Family Planning and Development: Aggregate Effects of Contraceptive Use*

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Abstract

What is the role of family planning interventions on fertility, savings, human capital investment, and development? To examine this, endogenous unwanted fertility is embedded in an otherwise standard quantity-quality overlapping generations model of fertility and growth. The model features costly fertility control and families can (partially) insure against a fertility risk by using costly modern contraceptives. In the event of unexpected pregnancies, households can also opt to abort some pregnancies, at a cost. Given the number of children born, parents decide how much education to provide and how much to save out of their income. We fit the model to Kenyan data, implement several family planning policies and decompose their aggregate effects. Our results suggest that given a small budget (up to 0.5 percent of GDP), legalizing and subsidizing the price of abortion is a more cost-effective policy for improving long-run living standards and reducing inequality than policies that either subsidize the price of modern contraceptives or subsidize basic education.

KEYWORDS: education, income per capita, contraception, abortion
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"Each family tries to come as close as possible to its desired number of children... Families with excess children consume less of other goods, especially of goods that are close substitutes for the quantity of children. Because quality seems like a relatively close substitute for quantity, families with excess children would spend less on each child than other families with equal income and tastes. Accordingly, an increase in contraceptive knowledge would raise the quality of children as well as reduce their quantity." (Becker, 1960, p. 218)

1 Introduction

What is the role of family planning interventions on fertility, savings, human capital investment, and development? Since Malthus (1798), population dynamics have been at the core of long-run economic analysis, and recent growth models (cf., Galor and Weil, 2000) have continued to emphasize this. A common view in economic growth theory is that high fertility mainly reflects desired family size and that parents are able to achieve their fertility target (cf., Barro and Becker, 1989). From this perspective, fertility changes are driven by parents' demand for children (e.g., quantity-quality substitution or declining infant mortality) and supply factors, such as family-planning interventions, should have no impact on family size. However, in reality, sometimes people want to have the children they conceive, and sometimes they do not. Though this statement may sound rather terse, there is evidence to back it up.[1] According to Bongaarts (2016) about 39 percent of annual developing-world pregnancies are unplanned, and roughly half of these end in induced abortions. In fact, in some countries, there is quite a substantial gap between actual realized fertility and wanted fertility; and this gap is also larger for relatively poorer households. The fact that contraceptive methods are costly and individuals sometimes resort to abortions in order to control their family sizes corroborates this idea. In sum, there seems to be a random aspect to fertility.[2]

When parents have children, a natural step that follows is to provide them with care and education. Needless to say, while children bring a variety of inestimable benefits to parents, they are costly both in terms of goods and time. For instance, education costs money: tuition fees, books, transportation, and foregone wages that could come from child labor. Education and childrearing are also costly in terms of time: parents usually transmit their values, religion, and culture to their children, and parents must furthermore take care of their children when they are sick.

When added together, the statements in the previous two paragraphs (i.e., the randomness of fertility and the cost of child care and education) imply that the educational attainment of children in practice may not be as high as in a situation in which parents

[1] We provide detailed empirical facts on this issue in Section 2.

[2] This is emphasized in Malthus (1798) in a time when modern contraceptive methods were not available. Malthus stated that "the passion between the sexes is necessary and will remain nearly in its present state" and the results of said passion are children. According to him, the population would grow quickly if it was not checked by the scarcity of food and its consequences, such as infectious diseases; or by voluntary restraint, such as abstaining from early marriages (cf., Voigtländer and Voth, 2013). Dasgupta (2000) argues that except under conditions of extreme nutritional stress, nutritional status does not appear to affect fecundity.

could perfectly control their fertility (cf., Becker, 1960). In the aggregate, this may imply that human capital may be lower due to the randomness of family size. In addition, if poor households have lower control of their family size, this can lead to more heterogeneity in fertility with consequences on the level and persistence of inequality in education and income.[3] This could also have an effect on a country's production output since workers will have lower skills. The natural question is whether or not such effects are important and how family planning interventions affect the fertility gap. This paper addresses these questions.[4]

Although the ability to control family size is present even in primitive societies through abortion, infanticide, and other practices, and some very effective contraceptive methods have been available for more than 100 years (cf., Himes, 1936), there still exists a gap between realized and desired fertility in developing countries (see Table 9 in Appendix A). In addition, this gap is negatively correlated with income (see Table 10 in Appendix A). For instance, the proportion of women with unmet need for contraception could be as high as 40 percent in the Democratic Republic of Congo (cf., The World Bank, 2010) and it is in general higher for low income households.[5] The empirical evidence also shows that there exists a significant negative relationship between the fertility gap and educational attainment across countries. That is, when fertility is closer to its desired level, educational attainment is higher. Moreover the fertility gap is lower in countries where contraceptive use is more widespread.[6] This last correlation holds even when country-fixed effects, which control for main religion and other cultural factors, and the level of development are taken into account (see Table 1). In some ways this is, at least for us, a surprising fact.

We develop a general macroeconomic equilibrium model to assess the questions above. The model economy is populated by overlapping generations. Households make a consumption and savings decision and imperfectly choose how many (quantity) children they want to have (demand factors). However, households may have more pregnancies than desired due to unexpected fertility shocks. Families can partially insure against this fertility risk by using costly contraception (supply factors). In the event of unexpected pregnancies, households can opt to abort some of the time, and abortion is also costly. Given the number of children born, parents decide how much (quality) education to provide them. Schooling is costly in terms of consumption goods and children rearing is costly in terms of the time. These features allow us to map indicators (e.g., the contraceptive

[3]Using data from Quebec from the 16th to the 18th century, Galor and Klemp (2015) also explore the absence of reliable contraceptive methods in the determination of fertility to show that moderate fecundity and thus predisposition towards investment in child quality was conducive to long-run reproductive success, reflecting the negative effect of higher fecundity on the education of each offspring.

[4]It is important to stress that this is not necessarily a paper about an overpopulation problem (cf., Ehrlich and Ehrlich, 1990; Easterlin, 1987). Family planning interventions may be justified even when the overall fertility rate is below the replacement rate, but when some households have a fertility rate above their desired level.

[5]The median for developing countries is 22 percent. According to this World Bank report, the definition of unmet need for contraception corresponds to the "proportion of currently married women who do not want any more children but are not using any form of family planning or currently married women who want to postpone their next birth for two years but are not using any form of family planning".

[6]These empirical facts are consistent with the conjectures postulated by Becker (1960).

prevalence rate, abortion rate, unwanted fertility, and unmet need for family planning) of reproductive behavior from the data into the model and to study different family planning interventions. On the production side of the economy, there is a standard representative firm which uses labor and capital as inputs to produce final goods. We solve for a stationary equilibrium.

The model parameters are fitted to match statistical moments from the Kenyan economy, a country in which the average fertility gap is 1.2 children, which is above the average (0.87) for all developing countries in our dataset. The average gap hides important heterogeneity since the gap between realized and wanted fertility is about 2 children for parents with a primary degree (8 years of schooling) and 0.6 for parents with more than 12 years of schooling. In the baseline economy there is substantial heterogeneity in education and income. In particular, we are able to replicate the fertility pattern (levels and heterogeneity) and the gap between realized and wanted fertility observed in the data. We show that how family planning policies affect fertility in our model is consistent with the estimates reported in the microeconometric literature, which gives us confidence to further explore the impacts of such policies on the economy. The benchmark model is then used to assess the importance of family-planning interventions on education, inequality, and income per capita. Counterfactual exercises are implemented to shed some light on the quantitative importance of contraception use. For instance, in a world without fertility risk (i.e. with no unwanted pregnancies), educational attainment would be higher by about 1.1 extra year of education. Together with a rise in the capital stock, this leads to a hike in income per capita of about 13 percent. We also investigate several policies commonly used, including policies targeted at the poor. We show that given a small government budget (say 0.5 percent of GDP), legalizing and subsidizing the price of abortion is the most cost-effective policy in improving living standards when compared to policies that subsidize either the price of modern contraceptives or education.

We also decompose the full effect of family planning interventions on the economy into three different channels: a general equilibrium effect due to price movements, a wanted fertility channel since desired fertility may change with policies, and the response of parents investment in education of their children. We show that to fully understand the effects of family planning policies on individual outcomes it is important to perceive the responses of households in terms of desired fertility to individual policies, as well as the interaction of these responses with households investment decisions. For instance, families target a higher wanted fertility rate when the fertility risk of unwanted pregnancies is reduced. This can mitigate some of the effects of family planning policies on reproductive behavior, investment, and income levels.

Our research is related to a large literature on the relationship between fertility and development. Most of the papers in this literature focus on the joint evolution of economic and demographic processes (cf., Barro and Becker, 1989; de la Croix and Doepke, 2003; Galor and Weil, 1996, 2000) represented by a negative relationship between fertility and income.[7] The main idea is that when income rises the opportunity cost of raising

[7]Our model can generate a negative correlation between fertility and income even when the desired family size is constant. This can happen because as income rises, modern contraceptive methods become

children rises and parents decrease their family size and invest more in each child (cf., Becker, Murphy, and Tamura, 1990). This is the quantity-quality trade-off, which depends on the income elasticity of the quantity and quality of children, postulated and explained intuitively by Becker (1960), which has been the dominant theoretical framework in the economics of fertility over the past decades (cf., Doepke, 2015). Economists have used this framework to understand the dynamics of economic development and whether or not fertility choice can help to explain such dynamics.[8] For instance, de la Croix and Doepke (2003) discuss the importance of differential fertility for development through the education channel, a channel that is further explored in Vogl (2016) and which is also important in our paper. However, unlike our work, most of these articles do not focus on costly contraceptive methods, fertility risks, and family intervention policies. Becker (1960) does discuss in detail the importance of contraceptive methods in controlling family size, but birth control techniques are not mentioned in his subsequent work (cf., Barro and Becker, 1989; Becker and Lewis, 1973).[9] Our interpretation is that the discussion of most of these articles focus on fertility in developed countries, such as the United States, where these contraceptive methods are affordable and readily available to the public. In addition, there is public awareness about their effectiveness in controlling pregnancies, and therefore the realized number of children is very close to the desired one. Our view is that this might not be the case for some developing countries, and this view seems to be backed by the empirical evidence (cf., Miller and Babiarz, 2016). In developing countries even when contraceptives can be obtained at low cost in public clinics , for example, they are often stocked out. Ashraf, Field, and Lee (2014) report a survey conducted by the United States Agency for International Development (USAID) between October and December 2007, in which it was found that more than half of the hospitals and health clinics in Zambia were stocked out of injectable vaccines (and pills) for more than 50% (30%) of the 90 days over which the survey was conducted. To our knowledge our paper is the first to consider explicitly fertility shocks, costly contraception choice, and abortion in a model of growth and development with endogenous population growth, and to investigate the aggregate effects of family planning interventions.[10] Baudin, de la Croix, and Gobbi (2016) also consider unwanted fertility by assuming that a share of couples cannot control fertility, but this differs

relatively cheaper and the gap between realized and wanted fertility decreases.

[8]This theoretical framework has also been used to understand a variety of related issues such as child labor, and episodes of baby booms and busts (cf., Doepke and Zilibotti, 2005; Greenwood, Seshadri, and Yorukoglu, 2005).

[9]Doepke (2015) states that "In the sense that the lack of knowledge of birth control among poorer households is assumed rather than derived from economic incentives, Becker's 1960 paper does not yet go all the way in founding fertility choice in economics." We provide economic foundation for that based on costly contraceptives and we show that this may be quantitatively important in some developing countries.

[10]Strulik (2017) also takes into account costly contraception in a model of growth. He abstracts from fertility shocks and heterogeneity among households, while we explore such dimensions. In addition, he focuses on the role of modern contraceptives in the fertility transition, and we concentrate on the impact of family planning interventions on individual and aggregate outcomes. The role of modern contraceptives in the fertility transition is also studied by Bhattacharya and Chakraborty (2017) in a model in which modern contraceptives are costly. In a recent article, de Silva and Tenreyro (2017a) investigates the role of changes in social norms in the fertility transition and how population policies might have changed such norms.

from our approach since we assume that fertility control is costly and the lack of ability to perfectly control pregnancies is derived from economic incentives.[11] They investigate a family planning policy which sets the percentage of couples able to control their fertility to one.[12] Ashraf, Weil, and Wilde (2013) also study the effects of policies which reduce fertility on investment and output per capita. Fertility is exogenous in their framework and they feed different population dynamics into a growth model to investigate how each affects output through different channels. In our case, fertility and the use of costly contraceptive methods are endogenous. This allows us not only to evaluate the effects of family planning interventions on output but also to show how the use of contraceptives, and thus fertility, changes along with other policies such as investment in education.

Our general idea relies on the assumption that family planning interventions have a first-order effect on fertility decisions. There is a bulk of evidence supporting this.[13] For instance, Bloom, Canning, Fink, and Finlay (2009) show that removing legal restrictions on abortion significantly reduces fertility and that this has a positive impact on female labor force participation. Joshi and Schultz (2013) study the long-run consequences of a randomized control trial of contraception provision in Matlab, Bangladesh. Their findings suggest that treatment villages experienced a decline in fertility of about 17 percent compared to control villages, and that the effects were persistent over a 20-year period. Sinha (2005) estimates similar effects of this family planning experiment on fertility. Using an experiment in Zambia, Ashraf, Field, and Lee (2014) show that the local average treatment effect estimation implies that use of family planning services during about two years of the experiment was associated with a 27 percent reduction in births. Using variation in the timing and location of the *Profamilia* program in Colombia, Miller (2010) finds that availability of modern contraceptives allowed women to postpone their first birth and to have about 5 percent fewer children in their lifetime.[14] Banerjee, Meng, Porzio, and Qian (2014) estimate the effects of birth control policies in China before the "one-child policy'. They show that family planning reduced fertility and increased savings. Our model helps to rationalize these findings since we integrate demand and supply factors in the determina-

[11]The authors also take fertility risks into account by assuming that the number of children who survive to adulthood within a family is a random variable. This approach is also taken by Sah (1991) and Kalemli-Ozcan (2003).

[12]In their quantitative exercises, the authors show that abstracting from the extensive margin in fertility choice might overstate the effects of family planning interventions on fertility by 5 percent.

[13]Subsection 5.3 summarizes some studies on the effects of family planning policies on fertility. See also de Silva and Tenreyro (2017b), May (2012), Miller and Babiarz (2016), and Schultz (2008), among many others.

