Polygyny and Poverty

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Abstract

Countries where polygyny (one man married to several wives) is allowed differ from monogamous countries in several demographic characteristics: Women marry extremely early, the age-gap between husbands and wives is large, fertility is high, and typically a brideprice is paid at marriage. In monogamous countries, on the other hand, parents traditionally gave a dowry (negative brideprice) to their daughters at marriage. Polygynous countries are also on average poorer than monogamous countries. This paper analyzes whether the marriage system can account for these observations. I present an overlapping generations model with a marriage market and endogenous fertility. Two different marriage systems are analyzed, one in which polygyny is allowed and one in which it is not (monogamy). I find that polygyny leads to higher fertility and age gaps than monogamy, and to a positive price for women, while the equilibrium brideprice under monogamy is negative. I also find that the capital-output ratio is lower under polygyny. The reason is that under polygyny investing in wives and selling children is an alternative investment strategy that crowds out investment in physical assets. To derive quantitative results, I calibrate the model to the average of polygynous countries. I find that banning polygyny decreases fertility by 30%, compared to a 40% difference in the data. The investment-output ratio roughly doubles and output per capita triples, which is close to the observed empirical differences.

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1 Introduction

Africa is the poorest continent in the world. Between 1965 and 1990, Africa's real GDP has exhibited no growth, while 17 countries in Sub-Saharan Africa grew at negative rates. At the same time, population growth has been extremely high. Sub-Saharan Africa's population is growing at 2.4 percent annually, which is almost twice the world average. This is caused by high fertility rates. The average total fertility rate in Sub-Saharan Africa was 5.2 in 2000, compared to only 3.2 in the Middle East and North Africa, 2.9 in East Asia and the Pacific, and 2.7 in Latin America and the Caribbean. In addition, investment rates are much lower than in other regions. Investment averages 10.9 % of GDP in Sub-Saharan Africa, compared to 17.2% in the Middle East and North Africa, 20.5% in East Asia and the Pacific, and 15.8% in Latin America and the Caribbean. This is qualitatively similar to what is found in growth regressions (Barro 1997): Investment is positively correlated with GDP per capita, while fertility is significantly negatively related to output per capita. These empirical observations are statements about correlations and not about causality, which leads to the following questions. Why do most Sub-Saharan African countries save so little? Through what channels does fertility affect output? And what determines fertility? This paper looks at differences in marriage systems as a basic determinant of both fertility and investment rates. In particular, this paper asks whether the high incidence of polygyny[1] in Sub-Saharan Africa plays a role in the lack of development in the region. I will show that one simple change (i.e. enforcing monogamy) can have significant effects on fertility, investment, and output simultaneously.

To assess the hypothesis that family structure affects aggregate variables such as output and capital stocks, I present an extensive empirical background in Section 2. Data is provided to show which countries still allow for polygynous marriages and what fraction of the population is engaged in this practice. I find that all but two of the countries with high levels of polygyny are in Sub-Saharan Africa. In these countries between 10 and 50 percent of the male population is engaged in a polygynous union. Nevertheless almost all men do marry. This shows that the Sub-Saharan African marriage pattern is very different from the common perception that polygyny means multiple wives only for a very small wealthy minority, as is the case in some Arab countries. Indeed,

[1]Polygyny is the state or practice of having more than one wife at one time. The term polygamy, which is often used as a synonym to polygyny, refers to both, a man having several wives (polygyny) or a woman having several husbands (polyandry).

the average numbers of wives per married men in the polygynous part of Sub-Saharan Africa is substantially above one, as high as 1.7 in some countries. I contrast aggregate variables for polygynous countries to a comparable group of monogamous countries. I find that women in polygynous countries marry on average 5.2 years earlier and have 2.6 children more than women in the monogamous group. The average age difference between husband and wife is 7 years, which is almost 4 years higher than in monogamous countries. In almost all countries with polygyny men pay a positive price for a wife; whereas giving dowries (i.e. paying a negative price for a woman) is a very common practice in monogamous countries. The macroeconomic differences are also striking; investment rates and capital-output ratios in monogamous countries are about twice as high as in polygynous ones, while per capita output is roughly three times as high.

I construct and analyze a theoretical model that demonstrates how polygyny can affect fertility and aggregate output. The model economy is populated by overlapping generations of men and women. Agents live for 3 periods, as children and as young and old adults. Apart from age and sex, agents are homogeneous. There is a market for wives in which fathers supply daughters, and in which adult men buy wives. Fertility is endogenously chosen by men. A man needs two inputs to produce a child: a fertile wife and resources to feed the child. Women are fertile only when they are young adults. A man can choose to marry either a wife of his own age or a wife that is a generation younger than him. Thus, the age gap between husbands and wives is endogenous. There is one consumption good that is produced with a standard technology using capital and labor as inputs. Wages and interest rates depend on the capital-labor ratio, which is endogenously determined by the agents' savings and fertility decisions. Two different economies are analyzed, one in which a man is allowed to have several wives (polygyny) and one in which he is allowed to have only one (monogamy).

I find that when allowed, polygyny occurs in equilibrium. It arises despite a balanced sex ratio precisely because the endogenous age gap adjusts: Marrying younger women in an environment where population size is growing makes polygyny possible. Under monogamy, on the other hand, there is no age gap in equilibrium. One key result is that the equilibrium in the polygynous society is characterized by a positive price of women, while monogamy leads to a negative price. Since in both scenarios the suppliers of women are the fathers, the different equilibrium prices have a big impact on the fertility decision. Knowing that daughters can be sold at a positive price acts as a subsidy to child-rearing, while a negative price is an effective tax on having children. At the same time these institutions affect the incentives to save. One channel affecting savings is that under polygyny, men face a trade-off between investing in physical assets or investing in wives. The return on wives are children, which provide a direct utility benefit and, under polygyny, also a monetary benefit in terms of the brideprice received for daughters. Hence, this alternative investment strategy partially crowds out investment in physical assets, leading to a lower capital-output ratio. The option of investing in wives is not available under monogamy, hence, there is no crowding out. A second channel is that under monogamy fathers save when young in anticipation of paying dowries when their daughters get married.

The model is then calibrated to match the investment and fertility rates in polygynous countries. To quantitatively assess the importance of the channels discussed above, I compute the steady state for the same parameters but now banning polygyny. The model can account for a substantial fraction of the differences observed in the data. The model predicts a surviving fertility differential of 1.4 children per women, compared to 1.5 in the data. Further, the model predicts an increase in the investment rate from 8.5% under polygyny to 18.4% under monogamy, which is similar in magnitude to the average investment rate in monogamous countries of 16%. Higher investment and lower population growth causes output per capita to go up by 276%. The observed difference in per capita output is roughly 150%. The model predicts an increase that is higher than the data because mortality is not taken into account. Calibrating the model to observed population growth rates instead of fertility rates lowers the output difference to 150%.

This paper is related to two strands of literature. The first is the primarily static economic analysis of the marriage market pioneered by Becker (1973, 1974), while the second is the dynamic analysis of fertility and savings decisions, with Barro and Becker (1989) being the standard reference. The focus on static environments to analyze the marriage market makes imbalances in the sex ratio the most important factor in determining the equilibrium brideprice (Becker 1974). Bergstrom (1994) provides a simple model that links the existence of brideprices to polygyny and endogenizes fertility.[2] Some people argue that dowry payments are not related to the marriage market, but should rather be interpreted as bequests given to daughters at marriage (Botticini and Siow 2002).[3] This inheritance interpretation, however, leaves open the question of why such bequests are not also given to daughters that live in polygynous societies. My paper introduces the

[2] Grossbard (1978) also links brideprices to polygyny but has not formal model.

[3] See also Brown (2002), Edlund (2001), and Zhang and Chan (1999) on this.

ideas put forth in the marriage literature into a dynamic context and explicitly relates marriage and fertility decisions. This allows the analysis of feedback effects, for example, the effects that marriage has on fertility, which in turn affects the supply of men and women in the next period, which then affects the marriage market equilibrium and so forth. The dynamic structure of my model also permits the analysis of demographic variables like age gaps and population growth rates, which are inherently dynamic phenomena.[4] Incorporating these dynamic effects is important as they lead to results which are significantly different from the static literature. First, I find a determinate sign of the brideprice for a monogamous society with a sex ratio of one and homogenous men and women.[5] Secondly, I show that a one-to-one sex ratio in a homogenous society does not preclude the occurrence of polygyny.[6] Finally, I find that steady state life-time utility for both men and women is higher when monogamy is prescribed by law, while Becker had argued that women are better off when polygyny is allowed. The reason for this difference is that in static models polygyny affects only how output is split up between husband and wives, while in this model polygyny significantly reduces output through its negative effect on savings decisions.

The standard model of fertility choice is Barro and Becker (1988, 1989). In this model, intergenerational external effects are the reason for bearing children. An alternative motive for producing children is to ensure old-age support.[7] In my model children are a consumption good, which can capture both of these motives. Incorporating a marriage market into a fertility model creates additional incentives (or disincentives) to have children because families take the future marriage prospects of their potential children into account. This channel links family structure to fertility and savings decisions and thereby to population growth and aggregate output. The ultimate goal of fertility models is typically to explain the demographic transition, which would then also explain why fertility levels differ across countries. One of the most convincing stories for the fertility decline is that it is triggered by a reduction in child mortality (Boldrin and Jones 2002). The story put forth in my paper complements the mortality explanation. Clearly, dif-

[4]The importance of the age gap (between husband and wife) in determining effective sex ratios and hence affecting the equilibrium price is also stressed in Rao (1993), who provides an empirical analysis in the rise in dowry payments in rural India.

[5]See Becker (1973) for his indeterminacy result.

[6]See Becker (1974) for his argument that either imbalances in the sex ratio or heterogeneity in men are necessary for polygyny.

[7]See for example Boldrin and Jones (2002).

ferences in mortality rates play a key role in understanding fertility differentials across countries. However, as documented in Section 2, they do not entirely explain the case of Sub-Saharan Africa.

More recently, some work has been done on analyzing the interaction of marriage norms and the economy. Edlund and Lagerloef (2002) compare love marriages with arranged marriages. The effect that positive brideprices (here a feature of arranged marriages) lower incentives to save is also present in their work.[8] Lagerloef (2002) provides a theory that jointly explains the decrease in polygyny and the increase in living standards. The argument crucially depends on the assumption that polygyny is a privilege reserved for the rich elite. Guner (1999) uses an overlapping generations model which generates family structure and inheritance rules endogenously, while allowing for polygynous marriages. While each of these papers deals with a particular aspect of my analysis, no attempt has been made so far to analyze the interplay of polygyny, marriage payments, fertility, and savings in one general framework.

