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Demographic transition in Africa: the polygamy and fertility nexus

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Demographic Transition in Africa: the Polygamy and Fertility Nexus*

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PRELIMINARY
(DO NOT QUOTE)

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Keywords: Fertility, Polygamy, Demography, Subsaharan Africa

JEL Classification: J12, J13

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1 Introduction

The African continent have reached by 2009 the billion population. Most of the African population growth is due to Sub-Saharan African (SSA) countries. Indeed, the population growth rate of African Arabic countries is less than 2% per year and their fertility rate is about 2.5 children per women. The demographic transition in these countries have begun in the early 1970's and have been evolving in a fast pace. Many Sub-Saharan African countries have not really started their demographic transition or are experiencing a very low demographic transition path[4]. The average total fertility rate of Sub-Saharan Africa is around 5.1 in 2009 illustrating an average growth rate of 2.5% during all the 2000's years. Despite the progress made in health care and education, namely in primary and secondary schooling, since the adoption of the Millennium Development Goals in the early 1990, the population growth rate is still high.

The aim of this paper is to analyze the role and effects of a strong cultural feature of African societies, namely polygyny, on the demographic patterns of SSA countries. We attempt to explain the impact of the family structure on SSA transition demographic path. The progress in education, in particular of women, and the reduction of infant mortality are seen as main drivers of demographic transition. In the classical scheme, the demographic transition begins with the decrease of the mortality rate, yielding a regime of high population growth rate, then the fertility rate decreases driving the population growth rate to a new stationary regime characterized by a low fertility and mortality rate (see Chesnais [1992] for a complete analysis). The Sub-Saharan African countries is featured by a persistence of a high fertility rate though that it is decreasing. As illustrated in Figure 1 below, while the infant mortality rate has declined steadily since the 1950's, the total fertility rate started to decline only in the late 1980's and then yielding a population growth rate at a lower pace. These figures confirm that to understand the behavior of SSA countries' fertility rate one should take into account variables that are intrinsically related to fertility behaviour Family structure is a direct candidate to explain fertility behavior.

Polygyny have been suspected to play a key role very early by demographers[5]. Muhsam (1956) and Dorjahn (1959) tried to establish an assessment of the role of polygamy in fertility[6]. Referring to the framework proposed by Davis and Blake (1956), three elements affects the process of reproduction: (i) exposure to the risk of pregnancy, (ii) the ability to conceive and (iii) successful gestation. Polygamy concerns the first element in different ways. First, a woman's fertility can be different within a polygamic household because of competition or substitution between spouses. Second, polygamy can affect also fertility by modifying the social norms on the size of families. It can therefore, by an externality effect, increase directly the fertility of non-polygamous households as well. Third, Polygamy could also lengthen the time spent in union, by lowering the age at which girls marry

[4]However, some as Kalemli-Ozcan (2010) consider that Africa's demographic transition have started.

[5]Through the paper we will use the term polygamy in the sense of a men with many wives, though that the exact definition is polygyny.

[6]see Lardoux and Van de Walle (2003) for recent studies on specific senegalese ethnies and Borgerhoff Mulder (1989) for studies on Kipsigis women in Kenya.

and favouring remarriage. As young women are more fecund, this could also favor overall fertility. All these factors may increase the fertility rate. Fourth, as advocated by Pison (1986) and others, polygamous structure may increase the nuptial rate in a society and therefore increase the number of child born and therefore have a positive impact on the population growth rate. In this paper, we will investigate the effect of polygamy on fertility by looking separately at those different mechanisms.

The paper presents empirical evidence on the impact of polygamy on fertility in Sub-Saharan Africa. Estimates using DHS data on twelve countries[7] (Nigeria, Senegal, Cote Ivory Coast, Cameroon, Rwanda, Tanzania, Uganda, Zimbabwe, Benin, Ghana, Malawi and Madagascar) with different legislation regarding polygamy are provided. Our estimation indicates that at the individual level polygamy has a negative impact on fertility rate. That is women in a polygamous structure tend to have a significant lower fertility rate than women in monogamous family. However, polygamy appears also to increase both the nuptial rate and the rate of remarriage after a loss or a separation. It also decreases the age of marriage. Moreover, average fertility happens to be substantially higher in the areas where polygamy is more frequent. When investigating causality, we first control by variables characterizing behaviors or beliefs of both men and women at the local level. Although correlated with both polygamy and fertility/nuptial those variables do not explain the previous correlations.

When we use the height of women an instrumental variable, it appears that at the cluster or regional level, polygamy and fertility are positively correlated. The height variable appears to be a good instrument correlated positively with polygamy and not correlated with the fertility rate. This result confirm the impact and the importance of the family structure. Our overall assessment indicates that family structure plays an important role in fertility behaviour and may explain the patterns of the Africa's demographic transition. Polygamy account for up to 0.7 point in fertility rate in some regions from our sample.

The paper is organized as follows : section (2) presents the conceptual framework and the data, section (3) shows how polygamy and fertility are correlated at individual level, section (4) investigates causality and the correlation between polygamy and fertility. In section (5) we simulate the effects of polygamy at the macro level on population growth rate depending on our sample.

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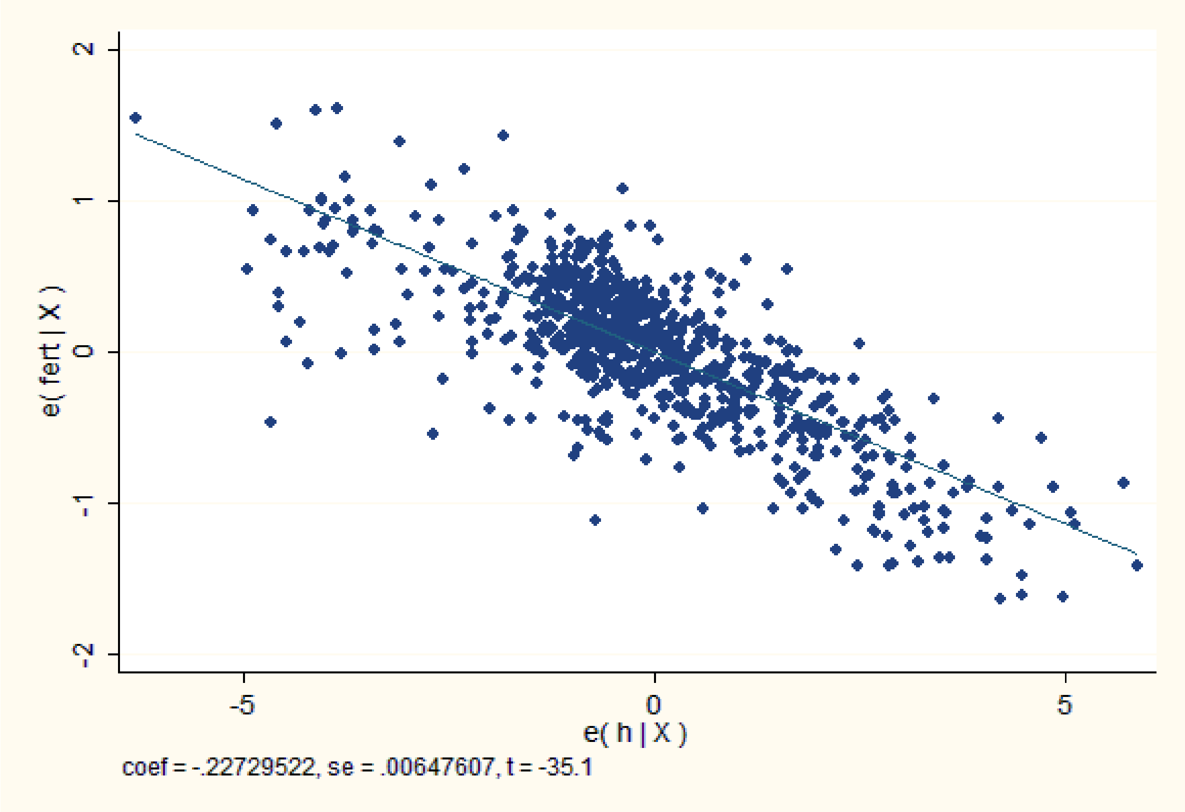
[7] The Demographic and Health Survey (DHS) used in this study was carried out by : the Statistical and Health Services (Ghana), the Institut National de la Statistique (Cote d'Ivoire), the Institut National de la Statistique (Benin), the Ministère du Plan et de l'Aménagement du Territoire (Cameroon, 1991), the Bureau Central des Recensements et Etudes de Population (Cameroon, 1998), the Institut National de la Statistique (Cameroon, 2004), the Centre National de Recherches sur l'Environment (Madagascar, 1992), the Institut National de la Statistique (Madagscar, 1997, 2003, 2008), the National Statistical Office (Malawi), the Federal Office of Statistics (Nigeria, 1990), the National Population Commission (Nigeria, 1999, 2003, 2008), the Office National de la Population (Rwanda, 1992, 2000), the Ministry of Economics (Rwanda, 2005), the Ministère des Finances (Senegal, 1992, 1997), the SERDHA (Senegal, 1999), the Ministère de la Santé, CRDH (Senegal, 2005, 2006), the National Bureau of Statistics (Tanzania), the Bureau of Statistics (Uganda) and the Central Statistical Office (Zimbabwe). ICF Macro, an ICF International company, provided financial and technical assistance for the survey through the USAID-funded MEASURE DHS programme (http://www.measuredhs.com).