[14]There is also a branch of the literature which focuses on different effects of fertility risk. Some examples are Goldin and Katz (2002) and Edlund and Machado (2015), which discuss the impact of the (availability of the) pill on several dimensions of women's education and careers. They do so for the US and without a focus on aggregate development, but they show that the diffusion of the pill had a first-order effect on the education of women and on the decision to marry. Kocharkov (2014) studies the relation between abortions and inequality. He also focuses on US data and, unlike our work, does not discuss aggregate impacts. Choi (2017) introduces fertility risk in a life-cycle model with consumption, savings and fertility decisions estimated for the US. He shows that differential fertility risk is essential in generating plausible life-cycle patterns of births and abortions across educational groups.

tion of fertility, which is not possible in a standard quantity-quality fertility model.[15] This paper therefore provides a bridge between the macro literature on fertility and growth and the empirical micro literature on family planning interventions, fertility, and human capital outcomes. In addition, with our framework it is possible to run and to evaluate a variety of counterfactual policies, not necessarily available in control trial experiments, and to disentangle different channels, such as the importance of general equilibrium effects. Therefore, we believe our paper is an important contribution to the literature on family planning policy and development, filling an existing gap with far-reaching implications for policies.

The remainder of this paper is divided into six additional sections besides this introduction. In order to motivate our study, some empirical facts are documented in Section 2. Section 3 presents a simplified version of the model to provide some key intuition and analytical results. Section 4 describes the model economy, which is used for quantitative analysis. Section 5 fits model parameters to the data, and Section 6 provides the quantitative analysis to measure the aggregate effects of family planning interventions on development. Section 7 contains concluding remarks.

2 Facts

In this section we describe the empirical facts which motivate our work.[16] Table 1 shows the regression results in which the dependent variable is the unwanted fertility, or the gap between actual and wanted fertility, and the explanatory variable of interest is the percentage of women who have ever used modern contraceptive methods. We have an unbalanced panel since the Demographic Health Surveys from USAID, which contain information on the fertility gap and contraceptive use across countries, are implemented in countries on different dates. There are 84 countries in total, but they appear in the sample in different frequencies and in years ranging from 1985 to 2010. Before we proceed with the analysis, it is important to emphasize up front that we do not aim to provide a causal effect of modern contraceptive use on the fertility gap, instead focusing on examining the relationship between the two. We are aware of issues related to unobservables which can drive the correlations between these two variables and reverse causality problems.[17]

Column (1) of Table 1 presents the estimated coefficients when we regress the fertility gap on the logarithm of per capita income and the percentage of women who have ever used modern contraceptive methods. As we can see, there is a negative associa-

[15] Choukhmane, Coeurdacier, and Jin (2016) show that the 'one-child policy' led to an increase in the savings rate and human capital accumulation in China. In our model family interventions, which decrease the gap between realized and desired fertility, also increase investment in physical and human capital.

[16] The descriptions of all data sources, summary statistics, and simple correlations are reported in Appendix A.

[17] Ideally we would instrument the use of modern contraceptive methods. One possibility would be to use the relative price of modern contraceptive methods (e.g., pills and condom) as an instrumental variable for the fraction of women who have ever used modern contraceptive methods, but we were unable to find historical data for this variable for the majority of countries.

Table 1: Relationship between unwanted fertility and the use of modern contraceptive methods. Data source: see data appendix for description and source of the variables used.

	Dependent variable: Unwanted fertility (fertility gap)					
	(1)	(2)	(3)	(4)	(5)	(6)
% of women who ever used modern contr. methods	-0.0015	-0.0100^{***}	-0.0052^{*}	-0.0056^{**}	-0.0135^{***}	-0.00911^{***}
	(0.0018)	(0.0033)	(0.0032)	(0.0022)	(0.0030)	(0.0033)
Log of per capita GDP	-0.0132	-0.0101	0.0447	-0.0905^{*}	0.0010	0.1027
	(0.0426)	(0.1562)	(0.1454)	(0.0504)	(0.1387)	(0.1413)
Wanted fertility				-0.1203^{***}	-0.1122^{*}	-0.2160^{***}
				(0.0388)	(0.0651)	(0.0688)
Country fixed effects	No	Yes	Yes	No	Yes	Yes
Decade fixed effects	No	No	Yes	No	No	Yes
Number of observations	200	200	200	200	200	200
Number of countries	80	80	80	80	80	80
R-squared	0.0078	0.8565	0.8632	0.0541	0.8601	0.8740

Notes: Standard errors are in parentheses. The symbols *, **, and *** imply that coefficients are statistically different from zero at 90, 95, and 99 percent confidence levels, respectively.

tion between unwanted fertility and the measure of modern contraceptive use, but this correlation is not statistically different from zero at the usual confidence levels. This negative correlation becomes statistically significant once we introduce country fixed effects, which control for time invariant effects such as legal origin, main religion, and other cultural factors. Notice that country fixed effects substantially increase the explanation of the observed variation in the fertility gap. According to specification (2) the gap between realized and wanted fertility is significantly lower in countries where contraceptive use is more widespread. Quantitatively this regression implies that an increase in one standard deviation (22 percentage points) in the percentage of women who have ever used modern contraceptive methods is associated with a decrease in the fertility gap of 0.22 of a child. The regression in Column (3) contains the same explanatory variables as the one in Column (2) but we also introduce dummies for each decade.[18] The correlation between the fertility gap and the percentage of women who have ever used modern contraceptive methods is weaker but still statistically different from zero at a 90 percent confidence level.

In Columns (4)–(6) of Table 1 we also add wanted fertility as an explanatory variable. Interestingly the fertility gap decreases with wanted fertility, and the negative association between the fertility gap and the percentage of women who have ever used modern contraceptive methods becomes stronger. This correlation is statistically different from zero at

[18]We do not introduce year fixed effects because the panel is unbalanced and some countries appear only once in the sample.

Table 2: Relationship between human capital attainment and fertility (unwanted and wanted).

	Dependent variable: Human capital attainment					
	(1)	(2)	(3)	(4)	(5)	(6)
Unwanted fertility	-0.1470^{**}	-0.0938^{*}	-0.2366^{***}	-0.1250^{***}	$-.0868^{***}$	-0.1179^{***}
	(0.0735)	(0.0556)	(0.0313)	(0.0278)	(0.0293)	(0.0279)
Wanted fertility		-0.2147^{***}	-0.2073^{***}	-0.0875^{***}		-0.0854^{***}
		(0.0180)	(0.0161)	(0.0187)		(0.0187)
Log of per capita GDP					0.0738^{*}	0.0604
					(0.0425)	(0.0395)
Country fixed effects	No	No	Yes	Yes	Yes	Yes
Decade fixed effects	No	No	No	Yes	Yes	Yes
Number of observations	188	188	188	188	188	188
Number of countries	64	64	64	64	64	64
R-squared	0.0210	0.4462	0.9759	0.9855	0.9833	0.9858

Notes: Standard errors are in parentheses. The symbols *, **, and *** imply that coefficients are statistically different from zero at 90, 95, and 99 percent confidence levels, respectively.

a 99 percent confidence level once wanted fertility is controlled in the regressions, which contradicts earlier results by Pritchett (1994).[19] The most complete specification explains about 87 percent of the observed variation in unwanted fertility.

Table 2 reports coefficients of regression of human capital attainment, measured by the average years of schooling of the total population aged 25 and over, on unwanted fertility for different specifications and controls. In all regressions there exists a significant negative relationship between the fertility gap and educational attainment across countries. That is, when fertility is closer to its desired level, educational attainment is higher. This correlation is negative and significant even after including country fixed effects, and decade dummies, and controlling for per capita income and wanted fertility. Fertility behavior (unwanted and wanted fertility) explains about 44 percent of the variation in education attainment in the sample, visible in Column (2). Educational attainment is also negatively correlated with wanted fertility, which reflects the quantity-quality trade-off.

Therefore what the reduced form evidence shows is that there might be a positive relationship between contraception use and education, via the reduction in the gap between actual and wanted fertility levels. Hence, the first question of this paper is: How much of the observed differences in education and income per capita can be explained by observed differences in contraception use and fertility outcomes? And second, what are the aggregate effects of family planning interventions on development and inequality? In order to

[19] The sample period in our regression is different from his since we have access to more recent observations, which might explain the difference.

address these questions, we present an equilibrium model of economic development in which the control of family size is costly.

3 Fixing Ideas

3.1 Demographics and endowments

This is a simplified version of the full model without uncertainty in fertility and heterogeneity among households, but which captures the long-run effects of costly contraceptive methods and through which we can provide key intuition and derive some analytical results. Individuals live for three periods: childhood, young adulthood, and old adulthood. Children do not make any economic decisions, but they can acquire skills. Young adults have one unit of productive time and are endowed with skills that they acquire during their childhood. They make the relevant economic decisions, including investment decisions. Old adults do not work and simply consume their savings. The production sector is characterized by a standard constant returns to scale technology, which depends on capital and efficiency units of labor.

3.2 Production

The consumption good is produced with a Constant Returns to Scale (CRS) technology that uses capital, K, and efficiency units of labor, L, as inputs. The technology is represented by:[20]

$$Y = AK^{\alpha}L^{1-\alpha},\ \alpha \in (0,1),\ A > 0. \tag{1}$$

Capital depreciates fully after use.

Let w be the wage rate and let R be the rental price of capital. Profit maximization implies that input prices are paid according to their marginal productivity, such that:

$$\begin{aligned} w &= (1-\alpha)AK^{\alpha}L^{-\alpha}, & (2)\\ R &= \alpha AK^{\alpha-1}L^{1-\alpha}. & (3) \end{aligned}$$

3.3 Households

Fertility: Couples can have up to $N > 0$ children, and they can control their family size, n, by investing in contraceptive use, such that:

$$n = N - \theta q,\ \theta > 0, \tag{4}$$

where $q \geq 0$ is the (intensity of) investment in contraception (e.g., the use of pills or/and condoms) and θ is related to the efficiency of contraception on birth control. Contraception is costly and the relative price of contraception is $\phi_q \geq 0$.

[20] In order to simplify the notation we will abstract from the subscript t to denote the time period and use the convention that object $'$ stands for future variables.

Human capital: Parents invest in the education of their children, $e \geq 0$, such that the human capital of their children is given by

$$h' = h(e) = e^{\zeta},\ \zeta \in (0, 1). \tag{5}$$

Investment in education is in terms of the consumption good. Children are also time consuming. Each child takes a fraction $\chi \in (0, 1)$ of her parents' time endowment. We assume that parents are able to provide some hours in the labor market even when they have the maximum amount of children, i.e., $\chi N < 1$.

Preferences and optimal decisions: Consumption of couples during the young adulthood period is denoted by c_y, while c_o' denotes consumption of the couple in the next period, when old. Preferences of households are represented by:

$$U(c_y, c_o', n, h') = \log(c_y) + \beta \log(c_o') + \gamma \log(n) + \xi \log(h'), \tag{6}$$

where β, γ, and ξ are positive numbers.

Let s denote savings during the young adulthood period. The problem of the couple is to choose c_y, c_o', q, s, and e to maximize (6) subject to (4), (5), and the following budget constraints:

$$c_y + s + \phi_q q + en = wh(1 - \chi n), \tag{7}$$

$$c_o' = R's. \tag{8}$$

Equation (7) states that consumption plus savings and expenditures on contraception and education equals income. Equation (8) implies that old couples consume their savings from the young adulthood period. Whenever $q > 0$, then the equations which describe the solution of this problem are:[21]

$$c_y = \frac{1}{(1 + \beta + \gamma)} \left(wh - \frac{\phi_q}{\theta} N \right), \tag{9}$$

$$s = \frac{\beta}{(1 + \beta + \gamma)} \left(wh - \frac{\phi_q}{\theta} N \right), \text{ and } c_o' = R's, \tag{10}$$

$$e = \frac{\xi\zeta}{(\gamma - \xi\zeta)} \left(wh\chi - \frac{\phi_q}{\theta} \right), \tag{11}$$

$$q = \frac{N}{\theta} - \frac{(\gamma - \xi\zeta)}{\theta(1 + \beta + \gamma)} \left(\frac{wh - \frac{\phi_q}{\theta} N}{wh\chi - \frac{\phi_q}{\theta}} \right), \tag{12}$$

$$n = \frac{(\gamma - \xi\zeta)}{(1 + \beta + \gamma)} \left(\frac{wh - \frac{\phi_q}{\theta} N}{wh\chi - \frac{\phi_q}{\theta}} \right). \tag{13}$$

We make the following assumption:

[21] When $q = 0$, we have that $n = N$, $c_y = \frac{wh(1-\chi N)}{1+\beta+\gamma\zeta}$, $s = \beta c_y$, $c_0' = R's$ and $e = \frac{\gamma\zeta}{(1+\beta+\gamma\zeta)} \frac{wh(1-\chi N)}{N}$.

Assumption 1: Let $N\chi < 1$ and $\frac{(\gamma-\xi\zeta)}{(1+\beta+\gamma)\chi} < N$.

The assumption that $N\chi < 1$ implies that even when fertility is at its maximum ($q = 0$), couples still supply a positive number of hours to the labor market. The second part of the assumption implies that when the price of modern contraceptive methods is zero ($\phi_q = 0$), then fertility is lower than the case in which there is no investment in modern contraceptive methods ($q = 0$). Observe that when ϕ_q goes to zero then fertility does not depend on labor income (wh). This is because when income rises the opportunity cost (time cost) of having more children rises (substitution effect), but since children are a normal good, then the income effect induces parents to have more children. With log-utility these two effects cancel each other out, and when $\phi_q = 0$ then fertility does not depend on income – see Equation (13). This is well explained in Jones, Schoonbroodt, and Tertilt (2010). When ϕ_q is positive then there is a negative association between fertility and income, as reported in the data. In this case richer parents can increase the intensity of their use of contraceptive methods in order to control family size. Without investment in modern contraceptive methods, fertility is equal to N.

One can argue that it is not necessary to explicitly add investment in contraceptives into a standard quantity-quality fertility model because parameter χ, which corresponds to the time cost of children, could capture that investment. Better access to contraceptives could be translated into a rise in parameter χ such that it would raise the quality of children (e) as well as reduce their quantity (n). In fact, the proportional changes in n and e due to a proportional variation in χ have opposite signs but equal magnitude. A fall in the price of contraceptives (ϕ_q) generates not only different quantitative but also qualitative effects. Indeed, a fall in ϕ_q also increases e and reduces n, but observe that parameter χ does not affect the consumption-saving decision, while the price of contraceptives does. In addition, family planning interventions which reduce the price of contraceptives have strong effects on the quantity and quality of children when income levels are low. Proposition 1 summarizes these findings.

Proposition 1. *Let Assumption 1 be satisfied and define $\epsilon_{z,\chi}$ and ϵ_{z,ϕ_q} as the elasticity of variable $z \in \{n, e\}$ with respect to χ and ϕ_q, respectively. Then whenever $q > 0$, we have that:*

(i) $\frac{\partial e}{\partial \chi} > 0$, $\frac{\partial n}{\partial \chi} < 0$ *and* $\frac{\partial s}{\partial \chi} = 0$. *Moreover,* $r_\chi = \frac{|\epsilon_{n,\chi}|}{\epsilon_{e,\chi}} = 1$.