This paper is structured as follows. Section 2 provides empirical evidence on the differences between polygynous and monogamous countries in the data. Section 3 sets up the model. The steady states under monogamy and polygyny are characterized in Section 4. Section 5 outlines the calibration and the quantitative results. Section 6 discusses some extensions to the model.

2 Empirical Background

In this paper, I argue that social norms determining family arrangements in a society can have an effect on demographic outcomes as well as on the macroeconomic performance of a country. This section provides some background on the incidence of polygyny, as well as on demographic differences across countries. Some of the data provided in this section will later be used to evaluate the model's predictions.

When talking about polygyny, the countries that most people think of are (middle-Eastern) Islamic countries. But while marrying up to four wives is generally accepted in the Arab world,[9] in practice polygyny is limited to a very small subgroup of the population in these countries. In Iran, only 1 percent of all married men have more

[8]Formally, their model does also allow for polygyny, but it does not happen in equilibrium.

[9]According to the Qu'ran a man is allowed to have up to four wives if he has the means to support them.

than one wife, and in Jordan about 3.8% of all married men live in a polygynous union. What is perhaps less well known is that many Sub-Saharan African countries[10] have much more wide-spread polygyny, with up to 50% of the male population being in a polygynous union. It is this second group that is the focus of this paper. The Table in Appendix A gives country-level demographic data for all countries where at least 10 percent of the male population is in a polygynous union.[11] The last column in the table gives the percentage of ever married men aged 45-49. Almost all men get married in this group of countries. This is worth emphasizing because a common perception is that two wives for some men means no wives for equally many men. The data shows that this is not true. Since the sex ratios in most countries do not deviate much from one, one wonders how high male marriage rates and a high incidence of polygyny are both possible.[12] The answer to this puzzle lies in the extremely high age gaps between husbands and wives coupled with a high population growth rate. Consider the simple example in which population doubles every generation and the age gap is an entire generation. In this extreme example, it is possible for *every* man to marry two wives.[13] The table in Appendix A shows that the difference in mean age at first marriage between men and women is almost 7 years in highly polygynous countries. Annual population growth in this area is currently 2.5 percent, which amounts to a 19% increase over 7 years. This would mean that on average each man could marry 1.19 wives, or put differently, 19% of the population could marry two wives. Note that as the average age gap takes only first marriages into account, the age gap with second wives has to be higher, which further increases the possible number of wives per men.

Polygynous countries differ from monogamous ones along several other demographic dimensions as well. One way to see this is to compute data averages for all polygynous countries and for all monogamous countries and to compare them. The problem with this simple comparison is that the group of monogamous countries includes countries

[10]Following the terminology employed by the United Nations, the term Sub-Saharan Africa includes all African countries South of the Sahara.

[11]Polygynous countries where less than 10% of all marriages are polygynous (and are hence excluded from the table) are Iran, Algeria, Syrian Arab Republic, Egypt, Pakistan, Morocco, Libya, Lebanon, Jordan, Tunisia, Yemen, India, Bahrain, Iraq, United Arab Emirates, Oman, and many of the other Sub-Saharan African countries.

[12]The highest sex ratios currently observed are no more than 8% more women than men. Thus, such an imbalance by itself cannot explain the levels of polygyny observed.

[13]Of course, this is not the only factor making widespread polygyny possible. Another component are high remarriage rates for women after their husband's death.

like the United States that differ from Sub-Saharan Africa in many respects. Instead of comparing polygynous countries with *all* monogamous ones, one should rather contrast them to a more comparable group. Given my modelling assumptions, a natural criterion is to select only countries where fathers make the marriage decision for their daughters. However, lacking a good measure of this feature, I have explored several other criteria for selecting countries. Note that almost all highly polygynous countries are located close to the equator, whereas for example European countries, for which the model is not a good approximation, are far away from the equator. To get a comparable group of monogamous countries, I therefore consider only those that have an absolute latitude of less than 20. There are about 60 monogamous countries fairly close to the equator, mainly in the Caribbean and the Pacific, parts of South America, and Africa, which I will simply call the monogamous group. The comparison between the polygynous and the monogamous groups is summarized in Table 1. An alternative criterion I have explored is to select monogamous countries based on income. This leads to very similar numbers (see Appendix B). Finally, averages for countries within Sub-Saharan Africa that have low levels of polygyny are also reported. In addition, the table includes data on Western Europe and North America.

The data reveals striking demographic differences between polygynous and monogamous countries (column 1 and 3). The average age difference between husband and wife in highly polygynous countries is 7 years compared to only 3.5 for the monogamous group. Most of this difference is caused by women marrying extremely early, more than 4 years earlier on average compared to women in monogamous countries. This pattern also manifests itself in the high proportions of married female teenagers: In polygynous countries 40 percent of females aged 15 to 19 are married, almost four times the rate for monogamous countries.

Women in polygynous countries have more children than in monogamous ones. One measure of fertility is the total fertility rate (TFR)[14] which in 1980 was 6.7 on average in polygynous countries compared to only 4.5 for monogamous countries. Demographers have pointed out the close link between infant and child mortality and fertility rates (Preston 1978).[15] One causal force typically given is that if many children die before adulthood, then parents need to produce more children to guarantee someone taking

[14] The number of live births per woman.

[15] Infant mortality is the percentage of live births that do not survive until age 1, while child mortality is the percentage of live births that die before the age 5.

Table 1: Demographics

Number of countries	High polyg.# (20)	Other SSA (27)	Monogamous $\|Latitude\| < 20$ (62)	North America Western Europe (21)
Measures of Fertility				
TFR, 1980	6.73	6.24*	4.55	1.84
TFR, 1990	6.2	5.73*	3.88	1.80
surviving 1 yr, 1980	5.47	5.09*	3.57	1.84
surviving 5 yrs, 1980	5.04	4.64*	3.56	1.84
avg. annual pop. growth, 1960-85	2.7%	2.6%	2.1%	0.8%
Mortality				
IMR, 1980	11.9	12.0	6.9	1.2
IMR, 1990	9.9	10.2	4.9	0.9
CMR, 1980	19.2	18.7	11.6	1.3
Demographics				
male age at marriage	25.8	26.6	26.9	29.3
female age at marriage	18.9	21.4***	23.4	26.8
age gap	6.9	5.09***	2.89	3.5
% women married by 19	40	21***	13	2
% population under 16, 1985	46	44*	38	20
Economic Variables				
$\frac{I}{Y}$ avg, 1960-85	8.5	12.8**	15.9	26.2
$\frac{K}{Y}$, 1985	1.0	1.5**	1.9	3.0
GDP p.c.,1980	1,029	1,360	2,587	11,950

Kuwait is excluded from this set because of its extremely high income due to oil reserves.
* significantly smaller (greater) than pol. countries at 10% level, ** 5% level, *** 1% level
Data Sources: See Appendix C

care of them in old age.[16] The table shows that infant mortality rates as well as child

[16] There is also the reverse force that lower fertility increases birth spacing which leads to lower child mortality. Despite a large amount of empirical research, the exact relationship between infant and child mortality and fertility, remains controversial (see for example Palloni and Rafalimanana (1999) and

mortality rates are indeed lower in monogamous countries. Therefore, a better measure of the number of children produced in a country is the number of surviving children. The table shows that mortality explains only part of the fertility differential across the two groups. There is a 2-child difference in the number surviving children (up to age 1). Another way to control for differences in mortality is to compare high polygyny countries to the other countries in Sub-saharan Africa.[17] The second column in the table shows data for these countries. Note that the average probability of dying before the first and the fifth birthday are almost identical in the two groups. Again, all measures of fertility are highest in the high polygyny region, for example the number of children born is roughly 10% higher in the highly polygynous group. Similarly, other demographic differences remain substantial: The average age gap for a married couple is only 5.1 years in the Sub-Saharan African control group, almost 2 years less than in the high polygyny group, while the proportion of women that gets married before the age 19 is 50% lower in the low polygyny group. These last two differences reinforce the argument made above that women marrying substantially older men is an important component of widespread polygyny.

Sub-saharan African countries with a high degree of polygyny are the poorest countries in the world. Their per capita GDP is 25% lower than that of the other countries in the region, and only 40% of the GDP of other monogamous countries located in the same latitude range. Differences in the output of countries are typically linked to differences in investment rates and hence capital stocks. The table therefore also shows data on these macroeconomic variables. Again, differences across the four groups of countries are substantial. Both capital-output and investment-output ratios are lowest in the polygynous countries. Compared to highly polygynous countries, investment rates are 50% higher in the rest of Sub-Saharan Africa and twice as high in the monogamous group.[18]

LeGrand and Phillips (1996)).

[17]There are almost 50 countries in Africa south of the Sahara, of which roughly half report polygyny rates of more than 10% while the other half has either lower rates or no data available.

[18]The investment output ratio provided is computed at PPP prices. Therefore, a low investment rate does not have to mean low savings, but could also be caused through a high price of investment goods in that country. However, the data shows similar differences for nominal savings rates (savings as a percentage of gross national product). The average savings rate for monogamous countries was 18.4% between 1960 and 1985, compared to only 13.5% for the polygynous group.

2.1 Brideprice and Dowry

The argument put forth in this paper implies differences in the direction of marriage payments across countries. Polygynous countries, it is argued, pay positive brideprices to acquire a wife while monogamous countries make a payment to the groom. It is therefore an obvious question whether we indeed observe this correlation between family arrangements and marriage payments in the data. Unfortunately, data on marriage payments is scarce. This section starts with some general background on marriage payments and then argues that the little data available is consistent with the implications of this paper.

A great variety of marriage payments are observed in the world (Goody and Tambiah 1973). The most commonly known is the *dowry*, which is the property that a wife or a wife's family gives to her husband upon marriage. Another fairly well-known practice is a payment from the groom to the bride's family at marriage, called the *brideprice*. Lesser known arrangements are gift or bride exchange, bride-service, and morgengabe.[19] The different systems are not always exclusive in that some cultures use a combination of the above. What matters most for the economic analysis is whether the sum of the various compensations is a net flow from the groom (or his kin) to the bride's kin or the reverse. For the purpose of this paper, I call any net transfer coming from the groom (or his family) a brideprice and any net transfer from the bride's side a dowry.