Figure 1: The correlation between education and fertility (our sample of countries, regional level)



2 Conceptual framework and data

2.1 The nexus between fertility and polygamy

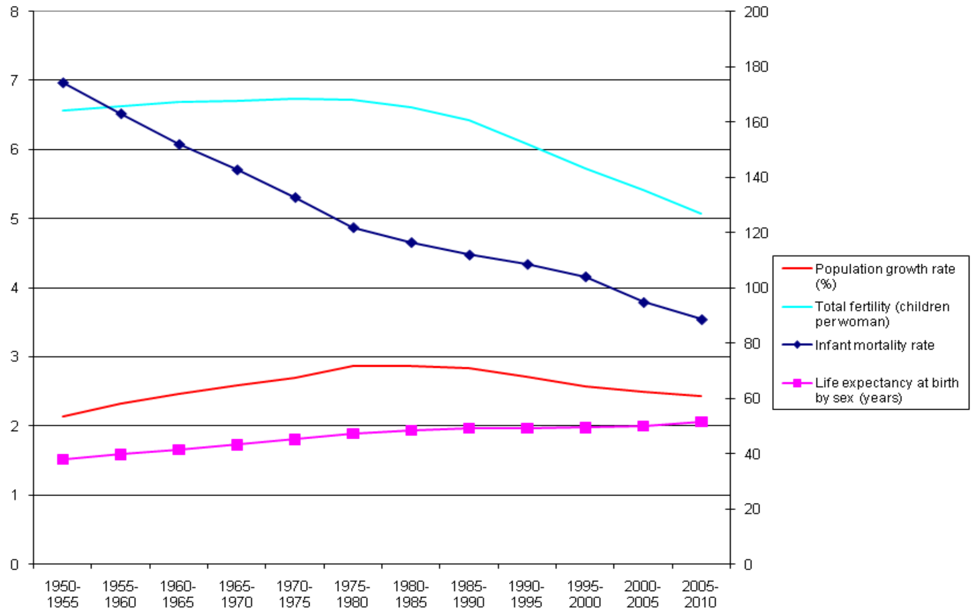
Sub-Saharan African countries are still experiencing a high population growth rate. The population average growth rate in SSA is 2.5 percent in 2009. The average total fertility rate is 5.1 child per women in 2009. Sub-Saharan African countries' fertility rate have decreased since the early 1980's. Some expect that it could have declined more (see Figure 1 below). However, the progress made on education and health care the last twenty years have not been translated into a great modification of the fertility rate. One specificity of African countries that could help explain the fertility behavior is the family structure. Progress in education and health care may not be enough to yield an acceleration of the demographic transition if the impact of the family structure is not taken into account[8]. Education decreases the fertility rate through its negative impact on the nuptial rate and its positive impact on contraception behavior and child health. But, polygamy may increase the nuptial rate then offsetting the education impact. Also, the family structure may have an effect either in the fertility behavior and in the education behavior[9].

In this paper, we intend to look at the implications of one specific element of the family structure, namely the existence of polygamy. We are considering, more specifically, the

[8]See Kalemli-Ozcan (2008) for an analysis of the demographic trends of SSA countries.

[9]Seee Lambert and al. (2010) for a study f the impact of polygamy on family's education investment.

Figure 2: Evolution of demographic patterns of Sub-Saharan Africa



extent of polygyny (men having many wives) and its consequences on the dynamics of the fertility rate.

Polygamy may have effects at then individual level and at the society level. Indeed, women in a polygamic family may compete in the number of children they have because it may raise their social status or in order to increase their share on inheritance. Also, if polygamy increase the marriage length for women, it may increase their fertility as their exposition to the pregnancy risk is increased. However, as men with many wives are less present for each wife, it may decrease pregnancy risk exposition. So the result maybe ambiguous in that respect. At the society level, polygamy could have substantial indirect effects. First, it may increase the nuptial rate (the number of marriages) in the society as it becomes easier for women to get married in a polygamic society. Second, it may increase the social norms in terms of number of children both for women and men, causing that in area where polygamy is frequent, the monogamous family will tend to have more children. The combination of these to elements could offset the eventual lower fertility rate of women in polygamous family.

2.2 Descriptive statistics

The data are taken from the DHS surveys. For each country, at least three surveys collected in different years are appended. Although polygamy seem to exist in every of the 48 countries of Sub-Saharan Africa, we have limited our study to a dozen of them. Marriage and fertility are supposed to vary both with time and age. To disentangle those two dimensions, we need to append at least three waves of surveys for each country. This limits our choices of countries.

To obtain significant results it may also be relevant to compare countries where the incidence of polygamy is very different. Finally, we also choose countries where laws about marriages and polygamy are different and moreover have changed during time, to benefit maybe from some "exogenous" variations in the practice of polygamy. In practice this assumption has been disappointing. It appears that legal changes rather follows changes in the practices rather than the contrary. The difficulties of several countries to pass ban laws (such as Uganda) or to enforce them (as in Senegal[10]) illustrates that reality. Only five countries have modified their law about polygamy, see table **??**. We tried to introduce in the sample comparable countries where polygamy has remained legal or unlawful. Madagascar happens to be the only country where polygamy is illegal and where three waves of the DHS surveys are available.

Table 1 : Sample of studied countries

Countries where polygamy...	
...has been legalized	Malawi (2004)
...has been abolished	Benin (2004), Burundi (1993), Cote ivory Coast (1964), Uganda (2003)
...is legal	Cameroon, Senegal, Ghana, Rwanda
...is unlawful	Madagascar

Years of legal change are indicated between brackets.

Table 2 below presents the average statistics for some variables in the different countries. Polygamy appears to be very frequent . It is more spread in western Africa than in the rest of the continent. For 42% and 46% of the women in Senegal and Benin respectively, their husband are polygamous while it is less than 20% in Eastern African countries. Mortality stands for the number of dead children before age one over 1000 births. It is still very high, reaching 73.8 in Malawi and 69.3 in Tanzania. Most of the women are involved in a "couple relationship", the percentage of women in a couple range from 49% in Rwanda to 83% in Tanzania. If we add the column of women formerly in a couple relationship, actually widows or divorced, it appears that being single is a relatively rare situations. Women are married young, before 20 year old in general in all countries. These different elements point the characteristics of the marital structure in the different countries.

[10]In Senegal, as in many other countries, man are suppose to choose a "polygamic" or "monogamic" status when they marry for the first time. However, it is common for men having chosen to be monogamic during their youth to marry latter a second wife. This law is difficult to enforce as the first spouse may have to choose between polygamy and a divorce.

Table 2: Average statistics for different variables and countries

	Polygamy	Fertility	Mortality	Involved	Formerly	Marital age	# obs.
Madgascar	0.03	2.79	42.0	0.67	0.13	18.5	38,644
Rwanda	0.11	2.71	53.0	0.49	0.16	20.0	28,293
Zimbabwe	0.15	2.42	32.8	0.61	0.13	18.7	20,942
Malawi	0.17	3.23	73.8	0.73	0.12	17.4	41,465
Ghana	0.24	2.82	38.6	0.70	0.08	18.8	20,012
Tanzania	0.26	4.01	69.3	0.83	0.10	17.6	60,556
Uganda	0.29	3.49	59.7	0.69	0.13	17.4	22,847
Cameroon	0.29	3.08	48.2	0.74	0.08	17.5	20,028
Cote ivory Coast	0.33	3.31	47.5	0.71	0.07	17.8	20,825
Nigeria	0.33	3.24	60.5	0.74	0.05	17.2	33,831
Senegal	0.42	3.59	47.5	0.80	0.05	17.1	29,505
Benin	0.46	3.18	49.8	0.74	0.05	18.2	29,504

"Polygamy" is measured as the percentage of women whose husband has several spouses. "Mortality" stands for the number of children (over 1,000) who died before reaching the age of one. "Involved" is the percentage of women in a couple. "Formerly" is the percentage of women who are widows, divorced or separated. "Marital age" is the average age at first marriage. All statistics are computed for women between 15 and 49.