(ii) $\frac{\partial e}{\partial \phi_q} < 0$, $\frac{\partial n}{\partial \phi_q} > 0$ *and* $\frac{\partial s}{\partial \phi_q} < 0$. *Moreover,* $r_{\phi_q} = \frac{\epsilon_{n,\phi_q}}{|\epsilon_{e,\phi_q}|} = \frac{wh(1-N\chi)}{wh-\frac{\phi_q}{\theta}N}$ *and* $\frac{\partial r_{\phi_q}}{\partial (wh)} < 0$.

Proof. For the partial derivative, simply use equations (10), (11), and (13) and take the corresponding partial derivatives with respect to χ and ϕ_q. For the elasticities, take the logarithm on both sides of equations (11) and (13) and differentiate either with respect to χ and ϕ_q. *Q.E.D.*

Let P denote the number of young adult households such that $P' = nP$. In equilibrium, demand equals supply in all markets. In the labor market this means that $L = P(1 - \chi n)h$, and in the capital market, $K' = Ps$. Let k denote physical capital per young household.

In equilibrium with $q > 0$ it can be shown that $h' = Dk'^{\zeta}$ with $D = \left(\frac{\xi\zeta}{\beta}\right)^{\zeta} > 0$, and $w(k) = (1-\alpha)D^{-\alpha}Ak^{\alpha(1-\zeta)}(1-\chi n(k))^{-\alpha}$. When $q = 0$, we also have that $h' = Dk'^{\zeta}$, and $w(k) = (1-\alpha)D^{-\alpha}(1-\chi N)^{-\alpha}k^{\alpha(1-\zeta)}$. In addition,

$$n(k) = \min\left\{N, \frac{(\gamma-\xi\zeta)}{(1+\beta+\gamma)}\left(\frac{(1-\alpha)D^{-\alpha}Ak^{\alpha+\zeta(1-\alpha)}(1-\chi n(k))^{-\alpha} - \frac{\phi_q}{\theta}N}{(1-\alpha)D^{-\alpha}Ak^{\alpha+\zeta(1-\alpha)}(1-\chi n(k))^{-\alpha}\chi - \frac{\phi_q}{\theta}}\right)\right\}. \tag{14}$$

Then the following proposition summarizes the fertility choice.

Proposition 2. *Let Assumption 1 be satisfied. Then it can be shown that* $n(k) \in \left(\frac{(\gamma-\xi\zeta)}{(1+\beta+\gamma)\chi}, N\right]$ *and*

(i) there exists a $\underline{k}(\phi_q) > 0$ *such that if* $k \leq \underline{k}(\phi_q)$*, then* $n(k) = N$*; and if* $k > \underline{k}(\phi_q)$*, then* $n(k) < N$*; in addition,* $\underline{k}'(\phi_q) > 0$*. Moreover,*

(ii) for $k > \underline{k}(\phi_q)$ *fertility is decreasing with capital accumulation, i.e.,* $n'(k) < 0$*.*

Proof. Let $N\chi < 1$. Then it can be shown that whenever $n(k) < N$, we have that

$$n'(k) = -\frac{\frac{(\gamma-\xi\zeta)}{(1+\beta+\gamma)}(\alpha+\zeta(1-\alpha))(1-\alpha)D^{-\alpha}Ak^{\alpha+\zeta(1-\alpha)-1}(1-\chi n(k))^{-\alpha}\frac{\phi_q}{\theta}(1-\chi N)}{1+\frac{(\gamma-\xi\zeta)}{(1+\beta+\gamma)}\alpha(1-\alpha)D^{-\alpha}Ak^{\alpha+\zeta(1-\alpha)}(1-\chi n(k))^{-\alpha-1}\frac{\phi_q}{\theta}(1-\chi N)} < 0.$$

In addition, $\lim_{k\to\infty} n(k) = \frac{(\gamma-\xi\zeta)}{(1+\beta+\gamma)\chi}$. Equation (14) defines a critical value

$$\underline{k}(\phi_q) = \left(\frac{N\phi_q(1+\beta+\xi\zeta)(1-\chi N)^{\alpha}}{\theta(1-\alpha)D^{-\alpha}A((1+\beta+\gamma)N\chi-(\gamma-\xi\zeta))}\right)^{\frac{1}{\alpha+\zeta(1-\alpha)}}, \tag{15}$$

which is positive by assumption. Moreover, we have that $n(k) = N$ for any $k \leq \underline{k}(\phi_q)$ and $n(k) < N$ for any $k > \underline{k}(\phi_q)$. In order to see this, observe that without the upper bound in the fertility choice, $n(k)$ would go to infinity as k would be sufficiently small such that $n(k)\chi$ would tend to 1. Therefore, given the continuity of $n(k)$, we have that there exists a $\underline{k}(\phi_q) > 0$ such that $n(\underline{k}(\phi)) = N$. Using the Implicit Function Theorem we can show that $\underline{k}'(\phi_q) > 0$. *Q.E.D.*

The condition that equilibrates the capital market implies that

$$k' = G(k;\phi_q) = \begin{cases} \frac{\beta(1-\alpha)D^{-\alpha}A(1-\chi N)^{-\alpha}k^{\alpha+\zeta(1-\alpha)}}{(1+\beta+\gamma\zeta)N} & \text{for } k \leq \underline{k}(\phi_q), \\ \frac{\beta\left((1-\alpha)D^{-\alpha}Ak^{\alpha+\zeta(1-\alpha)}(1-\chi n(k))^{-\alpha}\chi-\frac{\phi_q}{\theta}\right)}{\gamma-\xi\zeta} & \text{for } k > \underline{k}(\phi_q). \end{cases} \tag{16}$$

Finally, we have that

$$h' = Dk'^{\zeta}, \tag{17}$$

and therefore human and physical capital are positively related.

We can now prove the following about the system of equations given by (14)–(17):

Proposition 3. ***(Existence and uniqueness of equilibrium path)*** *For a given initial capital stock k_0, let h_0 be given by (17); then the dynamic system of difference equations (14)–(17) has a unique trajectory (solution).*

Proof. Given k_0 and the fact that h_0 is given by (17), we can use (14) to find $n(k_0)$, which is unique given that $n(k)$ is non-increasing and continuous in k. Then, we can use Equations (16) and (17) to find $k_1(k_0)$ and $h_1(k_0)$, respectively; and so on. *Q.E.D.*

Given the path for n_t, k_t, and h_t, we can find consumption and investment decisions (9)–(11), as well as investment in contraceptive methods, Equation (12). Asymptotically, the system may diverge to infinity, converge to a zero, or converge to a non-zero steady-state equilibrium. Observe that when $k < \underline{k}(\phi_q)$, we have that $\frac{\partial G(k;\phi_q)}{\partial k} > 0$, $\frac{\partial^2 G(k;\phi_q)}{\partial k^2} < 0$, and $lim_{k \to 0} \frac{\partial G(k;\phi_q)}{\partial k} = \infty$. Therefore, the system does not converge to a zero steady-state. If $\underline{k}(\phi_q)$ is sufficiently large,[22] then there will be a locally stable steady-state $k_N^* = G(k_N^*; \phi_q)$ in which $n(k) = N$. In this case, there is no investment in modern contraceptive methods ($q = 0$), and therefore family planning interventions do not have any effect on the long-run level of the capital stock, i.e, k_N^* is independent of ϕ_q. However, whenever $\underline{k}(\phi_q) < k_N^*$, then it can be shown that there exists a locally stable steady-state equilibrium $k^*(\phi_q) > \underline{k}(\phi_q)$ such that fertility decreases with capital accumulation, and family planning interventions have long-run effects on capital accumulation and output. This is summarized in the following proposition.

Proposition 4. *Let Assumption 1 be satisfied and ϕ_q be sufficiently small such that $\underline{k}(\phi_q) < k_N^*$. Then there exists at least one locally stable steady-state equilibrium for capital per young household, $k^*(\phi_q) = G(k^*(\phi_q); \phi_q)$, such that in the neighbourhood of $k^*(\phi_q)$, fertility decreases with capital accumulation, and family interventions which reduce the price of modern contraceptive methods increase the steady-state level of capital, i.e., $k^{*\prime}(\phi_q) < 0$.*

Proof. If $\underline{k}(\phi_q) < k_N^*$, then for any $k > \underline{k}(\phi_q)$ it can be shown that $\frac{\partial G(k,\phi_q)}{\partial k} > 0$, and $\lim_{k \to \infty} \frac{\partial G(k,\phi_q)}{\partial k} = 0$. This implies that $k' = G(k, \phi_q)$ has to cross (at least once) the 45 degree line ($k' = k$) from above, and this defines $k^*(\phi_q) = G(k^*(\phi_q); \phi_q)$, which is therefore locally stable. Fertility thus decreases with capital accumulation. Moreover, we can easily show that $k^{*\prime}(\phi_q) < 0$, which completes the proof. *Q.E.D.*

Corollary 1. *Let Assumption 1 be satisfied; then human capital increases with physical capital accumulation. If ϕ_q is sufficiently small such that $\underline{k}(\phi_q) < k_N^*$, then family interventions which reduce the price of modern contraceptive methods increase the steady-state level of human capital.*

Proof. This follows directly from Equation (17) and Proposition 4. *Q.E.D.*

Therefore, the above model is able to replicate the negative relationship between fertility and income through the intensity of the use of modern contraceptive methods. The

[22] For instance if the relative price of contraceptive methods is too high; see Equation (15).

model shows that the standard fertility model without the decision to invest in contraceptives cannot capture how family planning interventions affect the quantity and quality of children, as well as savings. This framework, however, corresponds to the simplified version of the model. Here agents are homogeneous, there is no uncertainty in the fertility decision, and households cannot rely on abortion to control family size. In addition, given prices, there are no unwanted births in the model. We believe that introducing such features is important in accurately assessing the effects of family planning interventions on fertility decisions, investment, inequality, and output. For instance, the homogenous nature of the framework prevents us from studying how reductions in the price of modern contraceptive methods affect the fertility decisions of different families, and how such reductions can affect the persistence of inequality in education and income. Below we describe a more elaborate version of our theoretical framework which we use for our quantitative analysis.

4 Model

4.1 Demographics and Endowments

Here we keep the environment as close as possible to the one presented in the previous section. As before, the economy consists of overlapping generations of individuals who live for three periods: childhood, young adulthood, and old adulthood. Children do not make any economic decisions and can acquire skills. Young adults are organized as couples and make the following economic choices: their desired number of children and the intensity of their contraceptive use. The number of pregnancies is, however, stochastic, and the realized and desired number of pregnancies may be different. The use of contraception can lower the chances of an unwanted pregnancy. Once the number of pregnancies is realized, young couples may decide to abort some of them to close the gap between the number of realized and desired children. But abortion is costly, both in terms of utility and in income. Young adults have one unit of productive time and are endowed with skills that they acquired during their childhood. They then invest their income into the education of their children, consume, and save. Old adults do not work and simply consume their savings.

The production side of the model is similar to the one presented in Subsection 3.2 with firms' optimal conditions given by (2) and (3).

4.2 Households

Desired and realized fertility: Young couples first decide on the number of children that they want to have, $\tilde{n}$.[23] Then, the number of pregnancies, p, is realized. We assume that

$$p - \tilde{n} = \max\{\eta - \theta q, 0\}, \tag{18}$$

[23] Since adults are organized as couples, we can view $\tilde{n}$ as the desired number of children that each household wants to have. We abstract from intra-household bargaining over fertility. Doepke and Kindermann (2016) explore in detail the consequences of bargaining over fertility for a set of European countries.

where $q \geq$ is the investment in contraception, η is a random variable with distribution $\Gamma(\eta)$ and support $[0, N]$, and θ is a positive parameter.[24] It is important to emphasize that even when modern contraceptive use is zero ($q = 0$) pregnancies will still have a deterministic (demand) component, $\tilde{n}$, and a stochastic component, η. We are not saying that without modern contraceptive methods families could not use traditional practices to control fertility (e.g., extended breast-feeding and sexual abstinence, among others). Equation (18) simply implies that the use of modern contraceptive methods can decrease the fertility gap relative to a situation without these birth control (supply) technologies. Contraceptive prevalence (or use) is jointly determined by both supply and demand factors and therefore is able to disentangle the importance of each factor in the determination of fertility.

Contraception is costly and the relative price of contraception is ϕ_q. This includes not only the price to buy modern contraceptives on pharmacies or to acquire (including transportation costs) them in public clinics, but also the fact that they might be stocked out, as reported by Ashraf, Field, and Lee (2014) in the case of Zambia. Therefore, ϕ_q corresponds to supply factors which might affect the use of modern contraceptive methods. Contraception also generates a utility cost $\Psi_q > 0$ whenever $q > 0$. In some cultures, modern contraception use can be associated with promiscuity and women may also have the fear of side effects and adverse reactions related to, for instance, the use of pills. In addition, there may potentially be intra-household disagreement (husband versus wife desired fertility), which is not explicitly modelled here, about the use of contraceptives. For instance, Ashraf, Field, and Lee (2014) show that when women receive access to contraception alone they report lower subjective well-being than when they receive access to contraception with their husbands, suggesting a psychosocial cost.[25] Therefore, the parameter $\Psi_q > 0$ corresponds to demand barriers to the use of modern contraceptive methods. Once the number of pregnancies is realized, the household can choose to abort some of them, a, in order to close the gap between the number of realized pregnancies and the desired number of children. Abortion is costly both in terms of utility, such that there are disutility costs $\Psi_a > 0$ whenever $a > 0$, and in terms of the consumption good. The relative price of abortion is ϕ_a. The realized number of children is:

$$n = p - a. \tag{19}$$

Observe that while investment in the use of modern contraceptives is an insurance against the risk of unwanted pregnancies, abortion is not an insurance since it terminates a pregnancy with certainty. However, both technologies incur costs and agents will take this into account when making their birth control choices.

Human capital: Parents invest in the education of their children, $e \geq 0$, such that the

[24] We could easily assume that instead of Equation (18), we have that $p - \tilde{n} = \eta - \theta q$. Then households could also have lower pregnancies than the desired fertility. We focus on relatively poorer countries in which we find that on average there is a positive gap between the realized and desired number of children for any level of parents' human capital.

[25] We are abstracting from externalities when fertility desires are influenced by the reproductive behavior of others (cf., Dasgupta, 1995, 2000). In this case family planning interventions may be optimal even when wanted fertility accords with realized fertility when such interventions can bring changes in social norms.

human capital of their children is equal to

$$h' = \epsilon \tilde{h}(e). \tag{20}$$

The function $\tilde{h}(e)$ is increasing, differentiable, and concave with respect to e, and the price of education in terms of the consumption good is $\lambda(e)$, which varies with e. We also assume that $\tilde{h}(0) > 0$ such that the quality of children's income elasticity is increasing with income, as postulated by Becker (1960) and explored by Greenwood, Seshadri, and Vandenbroucke (2005), to generate the secular decline in fertility and the increase in human capital. The shock $\epsilon \sim F(\epsilon)$ has positive support and summarizes unobserved factors that influence the human capital production process. Investment in education is in terms of the consumption good. Children are also time consuming. Each child takes a fraction $\chi \in (0, 1)$ of her parents time endowment and $N\chi < 1$.