Brideprices are most common today in African and Muslim countries. A typical brideprice in Africa consists of cattle. In many (non-African) Muslim countries, a brideprice consists of jewelry, money, gold, and/or land. Brideprices also used to be common in China. A dowry often consists of household items, jewelry, and clothes, but can also be a house or land.[20] Dowries were common in ancient Greece and Rome, and in Europe until the end of the 19th century. Europeans also brought this tradition to North and South America during the 17th and 18th century. Today, dowries are very popular in South Asia.

For each of the countries with high levels of polygyny (see Appendix A), I have reviewed country studies written by anthropologists and ethnographers. My finding is that brideprices are the norm in polygynous countries, with the exception of Bangladesh where both dowries and brideprices are currently given. Bangladesh is an interesting case

[19] A payment from the groom to the bride.

[20] Caldwell, Reddy, and Caldwell (1983) document that the dowry typically increases from menache onward. The authors also argue that dowries are highly correlated with the desirable qualities of the son-in-law in a way that brideprices did not for daughters-in-law.

Table 2: Polygyny and Brideprices

Polygyny/Monogamy	brideprice	dowry or no price
monogamous	37.5%	62.5%
less than 20 % pol.	52.8%	47.2%
more than 20% pol.	90.8%	9.2 %

Source: Hartung 1982

since marriage traditions have changed recently. Baden (1992) reports that dowries in Bangladesh are a new phenomenon; since the early 1970s, the Islamic "mehr" (brideprice) system has been supplanted by the dowry system.[21] Dowries were first seen in the urban middle class and then spread to rural upper and middle classes. Since polygyny is still fairly common in Bangladesh the use of brideprices is not very surprising in light of the theory provided. However, the question arises why dowries have recently become popular. It has been argued that this may partly be attributed to the importance of hypergamy, which allows women to marry up to a higher status group, but not men (Gaulin and Boster (1990) and Anderson (2001)). This practice creates an artificial surplus of women in each status group except for the lowest (as long as not too many men take more than one wife). Therefore hypergamy may be the reason why dowries are most popular in the highest status groups and why brideprices are still common for the lower ones.

Let us now turn to historical evidence. Information on marriage traditions gathered by ethnographers has been systematically organized by Murdock (1986) in his Ethnographic Atlas, which contains roughly 1,000 societies. Hartung (1982) uses this data to study the correlation of marriage payments with polygyny. He finds that more than 90% of all societies with widespread polygyny (more than 20% of all married men) use brideprices. On the other hand, Table 2 shows that 2/3 of the monogamous societies do *not* use brideprices. Botticini and Siow (2002) provide on overview of marriage payments in past civilizations. Out of 6 civilizations classified as polygynous, 4 pay a positive price to acquire a bride. Out of the 9 monogamous civilizations for which data on marriage payments in available, 7 are reported to use dowries as the predominant marriage payment.[22]

[21] See also Baden (1994) and Lindenbaum (1981).

[22] Most civilizations use several types of payment simultaneously. The statement made here refers to

While more and better data would be desirable, the evidence seems to suggest a high correlation between polygyny and the usage of brideprices, on the one hand, and between monogamy and the practice of dowry, on the other hand.

3 The Model

I consider an infinite-horizon, overlapping generations model. Agents live for 3 periods: as children, as young adults, and as old adults. Only adults make choices. Young adults are endowed with one unit of labor which they supply inelastically at wage w. Agents derive utility from consumption in both periods of their lives and from their children in the following sense. They receive utility from the number of children and disutility from the number of unmarried daughters. There are men and women in this economy. In order to have children, agents need to be married to someone of the opposite sex.

Fertility is endogenous. For simplicity, I assume that men choose the number of their off-springs. Other intra-family decision-making mechanisms are discussed in Section 6. Half the children are male, and half are female.[23] The cost of raising children depends on the number of wives and children a man has. Let $g(f_t, n_t)$ be the cost of child-rearing as a function of the total number of children born to the man in t, f_t and the number of (fertile) wives in t, n_t. The details of the child production technology are laid out in Section 3.3. I assume differential fecundity for men and women. While all adult men (independent of their age) are fertile, women are fertile only as young adults.[24]

There is a decentralized marriage market in which fathers can sell their daughters and men can acquire brides. Brides come in two ages, either as children (girls) or as adults (women). Let $p_t^g \in \mathbb{R}$ denote the price of girls at time t, and $p_t^w \in \mathbb{R}$ the price of a young adult women at time t. A negative price for a bride is interpreted as a dowry. Note that the price of girls and adult women need not coincide, since the timing of their fecundity is different. While adult women can bear children only during the current period, girls will be fertile in the next period. The potential buyers in the bride market are adult men of both ages. Since a man is fertile both when young and when old, he

the net payment (see the last column in Table 1 in Botticini and Siow (2002)).

[23] See Edlund (1999) for a framework in which the sex of a child is endogenous. Given that real world sex ratios deviate no more than 8% from one, even for the most extreme countries, this is of limited relevance for the questions addressed in this paper.

[24] Siow (1998) uses a similar framework to analyze how differential fecundity affects gender roles in monogamous unions.

can have children in either (or both) periods of his adult life. Therefore he has many options. Superscripts denote the age of a man, while subscripts refer to the type of wife. A young man can marry a girl, n_g^y, or an (adult) woman, n_w^y. Alternatively, he could marry a woman when he is old, n_w^o. It would never be optimal for an old man to marry a girl, since his wife would be fertile after the man's death, and this choice is subsequently omitted from the problem. The timing of births is also endogenous. A man can have children when he is young, f^y, or when he is old, f^o. Fathers take care of their daughters' marriage decisions. Let d_g^y be the number of girls a man gives into marriage when he is young, and d_g^o the number of girls given into marriage when he is old. Alternatively, daughters can stay with their parents for one period and then be given into marriage as young adults. Depending on when daughters were born, this would happen when fathers are old, d_w^o, or potentially after their death, d_w^d, where the superscript d stands for 'dead'. Then $d = d_g^y + d_w^o + d_y^o + d_w^d$ is the total number of married daughters.

In the following two different regimes will be considered: one in which polygyny is allowed, and one in which it is not. The two worlds are identical except for one constraint: in the monogamous world, a man can marry at most one wife.

3.1 Polygynous Society

In the polygynous society men are allowed to marry as many wives as they wish. To keep the model tractable, no integer restrictions are made on any of the variables. Recall that the subscripts g and w refer to 'girls' and 'women', and denote the age of the bride at the time of the marriage, while the superscripts y, o and d stand for 'young', 'old' and 'dead', corresponding to the age of the man.

3.1.1 Men

The choice variables for a man are consumption c, savings (investment in physical capital) s, number of wives n, number of children f, and how many daughters to sell d. Formally, the man's problem is as follows (time subscripts are suppressed for ease of exposition):

$$\begin{aligned}
\max_{c,s,n,f,d} \quad & \ln(c^y) + \beta \ln(c^o) + \gamma \ln(f^y + f^o) - v(\frac{f^y + f^o}{2} - d) \\
s.t. \quad & c^y + s^y + p_g n_g^y + p_w n_w^y + g(f^y, n_w^y) \leq w + p_g d_g^y \\
& c^o + s^o + g(f^o, n_g^y + n_w^o) \leq (1 - \delta + r) s^y + p_g d_g^o + p_w d_w^o \\
& 0 \leq p_w d_w^d + (1 + r - \delta) s^o \\
& d_g^y + d_w^o \leq \frac{f^y}{2} \\
& d_g^o + d_w^d \leq \frac{f^o}{2} \\
& c^y, c^o, s^y, s^o, f^y, f^o, n_g^y, n_w^y, n_w^o, d_g^y, d_g^o, d_w^o, d_w^d \geq 0.
\end{aligned} \tag{1}$$

where β is the discount factor, and γ captures how much a man cares about the number of children. The last term of the utility function is the disutility a man receives from having unmarried daughters. The return on investment is standard: gross interest rate $(1 + r)$ minus depreciation δ.

The first constraint is the budget constraint when young. The income during this period is the wage w, and potentially the revenues from selling daughters $p^g d_g^y$. Expenditures are made for consumption, the purchase of wives (girls and/or adults), and the cost of raising children during this period, $g(f^y, n_w^y)$. The budget constraint for an old man looks similar except that he is not allowed to buy any girl-brides.[25] The third constraint is a budget constraint for after the man's death. This may seem odd at first, but note that the brideprice may turn out to be negative, in which case a man may want to set up a "trust fund," s^o, to ensure that his daughters can get married even after he is deceased. The last two constraints simply say that a man cannot sell more daughters than the number of female children he has in the relevant period. Recall that always half of the children are female.

3.1.2 Women

Women have the same utility function as men. They receive utility from consumption, from having kids, and disutility from unmarried daughters. As men, women are endowed with one unit of labor when young adults and they need to save for their retirement.

[25] Allowing for this choice would not alter the results since a man would never choose to marry girls when he is old.

One crucial difference between men and women is their fecundity: women can bear children only when as young adults. A second important difference is that women are not allowed to marry more than one husband, that is, I assume that polyandry is not an option, moreover, the marriage decision is taken by her father. Finally, husbands make all decisions about child-bearing and finding grooms for their daughters. These assumptions are made to keep the problem tractable, alternative ways of intra-family decision-making are discussed in Section 6. Women also incur a cost of child-rearing. I assume that the cost of child-rearing incurred by all wives jointly is equal to the husband's payment.[26] Further, to treat women symmetrically, I assume that each of the wives incurs an equal share of this cost. Thus, the cost of child-rearing for a woman whose husband has a total of n wives and f children is $\frac{g(f,n)}{n}$. The number of children for an unmarried women is assumed to be always equal to 0.

Then the problem of a woman, given her father's and husband's decisions (f, n, d), is

$$\begin{aligned} &\max_{c^y, c^o, s} \ln(c^y) + \beta \ln(c^o) + \gamma \ln(\frac{f}{n}) - v(\frac{f}{n} - d) \\ &s.t. \;\; c^y + s + \frac{g(f,n)}{n} \leq w \\ &\qquad c^o \leq (1 + r - \delta)s \end{aligned} \tag{2}$$

In sum, the only choices left for a woman are consumption and savings decisions.