2.3 Taking into account infant mortality

Infant mortality rate is supposed to increase gross fertility because parents make more children in order to insure themselves against the loss of a baby. As infant mortality is likely to depend also on individual factors, it could be worthy to retrieve some information about it from the surveys. An obvious choice is to use the *actual* rate of death among the children of the women whose fertility we try to study. However, such a variable is strongly endogenous. Because the number of children born is a discrete and small variable, the *actual* mortality rate of a woman is a very uncertain measure[11] of the *theoretical* probability of death of her young children. To use that information however, we will use a Bayesian method to build individual mortality rate (see appendix B for the details of the construction). The main assumption is that the probability of death of a child does not depend on her rank into the brotherhood. Infant mortality is therefore assumed to be independent of the number of children a woman has[12].

3 Investigating the polygamy and fertility interactions with individual data

3.1 Polygamy and fertility at the micro level : a first estimation

Microeconomics regressions may allow to determine whether competition among spouses of a polygamous man increases fertility. We estimate the effects of polygamy on the total children born, whether they are still alive or not, i.e. the fertility rate at the individual level using the projecting infant mortality rate at the individual level. This estimation

[11] Especially for the women with a small number of children or no children at all

[12] This assumption is probably a crude approximation as the first pregnancies in a woman's life, especially if they went wrong, are likely to induce complications during following ones.

is run for currently married woman only and for each country separately. The relevance of such an estimation is jeopardized by the fact that women entering a marriage with a polygamous man may have special characteristics. To tackle that issue, we introduce several controls such as the length of marriage, the number of times the woman was married, if she is unfecond and dummies variables indicating her religion and the area she lives in[13] as well. Results are reported in table 3. We use OLS regressions (1), although the number of children is a discrete variable[14]

The fertility rate of a married woman i with characteristics X in a country j, denoted $\nu_m^{i,j}$ becomes, denoting π is the boolean variable indicating whether the woman i lives with a polygamous man and t a linear yearly trend:

$$\nu_m^{i,j} = \gamma^j \pi^i + X^i \beta^j + \alpha^j t + \varepsilon^i \tag{1}$$

Estimations results are reported in table 3 :

Table 3: Effect of polygamy on fertility at the individual level.

Country	Benin	Ivory Coast	Cameroon	Ghana	Madagascar	Malawi
Polygamy	-0.09^{**}	0.15^{**}	-0.18^{**}	-0.12^{**}	-0.09^{*}	-0.14^{**}
	(4.2)	(3.8)	(4.5)	(3.6)	(3.3)	(4.9)
Marriage length	0.90^{**}	0.78^{**}	0.82^{**}	0.76^{**}	0.79^{**}	0.83^{**}
	(57.1)	(41.1)	(33.1)	(41.8)	(51.7)	(46.9)
mort^r	28.70^{**}	4.66^{**}	7.50^{**}	13.61^{**}	12.50^{**}	5.41^{**}
	(25.7)	(3.7)	(5.2)	(11.2)	(22.4)	(7.1)
mort^i	5.50^{**}	4.24^{**}	-0.81	7.54^{**}	-0.58^{*}	12.08^{**}
	(17.8)	(8.8)	(1.9)	(15.2)	(2.8)	(42.8)
# obs.	21590	12046	12962	12718	26065	21282
adj. R^2	0.67	0.55	0.53	0.62	0.66	0.57
Country	Nigeria	Rwanda	Senegal	Tanzania	Uganda	Zimbabwe
Polygamy	-0.22^{**}	$-0.08^{\dagger}$	-0.21^{**}	-0.19^{**}	0.06	-0.36^{**}
	(4.4)	(2.5)	(5.4)	(5.7)	(1.6)	(5.1)
Marriage length	1.25^{**}	0.92^{**}	0.81^{**}	0.89^{**}	0.74^{**}	0.99^{**}
	(52.1)	(42.6)	(39.4)	(42.2)	(40.1)	(59.2)
mort^r	2.97^{*}	16.39^{**}	3.70^{**}	6.16^{**}	7.12^{**}	17.80^{**}
	(3.4)	(16.6)	(3.9)	(4.7)	(5.8)	(15.9)
mort^i	5.90^{**}	0.68	$0.79^{\dagger}$	0.64	11.21^{**}	-1.71^{**}
	(15.5)	(1.5)	(2.4)	(1.6)	(17.3)	(4.3)
# obs.	9070	14441	13738	14865	12402	24282
adj. R^2	0.72	0.63	0.63	0.65	0.66	0.53

Dependent variable is the total number of children ever born. OLS regressions.
T-stats are between brackets. †,*,** indicate significance at the 5%, 1% and 0.1% level.
Additional controls: Age, age^2, years of schooling, Rural, year trend, number of unions, "declared unfecond" dummy, religion and region dummies.

It appears that apart in Ivory Coast an Uganda, the practice of polygamy has a significant negative impact on fertility, once the duration of marriage is taken into account. It is to be noted that the number of spouses of the polygamous husbands has no significant impact on fertility. The duration of the union always increase fertility. Average infant mortality in the region ($mort^r$) and at the time the women were expecting[15] increases fertility in all countries as well. The Bayesian estimate of the probability of death of the children at the individual level ($mort^i$) is often positively correlated with fertility.

[13] Using dummy variables for the region and the urban/rural location.
[14] Regressions were also run using ordered logit models, which gave similar results.
[15] We calculate the average infant mortality in the region at the age of 20 for women who does not had children.

Several mechanisms could explain that all other things equal, women married with a man who has several spouses tends to have slightly less children. As pointed out by Pison (1986)[?] polygamous men may choose to marry less fecund (because of health condition or advanced age) women just to grant them a social status. A complementary explanation could be that, especially in urban areas, polygamous husband are often not living with their spouses. Polygamy may also been seen as a way to compensate for longer postpartum or breast-feeding period, which slows down the rhythm of pregnancy.

3.2 Direct effects of polygamy on fertility at regional level

To exhibit external effects of the practice of polygamy on fertility, we make the following assumption. We assume that nuptial, the age at which girls first marry and eventually fertility depend on social characteristics as well as norms of the region the woman is living in. However, the typical size of a DHS household survey does not usually allow to split countries into more than 20 areas, where one can calculate representative average of demographic figures. To underline the external effects of polygamy, we have to pool data for different countries. We define 140 geographical areas r by splitting the 12 countries into regions (see fig. **??**). As we can compute the incidence of polygamy and other representative social characteristics in those areas at different point in time, we are able to obtain 559 different groups $k = \{r, t\}$ of women (among 366,000 individual observations) by pooling the women living in the same region r and interviewed during the year t. The average number of individual in each group is about 650. The "local" social and cultural characteristics y_t^r are calculated by averaging the individual characteristics (such as polygamy or religion) within the groups k.

$$y_t^r = y^k = \frac{1}{\#k} \sum_{i \in k} y^i \tag{2}$$

Seeking a direct link between fertility and polygamy, we investigate whether or not fertility is higher in areas where the incidence of polygamy is also higher. We therefore add $polygamy^k$, the average incidence of polygamy for a given year and in a given region. We control also by the average human capital $education^k$ and the shares of the population affiliated to the main religions b in each group k, R_b^k. Descriptive statistics of the social/cultural characteristic by group are given in table 4:

Table 4: Descriptive statistics of social/cultural characteristics at the local level

Variable	# Obs.	Mean	Std. Dev.	Min	Max
$polygamy^k$	547	0.25	0.14	0.00	0.63
$education^k$	559	4.69	2.15	0.26	10.24
$Catholic^k$	504	0.25	0.19	0.00	0.85
$Protestant^k$	504	0.21	0.19	0.00	0.93
$Muslim^r$	504	0.29	0.33	0.00	1.00

Religions and schooling characteristics at the "local" level are embedded in the vector Y^k. The total fertility of a women i from the group k is given by:

$$\nu_m^{i,k} = \gamma\pi^i + X^i\beta + \zeta polygamy^k + Y^k\theta + \alpha t + \varepsilon^i \tag{3}$$

The effects of social norms/culture are measured by the vector θ. The "external" effect of polygamy on fertility is given by the coefficient ζ. We also use OLS regressions. Results are reported in table 5:

Table 5 : Directs external effect of polygamy on fertility

Dep. var.	total number of children ever born (OLS)							
$polygamy^k$	1.03^{**} (21.8)	0.81^{**} (18.5)	1.09^{**} (24.1)	0.59^{**} (7.4)	0.89^{**} (17.5)	0.71^{**} (15.0)	1.01^{**} (20.7)	0.58^{**} (6.4)
$education^k$	0.05^{**} (14.7)	0.02^{**} (6.0)	$0.01^{\dagger}$ (2.4)	0.02^{**} (4.0)	0.05^{**} (13.3)	0.02^{**} (4.7)	$0.01^{\dagger}$ (2.3)	0.01^{*} (2.8)
$mort^r$	10.81^{**} (44.6)	5.69^{**} (24.9)	5.22^{**} (22.8)	6.31^{**} (23.7)	10.58^{**} (39.2)	5.40^{**} (21.4)	5.01^{**} (19.9)	5.59^{**} (19.0)
$mort^i$	4.48^{**} (34.0)	3.64^{**} (29.7)	3.58^{**} (29.2)	3.55^{**} (28.7)	4.13^{**} (26.4)	3.34^{**} (23.1)	3.29^{**} (22.8)	3.20^{**} (22.0)
Marriage length	-	yes	yes	yes	-	yes	yes	yes
$Religion^k$	-	-	yes	yes	-	-	yes	yes
Country	-	-	-	yes	-	-	-	yes
# obs.	126167	126167	126167	126167	93946	93946	93946	93946
adj. R^2	0.57	0.63	0.63	0.64	0.59	0.65	0.65	0.65
Sample	All women in a relationship				Unique spouse only			

T-stats are between brackets. †,* ,** indicate significance at the 5%, 1% and 0.1% level.
Additional controls: Age, age^2, years of schooling, Rural, year trend, Body Mass Index, "declared unfecond" dummy, religion dummies.