Optimal decisions: Consumption of couples during the young adulthood period and old adulthood period are denoted by c_y and c_o', respectively. Preferences of couples are represented by the following utility function:

$$U(c_y, c_o', n, h'), \tag{21}$$

where $U(\cdot, \cdot, \cdot, \cdot)$ is differentiable, increasing, and concave in all arguments.

Let s be the savings of a young adult couple and $\mathbf{I}_{a>0}$ be an indicator function which equals one when $a > 0$ and zero otherwise. The problem of the couple with p realized pregnancies who invested q in contraception is to choose c_y, c_o', a, s, and e to maximize

$$\tilde{V}(h, p, q) = \max_{c_y, c_o', a, s, e \geq 0} \{E_\epsilon[U(c_y, c_o', n, \epsilon \tilde{h}(e))] - \Psi_a \mathbf{I}_{a>0}\}, \tag{22}$$

subject to (19) and (20),

$$c_y + s + \phi_q q + \phi_a a + \lambda(e) e n = wh(1 - \chi n), \tag{23}$$

$$c_o' = R' s. \tag{24}$$

$E_\epsilon[\cdot]$ corresponds to expectations over ϵ. Equation (23) corresponds to the budget constraint of the young couple. It implies that consumption plus savings of the household plus expenditures on contraception, abortion, and education must be equal to income. Budget constraint (24) states that in old adulthood, couples consume the principal and interest from their savings during the young adulthood period.

Let $\mathbf{I}_{q>0}$ be an indicator function which equals one when $q > 0$ and zero otherwise. The problem of a couple before the number of pregnancies is realized is to choose the number of desired children, $\tilde{n}$, and investment in contraception, q, in order to:

$$V(h) = \max_{\tilde{n}, q \geq 0} \{E_\eta[\tilde{V}(h, b, q) - \Psi_q \mathbf{I}_{q>0}]\}, \tag{25}$$

subject to Equation (18). The notation $E_\eta[\cdot]$ denotes that expectations are taken over the stochastic number of pregnancies summarized by the random variable η.

4.3 Equilibrium

In a competitive equilibrium, agents and firms optimally solve their problems and all markets clear. Let $x = (h, \eta)$ with $x \in \mathcal{X} = (0, \infty) \times (0, N)$. The couples' optimal behavior defines optimal policy functions $c_y(x)$, $c_o'(x)$, $s(x)$, $q(h)$, $a(x)$, $e(x)$, and $\tilde{n}(h)$. The stationary equilibrium in this economy is characterized by a stationary human capital distribution associated with the optimal behavior of couples and firms. To characterize the stationary human capital distribution, first define the following function,

$$\mathbf{1}(x, \epsilon, h') = \begin{cases} 1 & \text{if } h' = \epsilon \tilde{h}(e(x)) \\ 0 & \text{otherwise} \end{cases}.$$

The function above takes the value of one if a child coming from parents with a state x and a shock ϵ builds a human capital level h' . It takes the value of zero otherwise. Next, construct a transition probability function,

$$P(h'|x) = \int \mathbf{1}(x, \epsilon, h') dF(\epsilon),$$

which computes the probability that a child attains human capital level h' conditional on having parents with state x. Finally, note that the number of children of a household is given by

$$n(x) = \tilde{n}(h) + \max\{\eta - \theta q(h), 0\} - a(x).$$

Based on this, define the distribution function of human capital as

$$\Upsilon(h') = \frac{\int_{\mathcal{X}} n(x) P(h'|x) d\Upsilon(h) d\Gamma(\eta)}{\int_{\mathcal{X}} n(x) d\Upsilon(h) d\Gamma(\eta)}. \tag{26}$$

The distribution of human capital in the economy is Υ. The rate of population growth, g, in this economy is given by

$$1 + g = \int_{\mathcal{X}} n(x) d\Upsilon(h) d\Gamma(\eta). \tag{27}$$

The law of motion for the distribution presented in Equation (26) takes into account population growth as evidenced by the normalization in the denominator. Note that in this economy both capital and labor will grow with the rate of population growth. To pose a stationary representation of the equilibrium, one can de-trend these two variables in the following way,

$$L = \frac{L_t}{(1+g)^t},$$

and

$$K = \frac{K_t}{(1+g)^t}.$$

Definition: (Stationary Competitive Equilibrium) *A stationary competitive equilibrium for this economy consists of allocations for firms* $\{K, L\}$*, a collection of policy functions for households* $\{c_y(x), c_o'(x), s(x), q(h), a(x), e(x), \tilde{n}(h)\}$*, a stationary distribution* Υ*, a vector of prices* $\{w, R\}$*, and a population growth rate* g *such that:*

i. *Given the vector of prices* $\{w, R\}$*, the vector* $\{K, L\}$ *solves (2) and (3).*

ii. *Policy functions* $q(h)$ *and* $\tilde{n}(h)$ *solve value function* $V(h)$ *and*

$$p - \tilde{n}(h) = \max\{\eta - \theta q(h), 0\}.$$

iii. *Policy functions* $\{c_y(x), c_o'(x), s(x), a(x), e(x)\}$ *solve value function* $\tilde{V}(h, b, q)$*.*

iv. *Market clearing conditions are such that:*

$$\int_{\mathcal{X}} [c_y(x) + s(x) + \phi_q q(x) + \phi_a a(x) + \lambda(e) e(x) n(x)] d\Upsilon(h) d\Gamma(\eta) + \frac{1}{1+g} \int_{\mathcal{X}} c_o(x) d\Upsilon(h) d\Gamma(\eta) = AK^{\alpha} L^{1-\alpha}, \tag{28}$$

$$L = \int_{\mathcal{X}} h(1 - n(x)\chi) d\Upsilon(h) d\Gamma(\eta). \tag{29}$$

and

$$K' = \int_{\mathcal{X}} s(x) d\Upsilon(h) d\Gamma(\eta). \tag{30}$$

v. *The distribution of human capital* Υ *solves (26).*

vi. *The population growth rate is given by (27).*

5 Fitting the Model to the Data

In order to investigate the effects of family planning interventions on human capital dynamics, inequality, and income, we must assign values for the model parameters. We have prior information about some parameters, such as the capital share in income. Other parameters are specific to the analysis at hand and little is known about their magnitudes. Therefore, values for these parameters will be estimated such that the model matches key micro and macro moments of Kenya for the late 2000s, due to data restrictions. We use a minimum distance procedure which targets a set of data moments on wanted and unwanted fertility and family planning in terms of contraceptives and abortion conditional on education levels. These data moments are derived from the 2008 Kenya Demographic and Health Survey.[26] Matching the cross-sectional distributions of fertility and family

[26]Education here is used as a proxy for household labor income.

planning conditional on human capital ensures that the model delivers a credible link between fertility uncertainty, family planning instruments to mitigate it, and human capital accumulation. We concentrate on the following levels of education: *0 years of schooling*, *4 years of schooling*, *8 years of schooling*, *12 years of schooling*, and *16 years of schooling*. We also target several aggregate moments such as income inequality, the consumption-output ratio, and the capital-output ratio, among others. First, however, we need to impose functional forms for some of the expressions of our theoretical framework. Below we describe in detail these functions and how we calibrate and estimate model parameters.

5.1 Calibration and Estimation

Model period: The model period is assumed to be 20 years. This is consistent with the 2008–2014 average life-expectancy in Kenya of around 60 years (cf., The World Bank, 2015).

Production technology: Recall that we assumed a Cobb-Douglas production function. The capital share in income we get from the Penn World Tables (cf., Feenstra, Inklaar, and Timmer, 2015). We set it to $\alpha = 0.36$, which is consistent with the number estimated by Gollin (2002) for developing countries. Capital depreciates fully after use. The productivity parameter A is chosen such that total output per capita is normalized to 1. The production technology parameters are: A and $\alpha = 0.36$ (one to be estimated).

Fertility technology: The fertility shock η has the following cumulative distribution function: $\Gamma(\eta) = \left(\frac{\eta}{N}\right)^{\kappa}$, where N corresponds to the maximum number of unwanted pregnancies possible. We set the maximum number of unwanted pregnancies per woman to 10. In the grid for wanted fertility we also set the maximum number of wanted pregnancies to 10 so that a woman could have a maximum of 20 pregnancies in her lifetime. Since the model period is one year, this implies one pregnancy per year. The efficiency of contraception is determined by the product of θq. Different combinations of parameters ϕ_q and θ lead to identical choices of consumption and fertility. In order to resolve this issue, we normalize the price of contraception to one such that $\phi_q = 1$. The relative price of abortion is equal to $\phi_a > 0$. The fertility technology parameters are: $N = 10$, $\phi_q = 1$, κ, θ, and ϕ_a (three to be estimated).

Human capital function and child-rearing technology: The offsprings' human capital is given by $h' = \epsilon\tilde{h}(e)$. We assume that $\tilde{h}(e) = h_0 + h_1 e^{\zeta}$. The fixed component h_0 implies non-homothetic preferences over human capital. This feature and the time cost of children, χ, help us generate a negative relationship between fertility and parental income/education in the model.[27] We restrict the choice of education to five discrete options: no education, four years, eight years, twelve years, and sixteen years. Each of these five discrete levels bears an education cost. The vector of education costs $\lambda(e) \in \{0, \lambda_1, \lambda_2, \lambda_3, \lambda_4\}$ summarizes the amount of consumption goods parents need to forgo in order to finance the education of a child to one of these five attainment levels. The

[27] See Greenwood, Seshadri, and Vandenbroucke (2005) and Jones, Schoonbroodt, and Tertilt (2010) for more details.

unobserved ability that augments the human capital production, ϵ, is assumed to have a log-normal distribution with mean 0 such that $\ln \epsilon \sim N(0, \sigma_\epsilon^2)$. There is also the time cost of raising a child, χ. The parameters for this section are: χ, h_0, h_1, ζ, λ_1, λ_2, λ_3, λ_4, and σ_ϵ^2 (nine to be estimated).

Utility: Turning to preferences, the utility function takes the following functional form:

$$U(c_y, c_o', n, \tilde{h}(e)) = \log(c_y) + \beta \log(c_o') + \gamma \log(n) + \xi \log(\tilde{h}(e)).$$

There are also two costs related to the household's taste: the disutility of contraception use and abortions. Recall that these were defined as $\Psi_q \mathbf{I}_{q>0}$ and $\Psi_a \mathbf{I}_{a>0}$ with $\Psi_q > 0$ and $\Psi_a > 0$, where $\mathbf{I}_{q>0}$ and $\mathbf{I}_{a>0}$ are indicator functions when the use of modern contraceptives and abortion are positive, respectively. That is, households pay these costs if they engage in strictly positive use of each family planning option. Preference parameters are: β, γ, ξ, Ψ_q and Ψ_a (five to be estimated).

There are therefore 18 parameters of the model to be estimated via a minimum distance procedure. The parameters are estimated to match the normalization of output per capita to one and the following 22 data moments:

(i) Realized fertility rate and unwanted fertility rate by levels of education. Note that matching these two series implies that the level of wanted fertility is matched too. Source: 2008 Kenya DHS.[28] [**8** targets]

(ii) Abortion rates and the fraction of women using modern contraception by levels of education. Source: 2008 Kenya DHS and own calculation based on Westoff (2008).[29] [**8** targets]

(iii) Fraction of people in each education category. Source: 2008 Kenya DHS. [**3** targets]

(iv) Capital-output and consumption-output ratios. Source: Penn World Tables (cf., Feenstra, Inklaar, and Timmer, 2015) . [**2** targets]

(v) Gini coefficient of household labor income. Source: The World Bank (2015). [**1** target]

How do these data moments aid in the process of setting the model parameters? In a general equilibrium setup a change in any parameter affects all targets. However, some sets of data moments are more sensitive to certain parameters. The fertility and family planning targets ((i) and (ii)) conditional on human capital are useful in recovering preference parameters $\{\gamma, \zeta, \Psi_q, \Psi_a\}$ and the price of abortion ϕ_a, as well as the fertility uncertainty $\{\kappa\}$,

[28]In the model there are five levels of education: no schooling, 4 years of schooling, 8 years of schooling, 12 years of schooling, and 16 years of schooling. In the DHS survey there are four levels of education: No primary education, primary, secondary, and higher and more. Primary education in Kenya corresponds to 8 years of schooling. Therefore, in the map from the model to the data, we aggregate the no-education category and the 4-years-of-schooling category into one category, which corresponds to no primary education or from 0 to 4 years of schooling.

[29]The total abortion rate is calculated using Equation (7) of Westoff (2008). This equation defines a statistical relation of the total abortion rate with the total fertility rate and the contraceptive prevalence rate.

the efficiency of modern contraceptives θ, and the time cost per child χ. The distribution over educational categories (iii) identifies the cost parameters $\{\lambda_1, \lambda_2, \lambda_3, \lambda_4\}$. The capital to output ratio helps to pin down the discount factor β. Matching aggregate targets (iv) along with targets on fertility, family planning, education, and inequality (v) help us in setting parameters for the human capital accumulation process $\{h_0, h_1, \sigma_\epsilon\}$.

Let $\Theta = \{\beta, \gamma, \xi, \Psi_q, \Psi_a, h_0, h_1, \zeta, \chi, \sigma_\epsilon, \kappa, \theta, \phi_a, \lambda_1, \lambda_2, \lambda_3, \lambda_4, A\}$ be the vector of parameters to be estimated, and define the difference between the model-generated 22 moments and the normalization of output to one by $\mathcal{M}(\Theta)$, and the data moments $\mathcal{D}$ by $\mathbf{R}(\Theta) = \mathcal{D} - \mathcal{M}(\Theta)$. The minimum distance estimation amounts to choosing parameter values that minimize the squared form,

$$\hat{\Theta} = \arg \min_{\Theta} \mathbf{R}(\Theta)' \mathbf{W} \mathbf{R}(\Theta),$$

where $\mathbf{W}$ is a diagonal weighting matrix. We use an identity matrix in our base estimation. Table 3 reports the calibrated and estimated parameter values that result from the baseline estimation procedure above for Kenya.

