) . They are characterised by high fertility rates (Rwanda at 8.4 children per woman), high mortality rates (Liberia recorded the highest at 205.6) and low education enrollment rates (Niger recorded the lowest secondary enrolment rates).

Table 1: Descriptive Statistics & Correlation Matrix

Variables	Obs	Mean	Std.Dev	Min	Max	Sources
Fertility	2041	5.96	1.27	1.43	8.45	World Bank
Primary enrol	1683	81.35	32.98	7.86	207.81	World Bank
Secondary enrol	1296	26.07	22.71	1.06	122.20	World Bank
Tertiary enrol	1069	2.80	3.74	0.015	40.32	World Bank
Infant mort	1994	92.61	37.12	12.20	205.60	World Bank
Gdpcap	1821	1291.45	2065.92	50.04	13889.95	World Bank
	Fertility	Primary enrol	Secondary enrol	Tertiary enrol	Infant mort	Gdpcap
Fertility	1.000					
Primary enrol	-0.500*	1.000				
Secondary enrol	-0.812*	0.575*	1.000			
Tertiary enrol	-0.614*	0.382*	0.740*	1.000		
Infant mort	0.700*	-0.600*	-0.719*	-0.519*	1.000	
Gdpcap	-0.535*	0.358*	0.701*	0.447*	-0.479*	1.000

* significant at 5%

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 higher mortality rates increase fertility rates. Income per capita is negatively correlated with fertility suggesting that as countries become more developed, fertility rates start to decline. Secondary enrolment, tertiary enrolment and infant mortality also have higher correlations than the other determinants suggesting that they may be stronger predictors in explaining fertility.

Figure 2 illustrates a similar negative relationship between the different education variables and fertility rates. However most of the countries are clustered around 5 to 7 children with relatively low to medium average enrolment rates for the higher education levels. This statistical evidence suggests that the slow pace with which changes in enrolment rates take place may be contributing to the stalling of fertility declines in the region. Income per capita also shows a negative relationship with fertility rates, while infant mortality has a positive relationship in line with our expectations.

Figure 2: Correlations with fertility (Source: World Development Indicators)

3 Methodology

We estimate the following equation using panel data techniques:

$$\ln fertility_{it} = \alpha_i + \beta_1 \ln educ_{it-1} + \beta_2 \ln \inf ant_{it-1} + \beta_3 \ln gdpcap_{it-1} + \mu_{it} \qquad (1)$$

where $fertility$ represents the dependent variable, *educ* represents the three education variables, $\inf ant$ is infant mortality and *gdpcap* is income per capita. We expect a delay in the responsiveness of fertility rates to changes in the determinants during the transition. We therefore enter lagged explanatory variables in the specification to allow for this delay. 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 ordinary least squares (POLS) model which assumes homogeneity across the countries, that is they share common intercepts and slopes, and the regressors are not correlated with the error term. However this assumption can lead to downwardly biased results if correlation is present. Such an issue is likely to arise in this sample as countries like South Africa and Nigeria will not necessarily exhibit similar characteristics in education policies, access to technology, or geographic location. The fixed effects α_i model allows for these differences across countries through individual specific effects, giving more efficient estimates.

The fixed effects model on the other hand assumes no endogeneity between the regressors and error term which can also lead to downwardly biased coefficients. Since both statistical and economic endogeneity may be present in the model through unobserved heterogeneity across countries and reverse causality[4], we use fixed effects with instrumental variables (FE-IV) and System Generalised Method of Moments (Sys-Gmm) to minimise both heterogeneity and endogeneity issues. The FE-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, infant mortality and income per capita only.

We instrument the education variables with technology imported through globalisation (*global*

[4]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. Furthermore, 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 (Dreze & Murthi 2001). Lower fertility can also raise the level of income per capita through increased time spent at work instead of caring for children (Galor & Weil 1996).

tech), infant mortality with technology through immunisation against measles (*vaccine tech*) and income per capita with financial technology (*finance tech*). Finding external instruments always proves a difficult task in empirical analysis, however in our view, these instruments represent exogenous shocks to sub-Saharan countries that capture aspects of technology during the post-independence period.

According to Galor (2005) the industrialisation process was accelerated by the expansion of international trade. The technological progress which is associated with industrialisation creates a demand for the ability to analyse and evaluate new production possibilities, and this raises the incentive for education (Galor & Weil 2000). We introduce technological progress through globalisation as an instrument for education. It is taken from a dataset compiled by Dreher (2006) and updated by Dreher, Gaston and Martens (2008). The variable is made up of economic, social and political globalisation which represents the openness of a country through the flow of goods, technology, people, information and ideas.

Globalisation comes with continuous access to better technologies and we expect this benefit to be applicable to Sub-Saharan Africa which imports most of its technologies, such as machinery parts or technical assistance from foreign experts. For example, the region is home to foreign car manufacturers that contribute to the industrialisation process. These manufacturers use technologies that require skilled labour. This demand for labour creates an incentive for education. According to Andersen and Dalgaard (2011) greater international interaction between people from different nations facilitates the spread of ideas thus stimulating aggregate productivity. We therefore expect increased globalisation to increase the demand for education.

However being a globalised country does not necessarily lead to lower fertility as indicated in Figure 3. According to the globalisation index, countries such as Mali, Nigeria and Zambia are fairly open, ranging between 55 to 65, but high fertility rates of between 5 to 7 children per woman persist in these countries. On the other hand, Eritrea, Ethiopia and Sudan have relatively low globalisation indices but are characterised with relatively lower fertility rates. A more plausible channel is that the external wave of globalisation increased the demand for education by introducing technologies which expanded the industrialisation process in the region and required skilled labour.