3.2 Monogamous Society

The model is very similar to the above, with the additional restriction that a man can marry only one wife. The woman's problem is exactly the same as before. The new problem of the man can be written as

[26] This could easily be generalized to any other cost sharing rule between spouses. The qualitative results would not be affected by this.

$$
\begin{aligned}
\max_{c,s,n,f,d}\ & \ln(c^y) + \beta \ln(c^o) + \gamma \ln(f^y + f^o) - v(\frac{f^y + f^o}{2} - d) \\
s.t.\ \ & c^y + s^y + p_g n_g^y + p_w n_w^y + g(f^y, n_w^y) \leq w + p_g d_g^y \\
& c^o + s^o + g(f^o, n_g^y + n_w^o) \leq (1 - \delta + r)s^y + p_g d_g^o + p_w d_w^o \\
& 0 \leq p_w d_w^d + (1 + r - \delta)s^o \\
& d_g^y + d_w^o \leq \frac{f^y}{2} \\
& d_g^o + d_w^d \leq \frac{f^o}{2} \\
& n_g^y + n_w^y + n_w^o \leq 1 \\
& c^y, c^o, s^y, s^o, f^y, f^o, n_g^y, n_w^y, n_w^o, d_g^y, d_g^o, d_w^o, d_w^d \geq 0
\end{aligned}
\tag{3}
$$

3.3 Child Production

To have a child, a man needs two inputs, fertile wives and some consumption good. Given the number of wives and desired children, the amount of the consumption good required can be expressed as a cost function: $g(f, n)$. The following assumption is made on the functional form of the cost function.

Assumption 1 *$g(f, n)$ is weakly increasing in f, strictly decreasing in n, $g(f, n) > 0,\ \forall (f, n)$, and $lim_{n \to 0}\ g(f, n) = \infty$.*

This assumption assures that children are never for free, and that it is impossible to have children without a fertile wife. Moreover, the average cost of a child is non-decreasing in the number of children. Also, more wives can produce the same number of children at a strictly lower cost. For the numerical results, I assume the following functional form: $g(f, n) = \epsilon \frac{f^2}{n}$. This cost function corresponds to a constant returns to scale production function. Solving for f, the corresponding production function is $f = f(n, g) = \sqrt{\frac{ng}{\epsilon}}$, where g is the consumption good input into child production. This function is Cobb-Douglas. The description so far referred only to the man's child-rearing costs. Women incur an additional cost, which is assumed to be identical to the husband's cost. Note that the functional form chosen abstracts from externalities among the wives. It is neither beneficial nor costly to have co-wives around. This implies that the cost function for women is identical under both family arrangements: The cost for a woman of having f own children is always ϵf^2.

3.4 Population Dynamics

Let M_t be the number of young adult men alive in period t, call this generation t. We are interested in balanced growth paths of this economy, i.e. equilibria in which population grows at a constant rate and per capita variables are constant. Let $\eta = \frac{M_{t+1}}{M_t}$ denote the population growth factor. The number of men in $t+1$ is determined by the number of fathers in period t and how many children each of them has. Formally, the law of motion for M_t is $M_{t+1} = \frac{1}{2}[M_t f_t^y + M_{t-1} f_t^o]$. On the balanced growth path, this can be rewritten as

$$\eta^2 = \frac{1}{2}[\eta f^y + f^o] \tag{4}$$

3.5 Production

There is an aggregate technology that uses capital and labor to produce the consumption good. I assume a standard Cobb-Douglas production function, $Y_t = F(K_t, L_t) = AK_t^\alpha L_t^{1-\alpha}$. The firm maximizes profits. The equilibrium wage is $w_t = (1-\alpha)AK_t^\alpha L_t^{-\alpha}$ and the equilibrium interest rate is $r_t = \alpha AK_t^{\alpha-1} L_t^{1-\alpha}$. Each young adult supplies one unit of labor inelastically, hence aggregate labor supply is $L_t = 2M_t$. In equilibrium, the capital stock used for production in $t+1$ is equal to aggregate savings in t. Men potentially save when young and when old (as a trust fund for their daughter's marriage) and women may save when they are young. Hence, $K_{t+1} = (s^y + s_f)M_t + s^o M_{t-1}$.

The analysis in this paper focuses on balanced growth path equilibria where the capital-output ratio stays constant. Let $\xi = \frac{K}{Y}$. As we will see later, polygynous and monogamous societies differ in their capital-output ratios. In equilibrium, the aggregate capital-output ratio is related to individual decision-making in the following way:

$$\xi^* = \frac{K}{Y} = \frac{1}{A}\left(\frac{s^* + s_f^* + \frac{s^{o*}}{\eta^*}}{2\eta^*}\right)^{1-\alpha} \tag{5}$$

This expression shows that potential differences between polygynous and monogamous countries may be caused by two different factors: differences in saving rates and differences in the population growth rate.

The investment-output ratio and output per capita can be derived similarly

$$\frac{I}{Y} = \frac{K_{t+1} - (1-\delta)K_t}{Y_t} = [\eta^* - 1 + \delta]\,\xi^* \tag{6}$$

In standard models, the number of people is equal to the number of workers, which implies that output per capita is equal to output per worker. This is not true in this environment, since both children and old people do not work. Moreover, the relationship between output per worker and output per capita depends on how fast the population is growing, which is endogenous. The following equation derives this relationship formally.

$$Y_{pc} = \frac{Y_t}{2M_t + 2M_{t-1} + 2M_{t-1}} = \frac{\frac{Y}{L}}{1 + \eta^* + \frac{1}{\eta^*}} \;, \tag{7}$$

where output per worker is equal to $\frac{Y}{L} = A^{\frac{1}{1-\alpha}}(\xi^*)^{\frac{\alpha}{1-\alpha}}$.

3.6 Definition of Equilibrium

In addition to the markets for capital and labor, there are two non-standard markets in this economy: A market for female children and a market for adult women.

Consider the market for girls first. Girls are demanded only by young adult men, hence the total demand is $n_g^y M_t$. The supply, on the other hand, might come from young or old fathers, adding up to a total supply of $d_g^y M_t + d_g^o M_{t-1}$. Therefore, market clearing for girls is $n_g^y M_t = d_g^y M_t + d_g^o M_{t-1}$. On the balanced growth path, one can rewrite this equation by substituting η for the population growth rate.

$$n_g^y \eta = d_g^y \eta + d_g^o \tag{8}$$

Now, let us consider the market for young women. Supply of young adult women can come from fathers who had daughters when they were young or fathers who had daughters when they were old. The total supply of adult brides in t is $d_w^o M_{t-1} + d_w^d M_{t-2}$. The demand for adult brides may also come from two types of men, young and old. Market clearing for adult brides in period t is $d_w^o M_{t-1} + d_w^d M_{t-2} = n_w^y M_t + n_w^o M_{t-1}$. On the balanced growth path, this can be simplified to:

$$d_w^o \eta + d_w^d = n_w^y \eta^2 + n_w^o \eta \tag{9}$$

I solve for balanced growth paths of the two economies, that is, equilibria where population and output both grow at a constant rate and per capita variables stay constant. Since agents in this model are homogenous (except for age and sex), I focus on symmetric equilibria where all agents of a given age-sex type receive the same allocation.[27]

[27] I conjecture that there are no asymmetric steady states, and that the qualifier symmetric is therefore redundant. But this has not yet been proven.

Definition 1 *A symmetric balanced growth path for the economy where polygyny is allowed is an allocation: consumption* (c^y, c^o, c^y, c^o_f)*, savings* (s^y, s^o, s_f)*, number of wives* (n^y_w, n^y_w, n^o_w)*, numbers of children* (f^y, f^o_t)*, and numbers of daughters sold* $(d^y_g, d^o_g, d^o_w, d^d_w)$*, prices* (p^g, p^w, r, w)*, a population growth factor* η *and a capital-output ratio* ξ *such that*

- *Given prices,* (c, s, n, f, d) *solves the man's problem (1).*
- *Given prices and her father's and husband's decisions* (f, n, d)*,* (c^f, s^f) *solves the woman's problem (2).*
- *Market for girls clears (condition (8) holds).*
- *Market for adult women clears (condition (9) holds).*
- *Profit maximization:* $r = \frac{\alpha}{\xi}$ *and* $w = (1-\alpha)A^{\frac{1}{1-\alpha}}\xi^{\frac{\alpha}{1-\alpha}}$
- *Aggregate variables are consistent with individual decision-making:*
    1. ξ *is given by (5).*
    2. *Population dynamics evolves according to (4).*

Definition 2 *A symmetric balanced growth path for the economy where polygyny is banned is defined analogously, except that the man's problem is given by (3).*

4 Characterizing the Balanced Growth Path

We will see that whether monogamy is enforced or not makes a big difference, both qualitatively and quantitatively. In the following, I will first give some analytical results. Analytical results can be obtained for the sign of the brideprice, for the demographic structure (who marries whom, marriage age, age gap etc.), and for the relationship between the population growth rate, fertility rate, and the average number of wives per man. However, the entire model cannot be solved analytically.[28] Therefore, implications for fertility rates, savings rates, and output can be determined only numerically. Numerical results are presented and discussed in Section 5.

[28]The reason is that the equation determining the equilibrium brideprice under monogamy is a highly non-linear function. Under polygyny the equilibrium fertility rate is the solution of a polynomial equation of degree 4. In both cases, all other variables can be solved explicitly as functions of the brideprice and fertility respectively.

4.1 Polygyny

Proposition 1 *If polygyny is allowed, then on any balanced growth path equilibrium:*

1. *The brideprice is always strictly positive:* $p_t^g > 0$ *and* $p_t^w > 0$.
2. *There is an age gap between husband and wife* ($n_w^y = 0$).
3. *Men marry when young* ($n_w^o = 0$).
4. *Men have children when young* ($f^y = 0, f^o > 0$).
5. *Women are given into marriage as children* ($d_g^o > 0, d_g^y = d_w^o = d_w^d = 0$).

Proof. Part 1 is very intuitive. Suppose for some period the price of girls p_t^g was either negative or zero. Then a man would buy an infinite amount of wives, because it would make child production cheaper. This cannot be an equilibrium. Equally, if $p_t^w \leq 0$, both men of generation t and $t-1$ would demand an infinite number of wives. Parts 2 and 3 are discussed in Appendix D. Fertile wives are needed for child-production, which together with 2 proves 4. Part 3 together with market clearing implies that the only daughters given into marriage in equilibrium are girls. Since by part 4 only old men have girls part 5 follows immediately. □

Proposition 1 can be used to solve for all variables as a function of the equilibrium number of children per man. The population dynamics equation (4) gives the population growth factor: $\eta = \sqrt{\frac{f}{2}}$. From market clearing for girls (8) together with the population growth factor determined above, one can solve for the equilibrium number of wives $n_g^y = \sqrt{\frac{f}{2}}$. Finally, one might be interested in the total fertility rate (i.e. number of children per woman), which is given by $\frac{f}{n_g^y} = \sqrt{2f}$. Proposition 2 summarizes these additional results.