Table 3: Calibrated and estimated parameters

Parameter	**Description**	**Value**	**Comment**
Calibrated parameters (3 parameters)			
α	Capital share in income	0.36	Feenstra et al (2015)
N	Max. number of unwanted pregnancies	10	Normalized
ϕ_q	Price of modern contraceptives	1	Normalized
Estimated parameters (18 parameters)			
A	TFP parameter	0.6602	Moments (i)-(v)
β	Discount factor	0.5952	Moments (i)-(v)
γ	Utility weight on fertility	0.8819	Moments (i)-(v)
ξ	Utility weight on human capital	1.9252	Moments (i)-(v)
Ψ_q	Utility cost of contraception	0.0024	Moments (i)-(v)
Ψ_a	Utility cost of abortion	0.0804	Moments (i)-(v)
h_0	Human capital - fixed	4.6612	Moments (i)-(v)
h_1	Human capital - marginal	0.0349	Moments (i)-(v)
ζ	Human capital - curvature	2.1145	Moments (i)-(v)
χ	Time cost per child	0.0353	Moments (i)-(v)
σ_ϵ	Std of ability shock	0.5992	Moments (i)-(v)
κ	Fertility uncertainty	0.2830	Moments (i)-(v)
θ	Efficiency of contraception	347.5306	Moments (i)-(v)
ϕ_a	Abortion cost	0.0033	Moments (i)-(v)
λ_1	Education cost: 4 years of schooling	0.0047	Moments (i)-(v)
λ_2	Education cost: 8 years of schooling	0.0093	Moments (i)-(v)
λ_3	Education cost: 12 years of schooling	0.0646	Moments (i)-(v)
λ_4	Education cost: 16 years of schooling	0.2392	Moments (i)-(v)

Here are some comments on the estimated parameters. Since the model period corresponds to 20 years, then a discount factor of $\beta = 0.5952$ implies that agents discount the future at a real rate of 2.6 percent per year. Given the cost of each education level, we can observe that the utility weight on the quality of children is higher than the utility weight on the quantity of children. In addition, as expected, the utility cost of contraception is much smaller than the utility cost of abortions. Also, given that the maximum number of unwanted pregnancies is 10, the relative price of contraception is equal to one, and $\theta = 347.5306$, then with less than 3 percent of GDP it is possible to avoid any unwanted pregnancies in the model. The time cost per child is about 3.5 percent, which is roughly half the value calibrated by de la Croix and Doepke (2003). However, de la Croix and Doepke (2003) calibrated this parameter for the United States economy, while our baseline economy is Kenya; we should expect this time cost to be smaller for developing economies than for the United States. Finally, the human capital accumulation function features a large fixed component, $h_0 = 4.6612$, which helps in generating the quantity-quality trade-off observed in the data.

5.2 Model Fit

Now, we discuss the fit of the model with respect to targeted and some non-targeted moments. We estimated a total of 18 parameters by targeting 23 data moments and setting the normalization of output per capita to one. Table 4 reports these moments in the data and in the model.

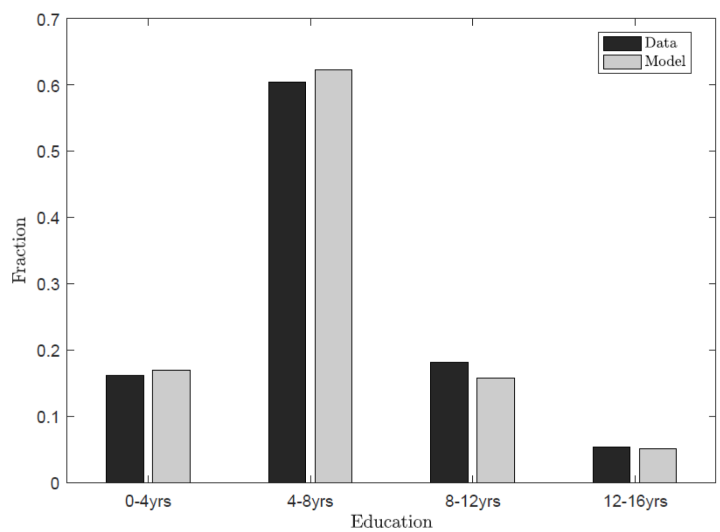


Figure 1: Data versus model - Fraction of adults by education. Source: 2008 Kenya DHS.

The model matches the fraction of adults in each education category very well, as seen

Table 4: Facts, Data versus Model

Statistics	Kenya, 2008 Data	Model
Targeted moments		
Adults with no primary education (%)	0.162	0.1699
Adults with 8 years of schooling (%)	0.604	0.6230
Adults with 12 years of schooling (%)	0.181	0.1571
Adults with 16 years of schooling (%)	0.053	0.0511
Fertility, parents with no primary education	6.7	6.3675
Fertility, parents with 8 years of schooling	5.5	5.5864
Fertility, parents with 12 years of schooling	4.9	4.9087
Fertility, parents with 16 years of schooling	3.1	4.2051
Unwanted fertility, parents with no primary education	0.9	1.1761
Unwanted fertility, parents with 8 years of schooling	1.8	0.9079
Unwanted fertility, parents with 12 years of schooling	1.3	0.7928
Unwanted fertility, parents with 16 years of schooling	0.6	0.5784
Abortions, parents with no primary education	1.06	0.8118
Abortions, parents with 8 years of schooling	0.68	0.7366
Abortions, parents with 12 years of schooling	0.65	0.6559
Abortions, parents with 16 years of schooling	0.97	0.6479
Modern contraceptive prevalence, parents with no primary education	0.12	0.1190
Modern contraceptive prevalence, parents with 8 years of schooling	0.348	0.3353
Modern contraceptive prevalence, parents with 12 years of schooling	0.418	0.4439
Modern contraceptive prevalence, parents with 16 years of schooling	0.521	0.5561
Income Gini	0.485	0.4788
Capital-to-output ratio, K/Y	1.57	1.3079
Consumption-to-output ratio, C/Y	0.7118	0.6644
Normalization of output per capita to one	1	1.051
Non-targeted moments		
Average returns to schooling	8.3	8.2
Unit abortion cost, % of GDP per capita	0.13-4.26	0.32
Contraception expenditure, % of GDP per capita	0.68	0.36

in Figure 1.[30] Interestingly, when we run a Mincerian regression with the model generated data to calculate the average returns to one additional year of schooling, we show that one additional year of schooling increases on average income by 8.1 percent. Schoellman (2012) estimated the returns to schooling in Kenya to be equal to 8.3 percent. Therefore, our model produces an average returns to schooling very close to the one observed in the data. Consequently our model is consistent on how human capital increases income, which is one of our key mechanisms of how family planning interventions might affect individual outcomes. The model does also a good job in reproducing the pattern of modern contraceptives prevalence and the total fertility rate conditional on the level of human capital observed in the data.[31] (See Figures 2(a) and 2(c).) Therefore, the model replicates qualitatively and quantitatively the trade-off between child quantity and quality which is present in the empirical evidence. The model does generate, however, a lower number of abortions than in the data for the lower tail and upper tail of the abortion distribution conditional on the level of education, but observed abortions in the middle of this distribution match well.[32] (See Figure 2(b).) Regarding unwanted fertility, the model overestimates by 30 percent this measure for adults with no primary education and underestimates by 50 percent this measure for adults with a primary education degree. (See Figure 2(d).) Since the fraction of adults with primary education is about 3.7 larger than the fraction of adults with no primary education, then if anything, the model underestimates the level of unwanted fertility. In fact, the overall gap between realized and wanted fertility is about 1.2 children for Kenya in 2008, while in the model this gap is 0.9185.

Regarding the aggregate measures, the model replicates fairly well the Gini index of income and is close to reproducing the capital-to-output ratio and the consumption-to-output ratio observed in the data. For the non-targeted statistics, the model, as mentioned previously, underestimates the aggregate level of unwanted fertility by 24 percent. Certainly there are other factors affecting unwanted fertility, such as infant mortality risks, which are not explicitly modeled in our framework. However, given that we underestimate unwanted fertility, we should also underestimate the effects of non-targeted family planning interventions on fertility and other outcomes. Notice that we also underestimate total expenditures on modern contraceptive methods as a share of per capita GDP by at least half of what is observed in the data.[33] Finally, we confirm that the abortion cost[34]

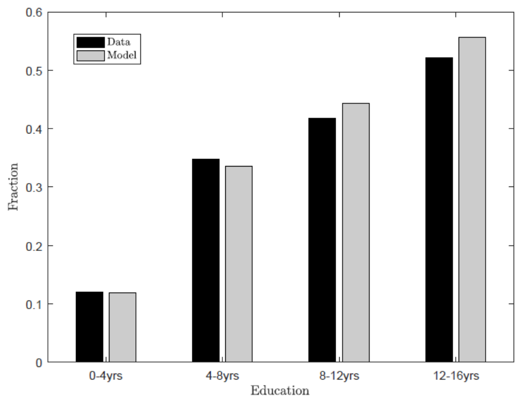
[30]The average years of schooling in the model is 7.68 years. In the DSH data the average years of schooling in Kenya is 7.83.

[31]Only at the very top of the human capital distribution does the model miss the fertility rate by underestimating it.

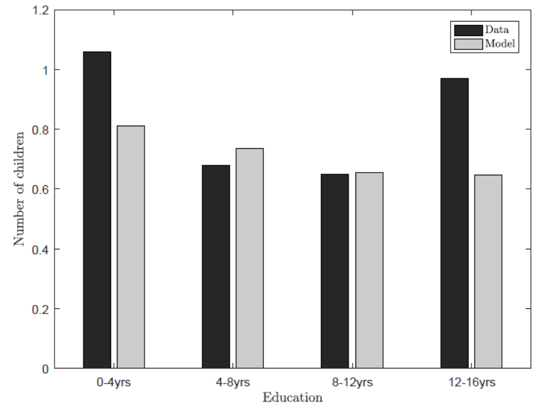
[32]We could introduce some heterogeneity in the utility cost of abortion in order to exactly reproduce the pattern of the data, but we abstain, as this would mechanically generate such patterns without adding any new insights to the analysis.

[33]We calculate expenditures on modern contraceptives in Kenya by using the proportion of adults adopting each method, and the commodity cost plus personal costs (ex., nurses and doctors) per couple year of protection of each method (cf., USAID, 2010). This gives an weighted average of US$6.41 per year of protection. Given that income per capita in Kenya in 2008 was US$938.57, this then implies a cost of 0.68 percent of GDP per capita. Notice that we are not capturing all costs associated with each method since our calculation does not take into account that some methods might not be available.

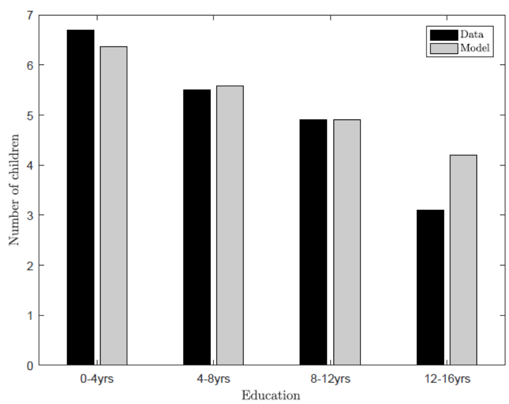
[34]The Constitution of Kenya permits abortion only when the life or health of the woman is in danger.



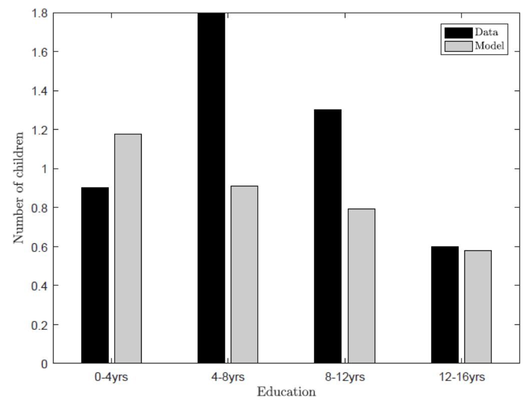
(a) Contraceptive prevalence by education



(b) Abortions by education



(c) Fertility by education



(d) Unwanted fertility by education

Figure 2: Data versus model - Selected statistics. Source: 2008 Kenya DHS.

as a fraction of per capita income generated in the model is in the lower range of what is observed in the data. Therefore, it does not seem that we are overestimating the values for the cost of modern contraceptives and abortion and therefore making them artificially important in our quantitative simulations on how family planning policy affects fertility, human capital accumulation, inequality, and income.

Before we implement a series of family planning interventions in our baseline model, we summarize the findings of key studies of the empirical literature, which recover the causal estimates of the effects of family planning policies on fertility and other individual outcomes. This is important in order to provide confidence that our family planning

Yet unsafe abortion remains a leading cause of maternal morbidity and mortality in Kenya (cf., Mohamed, Izugbara, Moore, Mutua, Kimani-Murage, Ziraba, Bankole, Singh, and Egesa, 2015). We have searched for anecdotal evidence on the cost of abortions in Kenya and find the price ranges from US$30-65, in illegal clinics and international charity Marie Stopes clinics (cf., Migiro, 2011; Robbins, 2013), to about US$1,000 in the Nairobi hospital. Given that a woman would abort on average one child in her lifetime, then we have that the effective unit cost of abortion in the model is in the range of what is observed in the data.

interventions do not overestimate their impacts on fertility, and therefore on aggregate variables.

5.3 Family Planning Interventions and Fertility: Model versus Data

The empirical development literature has produced well-identified causal estimates of the impacts of family planning interventions on fertility. These interventions include subsidizing the price of modern contraceptives, home delivery of such contraceptives, and programs to change male attitudes toward family planning.

Table 5 summarizes five studies.[35] The first study evaluates the impact of Profamilia, a large family planning program in Colombia. This program was founded in 1965 in Bogota and then it was spread to other cities in the country. Profamilia is considered a successful program in providing modern contraceptives at subsidized rates for poor women in urban and rural areas. The time of the launching of the program varied across counties, and this provides the source of variation that Miller (2010) explores to show that Profamilia reduced in 5 percent the fertility of women in their lifetime (about one-third of a child) in Colombia. According to Miller (2010) this program costs about 6 percent of per capita GDP per birth averted.

Another famous family planning intervention is the 1977 Maternal and Child Health and Family Planning (MCH-FP) program in the Matlab region in Bangladesh. The MCH-FP program had home delivery of modern contraceptives, follow-up services, and general advices to poor women in treatment villages. Maternal and child health services were added over time. Joshi and Schultz (2013) provide the background of the program and evaluate its impact on fertility and other variables. They show that the program in 1996 reduced completed fertility by 16 percent (0.78 of a child) in treatment villages when compared to control villages. The program has been criticized by its unrealistic cost since the cost per birth averted of the program was about 120 percent of per capita GDP. However, because the program offered a combination of family planning, maternal and child health interventions, then it is not possible to attribute the effects of the program to one of its actions, and to disentangle the cost-benefit of each component. Therefore, it is hard to compare both the effects and the costs of the type of family planning interventions we are able to implement in our theoretical framework with those from the MCH-FP program.

The Navrongo randomized control trial experiment in Ghana was based on the Matlab experiment in Bangladesh. It was launched in 1993 and the treatment arms combined family planning services with a variety of maternal and child health services. After five years, the reduction in completed fertility associated with the program was about 15 percent among married women (cf., Phillips, Bawah, and Binka, 2006). However, such effects on fertility have declined over time.[36] For reasons similar to those associated with the Matlab project, it is not straightforward to compare the effects on fertility of this program with those generated by our theoretical framework.