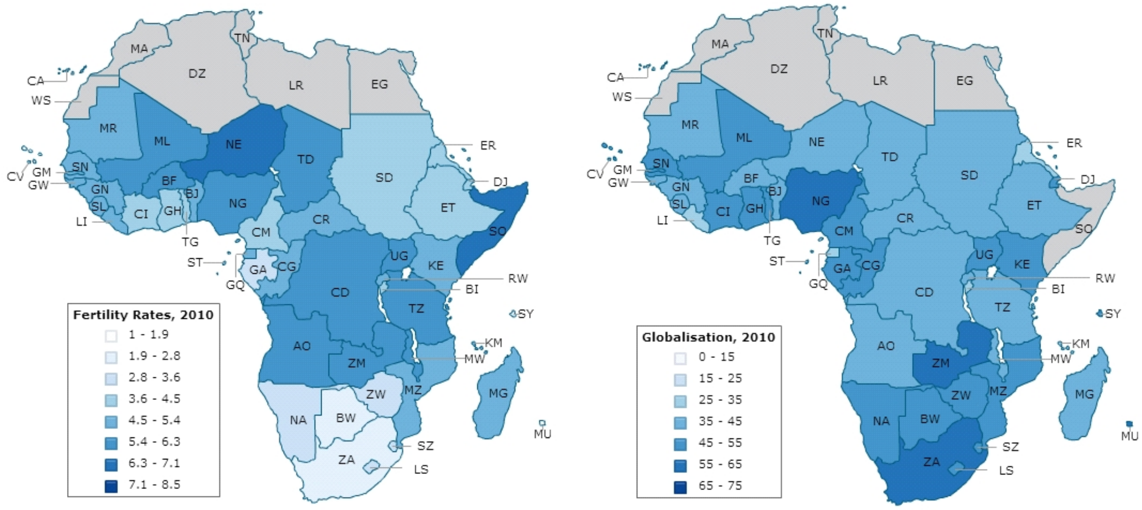

Figure 3: Globalisation and Fertility Rates (Source: Dreher et al. 2008; World Development Indicators)

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 are 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[5]. Results by Rodrik (1998) find that open countries with bigger governments have increased public expenditure towards education.

The instrument for mortality is another form of imported technology through the immunisation against measles (% of children ages 12-23 months). The variable is obtained from the WDIs[6]. Vaccinations are an exogenous shock to the region as 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 countries. Immunisations against measles is one such external program. WHO partnered with the United Nations and several other international organisations for routine measles vaccination

[5] 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.

[6] Other instruments used in literature for infant mortality include adult male mortality (Galloway *et al.* 1998), lagged mortality (Murtin 2013), malaria ecology and percentage of population at risk of malaria (Conley *et al.* 2007).

coverage program which coincides with the period under review. Statistical evidence in Figure 4 shows that fertility rates were already declining by the time the measles vaccinations coverage was effected. 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.

Moreover, Doepke (2005) and Murphy (2010) find that infant mortality rates had no effect on fertility rates in 17^{th} century Western Europe as mortality rates had already started declining nearly a century prior to the decline in fertility rates. 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 Chowdhury (1988) infant mortality rates fall due to technological advances in medicine and public health measures and this leads to a subsequent decline in fertility, while Conley *et al.* (2007) find that exogenous changes to child mortality through immunisations, improved nutrition, the advent of public health and safe drinking water are the basic drivers to reduced fertility rates.

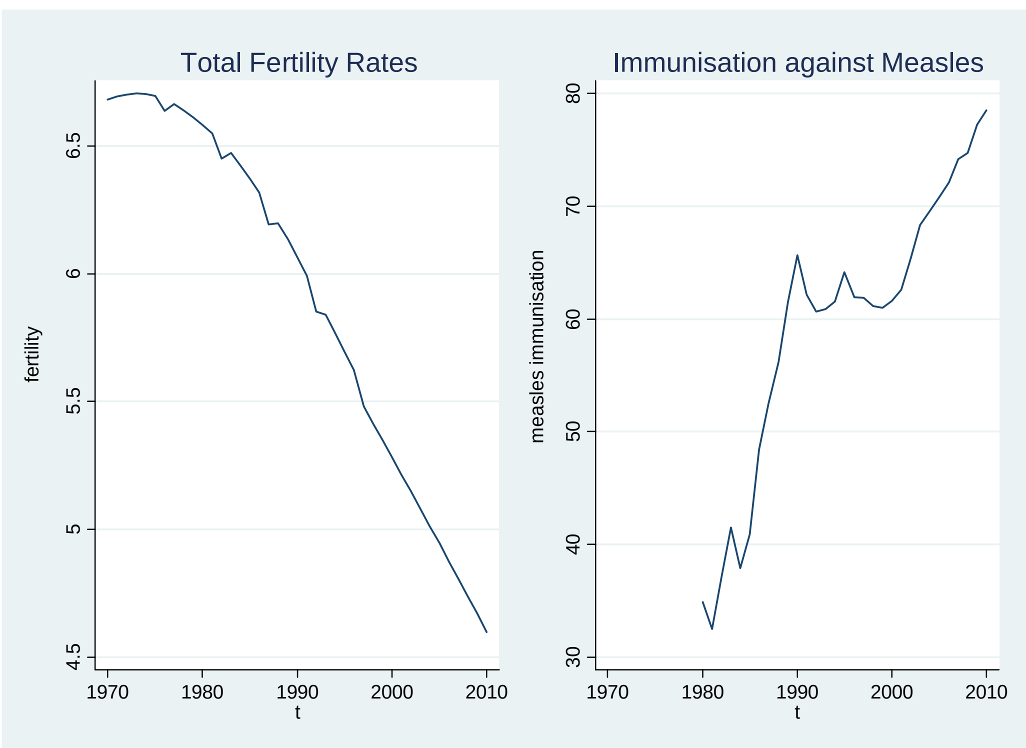

Figure 4: Fertility Rates and Measles Immunisation (Source: World Development Indicators)