Proposition 2 *The demographics along the balanced growth path of the polygynous society can be expressed as a function of the equilibrium number of kids per man, f, in the following way:*

1. *Number of wives per man is* $\sqrt{\frac{f}{2}}$.
2. *The total fertility rate is* $\sqrt{2f}$.
3. *Population growth is* $\frac{M_{t+1}}{M_t} = \sqrt{\frac{f}{2}}$.

Proposition 2 shows that polygyny is possible with a sex ratio of one and a homogenous population.[29] All that is needed to make general polygyny feasible is a growing population and men marrying younger women. Note also that if parameters are such that the equilibrium number of children is exactly 2, then the population is not growing and the equilibrium number of wives is exactly 1. So for specific parameter values monogamy can arise endogenously.

Using the results above, the man's problem can be rewritten as a simpler problem.

$$\begin{aligned} &\max_{c,f,n,s} \ln(c^y) + \beta \ln(c^o) + \gamma \ln(f) \\ &s.t. \quad c^y + s + pn \leq w \\ &\qquad c^o + g(f,n) \leq (1-\delta+r)s + p\frac{f}{2} \\ &\qquad \text{non-negativity constraints on all variables.} \end{aligned} \tag{10}$$

Note that the last term of the utility function dropped out because it is constant at $d_g^o = \frac{f}{2}$. The intuition is simply that given a positive price, it will always be optimal to sell all one's daughters, hence the disutility from unmarried daughters becomes irrelevant.

The first order conditions of this simplified problem are

$$f: \qquad \frac{\gamma}{f} + \frac{p\beta}{2c^o} = \frac{\beta}{c^o}\frac{\partial g}{\partial f} \tag{11}$$

$$n: \qquad \frac{p}{c^y} = \beta\frac{1}{c^o}\left(-\frac{\partial g}{\partial n}\right) \tag{12}$$

$$s: \qquad \frac{1}{c^y} \geq \beta\frac{1}{c^o}(1-\delta+r) \tag{13}$$

$$= 0, \text{ if } s > 0$$

The left hand side of equation (11) gives the marginal benefit from having children, which consists of two parts, the direct utility from having a large family, plus the revenues from selling daughters. A man chooses the number of children, k, such that this benefit is equal to the marginal cost of another child, which is the right hand side. Equation (12) equates the marginal costs and benefits from marrying another wife. The marginal cost is given by the costs of acquiring the wife, while the benefits are the reduced costs of child-rearing.[30] Equation (13) says that as long as savings are strictly positive, the

[29] Becker (1974) had argued that either an imbalance in the sex ratio or heterogeneity across men was a necessary condition for polygyny.

[30] Recall that $g(f,n)$ is decreasing in n by assumption, and hence the derivative is negative.

marginal utility from consuming when young has to be equal to the discounted marginal utility of consumption when old.

To show existence of a balanced growth path, it needs to be verified that the man's problem has a solution. Note that the cost function in the budget constraint makes the problem non-convex. Appendix D shows that the problem can be rewritten as a convex problem. The first order conditions to the transformed problem are then necessary and sufficient conditions for a maximizer of the man's problem. Existence can be proved by construction: As long as all first order conditions hold and markets clear, a non-trivial balanced growth path exists. Using the results from Proposition 1 and 2 one can solve for all variables as a function of the equilibrium number of children, f. The equilibrium number of children can then be determined by the first order condition with respect to k. The first order condition, evaluated at the equilibrium number of wives, turns out to be a polynomial equation of the order four. As long as this polynomial has a strictly positive root, a non-trivial balanced growth path exists and it has the properties discussed in this section. For certain combinations of parameters, this is not the case. Then no constant price exists that equates supply and demand for daughters. In these instances, the only equilibria are non-stationary. Further details on this are given in Appendix D.

4.2 Monogamy

This section characterizes the balanced growth path when polygyny is not allowed. In this world, no man can have more than one wife. In the last section, we saw that there are parameters such that monogamy is an equilibrium for the polygynous model. Obviously then this would also be an equilibrium for the monogamous model. In other words, if parameters are such that there is no population growth, then it is irrelevant whether polygyny is allowed or not. Restricting parameters to the case of strictly positive population growth is therefore crucial for generating interesting comparative statics results between the two marriage systems. I will show that as long as population growth is positive, the one-wife constraint is indeed binding, and the balanced growth paths of the two regimes differ along many dimensions. One additional assumption is needed for the results in this section.

Assumption 2 *Assume $v'(0)$ is proportional to the difference in utilities of a married and an unmarried woman.*

Assumption 2 says that the disutility from unmarried daughters is a fraction of the disutility that the daughter would suffer from being unmarried. This guarantees that fathers are always willing to pay large enough dowries to assure marriage for all daughters.[31] I will first show that under Assumption 2 men marry women their own age as long as the population is growing.

Proposition 3 *On the balanced growth path, either*

1. $n_w^y = 1$ *(and* $n_g^y = n_w^o = 0$*) or*

2. $\eta \leq 1$

Proof. From the market clearing equations (8) and (9) it follows that the following has to hold in equilibrium:

$$(d_g^y + d_w^o)\eta + d_g^o + d_w^d = (n_g^y + n_w^o)\eta + n_w^y \eta^2.$$

It follows from Assumption 2 that a father will sell all his daughters (independent of the brideprice). This can be used to rewrite the equation above in terms of children born:

$$\frac{f^y}{2}\eta + \frac{f^o}{2} = (n_g^y + n_w^o)\eta + n_w^y \eta^2$$

From the population law of motion (4) it follows that the left-hand side is equal to η^2, which can be used to rewrite the equation as

$$\eta = (n_g^y + n_w^o) + n_w^y \eta \tag{14}$$

Equation (14) together with the constraint from the man's problem that $n_g^y + n_w^o + n_w^y \leq 1$ implies that either $n_w^y = 1$ and $n_g^y + n_w^o = 0$ or that $\eta = \frac{n_g^y + n_w^o}{1 - n_w^y} \leq 1$ □

Proposition 3 says that age-gap marriages under monogamy are possible only as long as population is either constant or shrinking. Given that populations are growing in most developing countries, for the remainder of the paper I will focus on parameters such that population growth is strictly positive. The next proposition characterizes the balanced growth path for this case.

[31] If v does not satisfy Assumption 2, then a man might prefer to keep some daughters unmarried. For this case, there exists a monogamous equilibrium with an age gap and some daughters remaining unmarried. Preliminary results show that if the model is calibrated to match total fertility rates, then this implies an extremely high proportion of unmarried women (40%).

Proposition 4 *Any symmetric balanced growth path with positive population growth*[32] *has the following features:*

1. *Each man marries exactly 1 wife.*

2. *There is no age gap between husband and wife:* $n_w^y = 1$ *(and* $n_g^y = n_w^o = 0$*).*

3. *Men have children when they are young* ($f^y > 0, f^o = 0$)*.*

4. *Women are given into marriage as young adults* ($d_w^o > 0, d_g^y = d_g^o = d_w^d = 0$)*.*

5. *Population growth is* $\eta = \frac{M_{t+1}}{M_t} = \frac{f^y}{2}$*.*

Proof. Given the assumption of positive population growth, 1 and 2 follow immediately from Proposition 3. Then, since men marry a fertile wife when young, the child production technology implies that men have children while they are young, which is part 3. Market clearing together with 2 says that only adult daughters are given into marriage. By 3, adult daughters have old fathers (as opposed to dead fathers). This implies $d_w^o > 0$, and all other daughter variables are zero, which is 4. By assumption 2 we know that all daughters are sold, $d_w^o = \frac{f^y}{2}$. Using this and $d_w^d = n_w^o = 0$ (from 2 and 4), market clearing (equation 9) can be used to solve for the population growth factor $\eta = \frac{f^y}{2}$, which is 5. □

Using the results above, the problem of a man can be written as:

$$
\begin{aligned}
&\max \ln(c^y) + \beta \ln(c^o) + \gamma \ln(f) \\
&c^y + s + p + g(f,1) \le w \\
&c^o \le (1 - \delta + r)s + p\frac{f}{2}
\end{aligned}
\tag{15}
$$

A man living in a monogamous society faces a different decision problem from a man living in a polygynous environment. This can be illustrated by comparing the simplified monogamous problem (15) with the polygynous problem (10). The equilibrium timing of births will be different, which results in a different timing of the child-rearing expenditure.

[32] Of course, population growth is an endogenous variable. Really, this is an assumption on parameters. Parameters have to be such that $f > 2$ occurs in equilibrium. I have not been able to characterize the set of parameters under which the proposition is true, but there are many examples that do indeed satisfy this assumption. Intuitively, γ is required to be large enough and ϵ not to be too large, given the other parameters.

This can be seen from the first order conditions:

$$f: \qquad \frac{\gamma}{f} + \frac{\beta}{2c^o} p = \frac{1}{c^y}\left(\frac{\partial g}{\partial f}\right) \tag{16}$$

$$s: \qquad \frac{1}{c^y} = \frac{\beta}{c^o}(1-\delta+r) \tag{17}$$

These first order conditions differ from equations (11) - (13) in several respects. Firstly, there is no derivative with respect to the number of wives n. Secondly, the cost of bearing children is not discounted in equation (16) because the cost is borne earlier compared to a man living in the polygynous society. Finally, as we will see later, the equilibrium brideprices differ, which leads to different incentives to have children.

4.2.1 Equilibrium Dowry

As argued at the beginning of this section, in a monogamous BGP equilibrium with positive population growth, all men marry when young. It still remains to be shown that such an equilibrium exists and what determines the equilibrium brideprice. To show that an equilibrium with the demographics as described in Proposition 4 exists, one needs to show that there are prices (p^g, p^w) that make $(n_w^y = 1, n_g^y = n_w^o = 0, f^y > 0, f^o = 0, d_w^o = \frac{f^y}{2}, d_g^y = d_g^o = d_w^d = 0)$ an optimal choice for a man. Consider the following steps

1. Assume $p^g = \frac{p^w}{1-\delta+r}$. This makes a man indifferent between selling his daughters as girls, or waiting a period and selling them as young adults. It also makes a man indifferent between marrying a female child when young or marrying a young adult when he is old.

2. Since 1 establishes the indifference between two wife choices (n_g^y and n_w^o), all that is left to show is that marrying an adult bride when young (n_o^y) is weakly better than either of the two other possible brides or any convex combination. Note, however, that since kids are produced with a constant returns to scale technology using wives and the consumption good as inputs, using a convex combination of wives can never be cheaper than simply using the "cheapest" of the three types of wives. It is therefore sufficient to show that $n_w^o = 1$ is at least weakly worse than $n_w^y = 1$.