[35] Miller and Babiarz (2016) provide a more comprehensive overview of the empirical evidence.

[36] See Phillips, Jackson, Bawah, MacLeod, Adongo, Baynes, and Williams (2012).

Kearney and Levine (2009) use spatial (state) and temporal variation in the change in access (eligibility based on income) to family planning services in the United States through Medicaid in order to identify the causal effects of access to such services on fertility. They report a 8.9 percent reduction in completed fertility, and a cost of birth averted of about 18 percent of per capita GDP.[37] Therefore, even in developed countries such as the United States, it seems that supply-side family planning interventions can have sizeable effects on fertility.

Levine, Staiger, Kane, and Zimmerman (1999) use the timing of abortion legalization across states in America to investigate the effects of abortion legalization on fertility in the United States. Before 1967, abortion was illegal in the country. Between 1967 and 1970 some states legalized abortion under some circumstances, and abortion became fully legalized in 5 states in 1970. In 1973 the US Supreme Court made abortion legal nationwide in the country. They show that abortion legalization decreased fertility by 4 percent in states where abortion became legal relative to states where the legal status of abortion was unchanged. Since pregnant women could travel from states where abortion was illegal to states where abortion was legal, the authors suggest that the causal effect of changing the abortion law on fertility was much stronger (about 11 percent instead of 4 percent) when compared to states more than 750 miles away from where abortion was legalized.

When we improve access to modern contraceptives (decreasing the price ϕ_q) in our model, we show that such supply-side intervention generates a reduction in fertility of 6.86-8.3 percent[38] (depending on whether or not general equilibrium effects are taken into account), which are consistent with the estimates reported in empirical literature (see Table 5). The cost per birth averted would be 7.21 percent of per capita GDP when general equilibrium effects are considered, and 5.97 percent when they are not. Those numbers are very close to those reported by Miller (2010), which evaluates a type of family planning intervention that is close in nature to the one implemented in our counterfactual exercises.

Improving access to abortion in our model would also generate a reduction in fertility similar to those found in the empirical literature. When general equilibrium effects are taken into account, improvements in access to abortion reduce fertility in 5.23 percent (see Table 7 in Subsection 6.2). When price effects are not considered, then the reduction in fertility is roughly 5.41 percent. Such numbers are close to the estimated effects of legalizing abortion on fertility in the United States (cf., Levine, Staiger, Kane, and Zimmerman, 1999).

Therefore, the effects of family planning policies on fertility in our model are consistent with the microeconometric literature on family planning and fertility. This gives us confidence in our individual and aggregate effects of such policies, which are presented in the next section.

[37] Using a back-of-the-envelope calculation, they estimate a total cost of US$6,800 per birth averted in 2001. Then using the 2001 GDP per capita in the United States, the cost as fraction of income per capita is 18 percent. As they argue, this is probably an upper bound measure, since the cost of expanding the system was calculated by using the average cost of the program, and not the marginal cost of the existing program.

[38] Details of such intervention and others are found in Subsection 6.2, Table 7; and in Appendix B, Table 11.

Table 5: Studies of family planning interventions.

Study	Miller (2010)	Joshi and Schultz (2013)	Phillips et al (2006)	Kearney and Levine (2009)	Levine et al (1999)
Country	Colombia	Bangladesh	Ghana	United States	United States
Program	Profamilia	Matlab, MCH-FP Program	Navrongo, CHFP Project	Medicaid family planning services	Roe v Wade. Abortion legalization
Intervention	Launched in 1965. Family planning availability. Poor families pay lower price	Launched in 1977. Home delivery of contraceptives and follow-up services. Maternal and child health services	Launched in 1994. Home delivery of contraceptives and follow-up services. Changing males attitude	Launched in 1993. Availability of modern Contraceptives, as well as examinations and laboratory tests	1973 Supreme Court decision to legalize abortion nationwide (From 1967 to 1973, abortion was legal in some states)
Identification strategy	The time of the program across counties	Treatment versus control villages	Treatment versus control villages	Timing of change in eligibility across states	Timing of abortion legalization across states
Time horizon	Program started in 1965. Census of 1993	Census data of 1974 and 1982. Survey data of 1996	Surveys from 1995 to 2001	Annual data from 1990 to 2003	Annual data from 1966 to 1980
Effects on fertility	1993: 5% fewer children. Completed fertility	1996: 16% fewer children. Completed fertility.	2001: 15% fewer children. But not completed fertility.	2003: 8.9% fewer children. Completed fertility	1971-1973: 4% to 11% fewer children. Not completed fertility
Effects on other variables	No effects on the extensive margin of fertility. Strong effects on other variables	Other effects on child health but hard to disentangle from other actions	Effects on child mortality. But hard to disentangle from other actions	N/A	Significant effects on child outcomes (other studies)
Cost	6% of GDP per capita per birth averted	120% of GDP per capita per birth averted	N/A	18% of GDP per capita per birth averted	N/A

6 Quantitative Analysis

With all parameters calibrated and estimated we can now explore how the equilibrium properties of the model change with different family planning policies. Fertility is known to be an important determinant of individual and aggregate outcomes (cf., Becker, 1960; Galor and Weil, 2000; Schultz, 2008), but little is known about the aggregate and distributional effects of family planning policies. This is what we investigate now.

6.1 Extreme Scenarios

Table 6 reports key statistics of two extreme counterfactual experiments. (See also Figure 3.) In the first (*No fertility shocks*) experiment we consider an economy in which households can perfectly control family size such that we set the number of unwanted pregnancies exogenously to zero, $N = 0$, and therefore $p = \tilde{n}$ in Equation (18). There is no uncertainty in fertility and therefore no need to use modern contraceptives ($q = 0$) or rely on abortion ($a = 0$) to control reproduction. The theoretical framework boils down to a standard quantity-quality fertility model of economic growth. Unwanted fertility goes down to 0 and the average fertility goes down by about 0.4 of a child, i.e., total fertility is reduced by about 7 percent. This last result confirms that aggregate fertility is quite unresponsive to changes in contraceptive access and that the cross-country differences in fertility are mostly driven by the desired family size (cf., Pritchett, 1994).

However, the aggregate fertility measure hides important compositional differences. First of all, under the conditions of this counterfactual experiment the share of households without a primary education falls by 42 percent relative to the baseline. In Figure 3(b) we observe that fertility decreases for all education levels except for the highest level (16 years of schooling). For this group fertility increases because there are fewer resources spent on contraceptives and abortions, and agents can target a higher wanted fertility (income effect) since there is no risk of having unwanted pregnancies. Investment in human capital and in physical capital rise relative to the baseline. The average number of years of schooling increases by one year,[39] and the stock of physical capital increases by 20 percent relative to the benchmark case.[40] Such movements in inputs in production increase the real wage rate by 4 percent, decrease the interest rate by 7 percent, and increase output per capita by 13 percent relative to the baseline. This is a non-negligible effect. Inequality decreases and most of this reduction is concentrated at the bottom of the income distribution. The ratio for the 90th and 50th percentiles of income (90/50) remains roughly constant, but the ratio for the 90th and 10th percentiles of income (90/10) decreases by about 13 percent relative to the baseline. Although welfare is difficult to measure in an economy with endogenous fertility, as explained in Golosov, Jones, and Tertilt (2007),[41]

[39] This is mainly due to the decrease in the share of adults with no primary education, which decreases by 10 percentage points. See Figure 3(a).

[40] The capital-to-output ratio increases by 7.5 percent. This is consistent with estimates for China by Banerjee, Meng, Porzio, and Qian (2014), who find that the fertility rate increases the saving rate.

[41] This is because it is hard to compute the welfare of those who are not born and due also to the fact that

we still report that the average welfare of all households alive in an economy without fertility risks is higher than the average welfare in the benchmark case. It is important to emphasize that welfare is measured simply in *utils*, which implies that only an ordinal comparison can be inferred.

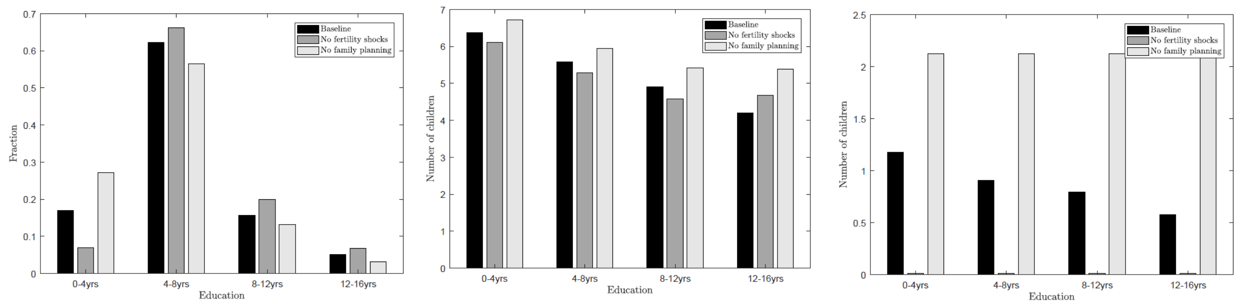
Table 6: Counterfactual experiments: Extreme cases, Kenya 2008

		Counterfactuals							
Statistics	Baseline	*No fertility shocks*				*No family planning*			
		Full exp.	Partial equil	Exog. fert.	Exog. educ.	Full exp.	Partial equil.	Exog. fert.	Exog. educ.
Output, input and prices									
Y^i_{pc}/Y^{basel}_{pc}	1	1.13	1.12	1.31	1.13	0.86	0.88	0.74	1.11
K^i/K^{basel}	1	1.21	1.18	1.68	1.21	0.81	0.84	0.61	1.21
Schooling (years)	7.68	8.78	8.75	9.07	8.78	6.61	6.72	6.16	7.93
w^i/w^{basel}	1	1.04	1	1.15	1.04	0.96	1	0.89	1.05
r^i/r^{basel}	1	0.93	1	0.78	0.93	1.07	1	1.21	0.92
Fertility and family planning									
Av. fertility	5.54	5.16	5.08	4.50	5.16	6.07	6.10	6.88	5.05
Av. unw. fert.	0.92	0	0	0	0	2.12	2.12	2.12	2.12
Contrac. use (% HHs)	33	0	0	0	0	0	0	0	
Pregn. aborted (%)	12	0	0	0	0	0	0	0	0
Av. contrac. exp./wh (%)	0.28	0	0	0	0	0	0	0	0
Inequality and welfare									
Gini index	0.48	0.47	0.47	0.47	0.47	0.47	0.48	0.47	0.48
Labor inc 90/50	3.83	3.89	3.88	4.05	3.89	3.56	3.69	3.44	3.44
Labor inc 90/10	12.57	10.89	10.88	10.63	10.89	10.96	10.93	9.82	12.04
Welfare	3.86	4.11	4.07	4.25	4.11	3.65	3.70	3.49	$-\infty$

In order to assess the main channels driving our results, we investigate the effects of shutting down general equilibrium effects (partial equilibrium), the wanted fertility (exogenous fertility) channel, and the education channel (exogenous education). By fixing the interest rate at the baseline level we are considering a small open economy in which not only the real interest rate is exogenously determined, but also (given the constant returns to scale production function) the real wage rate. The capital-effective labor ratio is determined by the interest rate and therefore in this particular case these two inputs in production must change in the same proportion. We observe that relative to the baseline the overall results are quite similar to the case of the full counterfactual experiment in which fertility is perfectly controlled and general equilibrium movements, which lead to changes in the capital effective labor ratio, do not seem to drive the overall results.

In the second decomposition exercise (Exogenous fertility) we exogenously impose the decision rules for desired fertility from the baseline economy into the economy with no fertility shocks. Notice that while households can target a higher wanted fertility rate than in the baseline when fertility is perfectly controlled, in this counterfactual exercise we shut

we do not possess an explicit dynastic structure. This caveat is valid for any welfare comparison in our paper.



(a) Fraction of adults by education (b) Fertility by education (c) Unwanted fertility by education

Figure 3: Counterfactual experiments: Extreme cases and baseline.

down this effect. The average fertility falls by about one child (instead of 0.4 of a child) relative to the baseline, which is similar to the decrease in unwanted fertility. Now, with artificially lower fertility, families can invest even more in physical and human capital than when wanted fertility is also endogenous. The average number of years of schooling of the adult population increases by 1.5 years and physical capital increases by 68 percent relative to the baseline. Consequently, output per capita increases by 31 percent instead of 13 percent. Therefore, understanding how targeted fertility decisions change with family planning interventions seems to be important in order to assess the full impact of these policies on individual and aggregate outcomes. In the final decomposition, we keep the policy function of education as in the baseline and let all other margins be adjusted. We observe that relative to the baseline, aggregate and distributional results are in equilibrium similar to when all channels are effective,[42] which suggests that endogenous changes in investment in education do not seem to be driving the economic effects of family planning interventions.

The second extreme case corresponds to the situation in which there is no possibility to control family size unless households change their wanted fertility rate. In order to implement this experiment in our model we simply need to make the utility cost of modern contraceptives and abortions to be so large that it is never optimal for households to use one of those two methods to control their fertility. Observe that households can still have different wanted fertilities depending on policies. Relative to the baseline, the average fertility increases by 0.54 of a child, while unwanted fertility increases from 0.92 to 2.12. Consequently, wanted fertility is clearly adjusted downward. Households invest less in human and physical capital and output decreases by 14 percent. Therefore, the difference in output per capita between an economy without any modern control of fertility to another in which there is perfect control of family size is of about 30 percent. In the model without access to modern contraceptives or abortion there is lower inequality relative to the benchmark case, which is due mostly to the reduction of the share of agents acquiring skills. The share of households in all education categories decreases with the only

[42]This is only in equilibrium. Off equilibrium, the policy functions are not necessarily identical to the case in which all channels are in place.

exception being for the share of households without a primary degree, which increases by 60 percent. Welfare in this case is reduced relative to the baseline. We also provide a decomposition of the full effect by shutting down different channels. As before, general equilibrium effects do not seem to be an important channel, since the model with fixed input prices yields similar results to the baseline. By assuming that the wanted fertility is unchanged, we notice that output would decrease even more than in the full experiment. This is rather intuitive since wanted fertility decreases when modern contraceptives and abortion are not available. Interestingly, output would rise if we keep the education policy unchanged. This is because fertility is lower and investment in education is higher in the benchmark than in the case without fertility control. When the education policy function is kept as in the baseline, households will decrease wanted fertility even more than in the full experiment and will also increase savings. Therefore, relative to the baseline, average years of schooling and physical capital would increase, as well as per capita output.

The following important conclusions emerge from these two extreme counterfactual experiments and their decomposition: (i), although reproductive behavior is mainly driven by demand as suggested by many economists (cf., Becker, 1960; Dasgupta, 1995; Pritchett, 1994), access to modern contraceptives and abortions indeed shape the distributional pattern of fertility and consequently human capital dynamics and savings of a society; (ii), family planning interventions can have sizeable effects on per capita income and seem to improve welfare, in particular of those households at the lower tail of the income distribution in a developing country like Kenya; and (iii), there is clearly an upper bound limit on how family planning policy can affect aggregate outcomes. This is mostly shown in the case of perfect family control (no fertility risks), since output per capita relative to the baseline increases by at most 13 percent. While this is indeed a large measure, it is a small fraction of the difference in income levels between Kenya and more developed or emerging market economies.