Technology through financial development is the instrument for income per capita. The variable measures money supply or M2 (money and quasi money as a percentage of GDP) which represents access to finance or credit and is obtained from the WDIs. Higher percentages of money supply indicate more developed financial sectors and hence more access to credit.

There is no obvious correlation between financial development and fertility rates in sub-Saharan Africa as countries such as Seychelles and South Africa have relatively highly developed financial sectors and low fertility rates, while Comoros and Kenya also have developed financial sectors but persistent high fertility rates. Swaziland has a relatively low developed financial sector but falling fertility rates, while Chad has a poorly developed financial sector with high fertility rates.

A likely channel is through income per capita. According to Galor & Zeira (1993) money supply affects economic activity through credit markets. People that can borrow have better purchasing power and this perceived increase in income per capita may increase or reduce fertility rates depending on the developmental stage the region is experiencing. Sustained access to credit markets can induce a substitution effect for quality over quantity of children (Schultz 2008).

We include the lagged dependent variable in the final estimator to allow 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 dynamic specification 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. We keep the technological instruments as external instruments in the specification. To reduce the possibility of instrument proliferation which may overfit endogenous variables and fail to expunge their endogeneity, we specify the number of lags of the instruments (in this case the second lag up to the tenth lag) and collapse the instrument set (Roodman 2009). System-gmm also takes care of serial correlation which is likely to be present in the lagged dependent variable. We include 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 one-step robust estimation.

4 Results

4.1 Baseline Results

We report our findings in Table 2 for both the pooled OLS and the fixed effects models[7]. The results indicate mostly a negative and significant relationship between enrolment and fertility rates, particularly for tertiary enrolment rates once we allow for heterogeneity amongst countries[8]. A ten percent increase in past enrolment rates decreases contemporaneous fertility rates by about two percent. The evidence suggests that despite sub-Saharan Africa's relatively low average tertiary enrolment rates of just under three percent and average secondary enrolment rates of twenty-six percent, education still plays a significant contributory role in reducing fertility. The magnitudes are however reduced in the multivariate regressions. The inclusion of infant mortality which explains a significant part of fertility decline compared to the other variables may be reducing the explanatory powers of education.

Infant mortality is positively and significantly related to fertility rates remaining robust with the inclusion of other associated variables and individual effects. A ten percent increase in past infant deaths increases current fertility rates by about four percent. These results indicate that either people decide to replace the children that did not survive in the previous period, or there is a delay in people's perceptions of the decreased risks of infant mortality and the effect on fertility is only witnessed in the next period when rates increase (Montgomery 2000). Survival of infants was relatively low in sub-Saharan Africa due to adverse health conditions during childbirth, and as a result women 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,

[7] Results with contemporaneous determinants remain similar with marginal changes in the magnitudes of coefficients. We also run regressions excluding Mauritius, Seychelles and South Africa as they appear to be outliers in the data and may bring in some bias. The results and conclusions drawn however are not significantly different to those reported for the full sample of countries. All additional results are available on request.

[8] 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, Beegle & Nyamete (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. The basic education at primary schooling level may increase their fecundity through health education but the girls may not have access to knowledge on preventative actions once they drop out of school and become sexually active.

infant mortality rates have gradually started to decrease. These initial results show evidence of a strong determinant for fertility decline in sub-Saharan Africa, more so than education and income per capita.

The results for income per capita are negative and significant. A ten percent increase in income per capita in the previous period is reflected in the current fertility declines of about one percent. The delay in the effect of income per capita on fertility captures the lag in people's responses to an increase in income. Initially an increase in income per capita has a pure income effect and raises the demand for children[9], but over time this effect is replaced by a substitution effect for investment in child education as income continues to increase which decreases fertility rates. This transition is typically found in the Post-Malthusian period where income per capita is rising at a faster rate than population growth.