The direct effect of polygamy on fecundity seems to be strong, whatever the configuration used. Infant mortality, both at the local and individual level appears to be highly correlated with fertility. The social (external) effect of polygamy decreases when controlling by the duration of the union. The practice of polygamy may lengthen the unions, presumably by lowering the age at which girls get married. Although polygamy is correlated with religious beliefs, it appears that polygamy on itself affects fertility, within both polygamous and monogamous households. As the social environment of the area is described by the average education and infant mortality, it is likely that the practice of polygamy witnesses rather local cultural particularities.

3.3 Effects of polygamy on nuptial

Polygamy could increase the share of married women. To test this assumption, we model the probability of being married with a probit model, equation (4). We assume that the probability of marriage depend on individual characteristics X^i but also on the local context Y^k and the incidence of polygamy $polygamy^k$. We control by age and education but also by the body mass index and if the women has been declared unfecond, as more healthy women may marry more easily. We control also by the average level of education among women, which captures the fact that women are more free to refuse (early) marriage in a society where they are collectively empowered by the education[16]. Religions dummies are also embedded in the vector Y^k.

$$p_n = \Phi\big(X^i\beta_n + \zeta_n polygamy^k + Y^k\theta_n\big) \quad (4)$$

[16]The causality between women education and marriages probably goes in both directions as societies more prone to gender equality and women independence probably also favor their education.

The probit model is estimated using the pooled data. Results are reported in the three left columns of table 6. It appears that whatever the controls used, women happen to be more frequently involved in a union in areas where polygamy is more frequent. Moreover the effect of polygamy is very significant.

3.4 Effects of polygamy on remarriage

Polygamy can also affects the share of women staying single after the end of an union, p_f because of the death of their husband, a divorce or a separation. We also use a probit model to estimate the effects of polygamy on the probability of staying single after having been formerly married (three right columns of table 6).

$$p_f = \Phi\big(X^i \beta_f + \zeta_f polygamy^k + Y^k \theta_f\big) \tag{5}$$

Table 6: Effects of polygamy on nuptial

Dep.	Prob. of not being single			Prob. of being divorced/widow		
$polygamy^k$	0.73^{**} (23.6)	0.80^{**} (24.6)	1.01^{**} (16.6)	-1.45^{**} (36.5)	-1.44^{**} (35.1)	-0.99^{**} (12.8)
$education^k$	-0.02^{**} (8.1)	-0.03^{**} (11.3)	-0.04^{**} (13.0)	0.00 (0.4)	0.00 (0.6)	0.00 (1.0)
$Religion^k$	-	yes	yes	-	yes	yes
Country	-	-	yes	-	-	yes
# obs.	179420	179420	179420	144720	144720	144720
pseudo R^2	0.22	0.24	0.24	0.05	0.05	0.06
Sample	All women			Excluding never married women.		

Probit regressions.

T-stats are between brackets. †,* ,** indicate significance at the 5%, 1% and 0.1% level.

Additional controls: Age, age^2, years of schooling, Rural, year trend, Body Mass Index, "declared unfecond" dummy, religion dummies.

It appears that again the incidence of polygamy increases the probability of remarriage. This variable always remain very significant. Women do remarry very frequently in polygamous societies. A patriarchal culture could explain at the same time polygamy and the importance of being married for a woman. However, remarriages are practically possible because there is more room, especially among middle age men[17] to accommodate those unions in a polygamic society. It also fasten the process.

3.5 Polygamy and first age of marriage

Although earlier weddings do not necessarily mean that women will plan to have more children, this practice could increase population growth. First, as younger women tend to be more fecund, it may increases the number of pregnancies. And second, even if this does not increase the total net fertility [18], it is likely to reduce the time between two consecutive generations. Indeed for a given fertility rate, the demographic growth tend to accelerate when mothers are younger. The practice of polygamy induces an unbalances

[17] As women tend to survive their husband, they are likely to remarry.

[18] That is the average number of surviving children per woman.

between men and women which push the girls to marry more quickly. To check that hypothesis, we regress, using OLS estimation, the age at which a women marries $a_m^{i,k}$ and individual and social characteristics, equation (6).

$$a_m^{i,k} = X^i\beta_m + \zeta_m polygamy^k + Y^k\theta_m + \varepsilon^i \tag{6}$$

The results are reported in table 7, first for all the women between 15 and 49 and second for women over 30 only.

Table 7: Effects of polygamy on women's marriage age

Dep.	Age at first marriage (OLS)					
π^k	-0.16	-0.34^{**}	-1.19^{**}	-1.20^{**}	-1.33^{**}	-1.39^{**}
	(1.9)	(3.9)	(7.5)	(8.0)	(8.5)	(4.9)
h^k	0.03^{**}	0.07^{**}	0.17^{**}	-0.02	$0.02^{\dagger}$	0.17^{**}
	(4.1)	(10.7)	(19.0)	(1.9)	(2.2)	(10.4)
$Religion^k$	-	yes	yes	-	yes	yes
Country	-	-	yes	-	-	yes
# obs.	144720	144720	144720	63059	63059	63059
adj. R^2	0.1	0.1	0.14	0.09	0.09	0.12
Sample	Once married women			Once married women over 30		

T-stats are between brackets. $^{\dagger}, ^{*}, ^{**}$ indicate significance at the 5%, 1% and 0.1% level.
Additional controls: years of schooling, Rural, year trend, Body Mass Index, weight, religion dummies.

Overall, marriage happens indeed earlier in areas where polygamy is more frequent. However, the effect of polygamy is not always significant when measured on all women. But this sample is probably not relevant as it induces a selection bias. Obviously, age at first marriage is only measured for women who already married. Therefore, when including the younger contestants, the places where women get married later are underrepresented. To solve this problem, we estimate the same relation for women over 30 only[19]. On that sample, the correlation between polygamy and the age at which women marry is larger and much more significant.

There appears to be a strong correlation between the practice of polygamy and both marriages and fertility. In the following section, we will try to address the question of causality in two dimensions. First we will look at potential omitted variables which could cause at the same time polygamy and nuptial/fertility.

4 Investigating causality

The correlation between fertility and polygamy is mostly due to the fact that women living in areas where the practice of polygamy is frequent tend to marry more and to have more babies. As women with a monogamous spouse also tend to have more children in those areas, it is very unlikely that higher fertility directly causes polygamy. To explain the correlation between polygamy and fertility two alternative scenarios can be suggested: (i) both fertility and polygamy could be induced by a third (unobservable) factor or (ii) the practice of polygamy could raise fertility. In this section one address both hypothesis, first by proposing variables to capture what could be cultural traits favoring gender differentiation, fertility and the male domination and second by proposing an instrument to test the causal link from polygamy to fertility.

[19] In average, women get married for the first time around 20.

4.1 Polygamy and conservatism

We make the underlying assumption that societies dominated by male interests tend to confine women in the reproductive function. In such societies, spouses and thus children are seen as exterior signs of wealth and male tend to accumulate both to compete in the society. If this assumption is correct variables related to gender discrimination and male domination should explain both the levels of fertility and the practice of polygamy. As those variables need to capture social norms and customs, one wants to compute indicators averaged at the local level S_t^{jr}. By introducing such variables into the previous equation, we will be able to check the robustness of the estimates. If the incidence of polygamy π_t^r become insignificant while controlling by the set of variables $(S^j r_t)$, the correlation between polygamy and fertility/nuptiality will only reflect local aspects of the culture and not any causal relationship.

As polygamy is correlated with lower age of marriage, higher fertility and lower schooling for women, it is tempting to search for indicators of some "conservative" sensitivity, in the sense that tasks and roles for men and women within the household and the society are much polarized. Fortunately, the DHS surveys provide a wealth of questions, to both men and women, allowing capturing cultural values and behaviors.

4.1.1 Men behaviors and polygamy

We retained seven kind of indicators to measure cultural beliefs and behaviors:

- **Age at which men marry**. If marriage is considered as a exterior sign of wealth, then men need to get richer to be able to marry and have children. In such society, the competitions for brides is supposed to delay men's wedding as young people tend to be poorer. Because men marry latter there is a structural unbalance between the number of men and women able to marry which could support the practice of polygamy.