6.2 Supply–side Policies

The successful strategy of supply–side family planning policies is to make modern contraceptives accessible to as many women as possible. In our model such policies should affect the relative price of contraceptives ϕ_q. Table 7 reports key statistics relative to the baseline for a counterfactual experiment in which households can access modern contraceptives without any monetary cost ($\phi_q = 0$). There is still a utility cost for using them, but since this estimated utility cost is negligible[43] the implication is that now all agents choose to fully insure against the fertility risk and there is no unwanted pregnancy or abortion. In this case there is perfect fertility control and effects for this supply-side policy on output, inputs, prices, and inequality are similar to the extreme scenario of no fertility shocks, which was previously investigated and discussed: output per capita increases by 13 percent. The cost of this policy is 2.74 percent of the baseline output per capita.[44]

[43] Recall that the estimated utility cost of using modern contraceptives is $\psi_q = 0.0024$ and the average utility in the baseline economy is 3.86.

[44] This implies a long-run multiplier of government expenditures on output per capita of 4.74.

This supply-side intervention generates a reduction in fertility of 6.86-8.3 percent (depending on whether or not general equilibrium effects are taken into account. see Table 11 in Appendix B). As reported previously, such numbers are close to the estimates reported in empirical literature (see Table 5). The cost per birth averted corresponds to 7.21 percent of per capita GDP when general equilibrium effects are considered, and 5.97 percent of per capita GDP when they are not.

Table 7: Counterfactual experiments: Supply and demand policies, Kenya 2008

Statistics	Baseline	**Supply Policies** Free contrac.	Free abortion	**Demand Policies** No disutil. of contrac.	No disutil. of abortion
Output, input, and prices					
Ypc relat. to the baseline	1	1.13	1.09	0.99	1.05
K relat. to the baseline	1	1.21	1.15	0.98	1.09
Av. years of schooling	7.68	8.78	8.46	7.65	8.09
w relat. to the baseline	1	1.04	1.03	0.99	1.02
r relat. to the baseline	1	0.93	0.95	1.01	0.97
Fertility and family planning					
Av. fertility	5.54	5.16	5.25	5.58	5.35
Av. unwanted fert.	0.92	0	0.42	0.91	0.51
% of HHs who use contrac.	33	100	12	34	0
% of pregn. aborted	12	0	22	12	23
Av. contrac. exp./wh (%)	0.28	0	0.08	0.28	0
Inequality and welfare					
Gini index	0.48	0.47	0.47	0.48	0.48
Labor income 90/50	3.83	3.89	4	3.83	3.95
Labor income 90/10	12.57	10.89	10.29	12.57	12.16
Welfare	3.86	4.11	4.02	3.85	3.96
Cost of the policy					
$Cost/Y_{pc}$ (current Y), (%)	0	2.43	0.43	-	-
$Cost/Y_{pc}$ (original Y), (%)	0	2.74	0.47	-	-

Another supply-side family planning policy is to offer abortions at no cost in public hospitals and clinics, such that ϕ_a is equal to zero. One practical problem with this policy is that abortion is still considered largely illegal in many countries, including Kenya[45] and most aborted pregnancies are terminated through illegal means. Therefore, before this policy could be implemented abortion laws in Kenya would first need to be relaxed. With this caveat in mind, we present results of this counterfactual experiment in the third

[45] According to Article 26 of the Constitution of Kenya, "Abortion is not permitted unless, in the opinion of a trained health professional, there is a need for emergency treatment, or the life or health of the mother is in danger, or if permitted by any other written law."

column of Table 7. The percent of pregnancies aborted almost doubles since women reduce their use of modern contraceptives. Unwanted fertility decreases by 0.5 of a child and total fertility decreases by 0.30 of a child as a result of this policy. This implies that families adjust their wanted fertility margin once this policy is implemented.[46] Most of the decrease in fertility is in the lower tail of the education distribution. Average years of schooling for the adult population rises from 7.68 to 8.46, and there is a 15 percent increase in the level of the capital stock relative to the baseline. As a result, output per capita increases by 9 percent relative to the baseline. Again, inequality decreases, and most of this reduction is due to relative improvements in the income of households at the lower tail of the income distribution. Welfare also increases but by less than the free contraceptive policy, which is the preferred policy according to this measure. Given the original unit price of abortion, the overall cost of this policy is relatively small. It corresponds to only 0.47 percent of the baseline output or about 8 percent of the total expenditure on education in Kenya. Therefore, with respect to their effects on output per capita, the free abortion policy seems to be more cost-effective than the free contraceptive policy.[47] Clearly, there is an important limitation for this comparison. When we internally estimated ϕ_a we were implicitly taking into account the unit price of existing abortions in Kenya, but with the knowledge that most of these abortions are taking place in illegal clinics, which can be relatively cheaper than in other official places. Nevertheless, according to Migiro (2011), international charity Marie Stopes performs abortions at prices from \$25 to \$60 in Kenya, and relative to per capita output this cost is in the range of what our model predicts for such a measure.

6.3 Demand–side Policies

Another set of family planning interventions are demand–side policies, which aim to illustrate the positive aspects of contraceptives and their efficacy in birth control. Favorable attitudes and behavior toward modern contraceptive methods can be achieved through improvements in, and greater male involvement with, family planning knowledge. These changes can in turn be effected through media campaigns and collaboration with community leaders (cf., Ashraf, Field, and Lee, 2014). In our model we implement this by reducing the utility cost of contraceptive use to zero. Table 7 contains some key statistics of such counterfactual experiments, and Table 12 in Appendix B reports the decomposition of the full effect. Since our estimated utility cost of modern contraceptive use is small,[48] we can see that such demand policies would have limited effects on the share of households

[46] The full effect is decomposed into three different channels (general equilibrium movements, wanted fertility margin, and education margin) in Table 11 in Appendix B.

[47] The long-run government expenditures multiplier on output per capita in this case is about 5 times higher than in the case of free access to contraceptives.

[48] This might not be the case for other countries. A recent piece from the *Economist* (2016) shows that in some countries there are still important barriers preventing couples from using modern contraceptives. For instance, "Greeks commonly believe that the pill and other hormonal contraceptives cause infertility and cancer. They also distrust intrauterine devices (IUDs), possibly because they have been taught that tampons are unhealthy." As a result, "in Greece abortion is seen as an ordinary form of birth control."

using modern contraceptives and therefore on reproductive behavior and real economic variables. This is true also for any exercise in which we shut down general equilibrium movements, the wanted fertility margin, or the education channel.

We also run another counterfactual with a family planning demand policy in which we reduce the utility cost of abortion. This is a much harder policy to implement in real life: Besides emotional side effects after an abortion, which may be able to be mitigated through counseling or other therapeutic help, there can also be adverse physical consequences associated with it. Therefore, although we think it worthwhile to execute and report on the counterfactual experiment in which the utility cost of abortion is reduced to zero, we know that it would be difficult to implement in practice. However, the utility cost of abortions can also be related to the fact that abortions are largely illegal in Kenya, as well as to taboos and social stigmas, which can prevent pregnant women from seeking abortion facilities. Given that this estimated cost in our model is much higher than the cost associated with the use of modern contraceptives, it is straightforward to observe that the potential effects on reproductive behavior and the economy are stronger for a reduction in the utility cost of abortion than a reduction in the utility cost of contraceptives. The percentage of pregnancies aborted when the utility cost of abortion is set at zero doubles relative to the baseline. Given the relative price of contraceptives, we can observe that no woman would choose to use modern contraceptives to control family size. They would rely only on abortion to prevent unwanted births. The average unwanted fertility decreases by 0.4 of a child, and moreover, it decreases for all education categories. Realized fertility decreases by 0.19 of a child, which suggests that households adjust wanted fertility upward. Output per capita increases by 5 percent relative to the benchmark economy and inequality is roughly unchanged. The decomposition shows that the wanted fertility margin and the investment education margin are the key channels in driving the overall results.[49] For obvious reasons, it is difficult to price the cost of such demand policies, which explains why we do not report the costs associated with them, as well as why we will mainly focus on supply–side reforms.

Our counterfactual experiments so far with supply and demand family planning interventions suggest clearly that there might be room for such policies to affect reproductive behavior and economic outcomes, which is consistent with the micro-level evidence on the impact of family planning policies on household behavior (cf., Joshi and Schultz, 2013). This is particularly true for those policies which improve access to and availability of modern contraceptives and facilities for women seeking abortion. It is, however, important to understand also the effectiveness of family planning interventions as a means of improving living standards in comparison to other policies such as investment in human capital. This is what we undertake next.

[49]The wanted fertility rises relative to the baseline when the utility cost of abortion is set to zero, which implies that the effect on income per capita is mitigated; investment in education rises. General equilibrium effects explain little of the overall movements in income and inequality. See Table 12 in Appendix B.

6.4 Birth Control versus Educational Policies

That family planning interventions can bring benefits to those who make use of them and can generate significant aggregate effects has been shown above. However, policy makers are faced with a menu of different development policies to choose from and therefore it is important to understand the cost-effectiveness of each policy. For instance, governments might choose to improve access to modern contraceptives and/or invest in education. The efficacy of family planning policies versus educational policies has long been a topic of debate in development economics (cf., Pritchett, 1994; Schultz, 2008). Furthermore, not only is the focus of policies important, but also how they are designed. Policies can be universal, so that the government subsidizes education for all children or distributes contraceptives freely to all women; or they can be targeted to specific groups, so that only relatively poor households receive cash transfers for keeping their children at school, or only poor women have free access to modern contraceptives. We now provide different experiments in which we shed some light on this debate. We will look at the aggregate and distributional effects of different policies taking into account their costs.

6.4.1 Universal Policies

There are a variety of different policies which can be introduced in our model but for issues related to their implementability in the real world, we will focus on policies which either subsidize access to modern contraceptives, or abortion, or subsidize education. In the first counterfactual policy the government offers a subsidy on the price of modern contraceptives to all women.[50] The level of this subsidy is such that expenditure on this policy corresponds to 0.5 percent of income. Some statistics of this policy relative to the baseline economy are shown in Table 8. The policy is effective in expanding the use of modern contraceptives since the fraction of women using such methods increases from 33 percent to 84 percent. Although the average fertility decreases by just 0.10 of a child, the effect of this policy on unwanted pregnancy is larger since unwanted fertility decreases by 0.34 of a child[51] and abortion is reduced by more than half. Human capital and physical capital investments rise as expected, and output per capita increases by roughly 2.7 percent. The average welfare also increases relative to the baseline. Subsidies for abortion can generate an even stronger effect on output. As shown previously, free access to abortion for all women would cost about 0.47 of baseline GDP and would increase output per capita relative to the baseline by 9 percent in the long run. This per capita output response is about 3.37 times larger than the effect on output per capita of a subsidy on the price of modern contraceptives.

Interestingly, if the government alternatively funds education so that all children, regardless of family income, have access to the first four years of primary education without any direct private cost, then fertility (due to an income effect) rises substantially by more

[50]The National Health Service (NHS) in England offers free modern contraceptives at an affordable cost to everyone (cf., the *Economist*, 2016).

[51]Clearly, the wanted fertility margin adjusts after the introduction of this policy. We do not report the decomposition of the full effect but such experiments are available upon request.

Table 8: Counterfactual experiments: Universal and targeted policies, Kenya 2008. Universal Policies: Subsidy on the price of modern contraceptives; subsidy on the price of abortion; and subsidy on basic education (0-4 years) for all families. Targeted Policies: Subsidy on the price of modern contraceptives for women with up to 8 years of schooling; subsidy on the price of abortion for women with up to 8 years of schooling; and subsidy on basic education for children with parents with up to 8 years of schooling.

		Universal Policies			**Targeted Policies** *Parents with up to 8 yrs of sch.*		
Statistics	Baseline	Subsid. contrac.	Subsid. abortion	Subsid. education (0-4 yrs)	Subsid. contrac.	Subsid. abortion	Subsid. education (0-4 yrs)
Output, input, and prices							
Ypc relat. to the baseline	1	1.027	1.091	0.977	1.025	1.087	1.033
K relat. to the baseline	1	1.04	1.15	0.95	1.04	1.14	1.04
Av. years of schooling	7.68	8.78	8.46	7.84	7.85	8.41	8.36
w relat. to the baseline	1	1.01	1.03	0.98	1.01	1.03	1.01
r relat. to the baseline	1	0.98	0.95	1.02	0.98	0.95	0.99
Fertility and family planning							
Av. fertility	5.54	5.44	5.25	5.73	5.45	5.25	5.52
Av. unwanted fert.	0.92	0.58	0.42	0.92	0.63	0.50	0.90
% of HHs who use contrac.	33	84	12	26	73	17	28
% of pregn. aborted	12	5	22	12	5	20	12
Av. contrac. exp./wh (%)	0.28	0.92	0.08	0.22	1.81	0.13	0.24
Inequality and welfare							
Gini index	0.48	0.48	0.47	0.48	0.48	0.48	0.47
Labor income 90/50	3.83	3.89	4	3.87	3.92	4.00	4.04
Labor income 90/10	12.57	12.21	10.29	12.03	12.21	10.73	12.10
Welfare	3.86	3.91	4.02	3.89	3.90	4.01	3.98
Cost of the policy							
$Cost/Y_{pc}$ (current Y), (%)	0	0.50	0.43	0.50	0.50	0.35	0.50
$Cost/Y_{pc}$ (original Y), (%)	0	0.51	0.47	0.49	0.51	0.38	0.52

than a child. Children become relatively cheaper and parents respond to that by having more children. Although schooling also rises and inequality decreases, the net effect on output per capita of this policy is negative. In fact, output per capita would decrease if the government subsidized 4–8 years of education, 8–12 years of education, or 0–12 years of education. The main driver behind this fall in output is the rise in fertility when primary or secondary education is universally subsidized. Output per capita only rises when the government subsidizes higher education, but this policy is rather regressive and inequality rises relative to the baseline. Average welfare relative to the baseline rises in all three universal policies reported in Table 8 and its highest level is achieved when abortion is subsidized. From these policy experiments we can conclude that universal subsidies in early education are less effective than public investment in modern contraceptives or abortion to raise per capita income and to control fertility. The largest reduction in inequality, measured by the ratio of the 90th percentile to the 10th percentile of income, also occurs when abortion is subsidized.

6.4.2 Targeted Policies

Now we focus our analysis on targeted policies. Table 8 reports results for three different targeted policies: a subsidy on the price of modern contraceptives for women with up to 8 years of schooling (a primary degree); a subsidy on the price of abortion for women with up to 8 years of schooling (a primary degree); and a subsidy on basic education (0-4 years) for the children of the parents with up to 8 years of schooling (a primary degree).[52] The policy would cost up to 0.5 percent of GDP.