Table 2: Pooled OLS and Fixed Effects

	1	2	3	4	5	6	7	8	9	10
FERTILITY	POLS	POLS	POLS	POLS	POLS	POLS	POLS	POLS	POLS	POLS
Primary enrol $_{t-1}$	-0.235***					0.068***	0.003			0.099***
	(0.010)					(0.021)	(0.008)			(0.017)
Secondary enrol $_{t-1}$		-0.229***				-0.224***		-0.050***		-0.090***
		(0.010)				(0.023)		(0.008)		(0.014)
Tertiary enrol $_{t-1}$			-0.139***			-0.021			-0.005	0.015
			(0.009)			(0.016)			(0.006)	(0.010)
Infant mort $_{t-1}$				0.473***			0.422***	0.384***	0.440***	0.426***
				(0.010)			(0.013)	(0.016)	(0.018)	(0.020)
Gdpcap $_{t-1}$					-0.170***		-0.067***	-0.056***	-0.060***	-0.055***
					(0.008)		(0.005)	(0.006)	(0.007)	(0.008)
Observations	1,628	1,252	1,047	1,924	1,752	847	1,450	1,124	975	789
F test	524.05***	531.14***	227.64***	2091.98***	447.09***	110.13***	811.35***	662.26***	458.45***	278.78***
R-squared	0.187	0.459	0.291	0.658	0.366	0.413	0.720	0.738	0.717	0.736
	1	2	3	4	5	6	7	8	9	10
FERTILITY	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE
Primary enrol $_{t-1}$	-0.200***					0.039	0.021			0.074
	(0.033)					(0.064)	(0.042)			(0.062)
Secondary enrol $_{t-1}$		-0.172***				-0.042		-0.067		-0.011
		(0.029)				(0.050)		(0.044)		(0.058)
Tertiary enrol $_{t-1}$			-0.108***			-0.093***			-0.060***	-0.057**
			(0.015)			(0.022)			(0.021)	(0.024)
Infant mort $_{t-1}$				0.437***			0.406***	0.251***	0.208***	0.239***
				(0.042)			(0.056)	(0.087)	(0.064)	(0.078)
Gdpcap $_{t-1}$					-0.120***		-0.112*	-0.143***	-0.073	-0.120*
					(0.066)		(0.061)	(0.052)	(0.062)	(0.061)
Observations	1,628	1,252	1,047	1,924	1,752	847	1,450	1,124	975	789
F test	36.62***	34.22***	49.81***	107.67***	3.33*	13.51***	39.44***	32.58***	36.87***	27.60***
R-squared	0.155	0.380	0.429	0.774	0.515	0.440	0.487	0.530	0.520	0.559
Number of i	47	47	47	48	47	47	46	46	46	46
Country FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

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

[9] 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 Technological Progress

According to the various theories, technological progress has been instrumental in raising the demand for education, increasing income per capita continuously and reducing infant mortality (Becker *et al.* 1990, Conley *et al.* 2007, Galor and Weil 2000). The assumptions made by the pooled OLS and fixed effects models may lead to downwardly biased coefficients as discussed in Section 3. The coefficients reported in Table 3 are larger once we allow for heterogeneity and endogeneity. The inclusion of the technological progress instrument through globalisation improves the explanatory powers of all three education estimates, particularly the primary enrolment rates. Education coefficients are negative and mostly significant in reducing fertility rates. The negative effects for education remain robust across the bivariate and multivariate regressions.

The results support the unified growth theory which emphasises the role of technology in increasing both the demand and returns for education leading to a child quantity-quality trade-off. Globalisation is positively and significantly related to education. The technology imported through goods, people and ideas has expanded industrialisation in sub-Saharan Africa creating demand for skilled labour which acts as an incentive for increased education. The immunisation against measles reduces infant mortality in sub-Saharan Africa which is in line with expectations given the introduction of measles vaccinations' programmes from international organisations. Financial development increases income per capita by increasing people's purchasing power through access to credit. This rising income effect encourages people to invest in child quality rather than quantity which reduces fertility (Galor & Weil 1999).

The identifying instruments are statistically significant in the first stage regressions, as well as the F-tests for joint significance which minimises the issues of weak instruments. We fail to reject the null hypothesis for the Hansen J-test for exogeneity and conclude that our instruments are exogenous and valid. We also fail to reject the Arellano-Bond test for no second-order serial correlation. The F-statistics are statistically significant for overall joint significance of the regressors indicating that the models are correctly specified.

Interesting to note is that the technological instruments do not improve the estimates for infant mortality and income per capita, despite being valid instruments. Both variables lose explanatory significance. Technological progress appears to be more effective in reducing fertility rates through the education channels than the health and wealth channels.

Table 3: Fixed Effects with Instrumental Variables and System-GMM

	1	2	3	4	5	6	7	8
FERTILITY	FE-IV	FE-IV	FE-IV	FE-IV	FE-IV	FE-IV	FE-IV	FE-IV
Primary enrol $_{t-1}$	-0.590***					-0.743***		
	(0.028)					(0.267)		
Secondary enrol $_{t-1}$		-0.248***					-0.583**	
		(0.010)					(0.297)	
Tertiary enrol $_{t-1}$			-0.144***					-0.501**
			(0.006)					(0.234)
Infant mort $_{t-1}$				0.526***		-0.170	-0.281	-0.831
				(0.029)		(0.253)	(0.346)	(0.621)
Gdpcap $_{t-1}$					-0.676***	-0.090	0.287	0.646
					(0.159)	(0.135)	(0.394)	(0.437)
Observations	1,529	1,174	1,004	1,364	1,641	1,017	750	651
F test	445.51***	657.19***	667.75***	336.62***	18.09***	93.67***	72.89***	25.67***
R-squared	0.204	0.541	0.321	0.790	0.524	0.151	0.031	0.536
Number of i	46	46	45	48	47	46	46	45
Country FE	YES	YES	YES	YES	YES	YES	YES	YES
First Stage Regressions								
Global tech $_{t-1}$	0.852***	2.009***	3.227***			0.667***	1.297***	2.256***
	(0.031)	(0.052)	(0.090)			(0.037)	(0.067)	(0.122)
Vaccine tech $_{t-1}$				-0.240***		-0.108***	-0.126***	-0.092***
				(0.011)		(0.012)	(0.014)	(0.013)
Finance tech $_{t-1}$					0.083***	0.119***	0.096***	0.072**
					(0.018)	(0.023)	(0.027)	(0.028)
F test weak instruments	753.49***	1477.40***	1293.53***			209.88***	239.12***	220.41***
F test weak instruments				452.77***		479.33***	323.80***	347.94***
F test weak instruments					20.23***	49.56***	36.33***	18.90***