3. To show that an balanced growth path exists, all that is left to show is that there

is a price p^w such that a same-age marriage is weakly better than an age-gap marriage, which is discussed in Appendix E.

Proposition 5 *If* $\frac{wA}{\epsilon(\gamma+2\beta+2)} < 4(1+r-\delta)$ *and population growth is positive*[33] *then there exists a symmetric BGP equilibrium and it has the following additional properties:*

1. $p^w < 0$
2. $p^g = \frac{p^w}{1-\delta+r}$
3. $f^* < 2(1-\delta+r^*)$

Again, as in the polygynous model, for some parameters, no symmetric balanced growth path will exist. For certain parameters, it may also be the case that there is a balanced growth path involving positive brideprices. A complete characterization of these possibilities has not been derived yet.

4.3 Discussion of the Analytical Results

This section summarizes and discusses the differences in the balanced growth paths under the two regimes. This discussion is based on Propositions 1-5 from the previous section. Since shrinking population sizes is very uncommon, this section focuses on the case of strictly positive population growth. The propositions imply three qualitative differences between the two environments: the price of a bride, the female marriage age, and the age gap between husband and wife. Further quantitative differences will be discussed in the next section.

The first difference is the price of a bride. Proposition 1 says that under polygyny the price of a bride is always strictly positive. The intuition is simple, if wives cost nothing, there would be an infinite demand. Proposition 5 gives conditions under which the price in the monogamous world is strictly negative.[34] Note also that this brideprice is not

[33] Again, ideally this should be expressed as an assumption on exogenous parameters only. However, I have not been able to obtain an explicit characterization of the set of parameters that satisfy this condition. One way of thinking about the condition as stated is that if the production function was linear, then r and w were fixed and the above was indeed a restriction on parameters. Secondly, this condition will be a useful check for the calibration exercises. A calibration will uniquely pin down r, w, and f, and hence, the condition can be checked.

[34] The intuition that outlawing polygyny reduces demand and hence leads to a decrease in the brideprice was first pointed out by Becker (1974), see also Grossbard (1978). However, so far no mechanisms have been suggested explaining why this decrease in the brideprice would lead to a negative price.

unique. Any other negative price that is bigger in absolute value also clears the market. A general indeterminacy result in the marriage price within monogamous societies was first pointed out by Becker (1973): If the sex ratio is one and there is no heterogeneity, then any price (positive or negative) is associated with an equilibrium, as long as the price is such that everyone prefers marriage over remaining single. The intuition is that a sex ratio of one leads to flat supply and demand curves as long as everyone wants to get married. Note that in this paper despite a sex ratio of one and homogenous agents, the indeterminacy is considerably reduced. In particular, Proposition 5 gives conditions such that the price is always strictly negative. The reason for this reduction in the indeterminacy is twofold. The biological fecundity differences between men and women create an asymmetry between the sexes and the endogenous choice of marriage age lets the effective sex ratio deviate from one. The ultimate goal of marriage in this model is to produce children. Women could do this either with men who are their own age or with men who are older than them. Men, on the other hand, can have children with women of the same generation or with women of a younger cohort. Given a growing population, there will always be more people in the later cohorts, which could translate into a surplus of brides if the wrong matches were made. To avoid this, women (or in this case their fathers) are willing to pay. For a man, the relevant outside option is not to remain single but to marry someone from the next generation. This is always possible, and hence men are never willing to pay a price that is higher than the utility difference to this outside option. Women do not have such an outside option. Women cannot afford to wait a period, because they would lose their fecundity and thereby be essentially worthless to the opposite sex. This biological fecundity difference translates into asymmetric outside options for men and women, which rules out many potential equilibrium prices.

We now turn to differences in the age at marriage and the age gap between husband and wife. My model allows only a limited analysis of these variables since people live for only three periods. Thus, for example, the model cannot explain why the average age gap in the U.S. has decreased by 3% annually since 1950.[35] Nevertheless, the model has something to say about demographics. It follows from Propositions 1 and 4 that while men under both regimes marry at the same age, women marry earlier under polygyny. This leads to a larger age gap between husbands and wives under polygyny. The intuition for high age gap in polygynous societies is twofold. First, as argued before, polygyny leads to a positive price for girls. The positive price is an incentive for fathers to sell

[35] See Bergstrom and Bagnoli (1993).

their daughters at a young age.[36] Another way to see this is that polygyny makes brides a scarce resource. A young man who wants to find a bride, may discover that all adult women are already married to someone else. Thus, the only way he can secure a wife for himself is to marry a really young girl and then start a family with her at some time in the future.[37]

These three demographic differences are observed qualitatively in the data. Women marry 5 years earlier and the percentage of married female teenagers is more than triple in polygynous countries compared to monogamous countries. Secondly, the age gap is 4 years higher in the high polygyny group. Male marriage ages differ much less, the gap is only one year. The model also implies that the male age at childbirth is higher under polygyny. Unfortunately no cross country data on average ages of parents is available to verify this implications.

5 Calibration and Numerical Results

The main hypothesis of this paper is that polygyny leads to low income per capita through its negative effect on savings and its positive effect on fertility, which both lower the per capita capital stock. This section provides numerical results to assess the importance of these channels quantitatively. The counterfactual experiment here is, suppose family structure (polygyny or monogamy) was the *only* difference between two countries, how distinct would they be? In particular, we want to know how much of the income and fertility differences between the highly polygynous Sub-Saharan African countries, on the one hand, and monogamous countries close to the equator, on the other hand, can be explained solely on the basis of family structure.

The model is calibrated to the average of polygynous countries (see Table 1). This means that parameters are chosen such that the steady state matches the fertility rate and investment rate as observed in polygynous countries. The numerical experiment is to compute the monogamous steady state using the same parameters and compare the two steady states.

[36] A famous example of this is the fashion model Waris Dirie, who was supposed to be sold for 4 camels at the age of 10, and therefore fled from Somalia to England. The camels were desperately needed to feed the remaining children. See Dirie and Miller (1998) for her autobiography.

[37] In traditional societies, girls frequently were promised in marriage while they were infants, or even before they were born (Meekers 1992).

5.1 Calibrating the Polygynous Economy

The model has 6 parameters that need to be calibrated to derive quantitative results: two utility parameters γ and β, three technology parameters A, α and δ and one parameter in the child-production technology, ϵ.

Table 3: Calibration Overview

Parameter	Value	Fact
γ	0.64	surviving number of kids = 5.04
β	0.46	annual discount factor = 0.95
ϵ	69.9	$\frac{I}{Y} = 8.52\%$
A	321	GDP p.c. normalized to 1029
α	0.5	income share of capital = 50%
δ	0.66	7% annual depreciation

To determine the appropriate values for the parameters, some assumptions linking the model to observable data need to be made. Firstly, a model period is chosen to be 15 years because that is roughly the age when fecundity starts for most women. Moreover, life-expectancy in most of the countries of interest is between 40 and 50 years, which makes three 15-year periods an appropriate choice. Secondly, since this model abstracts from mortality, I use the fertility variable in the model to mean surviving fertility, i.e. number of children reaching at least the age five. In the following, fertility is taken to mean surviving number of children.

The TFP parameter A is a pure scale parameter used to normalize per capita output to the level in the data, \$1029. The annual discount factor is set equal to 0.95 in line with the macro literature. $\delta = 0.66$ is chosen to give 7% annual depreciation. The capital-share of income is chosen to be $\alpha = 0.5$.[38] The remaining 2 parameters, γ and ϵ, are calibrated to match the surviving number of children and investment rates from Table 1. Table 3 summarizes the calibration procedure. The sensitivity of the results to some of the details of the calibration is discussed in Appendix F.

[38] The reason that α is chosen to be higher than in the standard macro literature is that data indicates a higher capital-share for agricultural societies. See Boldrin and Jones (2002).

Table 4: Numerical Results (Benchmark)

	Polygyny model & data	Monogamy model	Monogamy data
Fertility	5.04	3.61	3.56
Investment rate	0.0852	0.185	0.16
GDP per capita	1,029	3,869	2,587

5.2 Results

Table 4 summarizes the results. It shows that allowing for polygyny induces men to marry several wives, to have more children, and to save less. The table shows that the magnitudes predicted by the model compare well to the data. The polygynous steady state leads to a fertility rate that is 30% lower than the monogamous one, compared to a 40% lower fertility rate in the data. Thus, the model accounts for three quarters of the observed fertility differential. The model also predicts that savings are about twice as high under monogamy, which again compares well to the data. Output per capita is 276% higher in the monogamous steady state compared to the polygynous one. The output difference in the data is only 150%. The main reason for this over-prediction in GDP per capita is the abstraction from mortality in this model, which implies too high population growth rates for both regimes. Correcting for mortality would decrease the output difference.

Table 5 compares the model's implied average number of wives, population growth rates, and age gaps to the data. The model does less well in replicating the demographic features of the data quantitatively. This is partly due to the limited number of periods, and partly due to abstracting from mortality. However, the model is able to replicate the demographic differences qualitatively. Recall that, due to the limited number of periods in the model, the age gap can only be either 0 or 15. Under polygyny, it turns out to be 15, which is about twice the observed number. The average number of wives and the population growth rates implied by the model are also significantly higher than observed in the data, both for polygynous and monogamous countries. The reason is that mortality is not taken into account here. If people died during the ages 5 and 45 in my model, then population growth would be much lower than what is reported in Table 5, which would also lower the average number of wives.

Table 5: Demographics (Benchmark)

	Polygyny		Monogamy	
	Model	Data	Model	Data
Wives per man	2.5	1.4	1	1
Age gap	15	7	0	3
Annual population growth	6.3%	2.7%	4.0%	2.0%

Table 6: Calibration 2: matching the population growth rate

	Polygyny	Monogamy
Investment rate	0.085	0.126
GDP p.c.	1029	2597
Fertility rate	2.98	2.05
Annual pop. growth	2.7%	0.2%
Avg. # of wives	1.49	1.0

One way to take mortality into account is to calibrate the model to match population growth rates instead of fertility rates. Results are reported in Table 6. Taking mortality into account in the above way, gives a better fit for the average number of wives under polygyny. To fit the lower implied fertility rate, the calibration requires the cost of child-rearing to go up considerably. This leads to an extremely low fertility rate under monogamy, barely above the replacement ratio.