- **Men out of job**. In the same spirit, men without a job are less likely to find a bride and to sustain a big family.

- **Men with tertiary education** A society which values education is less likely to put emphasis on the size of household as a sign of success. Societies with an educated elite may lead to different norms toward polygamy and fertility.

- **Faithfulness of men**. Faithfulness (of husbands) may be considered as an indicator of machismo. In the DHS, the male contestants are indeed asked to report the number of sex partners (beside their spouses) they had during the last 12 months. We consider a man to be unfaithful if he had sex with a woman which is not his legitimate partner. In this case $u^i = 1$[20].

- **Bias toward male babies**. Another way to catch a bias toward men in the society is to look at preferences regarding the gender of babies. In the DHS, contestants (both men and women) are asked about the "ideal" number of boys $\#^*_{boys}$ and girls $\#^*_{girls}$ they would like. This allows calculating a gender-bias indicator for men mgb and women wgb eq (7):

$$\{mgb, wgb\} = \frac{\#^*_{boys} - \#^*_{girls}}{\#^*_{boys} + \#^*_{girls}} \tag{7}$$

[20] and 0 otherwise.

When there is no bias, xgb is equal to zero. It is positive for a bias toward boys and negative for a bias toward girls.

- **Occupation of men**. Labor intensive professions such as agriculture or trade may push men to marry several times to produce workforce for their business.
- **Tolerance to domestic violence**. In the DHS women were also asked if they found justified that a husband beat his wife if she refuses to have sex. The tolerance of domestic violence from the women side is another side of male domination.
- **Duration of breastfeeding**. Longer breastfeeding period is often associated with longer time of amenorrhoea[21] and abstinence. Longer duration of breastfeeding may in turn favor polygamy as well.

The partial correlations (regional averages) of those variables are reported in table 8. Except for the duration of breastfeeding and the age of marriage for men, the polygamy and fertility variables tend to be correlated as expected with the "cultural" indicators.

Table 8: Partial correlations between being in couple and cultural variable

	In a couple	Formerly married	Polygamy
Tolerance to beating	0.45	−0.16	0.48
Man male bias	0.13	−0.30	0.44
Breastfeeding duration	0.16	0.26	−0.06
Cheating	0.15	0.19	0.16
Man wedding age	−0.27	−0.14	0.15
Woman male bias	0.18	−0.36	0.46
Man schooling	−0.39	0.03	−0.34
Man tertiary education	−0.25	0.01	−0.13
Man without job	−0.38	−0.02	−0.27

Partial correlations between the probabilities of being in a couple, of having been formerly married and the number of children with a selection of "cultural" indicators at the regional level.

4.1.2 Controlling for a "gender-biased" sensitivity

The above variables are therefore good candidates to measure some "gender-biased" or conservative sensitivity. To test whether the correlation within polygamy and fertility is due to a culture of conservatism one introduces the previous indicators (still averaged at the regional level) into the regressions of fertility or marriage at the individual level along with the average incidence of polygamy at the regional level as in regressions (3), (4) and (5) with S^k being a subvector of Y^k. The results are reported in table 9.

[21] Absence of menstrual period, often induced by a recent pregnancy and breastfeeding.

Table 9: Effects of gender-biased sensitivity on fertility and marriages.

Dep. Var	Fertility (# born child.)	Never * married	Formerly* married	Age 1st marriage
Unfaithful^k	0.4 ** (13.2)	-0.58^{**} (16.1)	-0.01 (0.5)	1.3 ** (11.9)
Men boys bias^k	1.65^{**} (9.9)	-0.49^{**} (3.0)	-1.26^{**} (7.8)	-5.36^{**} (9.0)
No work^k	0.3^{**} (5.1)	1.35^{**} (26.0)	0.28^{**} (5.5)	1.7^{**} (8.5)
Tertiary^k	-0.33^{**} (4.7)	0.1 (1.5)	-0.23^{**} (3.5)	0.58^{**} (2.3)
Women boys bias^k	-2.14^{**} (10.3)	3.16^{**} (16.7)	-2.03^{**} (10.2)	14.99^{**} (20.6)
Violen. Tolerance^k	0.54^{**} (9.3)	-0.19^{**} (2.9)	0.36^{**} (6.4)	-1.67^{**} (8.4)
Breastfeeding^k	-0.01^{**} (4.3)	-0.02^{**} (6.1)	0 (1.1)	0.17^{**} (14.6)
Polygamy^k	0.96^{**} (11.8)	-0.19^{*} (2.4)	-0.99^{**} (12.9)	-1.69^{**} (6.0)

$\star$ indicates probit (vs OLS) regressions. Controls: age, age^2, schooling, religion (individual and local), average schooling at the local level and country fixed effects.

It appears that although all those variables explain at the same time polygamy and nuptiality/fertility, they do not explain the essence of the correlation between polygamy and fertility. Although those variables may be only crude measures of the cultural traits of the population, it shows that the correlation between fertility and polygamy is unlikely to be a pure artifact.

4.2 Polygamy and height

4.2.1 Marriage and woman's height at the micro level

To deal with endogeneity we consider in this section the impact of women's height on both polygamy and fertility. Interestingly as reported in the DHS the height of women seem to matter for marriage. Two complementary explanations can be brought forward to explain this phenomenon. Height is known to be correlated with health status during childhood. As a consequence, tall women can be more better off first because their height can be seen as a sign of good health. As beauty is also very likely to be correlated with health, taller women could also be regarded as prettier, leading to more frequent marriages.

At the micro level, regressions support the claim that taller women are more valued as spouses. If this assumption is to be true, then a population with a larger proportion of tall women, all other things equal (especially on the man side), is likely to have a higher rate of marriage. The effect of height on polygamy is *a priori* ambiguous but one suggests that taller women can favor polygamy for two symmetric reasons:

(i) Let us assume that polygamous men have unobservable characteristics which make them more likely to marry. If polygamous men are choosier than monogamous ones and tall women are more valued, the pool in which polygamous men choose their brides from will be larger in a society with taller women. In a matching perspective, taller women should increase the incidence of polygamy.

(ii) If we assume conversely that polygamous men have unobservable characteristics which make them more valuable for brides, taller women, if more valued, are likely to be pickier about the choice of their spouse and will also prefer to marry a polygamous man.

4.2.2 Identification assumption

To identify the causal link between polygamy and fertility we make the following assumptions:

Taller women are more valued in the perspective of an union

A higher share of tall women in the population favors both marriage and polygamy

To challenge the first assumption, we run regressions at the micro level about the probabilities of being married, being married with a polygamous man, the average age of first intercourse and marriage and the number of children. The results presented in table 10 support indeed the first assumption.

Table 10: Effects of height on marriage and fertility (Individual regressions)

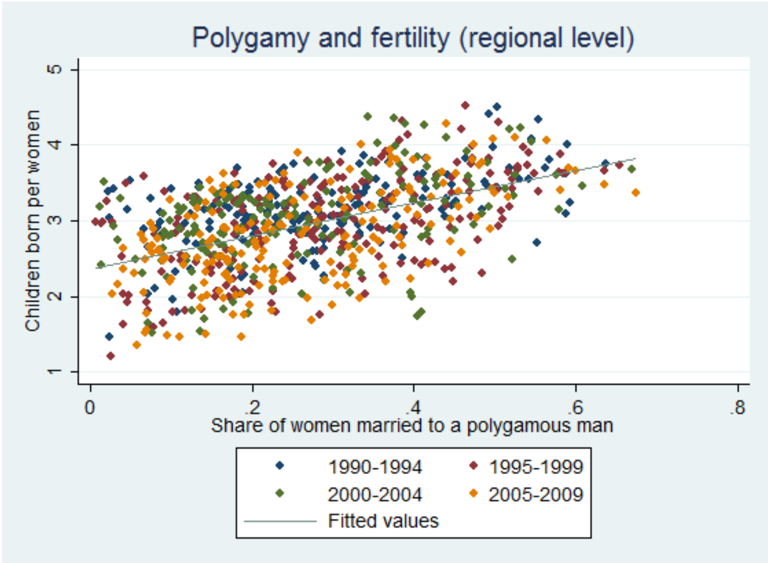
	Probit In a couple	Probit In polygamous union	Probit Declared infecund	OLS Age 1st intercourse	OLS Age 1st Marriage	OLS Fertility (# born child.)
Age	0.05*** (125.0)	0.02*** (45.6)	0.05*** (60.4)	0.32*** (199.8)	0.09*** (78.7)	0.26*** (428.8)
Year	−0.05*** (52.3)	−0.004*** (3.8)	0.03*** (15.4)	−0.17*** (43.1)	0.001 (0.5)	−0.07*** (57.5)
Schooling	−0.04*** (40.7)	−0.03*** (18.4)	−0.01*** (5.3)	0.08*** (23.6)	0.23*** (97.5)	−0.04*** (33.4)
Rural	0.29*** (33.1)	0.19*** (19.4)	−0.05** (3.3)	0.2*** (6.1)	−0.5*** (23.5)	0.35*** (31.6)
Muslim	0.32*** (28.1)	0.29*** (15.1)		0.2*** (4.5)	−0.72*** (25.4)	−0.01 (1)
Cathol.	−0.04*** (4.7)	−0.10*** (9.0)		0.03 (0.8)	0.19*** (7.9)	−0.02* (2)
Tradi.	0.23*** (10.0)	0.31*** (16.5)		−0.14 (1.8)	−0.42*** (8.9)	0.05* (2.3)
Height	2.39*** (14.6)	0.58** (3.1)	−2.41*** (7.3)	15.6*** (23.3)	3.02*** (6.9)	−0.06 (0.3)
# union>1						−0.37*** (30.4)
Ideal # child.						0.003*** (17)
Age 1st marr.						−0.21*** (157.4)
Polygamy						−0.04** (3.3)
R2	0.16	0.11	0.14	0.21	0.17	0.64
# obs.	179944	125967	179834	176894	143632	125450

Controls: country fixed effects.