	1	2	3	4	5	6	7	8	9	10
FERTILITY	Sys-Gmm	Sys-Gmm	Sys-Gmm	Sys-Gmm	Sys-Gmm	Sys-Gmm	Sys-Gmm	Sys-Gmm	Sys-Gmm	Sys-Gmm
Primary enrol $_{t-1}$	-0.015***					-0.034***	-0.020***			-0.003
	(0.002)					(0.009)	(0.007)			(0.013)
Secondary enrol $_{t-1}$		-0.013***				0.015		-0.013**		-0.017
		(0.002)				(0.009)		(0.005)		(0.012)
Tertiary enrol $_{t-1}$			-0.018***			-0.004			0.001	0.005
			(0.003)			(0.003)			(0.006)	(0.004)
Infant mort $_{t-1}$				-0.038***			-0.019	0.032	0.065***	0.009
				(0.013)			(0.013)	(0.020)	(0.021)	(0.014)
Gdpcap $_{t-1}$					-0.011***		0.007*	-0.004	-0.020***	-0.000
					(0.002)		(0.004)	(0.007)	(0.004)	(0.004)
Fertility $_{t-1}$	1.032***	1.015***	0.999***	1.091***	1.036***	1.053***	1.067***	0.952***	0.904***	1.005***
	(0.006)	(0.003)	(0.002)	(0.034)	(0.008)	(0.011)	(0.035)	(0.036)	(0.050)	(0.034)
Observations	1,524	1,169	1,004	1,360	1,636	811	1,013	746	651	496
F test	335081.74***	491241.34***	193722.95***	403412.40***	261390.31***	70669.18***	291983.36***	228842.72***	78912.82***	239327.74***
Hansen J test p-value	0.256	0.241	0.231	0.001	0.011	0.893	0.370	0.483	0.433	0.954
AR (2) p-value	0.164	0.364	0.102	0.197	0.206	0.015	0.163	0.360	0.146	0.123
Number of instruments	21	21	21	21	21	41	43	43	43	63
Number of i	46	46	45	48	47	45	46	46	45	45
Country FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

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

External instruments included in the sys-gmm specification are technology through globalisation, immunisations against measles and financial development.

The baseline results indicate that infant mortality and income per capita are robust determinants of fertility decline in the absence of technological progress. However their economic effect and significance is greatly reduced once we allow for endogeneity through technological instruments. The results are in favour of the unified growth theory which highlights that education augmented with technological progress brings about declining fertility rates.

4.3 Gender Gap Theory

We further extend the analysis by exploring the relationship between the gender gap in wages and fertility rates. A reduction in the education gender gap suggests that there is an increase in female education which raises their opportunities for employment and wages. A reduction in the labour force gender gap suggests that there is an increase in female labour force participation which also raises their wages. Both these channels indicate a reduction in the wage gender gap.

Traditionally sons were favoured over daughters for education because they could enter the labour market which was still physically intensive and bring in income, while daughters could bring in income through customary bridal prices which meant girls married early and had children early (Ainsworth *et al.* 1996, Dreze & Murthi 2001). However these traditional barriers have been slowly eroding over time. Several papers find that increased female education has a negative impact on fertility because it raises awareness of early contraceptive use, delays marriage entry, increases female bargaining power in households regarding fertility preferences, encourages women to invest in the education of their children and increases opportunities for women to enter the labour market (Ainsworth *et al.* 1996, Dreze & Murthi 2001, Shapiro & Tambashe 1997, Strulik 2016).

On the other hand, studies find that the influence of male education is negligible on fertility declines. Although Dreze & Murthi (2001) do not find a significant association between male literacy and fertility rates, they do not dispute that male education is still 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.

The reduction in the labour force participation gender gap raises the opportunity cost of having children. Female labour force participation rates decrease fertility because of higher female wages which increase the opportunity costs involved in raising children resulting in a substitution effect, while male labour force participation rates appear to have a pure income effect in raising the demand for children (Galloway *et al.* 1998, Galor & Weil 1996). The old age hypothesis comes into play with the male labour because higher wages for men encourage marriage, and children are often seen as a productive asset to increase household incomes and as security in the parents' old age. In patriarchal societies, such as those found in sub-Saharan Africa, reproductive decisions and use of contraceptives are often made by the husband (Caldwell *et al.* 1992, Dreze & Murthi 2001, Galor & Weil 1999).

We use the mean years in school for women and men (*female educ and male educ*) to represent the education gender gap. These variables measure the average number of years of school attended by all people in the age and gender group specified, including primary, secondary and tertiary education (15 to 44 years for women which represents the reproductive age for most women, and 25 years plus for men). The data is obtained from the Institute for Health Metrics and Evaluation on the Gapminder database. The female and male labour force participation rates which represent the labour force gender gap (*female labour and male labour*) are taken from the WDIs and measure percentages of males and females in the labour market from 15 years onwards.

Figure 5 indicates that female education for the reproductive age has been increasing significantly over the years while male education has remained relatively constant over the years. This suggests a reduction in the gender gap for schooling, while the labour market exhibits little convergence between men and women. Even though the labour force participation rates for women appears to be increasing at the same time as the male participation rates are declining, there is evidence of some delay in the reduction of gender gap in wages. The delay may be brought on by a slow industrialisation process in the region which delays the expansion of the labour market for more jobs that accommodate women's attributes.