The model also has implications about the size of marriage payments and about the total amount of resources that is spent on child-rearing. Table 7 reports the results for the benchmark calibration. Note that marriage payments vary considerably across regimes. The total amount spent on brideprices in the polygynous economy is only a fourth of what is spent on dowries in the monogamous economy. This also shows that it is not necessary for brideprices to be large in order to have large effects on aggregate savings. For the calibration total brideprice payments amount to only 4% of GDP. Secondly, the table shows that total expenditures on children are much higher under polygyny than under monogamy. In fact, more than 40% of GDP is spent on producing children in a polygynous country, while only 7% of resources are used on child production in the

Table 7: Further implications of the Model (benchmark)

	Polygyny	Monogamy
Total child-rearing costs/GDP	0.44	0.07
Total marriage payments/GDP	0.04	0.15
Male utility	12.5	13.7
Female utility	9.3	13.2

monogamous world. The reason for this large difference is twofold. Most obviously, polygynous countries have more children. But secondly, because the marginal cost of an additional child per women is increasing, this drives up the per child cost. The model was not calibrated to match data along these two dimensions. These additional predictions could therefore be used to further assess the reasonableness of the model. Since data on these magnitudes is not easily available, this is left for future work.

5.3 Welfare

A natural question to ask is what regime would make people happier. Families have more children under polygyny, and since children enter the utility function, this could in principle outweigh the lower GDP per capita. Table 7 also includes steady state utility for men and women under both regimes. Utility is higher under monogamy and differences are large, which shows that the additional utility from more kids is more than offset by the lower income. This shows that a ban on polygyny would benefit both men and women. Why is a restriction on the consumers problem beneficial in this framework? First, it is important to point out that the comparison above is a steady state comparison. If a country in the polygynous steady state unexpectedly passed a law that outlawed polygyny, it is not true that indeed *everybody* would benefit from this. The initial old men would be worse off, because they own an "asset" (daughters) that suddenly changes from a high-return asset into a burden (negative returns). But could the initial old be compensated? I conjecture that this is impossible because compensation for the initial old would mean less investment, which would further decrease the capital-output ratio.[39] To prove this conjecture, one needs to know if the polygynous steady

[39] To illustrate this point in a very simple framework consider an endowment OLG economy (without population growth), where people live for two periods and are endowed with 1 unit of the consumption

state is efficient or if it is Pareto dominated by some other allocation. However, Pareto efficiency is not defined for models with endogenous fertility. To see why, note that efficiency requires a person by person comparison of allocations. So if two allocations involve a different number of people, a comparison cannot be made for those that exist only in one of the two allocations. A new concept is needed before one can answer the questions posed above.

The logic explained so far is not the only reason for why a restriction on the consumer's problem increases steady state utility. A second force present in the model is the following. When consumers decide how much to invest in the physical asset and how much to invest in children, they are equalizing returns on both assets. However, the private return (direct utility and brideprice) on children is not equal to the social return (direct utility and wages). More children, taking investment decisions as given, mean a lower capital-output ratio, and therefore lower wages. This effect is not taken into account by parents deciding how many children to bear. This externality is mitigated under monogamy because the negative brideprice effectively constitutes a tax on having children, while the effect is reinforced under polygyny where the positive brideprice acts like a subsidy of child-rearing. Again, to assess the extent of this inefficiency, a concept of efficiency is needed that is well-defined for economies with endogenous populations.

6 Discussion

This paper analyzed the macroeconomic consequences of allowing men to marry multiple wives. It was shown that banning polygyny has large effects along several dimensions. The increased demand for wives created by allowing polygyny causes the value of a brides to be strictly positive, while it is typically negative when men are restricted to marrying one wife. Therefore, when polygny is allowed, buying wives and later selling daughters becomes a profitable investment strategy that partially crowds out investment in physical assets. The positive brideprice acts like a subsidy to child-rearing which increases fertility. Low investment and high population growth both contribute to a lower capital-output ratio, and thereby to lower output per capita. The numerical experiment shows that

good when young and with 9 when old. The only equilibrium is autarky. Suppose a law was passed that said old people are not allowed to eat more than 5 units of the consumption good. Assuming a concave utility function, this would increase the utility of everyone except for the initial old. But it would be impossible to compensate the old and make everybody better off.

enforcing monogamy reduces fertility by 30%, doubles the investment rate, and triples the capital-output ratio as well as output per person. These magnitudes compare well to the data. This suggests that although the practice of polygyny is certainly not the sole cause of poverty it is an important contributing factor for continuing underdevelopment in those places where it is practiced on a large scale.

I also found that steady state utility for both men and women is higher under monogamy. This seems to imply that everyone would benefit from a law that prohibits polygyny. Perhaps this explains why indeed many countries have such laws.[40] On the other hand, it raises the question, why wouldn't all countries enforce monogamy then? As emphasized in Section 5.3, the welfare comparison is a statement about steady states and it is not clear that along the transition all consumers would be better off. In particular, the initial old might object to such a change and I conjectured that they could not be compensated. To further explore these issues, one would need to look at the transitional dynamics. Suppose a country was in the polygynous steady state, and a law was proposed for banning polygyny from now on for all future generations. Who would vote for such a law? Similarly, which (if any) members of a monogamous society would vote for a law that allows marriages to multiple wives for current and all future generations? Computing transitional dynamics would be necessary to answer these questions. This is left for future research.

Several modelling choices were made to make the model tractable. One would like to know how sensitive results are to these choices. In the remainder of this section, I discuss a few extensions and modifications. Firstly, the model assumes that women are not involved in the fertility decision. One would like to know how robust the findings are to intra-family bargaining. What would happen if a wife could pay her husband in exchange for having fewer children? Would this significantly alter the results? In other words, how inefficient is the intra-family decision process? Any efficient outcome to a bargaining game between spouses can be found as a solution to the following problem: The husband chooses all variables subject to the constraint that his wife/wives receive/s a some utility $\bar{U}$. By choosing various values for $\bar{U}$, differences in bargaining power between spouses can be captured. Preliminary results show that incorporating efficient bargaining into the model does not change the results qualitatively. Obtaining quantitative implications

[40] Alternatively, some people have argued that polygyny arises when relative female labor productivity is extremely high, for example in countries where hoes are used for cultivating land. As countries move to plow cultivation, men prefer to invest in machines instead of wives and polygyny disappears. See Jacoby (1995) and Boserup (1989).

is less obvious. How would one calibrate the bargaining power, i.e. the utility level for women? And should one choose the same $\bar{U}$ under polygyny and monogamy? This may lead to the wrong comparison, because, as seen before, polygyny leads to lower GDP per capita. Hence, equalizing utility for women across regimes would imply that women are receiving very different *shares* of total output under the two regimes. On the other hand, choosing different female utility levels across the two regimes raises the question of how to determine this difference. Independent evidence on bargaining power of women in various countries would be needed.

Another way to test how robust the results are with respect to intra-family decision making would be to modify the model as follows. Assume that the only role of women is to produce children. Then women could be treated solely as an input into child production, but there would not be a separate maximization problem for women. I have solved this modified problem and find that the quantitative *differences* between polygyny and monogamy are similar to the results presented in this paper. However, the modified model is simpler, which makes it not possible to calibrate it to the average polygynous country. No parameters exist that lead to an equilibrium investment rate of only 8 percent. High interest rates implied by the low capital stock would always make men save more than 8 percent. This problem does not occur in the richer model presented in this paper because higher fertility leaves women with less income and therefore induces them to save less relative to men. Through this channel it is possible to have extremely low investment rates occur in equilibrium despite of high interest rates. It is however, possible to calibrate this modified model to the average monogamous country. The results are similar to the benchmark calibration of the original model. See Appendix G for details.

Another modelling choice that was made to keep the model tractable concerns the way children enter into the utility function. Fathers care only about total family size, which means that children born later in life are not discounted. Again, this assumption was made to keep the model tractable. But it would be interesting to explore a different specification. In particular, suppose parents were altruistic in the sense of Barro and Becker (1989), would this change any of the implications? Altruistic parents would take the trade-off between quantity and quality of children into account. This could potentially induce parents to have fewer children and save more, leading to a higher capital stock and higher wages for the children. Since this effect would be present under both family arrangements, it is unclear whether the quantitative differences between the two environments would change much.

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A Data on Polygynous Countries

Country	Region	Pol1	Pol2	Price	TFR	CMR	Gap	Marr1	Marr2
Malawi	ssa	10.2	.	B	7.6	265	5	43.6	98.2
Bangladesh	sa	11.3	.	BD	6.1	211	7.5	51.3	99.3
Kuwait	mena	11.7	.	.	5.3	35	3.3	13.2	96.3
Kenya	ssa	12.5	1.2	B	7.8	115	5.2	16.7	98.8
Centr. African Rep.	ssa	13.3	1.3	B	5.8	.	5	42.3	99.0
Niger	ssa	15.2	1.3	B	8	317	6.8	61.9	99.6
Uganda	ssa	15.8	.	B	7.2	180	4.3	49.8	96.9
Sudan	ssa	15.9	1.2	B	6.1	145	5.9	21.3	96.3
Tanzania	ssa	15.9	1.2	B	6.7	176	5.8	.	97.1
Ghana	ssa	16.3	1.2	B	6.5	157	7.5	22.4	98.9
Congo (Zaire)	ssa	19.5	1.3	B	6.6	210	5.3	74.2	95.4
Cote d'Ivoire	ssa	20.2	1.3	B	7.4	170	7.8	27.7	98.4
Chad	ssa	22	.	B	6.9	235	6.5	48.6	100
Gabon	ssa	27.3	1.4	.	4.5	.	7.8	15.9	87.2
Mali	ssa	29.3	1.3	B	7.1	.	9.2	49.7	99.6
Benin	ssa	31	1.4	B	7	214	6.6	29.1	.
Congo	ssa	31.9	1.6	B	6.3	125	5.1	55.5	92.9
Togo	ssa	31.9	1.5	B	6.8	188	8	19.9	98.9
Guinea	ssa	37.1	1.6	B	6.1	.	10.8	49	99.7
Burkina Faso	ssa	40.2	1.7	B	7.5	.	8.6	34.6	97.2
Senegal	ssa	40.7	1.5	B	6.8	.	8.4	43.8	95.4
Cameroon	ssa	55.6	1.4	B	6.4	173	7.4	35.8	99.2
Average		23.9	1.38		6.5	157	6.7	29.2	97.3

Comments: . indicates no data available

Region: ssa = Sub-saharan Africa, sa = South Asia, mena = Middle East and North Africa

Polygyny 1: Percentage of married men in a polygynous union

Polygyny 2: Average number of wives per married men

Price: B=Brideprice, D=Dowry

TFR: Number of births per women, 1980

CMR: Number of live births per 1000 that die before the age 5, 1980

Gap: Average marriage age of men minus average marriage age of women

Marr1: Proportion of ever-married women aged 15 to 19

Marr2: Proportion of ever-married men aged 45-49

Data Sources: See Appendix C.