More specifically:

- Taller women get more often married, once taken into account other important factors such as education, age, religion and location.

Figure 3: Polygalmy and fertility correlations



- But taller women experience in average their first intercourse latter and also tend to marry when they are older. Taller women seem indeed choosier as they take more time to marry while having a higher probability of union.
- Taller women are more rarely declared infecund which may provide a rationale for their value as spouses in societies which put emphasis on children.
- Taller women are also more married to polygamous husbands. Height seems to be valued by indeed by both polygamous and monogamous husbands.
- When controlling for polygamy the height of women has no influence on the number of children at the individual level: tall women do not have more children all other things equal. As a consequence, height seems to be a good instrument of polygamy.

As height is correlated with health status during childhood, one could argue that the correlation between height and fertility just traduce the fact that healthier women are more likely to deliver a baby. However, first we control for infant mortality, which is strongly correlated with health quality and second height is not correlated with fertility once polygamy is taken into account.

4.2.3 Results

Using all available DHS surveys in Subsaharian Africa, we pooled together 652 observations from NN countries. Most of the countries have two or three observations. After controlling by age, education, religion, infant mortality, year of survey and age of marriage and country fixed effects, the incidence of polygamy happens to be positively correlated with fertility. In other words, in regions where polygamy is more frequent, the fertility rate tend to be higher (see table 11).

Table 11: External effect of polygamy on fertility (Regional regressions)			
	OLS Polygamy	OLS Fertility	IV Fertility
Polygamy	–	0.52^{***} 4.4	1.54^{*} 2.3
age	0.01 1.6	0.20^{***} 17.6	0.19^{***} 15.8
rural	0.01 0.6	0.42^{***} 9.3	0.40^{***} 8.4
Schooling	-0.03^{***} 10.9	-0.06^{***} 5.6	-0.03 1.4
height	0.0014^{***} 4.7	0.0014 1.6	–
year	0.0014 1.7	-0.01^{**} 2.6	-0.01^{**} 3.0
traditional	-0.07^{*} 2.4	-0.21^{*} 2.5	-0.14 1.3
muslim	0.01 0.4	-0.16^{**} 2.8	-0.17^{**} 2.8
catholic	-0.06^{*} 2.3	-0.20^{**} 2.8	-0.14 1.6
mortality	0.15 1.6	1.65^{***} 5.9	1.52^{***} 5.0
Age at first marriage	–	-0.12^{***} 11.0	-0.21^{***} 157.4
R2	0.74	0.88	0.87
# obs.	652	652	652

Controls: country fixed effects.

Regressions using variables averaged at the regional level by year of survey.

To instrument polygamy, we regress the average share of married women within a polygamous household on age, education, main religions, year of survey and the average height of interviewed women and country fixed effects. Average height is very significantly correlated with the incidence of polygamy at the regional level. According to the instrumental regression, the impact of polygamy on fertility is much stronger that OLS regressions anticipated. The coefficient is also less significant because unfortunately the height is not a very strong instrument.

In conclusion, it is likely that the impact of polygamy on fertility is indeed causal and its magnitude cannot be neglected.

5 Simulating the impact of polygamy at the macro level

5.1 Framework

At the micro level, polygamy reduces the gross fertility rate of married women. At the same time, a rise in the share of women living within a polygamic household both increases average fertility and nuptiality. As women in a union have far more children that the single ones, polygamy may increases the overall fertility rate. The impact of polygamy on the average fertility rate is therefore the sum of three contradictory effects: polygamy reduces fertility within the married couple but increases fertility both directly and through higher fertility.

To calculate the net effect of polygamy, let us consider the women with the vector of characteristics X, whose marital status s can be never married (n), currently married or in a relationship (m) or single but formerly married (f). Let us designate ν_X^s the fertility rate of the woman with characteristics X and marital status s. Let us also denote p_X^s the probability that the marital status of such a woman be s. The average fertility rate of a woman with characteristics X, ν_X is therefore:

$$\nu_X = \nu_X^n p_X^n + \nu_X^f(1-p_X^n)p_X^f + \nu_X^m(1-p_X^n)(1-p_X^f) \tag{8}$$

Let us denote π the local share of women married to a polygamous man. Polygamy is not to influence the fertility rate of unmarried woman directly[22]. The marginal effect of the incidence of polygamy on fertility is therefore:

$$\frac{d\nu_X}{d\pi} = (1-p_X^n)\left(\frac{d\nu_X^f}{d\pi}p_X^f + \frac{d\nu_X^m}{d\pi}(1-p_X^f)\right) + \frac{dp_X^n}{d\pi}\Big(\nu_X^n - \nu_X^m - p_X^f(\nu_X^f - \nu_X^m)\Big) + \frac{dp_X^f}{d\pi}(\nu_X^f - \nu_X^m)(1-p_X^n) \tag{9}$$

The first term measures the direct effect of polygamy on fertility. The second term represents the effect of polygamy on fertility via the raise in the nuptiality rate whereas the third term stands for the effect of polygamy on the probability remariage. Unfortunatey no information is available in the DHS surveys to determine whether a formerly married woman was bound to a man with several spouses or not. One makes the assumption that polygamy has the same effect on fertility for currently and formerly married women.

$$\frac{d\nu^f}{d\pi} \approx \frac{d\nu^m}{d\pi} \tag{10}$$

Moreover, thanks to the linear econometric specification (in eq. **??**) chosen to estimate the microeconomic effect of polygamy on married women, one has:

$$\frac{d\nu^m}{d\pi} = \zeta \tag{11}$$

As the probability p_n is modelled with a probit model, one can write using (**??**):

$$\frac{dp_X^n}{d\pi} = \zeta_n \Phi'(X^i\beta_n + \zeta_n\pi^k + Y^k\theta_n) \tag{12}$$

This expression can be simplified by evaluating the marginal probit function at the mean, with $s = \{n, f\}$

$$\frac{dp_X^s}{d\pi} \approx \zeta_s E\Big[\Phi'(X^i\beta_s + \zeta_s\pi^k + Y^k\theta_s)\Big] \equiv \frac{dp^s}{d\pi} \tag{13}$$

These allows to simplify the previous expression.

$$\frac{d\nu_X}{d\pi} \approx (1-p_X^n)\frac{d\nu^m}{d\pi} - \frac{dp^n}{d\pi}\Big(\nu_X^n - \nu_X^m - p_X^f(\nu_X^f - \nu_X^m)\Big) - \frac{dp^f}{d\pi}(\nu_X^f - \nu_X^m)(1-p_X^n) \tag{14}$$

One can use this equation to evaluate the overall impact of polygamy on aggregate fertility by integrating the previous equation over all the characteristics X. Let us note ϕ_X the frequency of women with the vector of characteristics X in the overall population. Let us note $J = M \cap N \cap F$ the overal population of women, whether they are married ($\in M$), never been married ($\in N$) or were formerly married ($\in F$). Asymptotically, the expectancy over characteristics equals the average over the population:

$$\frac{dE[\nu]}{d\pi} = E\left[\frac{d\nu}{d\pi}\right] = \frac{1}{\#J}\sum_{j\in J}\frac{d\nu^j}{d\pi} = \sum_X \frac{d\nu_X}{d\pi}\phi_X \tag{15}$$

[22] That is $\frac{d\nu_X^n}{d\pi} = 0$

If the estimator of p_n is unbiased, one has also asymptotically the following equality, which allows to calcule easily the expectancy of p_n.

$$\sum_X p^i_X \phi_X = \frac{\#I}{\#J} \equiv p^i \tag{16}$$

However, the agregate fertility rate among the group i, ν^i should be calculated using the projection of v^i_X on the overall population and not on using average fertility among only among i.

$$\sum_X v^i_X \phi_X = \frac{1}{\#J} \sum_{j\in J} \nu^i_j \neq \frac{1}{\#I} \sum_{j\in I} \nu_j \tag{17}$$

Let us note $E_X[\nu^i] \equiv \sum_X \nu^i_X \phi_X$ to ease the calculations. The sought expectancy (13) becomes:

$$E\left[\frac{d\nu}{d\pi}\right] \approx (1-p^n)\frac{d\nu^m}{d\pi} - \frac{dp^n}{d\pi}\Big(E_X[\nu^m] - E_X[\nu^n] - p^f(E_X[\nu^m] - E_X[\nu^f])\Big) - \frac{dp^f}{d\pi}(1-p^n)(E_X[\nu^m] - E_X[\nu^f]) \tag{18}$$

5.2 Results

We use estimates obtained using country fixed effects, to estimate the effect of a sudden disappearance on polygamy. Results are reported by country in table 12.