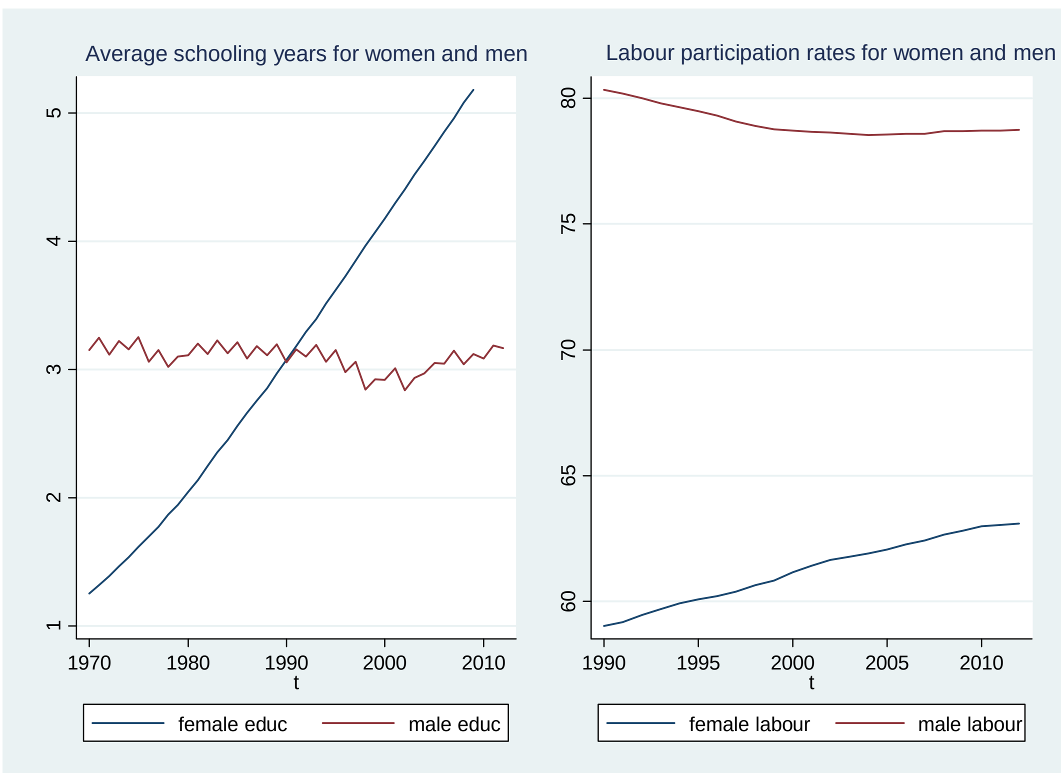

Figure 5: Gender gap in education and labour participation rates (Sources: WDIs, Gapminder)

We control for heterogeneity and endogeneity by using the same technological instruments. Technological progress works in the same way as with the other education variables to increase male and female education. Technology has also been attributed to the decrease in the gender gap in relative wages through increased labour opportunities for women (Galor & Weil 1996).

Results in Table 4 and Table 5 indicate that there is a significant trade-off between the number of years women spend in school and the number of children they have. Schooling delays fecundity. The number of years women spend in school can also indicate the quality of women's education. The higher the quality, the greater the chances of gaining employment in the labour market. This relationship remains robust after controlling for country specific effects, endogeneity, and in conjunction with other associated variables. The number of years men spend in school, though negative, plays a negligible role in decreasing fertility rates, while the female labour participation rates have inconclusive results.

The higher female labour participation rates bring about a substitution effect as women spend more time working and less time rearing children. However, if changes in social stereotyping of women's role in child rearing lags behind changes in education, then the effect of female labour participation rates on fertility is weakened and in some cases may increase fertility initially (Lehr 2009). Snyder (1974) also highlights that in Africa, the absence of the child quantity-quality trade-off could stem from the willingness of extended families to assist parents with the children's educational expenses. The male labour force participation rates have an opposing effect of increasing fertility rates. This is in line with literature that find that male wage rates have an income effect which raises the demand for children. This positive effect is characteristic of societies dominated by men where children are considered investment in labour such as farming and for security in old age (Bongaarts & Casterline 2012).