A targeted subsidy on the price of modern contraceptives for women with up to 8 years of schooling (a primary degree) increases the share of women using such contraceptive methods, but by less than the universal policy reported previously. The fraction of women using modern contraceptives increases from 33 percent to 70 percent with this policy, but it jumps to 84 percent when the universal policy is implemented. Additionally, average wanted fertility decreases by about 0.09 of a child and the average unwanted fertility by 0.29 of a child. Investment in human and physical capital rise and output per capita increases by roughly 2.5 percent. These numbers are bit less than in the universal policy, which is explained by the fact that in the baseline equilibrium there are also unwanted pregnancies among women with a secondary or a higher degree and a universal policy would increase the intensity of modern contraceptive use for all women, and not only those at the lower tail of the human capital distribution.

Making abortion free for women with up to 8 years of schooling would cost 0.38 percent of baseline output. Compared to the subsidy on modern contraceptive prices for women with the same amount of schooling, the abortion subsidy is much more effective in reducing unwanted fertility and total fertility, and consequently on increasing investment in human and physical capital. This subsidy increases output per capita by 8.7 percent relative to the baseline or about 3.24 times the increase in output per capita when the use of modern contraceptives is subsidized for women with the same amount of schooling.

Finally, the last column of Table 8 reports results for the experiment in which basic education (0–4 years) is subsidized for all children of parents with up to 8 years of schooling. Educational attainment increases, and output per capita relative to the baseline increases by 3.3 percent. Average realized and unwanted fertility are roughly unchanged. Relative to the other two targeted policies, this targeted subsidy on education generates a larger impact on output per capita than the subsidy on the price of modern contraceptives, but smaller effect on income per capita when abortion is subsidized.

7 Conclusions

The role of family planning policies in endogenously affecting fertility, savings, human capital investment, and income per capita levels has not been explored in the macro/growth literature. Conventional macroeconomics wisdom ascribes family size to demand or the

[52] We implemented several other targeted policies. We choose to report results for this policy because it is the one in which the subsidy on education generates the largest positive effect on per capita income. Table 13 in Appendix B contains results with policies which target women with up to 4 years of schooling.

quantity-quality trade-off, which implies that family planning interventions should not have major impact on the economy (cf., Pritchett, 1994). This view has a major shortcoming: micro development literature shows that improving access to modern contraceptives, legalizing abortion, and/or improving knowledge about the efficacy of each method can have important effects on individual outcomes (cf., May, 2012; Schultz, 2008). Our paper contributes to the existing literature by embedding endogenously unwanted fertility in an otherwise standard quantity-quality overlapping generations model of population and growth with heterogenous households. Our theoretical model has several novel characteristics: Fertility control is costly and families can (partially) insure against a fertility risk by using costly contraception. In the event of unexpected pregnancies, households can also opt to abort some pregnancies, at a cost. Given the number of children born, parents decide how much education to provide and how much to save out of their young adulthood income. We calibrated and estimated the model to Kenya data, such that key empirical statistics are matched. Kenya is used as an illustration, but clearly the model is general enough and could be estimated using data for different developing countries.

We show that the standard macro view is in part correct since aggregate fertility is indeed mainly driven by desired family size. The difference between the fertility rate of our baseline (2008 Kenyan economy) model, in which fertility is costly controlled through modern contraceptives, and a model in which fertility is fully controlled through costless contraceptives is just 0.4 of a child. However, access to modern contraceptives and abortions indeed shapes the compositional pattern of fertility and consequently the human capital dynamics and savings of a society, and family planning interventions can have sizeable effects on individual outcomes and aggregate variables. This is due to the fact that the aggregate fertility measure hides important distributional issues since the gap between realized and wanted fertility can be three times larger for low–income families than high–income families. Our counterfactual exercises show that if modern contraceptive methods are freely provided to all women, then output per capita would increase by 13 percent relative to the baseline economy, and that would cost about 2.43 percent of per capita output. If abortion is freely offered then the rise in output per capita would be roughly 9 percent; such a policy would cost 0.43 percent of per capita GDP. Interestingly, our results suggest that with a small government budget (say, up to 0.5 percent of per capita GDP), legalizing and providing safe abortion care might be the most cost-effective policy for improving long-run living standard and reducing inequality when compared to policies that either subsidize the price of modern contraceptives or subsidize basic education.

We decompose the full effect of family planning interventions on the economy into three different channels: a general equilibrium channel (price movements), a wanted fertility channel (how desired fertility changes with family policies), and the investment in education channel. We show that to fully understand the effects of family planning policies on individual outcomes it is important to perceive the responses of household choices on desired fertility, savings, and investment in children's education. For instance, families usually target a higher wanted fertility rate when the fertility risk of unwanted pregnancies is reduced, which can mitigate some of the effects of family planning policies on reproductive behavior, investment, and income levels. Knowing this could affect which plans policymakers will choose to pursue and implement.

Our fertility model can be used to investigate important unresolved questions such as the role of access to modern contraceptives in affecting structural transformation, female labor force participation, and social security. Future research can potentially address these and other related questions.

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A Data Appendix

The definitions and source for the variables used in Section 2 are described below. Table 9 contains summary statistics of these variables, and Table 10 reports correlations for them.

Human capital attainment: Educational attainment of the total population aged 25 and over. Variable: Average years of schooling. Barro and Lee (2013). We implemented linear interpolation for some countries and years.

Real GDP per capita: Real GDP per capita. Heston, Summers, and Aten (2012); Penn World Table Version 7.1; Center for International Comparisons of Production, Income, and Prices at the University of Pennsylvania, May 2011. Variable used: PPP Converted GDP Per Capita (Chain Series), at 2005 constant prices.

Total fertility rate: Data from the Demographic and Health Surveys (DHS), available at http://www.measuredhs.com/, using the STATCompile. Total fertility rate for the three years preceding the survey. Selected countries and years (1985–2010). Total of 84 developing countries. The panel is unbalanced with some countries having only one observation and others having up tp 6. The years are not necessarily the same across countries.

Wanted fertility rate: Data from the Demographic and Health Surveys (DHS), available at http://www.measuredhs.com/, using the STATCompile. Total wanted fertility rate for the three years preceding the survey. Selected countries and years (1985–2010). Total of 84 developing countries. The panel is unbalanced with some countries having only one observation and others having up to 6. The years are not necessarily the same across countries.

Percent of women using modern contraceptive methods: Data from the Demographic and Health Surveys (DHS), available at http://www.measuredhs.com/, using the STAT-Compile. Percent of women using modern contraceptive method for the three years preceding the survey. Selected countries and years (1985–2010). Total of 84 developing countries. The panel is unbalanced with some countries having only one observation and others having up to 6. The years are not necessarily the same across countries.

Countries in the DHS surveys: Albania, Armenia, Azerbaijan, Bangladesh, Benin, Bolivia, Botswana, Brazil, Burkina Faso, Burundi, Cambodia, Cameroon, Cape Verde, Chad, Colombia, Comoros, Congo (Brazzaville), Cote d'Ivoire, , Democratic Republic of Congo, Dominican Republic, Ecuador, Egypt, El Salvador, Eritrea, Ethiopia, Gabon, Georgia, Ghana, Guatemala, Guinea, Guyana, Haiti, Honduras, India, Indonesia, Jamaica, Jordan, Kazakhstan, Kenya, Kyrgyz Republic, Lesotho, Liberia, Madagascar, Malawi, Maldives, Mali, Mauritania, Mexico, Moldova, Morocco, Mozambique, Namibia, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Paraguay, Peru, Philippines, Rwanda, Sao Tome and Principe, Senegal, Sierra Leone, South Africa, Sri Lanka, Sudan, Swaziland, Tanzania, Thailand, Timor-Leste, Togo, Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, Uganda, Ukraine, Uzbekistan, Vietnam, Yemen, Zambia, and Zimbabwe.

Table 9: Summary statistics.

	Number of Observations	Mean	Standard Deviation	5% Percentile	95% Percentile
Real GDP per capita	224	2672.88	2259.86	472.12	7047.1
Human capital attainment	191	2.02	0.45	1.24	2.83
Total fertility rate	221	4.37	1.47	2.3	6.7
Wanted fertility rate	221	3.50	1.41	1.7	6
Difference in actual and wanted fertility	221	0.87	0.47	0.20	1.8
% of women using modern contraceptive methods	201	40.98	21.78	9	73.9

B Additional Experiments

This appendix contains three additional tables. Table 11 provides the decomposition of the two supply policies (free modern contraceptives and free abortion) presented in Table 7, while Table 12 contains the decomposition of the two demand policies (no disutility

Table 10: Simple correlations.

	Real GDP per capita	Human capital attainment	Realized fertility	Wanted fertility	Fertility gap	% of women using modern contr. methods
Real GDP per capita	1					
Human capital attainment	0.5301	1				
Realized fertility	-0.6279	-0.6588	1			
Wanted fertility	-0.6037	-0.6616	0.9484	1		
Fertility gap	-0.1522	-0.1451	0.2818	-0.0369	1	
% of women using modern contr. methods	0.5267	0.5230	-0.7590	-0.7574	-0.0860	1

from contraceptives and no disutility from abortion) presented in Table 7. Finally, Table 13 reports statistics for the experiments in which the targeted group corresponds to all parents with up to 4 years of schooling.

Table 11: Decomposition: Supply policies, Kenya 2008

Statistics	Baseline	**Supply Policies**							
		Free contraceptives				*Free abortion*			
		Full exp.	Partial equil	Exog. fert.	Exog. educ.	Full exp.	Partial equil.	Exog. fert.	Exog. educ.
Output, input, and prices									
$Y_{pc}^{i}/Y_{pc}^{basel}$	1	1.13	1.12	1.31	1.13	1.09	1.07	1.13	1
K^{i}/K^{basel}	1	1.21	1.18	1.68	1.21	1.15	1.11	1.24	1.01
Schooling (years)	7.68	8.78	8.75	9.07	8.78	8.46	8.46	8.58	7.65
w^{i}/w^{basel}	1	1.04	1	1.15	1.04	1.03	1	1.05	1
r^{i}/r^{basel}	1	0.93	1	0.78	0.93	0.95	1	0.91	0.99
Fertility and family planning									
Av. fertility	5.54	5.16	5.08	4.50	5.16	5.25	5.24	5.11	5.57
Av. unw. fert.	0.92	0	0	0	0	0.42	0.37	0.57	0.62
Contrac. use (% HHs)	33	100	100	100	100	12	17	17	15
Pregn. aborted (%)	12	0	0	0	0	22	22	20	19
Av. contrac. exp./wh (%)	0.28	0	0	0	0	0.08	0.10	0.12	0.09
Inequality and welfare									
Gini index	0.48	0.47	0.47	0.47	0.47	0.48	0.47	0.47	0.48
Labor inc. 90/50	3.83	3.89	3.88	4.05	3.89	4	4	4.19	3.96
Labor inc. 90/10	12.57	10.89	10.88	10.63	10.89	10.29	10.30	10.96	12.05
Welfare	3.86	4.11	4.07	4.25	4.11	4.02	3.99	4.06	3.89
Cost of the policy									
$Cost/Y_{pc}$ (current Y), (%)	0	2.43	2.45	2.08	2.43	0.43	0.44	0.36	0.40
$Cost/Y_{pc}$ (original Y), (%)	0	2.74	2.74	2.71	2.74	0.47	0.48	0.40	0.41

Table 12: Decomposition: Demand policies, Kenya 2008

Statistics	Baseline	**Demand Policies**							
		No disut. of contr.				*No disut. of abortion*			
		Full exp.	Partial equil	Exog. fert.	Exog. educ.	Full exp.	Partial equil.	Exog. fert.	Exog. educ.
Output, input, and prices									
$Y_{pc}^i / Y_{pc}^{basel}$	1	0.99	1	1	1	1.05	1.05	1.10	1
K^i / K^{basel}	1	1.21	0.98	1	1	1.09	1.07	1.18	1.01
Schooling (years)	7.68	7.65	7.68	7.68	7.65	8.09	8.06	8.26	7.75
w^i / w^{basel}	1	1	1	1	0.99	1.01	1	1.04	1
r^i / r^{basel}	1	1	1	1	1.01	0.97	1	0.93	0.99
Fertility and family planning									
Av. fertility	5.54	5.58	5.56	5.54	5.58	5.35	5.32	5.16	5.53
Av. unw. fert.	0.92	0.91	0.91	0.92	0.91	0.51	0.52	0.59	0.66
Contrac. use (% HHs)	33	34	34	33	34	0	0	0	0
Pregn. aborted (%)	12	12	11	12	12	23	23	23	21
Av. contrac. exp./wh (%)	0.28	0.28	0.29	0.28	0.28	0	0	0	0
Inequality and welfare									
Gini index	0.48	0.48	0.48	0.48	0.48	0.47	0.47	0.47	0.48
Labor inc. 90/50	3.83	3.83	3.83	3.83	3.83	3.95	3.95	4.19	3.85
Labor inc. 90/10	12.57	12.57	12.57	12.57	12.48	12.16	12.16	11.48	12.18
Welfare	3.86	3.85	3.86	3.86	3.85	3.96	3.94	4.01	3.89
Cost of the policy									

Table 13: Counterfactual experiments: Targeted policies, Kenya 2008. Targeted Policies: Subsidy on the price of modern contraceptives for women with up to 4 years of schooling; subsidy on the price of abortion for women with up to 4 years of schooling; and subsidy on basic education for children with parents with up to 4 years of schooling.

Statistics	Baseline	**Targeted Policies** *Parents with up to 4 yrs. of sch.* Subsid. contrac.	Subsid. abortion	Subsid. education (0–4 yrs)
Output, input, and prices				
Ypc relat. to the baseline	1	1.02	1.01	0.98
K relat. to the baseline	1	1.03	1.02	0.95
Av. years of schooling	7.68	7.90	7.84	7.94
w relat. to the baseline	1	1.01	1.01	0.98
r relat. to the baseline	1	0.99	0.99	1.03
Fertility and family planning				
Av. fertility	5.54	5.48	5.50	5.74
Av. unwanted fert.	0.92	0.73	0.80	0.98
% of HHs who use contrac.	33	46	31	26
% of pregn. aborted	12	10	14	11
Av. contrac. exp./wh (%)	0.28	0.26	0.27	0.22
Inequality and welfare				
Gini index	0.48	0.48	0.48	0.48
Labor income 90/50	3.83	3.85	3.85	3.82
Labor income 90/10	12.57	12.10	12.10	12.56
Welfare	3.86	3.91	3.89	3.89
Cost of the policy				
$Cost/Y_{pc}$ (current Y), (%)	0	0.38	0.08	0.49
$Cost/Y_{pc}$ (original Y), (%)	0	0.40	0.08	0.47