Table 12: Macro effects of polygamy on total fertility

Country	Direct	via marriage	via remarriage	Total
Benin	0.08	0.03	0.06	0.17
Cote d'Ivoire	0.07	0.04	0.04	0.15
Cameroon	0.06	0.02	0.03	0.10
Ghana	0.05	0.02	0.02	0.09
Madgascar	0.01	0.00	0.00	0.02
Malawi	0.04	0.01	0.01	0.06
Nigeria	0.06	0.04	0.04	0.13
Rwanda	0.04	0.02	0.01	0.08
Senegal	0.06	0.04	0.07	0.17
Tanzania	0.04	0.02	0.03	0.09
Uganda	0.07	0.03	0.03	0.13
Zimbabwe	0.05	0.01	0.01	0.07

6 A simple theoretical network model

6.1 Polygynous women on average have fewer children than monogamous women

In this section, we outline a very simple model that predicts the effect of polygyny on fertility. Assume that a man m has l identical wives $w_1, ..., w_l$. Each individual derives utility from having children. A child is conceived out of the consent of his two parents, and is raised with resources contributed by both. Denote by u_m and y_m the man's utility function and endowment (endowment includes all types of resources needed to raise a child such as financial resources, time, attention, etc.), and by u_w and y_w each wife's utility function and endowment. We assume that utilities are strictly concave and increasing in the number of children. Let x_i, $i = 1, ..., l$, be the amount of resources allocated by m to raise children born to w_i. We have $y_m = x_1 + ... + x_l$.

Each wife w_i thus maximizes the function $u_w(n)$ subject to the constraint $cn = x_i + y_w$ where n is the number of children and c the cost of rearing a child. The solution to this maximization problem is straightforward and is $n_i^* = \frac{x_i + y_w}{c}$.

Note that the total number of children that the man will get from all his wives is $n_m^* = n_1^* + ... + n_l^* = \frac{x_1+y_w}{c} + ... + \frac{x_l+y_w}{c} = \frac{x_1+...+x_l+ly_w}{c} = \frac{y_m+ly_w}{c}$, and his utility from those children will be $u_m^* = u_m(\frac{y_m+ly_w}{c})$, which does not depend on how he allocates his endowment across his different wives.

On average, each wife will have $n_w^* = \frac{n_m^*}{l} = \frac{y_m}{lc} + \frac{y_w}{c}$ children[23], n_w^* is strictly decreasing in l, which shows that on average, a woman who has more co-wives has fewer children than a woman who has less co-wives, which also implies that women in polygynous households have fewer children than those in monogamous households. However, n_m^* is strictly increasing in l, which means that the total number of children that a man has increases with the number of wives that he has.

6.2 Nuptial is higher in a polygynous culture than in a monogamous culture

In this section, we examine the relationship between polygyny and the number of unions. We draw on the model of a hierarchical mating economy in Pongou (2009a). We consider a two-sided mating economy with men (M) and women (W). Each enjoys having a marital relationship with someone from the opposite side. Men are ranked based on their socioeconomic status. For simplicity, we assume that there are two classes of men M_1 and M_2, with M_1 representing the upper class, and M_2 representing the lower class. Men in M_1 have the ability (maybe financial) to get married, and men in M_2 do not (M_2 may be empty). We do not make such distinction between women.

Our goal is to determine the number of marriages under two exogenous cultures: (1) the monogamous culture where each individual can have at most one partner; and (2) the polygynous culture where men can have more than one wife whereas each woman can have at most one husband.

In the monogamous culture, it is straightforward that only $|M_1|$ men and $|M_1|$ women will get married. In the polygynous culture, assume that the number of women demanded by each man is $x > 1$. If $|M_1|x \geq |W|$ (that is, the demand for wives by men is greater than the number of women), then all women will get married (but some men in M_1 may remain unmatched). If $|M_1|x < |W|$, only $|M_1|x$ women will get married, and all men in M_1 will get married. In both cases, the number of marriages exceeds $|M_1|$ (the number of marriages in the monogamous culture). Note that if M_2 is empty, the number of marriages will be equal in both cultures, but some men may remain unmatched in the polygynous culture because of competition for women.

[23] An alternative way of solving this problem would have been to assume a unitary household model in which all incomes are pooled together and the husband, acting as a social planner, decides how many children (n_i) to give each wife w_i. The husband would then maximize the following aggregate utility function:

$u(n_m, n_1, ..., n_l) = u_m(n_m) + u_1(n_1) + ... + u_l(n_l)$

subject to $n_m = n_1 + ... + n_l$ and $cn_m = y_m + ly_w$. It is easy to see that the solution to this problem is the egalitarian solution $n_i^* = n_w^* = \frac{y_m}{lc} + \frac{y_m}{c}$ for all $i = 1, ..., l$ and $n_m^* = \frac{y_m+ly_w}{c}$.

6.3 Is the aggregate number of children greater in a polygynous culture than in a monogamous culture?

In this section, we investigate the effect of matrimonial culture on the total number of children in a society. Our analysis draws on the first and second sections.

In a monogamous culture, all men in M_1 get married and $|M_1|$ women get married. From Section 1.1, we know that each woman married to a monogamous man has $\frac{y_m}{c} + \frac{y_w}{c}$ children. Therefore, the aggregate number of children will be $(\frac{y_m}{c} + \frac{y_w}{c})|M_1|$.

Now assume a polygynous culture.

a) If $|M_1|x < |W|$, all men in M_1 will get married, and only $|M_1|x$ women will get married. Each married man has x wives, and thus $\frac{y_m+xy_w}{c}$ children. So the total number of children will be $\frac{y_m+xy_w}{c}|M_1| > (\frac{y_m}{c} + \frac{y_w}{c})|M_1|$ (the total number of children in the monogamous culture).

b) If $|M_1|x \geq |W|$, then all women will get married (but some men in M_1 may remain unmatched). Note that this case includes the case in which M_2 is empty.

b-1) If M_2 is empty, a monogamous matching in which each individual has one partner may emerge, and the total number of children will be that of the monogamous culture. However, a polygynous matching may emerge as well, and it is clear that each woman will have at most the number of children she would get in the monogamous culture, with some women having strictly less. Therefore the total number of children will be strictly smaller than in the monogamous culture.

b-2) If M_2 is not empty, the number of men in M_1 who will get married will be at least $\left\lceil \frac{|W|}{x} \right\rceil$ and at most $|M_1|$. If the number of men who get married is $\left\lceil \frac{|W|}{x} \right\rceil$, it is easy to prove that depending on the value of x, the total number of children may be smaller than $(\frac{y_m}{c} + \frac{y_w}{c})|M_1|$, the number of children in the monogamous culture. However, if the number of men who get married is $|M_1|$, then we return to case a) where the total number of children strictly exceeds that of the monogamous culture. The prediction here is thus ambiguous.

References

Borgerhoff Mulder, M. (1989), "Marital Status and Reproductive Performance in Kipsigis Women: re-evaluating the Polygyny-Fertility Hypothesis", Population Studies, 43, pp. 285-304.

Chesnais, J.C. (1992), "The Demographic Tra,sition: Stages, Patterns and Economic Implications", Clarendon Press, Oxford.

Davis, K. and J. Blake (1956), "Social structure and fertility: An analytic framework", Economic Development and Cultural Change, vol. 4, pp. 211-235.

Dorjahn, V. R. (1959), "The factor of Polygyny in African demography" in W. R. Bascom and M. J. Herskovits (eds), Continuity and Change in African Cultures, Chicago.

Galor, O. (2005), "The Demographic Transition and the Emergence of Sustained Economic Growth", Journal of European Economic Association, 3, PP. 494-504.

Kalemli-Ozcan, S. (2010), "AIDS, Reversal of the Demographic Transition and Economic Development: Evidence from Africa, NBER Working Paper 12181.

Lardoux, S. and E. Van de Walle (2003), "Polygamie et fécondité en mileu rural sénégalais", Population, 58(6), PP. 807-836.