Table 4: Pooled OLS and Fixed Effects

	1	2	3	4	5	6	7	8	9	10	11	12	13
FERTILITY	POLS	POLS	POLS	POLS	POLS	POLS	POLS	POLS	POLS	POLS	POLS	POLS	POLS
Female educ $_{t-1}$	-0.183***				-0.183***		-0.043***				-0.047***		-0.069***
	(0.007)				(0.008)		(0.005)				(0.007)		(0.013)
Male educ $_{t-1}$		-0.038***			-0.058***			-0.013**			-0.026***		-0.008
		(0.008)			(0.007)			(0.006)			(0.007)		(0.009)
Female labour $_{t-1}$			0.144***			0.075***			0.017			-0.034***	0.009
			(0.026)			(0.028)			(0.013)			(0.012)	(0.016)
Male labour $_{t-1}$				0.629***		0.533***				0.420***		0.457***	0.196***
				(0.073)		(0.085)				(0.043)		(0.046)	(0.064)
Infant mort $_{t-1}$							0.372***	0.401***	0.409***	0.432***	0.353***	0.434***	0.359***
							(0.015)	(0.013)	(0.015)	(0.014)	(0.018)	(0.015)	(0.025)
Gdpcap $_{t-1}$							-0.047***	-0.061***	-0.081***	-0.064***	-0.049***	-0.065***	-0.058***
							(0.005)	(0.006)	(0.007)	(0.005)	(0.006)	(0.006)	(0.010)
Observations	1,888	1,468	1,034	1,034	1,386	1,034	1,616	1,260	1,000	1,000	1,180	1,000	656
F test	743.53***	24.65***	31.49***	73.27***	263.05***	43.12***	753.85***	569.14***	452.85***	496.60***	409.15***	365.91***	140.93***
R-squared	0.391	0.010	0.031	0.060	0.400	0.067	0.707	0.703	0.707	0.731	0.71	0.732	0.720
	1	2	3	4	5	6	7	8	9	10	11	12	13
FERTILITY	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE	FE
Female educ $_{t-1}$	-0.189***				-0.194***		-0.152***				-0.173***		-0.292***
	(0.025)				(0.028)		(0.053)				(0.051)		(0.082)
Male educ $_{t-1}$		-0.030			-0.030			-0.030			-0.029		-0.029
		(0.033)			(0.027)			(0.024)			(0.026)		(0.033)
Female labour $_{t-1}$			-0.595***			-0.829***			-0.413**			-0.507**	0.142
			(0.165)			(0.236)			(0.199)			(0.218)	(0.169)
Male labour $_{t-1}$				0.958**		1.204***				0.692*		0.889**	0.289
				(0.427)		(0.421)				(0.366)		(0.405)	(0.333)
Infant mort $_{t-1}$							0.149	0.401***	0.241***	0.284***	0.105	0.218***	-0.004
							(0.098)	(0.047)	(0.044)	(0.046)	(0.102)	(0.042)	(0.082)
Gdpcap $_{t-1}$							-0.079	-0.131**	-0.060	-0.047	-0.172***	-0.060	-0.124
							(0.050)	(0.062)	(0.045)	(0.040)	(0.058)	(0.042)	(0.082)
Observations	1,888	1,468	1,034	1,034	1,386	1,034	1,616	1,260	1,000	1,000	1,180	1,000	656
F test	55.94***	0.87	12.95***	5.03**	26.31***	7.74***	26.99***	33.35***	19.09***	20.70***	20.84***	16.73***	22.85***
R-squared	0.443	0.009	0.182	0.069	0.444	0.289	0.520	0.517	0.459	0.447	0.574	0.515	0.652
Number of i	48	48	47	47	48	47	47	47	46	46	47	46	46
Country FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

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

The coefficients for the FE-IV model are again larger due to the external variation from the instruments which reduces the endogeneity bias. As expected globalisation increases both male and female education. However, the same technology instrument decreases male labour participation rates and increases female labour participation rates suggesting that men's comparative advantage has been reduced by jobs that require less physical strain and more mental ability. These jobs play more to women's strengths raising their comparative advantage over men in the labour market. Technological progress increases returns on female labour which allow wages to keep rising. The associated rise in female wages increases the opportunity costs of raising children and lowers fertility. The economic effect of the male labour participation rates is significantly reduced with the inclusion of other variables, particularly in the system-gmm estimation which allows for use of more instruments.

The identifying instruments remain statistically significant in the first stage regressions, as well as the F-tests for weak instruments indicating that the instruments are still valid. We fail to reject the null hypothesis for the Hansen J-test for exogeneity of instruments and the Arellano-Bond test for no second-order serial correlation. The F-statistics for overall joint significance of the regressors are statistically significant indicating that the models are correctly specified.

Table 5: Fixed Effects with Instrumental Varibles and System-Gmm

	1	2	3	4	5	6	7	8
FERTILITY	FE-IV	FE-IV	FE-IV	FE-IV	FE-IV	FE-IV	FE-IV	FE-IV
Female educ $_{t-1}$	-0.228***				-0.100*			
	(0.006)				(0.051)			
Male educ $_{t-1}$		-2.222***				-1.420		
		(0.621)				(2.039)		
Female labour $_{t-1}$			-2.986***				-0.081	
			(0.222)				(0.477)	
Male labour $_{t-1}$				11.558***				0.180
				(1.685)				(1.029)
Infant mort $_{t-1}$					0.271**	-0.511	0.341***	0.361***
					(0.108)	(1.573)	(0.099)	(0.051)
Gdpcap $_{t-1}$					-0.289***	-0.872	-0.225***	-0.206*
					(0.091)	(1.291)	(0.058)	(0.114)
Observations	1,759	1,328	963	963	1,138	867	898	898
F test	1299.57***	12.82***	181.04***	47.06***	206.63***	7.75***	156.14***	163.65***
R-squared	4.406	0.003	0.071	0.062	0.718	0.139	0.691	0.715
Number of i	47	47	46	46	47	47	46	46
Country FE	YES	YES	YES	YES	YES	YES	YES	YES
First Stage Regressions								
Global tech $_{t-1}$	2.132***	0.232***	0.140***	-0.036***	1.198***	0.381***	0.120***	-0.054***
	(0.035)	(0.064)	(0.010)	(0.005)	(0.031)	(0.087)	(0.012)	(0.006)
Vaccine tech $_{t-1}$					-0.091***	-0.084***	-0.140***	-0.140***
					(0.009)	(0.010)	(0.019)	(0.019)
Finance tech $_{t-1}$					0.035***	0.160***	0.030***	0.030***
					(0.026)	(0.022)	(0.030)	(0.030)
F test weak instruments	3678.84***	13.03***	181.99***	46.05***	943.69***	10.09***	64.06***	25.12***
F test weak instruments					485.32***	367.51***	385.75***	385.75***
F test weak instruments					35.04***	41.89***	47.80***	47.80***

	1	2	3	4	5	6	7	8	9	10	11	12	13
FERTILITY	Sys-Gmm	Sys-Gmm	Sys-Gmm	Sys-Gmm	Sys-Gmm	Sys-Gmm	Sys-Gmm	Sys-Gmm	Sys-Gmm	Sys-Gmm	Sys-Gmm	Sys-Gmm	Sys-Gmm
Female educ $_{t-1}$	-0.014***				-0.015***		-0.005				-0.008**		0.010*
	(0.002)				(0.003)		(0.005)				(0.004)		(0.005)
Male educ $_{t-1}$		-0.018***			-0.002			0.002			-0.006**		-0.003
		(0.004)			(0.002)			(0.006)			(0.003)		(0.004)
Female labour $_{t-1}$			-0.022***			0.001			-0.012**			-0.011	-0.008
			(0.004)			(0.004)			(0.005)			(0.009)	(0.009)
Male labour $_{t-1}$				-0.022***		-0.023***				-0.013**		-0.003	-0.014
				(0.003)		(0.005)				(0.006)		(0.012)	(0.009)
Infant mort $_{t-1}$							0.028	0.034	0.019***	0.017***	0.002	0.020***	0.010
							(0.022)	(0.022)	(0.006)	(0.006)	(0.019)	(0.006)	(0.007)
Gdpcap $_{t-1}$							-0.009	-0.012*	-0.007***	-0.006**	-0.003	-0.007***	-0.004
							(0.006)	(0.007)	(0.002)	(0.002)	(0.005)	(0.002)	(0.003)
Fertility $_{t-1}$	1.002***	1.006***	1.046***	1.051***	1.004***	1.051***	0.959***	0.952***	1.000***	1.005***	1.006***	1.001***	1.033***
	(0.001)	(0.002)	(0.010)	(0.008)	(0.001)	(0.007)	(0.036)	(0.040)	(0.012)	(0.013)	(0.031)	(0.013)	(0.015)
Observations	1,754	1,323	963	963	1,278	963	1,134	863	898	898	824	898	619
F test	423849.68***	251261.77***	771952.87***	1320000***	268022.12***	831538.09***	242584.34***	144990.30***	388516.68***	518943.46***	460003.58***	300734.17***	410273.67***
Hansen J test p-value	0.029	0.027	0.061	0.094	0.156	0.286	0.352	0.235	0.393	0.452	0.721	0.649	0.993
AR (2) p-value	0.159	0.307	0.231	0.235	0.300	0.235	0.168	0.308	0.252	0.255	0.308	0.252	0.055
Number of instruments	21	21	21	21	31	31	43	43	43	43	53	53	73
Number of i	47	47	46	46	47	46	47	47	46	46	47	46	46
Country FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

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

External instruments included in the sys-gmm specification are technology through globalisation, immunisations against measles and financial development.

The coefficients for infant mortality and income per capita remain in line with the baseline results. As the region continues to transition, more and more children are perceived as an economic burden leading to a focus on the cost of children and the quantity-quality trade-off as income rises (Dreze & Murthi 2001). While Shapiro and Gebreselassie (2008) find that several countries in sub-Saharan Africa are experiencing stalling fertility declines brought on by the slow pace of socioeconomic development such as changes in women's education and infant mortality, our results indicate that the stalling may be coming through the slow changes in the labour market. The results indicate that schooling for women, and not employment status of women is associated with lower fertility rates in sub-Saharan Africa. There is a gender gap reduction in the education system as traditional views regarding role of women change, more so than the labour market which is still dominated by gender bias in some sectors.

5 Conclusion

This paper looks at the macro-evidence of the fertility transition in sub-Saharan Africa with emphasis on the role of technology through education. Overall, the findings favour the predictions made by the unified growth theory for a Post-Malthusian period where increased investments in education induce a trade-off between quantity and quality of children. This effect is stronger with the inclusion of technology which is also in line with the unified growth theory that technological progress increases demand for educational attainment resulting in lower fertility rates. Evidently the on-going process of industrialisation in sub-Saharan Africa is contributing to the fertility declines through increased incentives for education and inducing a similar demographic transition as the Western predecessors experienced more than a century ago.

We also confirm some evidence in support of infant mortality rates raising fertility rates, as well as income per capita reducing fertility rates. In the absence of technological progress, the results from infant mortality rates and income per capita also place sub-Saharan Africa in the Post-Malthusian period. However the effects from infant mortality and income per capita are reduced by the inclusion of the technology instruments indicating that for this particular region, technological progress is more effective through the education channel in explaining the fertility transition. Results from the education gender gap variables indicate economies that are becoming more inclusive of women and abandoning traditional values. However the process is delayed by a patriarchal structure in the labour market that persists to modern day.

Fertility decline has begun in sub-Saharan Africa. However to avoid stalling of the demographic transition will depend on the improvements in conditions that are conducive to fertility decline such as education and inclusiveness of gender. Sustaining these conditions in the absence of technology may undermine the demographic transition. If evidence, not only from this research but previous empirical work discussed in the paper, indicates that empowering women at low stages of development encourages households to adopt early contraceptives and provide better education for the future generation, then creating incentives for increased education for women may assist in accelerating the fertility declines in the region. A possible avenue may be to stimulate continuous industrialisation. Technology creates the necessary incentives to encourage investment in education through increased demand for skilled labour and higher wages. Technology also creates an expanded labour market with increased opportunities for female labour which in turn encourages women to obtain education. These incentives may assist in discouraging early pregnancies and delaying marriages in sub-Saharan Africa.

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