Muhsam, H. V. (1956), "The fertility of polygamous marraiges", Population Studies, 10, pp. 3-16

Pison G., “La démographie de la polygamie”, Population, vol. 41(1), (1986), pp. 93-122.

Appendix

A) Data information

	DHS II	DHS III	DHS IV	DHS V
Benin		1996	2001	2006
Cameroon	1991	1998	2004	
Cote ivory Coast		1994, 1998		2005
Ghana		1993	1998, 2003	2008
Madgascar	1992	1997	2003	
Malawi	1992		2000, 2004	2008
Nigeria	1990		1999, 2003	2008
Rwanda	1992		2000	2005
Senegal	1992	1997	2005	
Tanzania	1991	1996	1999, 2003, 2004	2005, 2007
Uganda		1995	2000	2006
Zimbabwe		1994	1999	2005

	DHS II	DHS III	DHS IV	DHS V
Benin		1996	2001	2006
Cameroon	1991	1998	2004	
Cote d'Ivoire		1994, 1998		2005
Ghana		1993	1998, 2003	2008
Madgascar	1992	1997	2003	
Malawi	1992		2000, 2004	2008
Nigeria	1990		1999, 2003	2008
Rwanda	1992		2000	2005
Senegal	1992	1997	2005	
Tanzania	1991	1996	1999, 2003, 2004	2005, 2007
Uganda		1995	2000	2006
Zimbabwe		1994	1999	2005

Table 1: DHS surveys used

B) Building individual infant mortality rate

B.1) Assumptions and framework

The main assumption is that the probability of death of a child does not depend on her rank into the brotherhood. Infant mortality is therefore assumed to be independent of the number of children a woman has[24].

One assumes that the infant's probability of death of a woman i can be decomposed into two components, a function $\mu(\bullet)$ of the observable individual characteristics X^i and an additional idiosyncratic probability z^i. To estimate the idiosyncratic component, we will

[24]This assumption is probably a crude approximation as the first pregnancies in a woman's life, especially if they went wrong, are likely to induce complications during following ones.

use k^i and n^i, respectively the number of children dead[25] and the total children the woman had.

$$\mu^i = \mu(X^i) + z_i \tag{19}$$

If we consider now the observed value of the mortality rate for a woman, it can only take discrete values which depends on n.

$$m^i = \frac{k^i}{n^i} \in \left\{\frac{p}{n^i}\right\}_{p=0}^{n^i} \tag{20}$$

Thus, the actual value of the mortality rate at the individual level depends on the number of children:

$$m^i = m(\mu^i, n) \tag{21}$$

Indeed if we consider the conditional probability of m^i given n and μ^i:

$$\mathcal{P}\left(\frac{k}{n}|n, \mu^i\right) = \binom{n}{k}(\mu^i)^k(1-\mu^i)^{n-k} \tag{22}$$

We can inverse this and compute the probability μ^i from m^i using the Bayes formula:

$$\mathcal{P}\left(\mu^i|n, m^i\right) = \frac{\mathcal{P}\left(m^i|n, \mu^i\right) \times \mathcal{P}(\mu^i)}{\int P(m^i|n, \mu^i) \times \mathcal{P}(\mu^i)} \tag{23}$$

The infant mortality's probability is to be computed at the individual level using Bayesian methods. To do so, we should first define a prior distribution of the idiosyncratic component z^i.

B.2) Using beta distributions to model priors

A natural candidate for the prior distribution is the uniform one. Assuming that $\mu^i \sim \mathcal{U}([0,1])$ allows calculating very easily the posterior distribution.

$$\mathcal{P}\left(\mu^i|n, m^i\right) = \frac{\binom{n}{k}(\mu^i)^k(1-\mu^i)^{n-k}}{\binom{n}{k}\int_0^1 x^k(1-x^i)^{n-k}dx} = \frac{(\mu^i)^k(1-\mu^i)^{n-k}}{\frac{(n-k))k!}{(n+1)!}} \tag{24}$$

We can therefore deduce the conditional expectancy for μ^i:

$$E\Big[\mu^i|n, m^i\Big] = \frac{(n+1)!}{(n-k)!k!}\int_0^1 x^{k+1}(1-x)^{n-k}dx = \frac{k+1}{n+2} \underset{n\to\infty}{\rightarrow} \mu^i \tag{25}$$

With such a "blind" prior, the empirical value converges to the actual probability for a very high number of children. But as the expectancy of the prior is arbitrary high equalling $\frac{1}{2}$, the estimates of μ^i for women with few children are largely biased upward. For instance a woman whose only child died as a mortality estimated to $\frac{2}{3}$, which is not plausible.

As $\mu^i \in [0,1]$ another convenient prior distribution is the beta distribution, $\mu^i \sim \mathcal{B}(\alpha, \beta)$.

[25] Here we call "dead" a child who did not survive beyond his first anniversary.

Let us assume that the idiosyncratic component z is such that the resulting probability μ^i is distributed according to a beta distribution on [0,1], where Γ is the Gamma function[26].

$$\mathcal{P}(\mu^i) = g(\mu^i) = \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)}(\mu^i)^{\alpha-1}(1-\mu^i)^{\beta-1} \tag{26}$$

Interestingly, the parameter α and β can be set to replicate the expectancy and the variance of any prior distribution on [0,1]:

$$E[\mu^i] = \frac{\alpha}{\alpha+\beta} \ , \ V[\mu^i] = E[\mu^i] \times \frac{\beta}{(\alpha+\beta)(1+\alpha+\beta)} \tag{27}$$

$$\alpha = \frac{E^2(1-E)}{V} - E \ , \ \beta = \frac{\alpha(1-E)}{E} \tag{28}$$

The posterior probability of μ^i for k and n given remains conveniently a beta distribution:

$$\mathcal{P}(\mu^i|k,n) = \frac{(\mu^i)^{k+\alpha-1}(1-\mu^i)^{n-k+\beta-1}}{\int_0^1 x^{k+\alpha-1}(1-x^i)^{n-k+\beta-1}dx} \Rightarrow \mu^i \sim \mathcal{B}(k+\alpha, n-k+\beta) \tag{29}$$

Therefore, we can deduce the posterior expectancy of the sought probability μ^i using the proprieties of the Beta distribution:

$$E\Big[\mu^i|k,n\Big] = E\Big[\mathcal{B}(k+\alpha, n-k+\beta)\Big] = \frac{k+\alpha}{n+\alpha+\beta} \tag{30}$$

The posterior expectancy can be rewritten as a linear combination of the prior expectancy $E^0[\mu^i]$ and the observable mortality rate m^i. The weights depends of the expectancy and the variance of the prior distribution and the number of children.

$$E\Big[\mu^i|m^i,n\Big] = m^i\frac{n}{n+w_{E,V}} + E^0[\mu^i]\frac{w_{E,V}}{n+w_{E,V}} \ , \ w_{E,V} = \frac{E^0(1-E^0)}{V^0} - 1 \tag{31}$$

As expected, the Bayesian estimates relies more on the prior for the women with few children. Also, the more accurate the prior distribution is[27], the more the prior distribution matters for the posterior estimates.

B.3) Empirical estimation of the individual probability of infant mortality

We start by calculating for each region and area (rural or urban) the average mortality rate for babies born into a specific period, $mort_t^r$. We distinguish first the period 1960-1979[28] and each five years span between 1980 and 2010. The indicator $mort_t^r$ is calculated as the ratio between the total number of infants dead within an area and a given period and the total number of children born in the same area and during the same period. This indicator attends to measure the external factors[29] influencing infant mortality. We introduce it in a probit model to estimate E^0. We regress, for each

[26] $\Gamma(z) = \int_0^\infty t^{z-1}e^{-t}dt$, $\Gamma(n) = (n-1)!$ if n is an integer

[27] that is the lower the variance V^0 of the prior distribution is.

[28] Because all DHS surveys only focussed on women less than 50, only a few children are born before 1980.

[29] Which are not related to the characteristics of the parents.

country separately, the *actual* mortality rate m^i, see equation. (32). We introduce also the year during which the woman was pregnant for the first time t_{p1}, the age a_{p1} and squared age at which the woman was pregnant for the first time and the mother's years of schooling h^i.

$$\mathcal{P}(m^i) = \Phi\left(\mu_0 + \mu^t t_{p1} + \mu^a a_{p1} + \mu^{aa} a_{p1}^2 + \mu^h h^i + \mu^r mort_t^r\right) \tag{32}$$

The expectancy E^0 is then set (33):

$$E^0 \equiv \mathcal{P}\Big(m^i | t_{p1}, a_{p1}, h^i, mort_t^r\Big) \tag{33}$$

It is difficult to estimate V^0 for such a regression. We will assume therefore that (34)[30]:

$$V^0 \equiv (E^0)^2 \tag{34}$$

[30] In practice, this convention does not modify much the results.