B Alternative group of monogamous countries

The following table extends Table 1 for a group of monogamous countries that are selected based on income instead of latitude. Here only such monogamous countries are included that have a GDP per capita that is below the median in 1985.[41] The data is very similar to what is reported in Table 1. The biggest difference is that GDP per capita is much lower, which is logical given that these countries were selected based on low income.

Number of countries	(30)
Measures of Fertility	
TFR, 1980	5.4
TFR, 1990	4.7
surviving 1 yr, 1980	4.3
surviving 5 yrs, 1980	4.0
avg. annual pop. growth, 1960-85	2.2%
Mortality	
IMR, 1980	9.1
IMR, 1990	6.8
CMR, 1980	14
Demographics	
male age at marriage	26.2
female age at marriage	22.2
age gap	4.1
% women married by 19	15.6
% population under 16, 1985	41.9
Economic Variables	
$\frac{I}{Y}$ avg, 1960-85	0.13
$\frac{K}{Y}$, 1985	1.6
GDP p.c.,1980	1,518

Data Sources: See Appendix C

[41] Note that the group of countries selected by the latitude criterion in Table 1 includes several monogamous countries for which income data is not available.

C Data Sources

This appendix lists the sources of data used throughout this paper. Data on polygyny is from the United Nations (1990) and from Bankole and Singh (1998). Fertility and mortality rates are from the World Bank (2002). The UN Population Division (2000) provides data on the fractions of men and women that are married, as well as on average ages at first marriage and the age gap between husbands and wives. Population growth rates and life expectancy is from the Population Reference Buerau (2000). The macroeconomic variables (capital-output ratios, investment rates and GDP per capita) are from the Penn World Tables, Version 5.6a (1995). See Summers and Heston (1991) for a description of the Penn World Tables.

D Polygyny Details

The cost function on the left-hand side of the man's problem makes the budget set a non-convex set. However, a simple change of variables makes the problem convex. Let I^y be investment into children when young, and I^o when old. Then the number of children that can be produced is $f^y = \sqrt{\frac{I^y(n_w^y)}{\epsilon}}$ when young and $f^o = \sqrt{\frac{I^o(n_g^y+n_w^o)}{\epsilon}}$ when old. So in the modification, a man chooses two types of input into child production, instead of choosing the number of children, which then implies some cost to the man. The modified problem is completely isomorph to the original one. As argued before, given positive prices (implied by Proposition 1), the last part of the utility function becomes irrelevant and is therefore omitted here. Positive brideprices together with the no-borrowing constraint also imply that a man would never arrange a marriage for after his death. Hence $d_w^d = 0$. This implies that a man would want to marry all daughters born when he is old to be married during that period, $d_g^o = \frac{f^o}{2}$. These simple arguments are used below to eliminate a few choice variables from the man's problem.

$$
\begin{aligned}
\max_{I^y, I^o, d_w^o, n_g^y, n_w^y, n_w^o} \quad & \ln(c^y) + \ln(c^o) + \gamma \ln(f^y + f^o) \\
& c^y + s^y + p_g n_g^y + p_w n_w^y + I^y \leq w + p^g(\frac{f^y}{2} - d_w^o) \\
& c^o + s^o + p_w n_w^o + I^o \leq (1+r)s^y + p_g \frac{f^o}{2} + p_w d_w^o \\
& d_w^o \leq \frac{f^y}{2} \\
& f^y \leq \sqrt{\frac{I^y n_w^y}{\epsilon}} \\
& f^o \leq \sqrt{\frac{I^o(n_g^y + n_w^o)}{\epsilon}} \\
& \text{non-negativity constraints on all variables}
\end{aligned}
\tag{18}
$$

D.1 Proof of Proposition 1

Part 2 and 3 of the proposition can be proved by contradiction. Essentially, this proof works by showing that the 'wrong' wife choices always lead to a contradiction between market clearing, on the one hand, and the first order conditions, on the other hand. For part 2, assume that n_w^y was strictly greater than 0. Then, there has to be someone wanting to sell adult daughters: $d_w^o > 0$ or $d_w^d > 0$. But $d_w^d > 0$ is never optimal given that $p^w > 0$ and given the no borrowing constraint. So $d_w^o > 0$ implies that some children are born to young fathers, $f^y > 0$. Can these choices ever be optimal? The possibility of corner solutions implies that the first order conditions may or may not be binding. Therefore different cases need to be considered. Consider first the case where $n_w^o = 0$ and $d_w^o = \frac{f^y}{2}$ and all other variables are strictly interior. Manipulating the first order conditions for this case, and using market clearing, it can be shown that this would be an optimal choice only if $p^g = p^w$. This would also imply that $\frac{c^o}{c^y \beta} = 1$. However, because savings are possible, we also have $\frac{c^o}{c^y \beta} \geq (1 + r - \delta) > 1$. Which leads to a contradiction. All other cases can be ruled out by a similar logic. In essence, as long as $n_w^y > 0$, there is no price vector (p^g, p^w) at which $n_w^y > 0$ is optimal and markets clear. A similar logic works for part 3. Assuming that $n_w^o > 0$, a contradiction between market clearing and optimization behavior can be derived. Further details are available upon request.

D.2 Existence

To prove that a balanced growth path (BGP) exists, it needs to be shown that there exits stationary prices and an allocation such that markets clear and agents are optimizing. By Propositions 1 and 2 we know already that if a BGP exists, it has very specific characteristics. It was also shown that bride market clearing can be reduced to a simple relationship between the equilibrium number of wives and children: $n = \sqrt{\frac{f}{2}}$. It needs to be shown that there exists a price vector (p^g, p^w) such that those choices are optimal. Since the modified man's problem is convex, we know that the first order conditions are necessary and sufficient for maximizing behavior. The first order conditions are

$$
\begin{aligned}
I^y: &\quad \frac{\gamma}{f^y + f^o}\frac{\partial f^y}{\partial I^y} + \frac{\gamma}{2}\frac{\partial f^y}{\partial I^y} + \frac{p_g}{2c^y}\frac{\partial f^y}{\partial I^y} \leq \frac{1}{c^y} \\
I^o: &\quad \frac{\gamma}{f^y + f^o}\frac{\partial f^o}{\partial I^o} + \frac{\beta p_g}{2c^o}\frac{\partial f^o}{\partial I^o} \leq \frac{\beta}{c^o} \\
n_w^y: &\quad \frac{\gamma}{f^y + f^o}\frac{\partial f^y}{\partial n_w^y} + \frac{\gamma}{2}\frac{\partial f^y}{\partial n_w^y} + \frac{p_g}{2c^y}\frac{\partial f^y}{\partial n_w^y} \leq \frac{p_w}{c^y} \\
n_g^y: &\quad \frac{\gamma}{f^y + f^o}\frac{\partial f^o}{\partial n_g^y} + \frac{\beta p_g}{2c^o}\frac{\partial f^o}{\partial n_g^y} \leq \frac{p_g}{c^y} \\
n_w^o: &\quad \frac{A}{f^y + f^o}\frac{\partial k^o}{\partial n_w^o} + \frac{\beta p_g}{2c^o}\frac{\partial k^o}{\partial n_w^o} \leq \frac{\beta p_w}{c^o} \\
d_w^o: &\quad \frac{\beta p_w}{c^o} \leq \frac{p_g}{c^y} + \psi \\
s^y: &\quad (1+r)\frac{\beta}{c^o} \leq \frac{1}{c^y} \\
C.S.: &\quad \psi[\frac{f^y}{2} - d_w^o] = 0
\end{aligned}
$$

Existence can now be shown by guessing a solution and verifying that all conditions actually hold. The guess here is $(f^y = 0, f^o > 0, I^y = 0, I^o > 0, n_g^y > 0, n_w^o = n_w^y = d_w^o = 0, s > 0)$. Given the guess, only the FOCs with respect to I^y, n_w^y, and s have to hold with strict equality. It is straightforward to verify that as long as $p^w \geq \frac{c^o}{\beta c^y}p^g$, none of the FOCs that have to hold with weak inequality is violated. We can then use the FOCs with respect to n_w^y and s to solve for p^g and for s analytically as a function of the number of children, f. All other variables can then also be expressed as a function of f. Then the first order condition with respect to I^y can be used to solve for the equilibrium f, using the production function for children. This turns out to be a polynomial of degree 4. Let $X = 2\beta\epsilon + \frac{\gamma}{1+\beta}\beta\epsilon - \frac{\gamma}{1+\beta}\epsilon + \gamma\epsilon$, $Y = \frac{\beta\epsilon}{1-\delta+r} - \frac{\epsilon\gamma}{(1+\beta)(1-\delta+r)} + \frac{\gamma\epsilon}{1-\delta+r}$, and $Z = \frac{\gamma}{1+\beta}\beta(1-\delta+r)w$.

Then the relevant equation becomes

$$Y^2 f^4 - 2X^2 f^3 + 2YZf^2 + Z^2 = 0 \tag{19}$$

As long as this equation has a real positive solution, a solution to the maximization problem (given w and r) exists. It is now straightforward to show that prices (w, r) exist that clear the markets for labor and capital. Further details available upon request.

E Proof of Proposition 5

Claim: Under certain conditions on parameters, there exists a price $p < 0$ s.t. a man is indifferent between marrying when young and marrying when old. This price clears the market.

Proof. Writing the problems using a present value budget constraint will make the comparison more obvious. Let the superscripts 'sa' and 'ag' stand for *same age* and *age gap* marriage respectively. Then the maximization problems can be written as follows.

$$\begin{aligned} V^{sa}(p) &= \max_{c^y, c^o, f} \ln(c^y) + \beta \ln(c^o) + \gamma \ln(f) \\ & c^y + \frac{c^o}{1-\delta+r} + g(f,1)f \leq w - p\left(1 - \frac{\frac{f}{2}}{1-\delta+r}\right) \end{aligned} \tag{20}$$

$$\begin{aligned} V^{ag}(p) &= \max_{c^y, c^o, f} \ln(c^y) + \beta \ln(c^o) + \gamma \ln(f) \\ & c^y + \frac{c^o}{1-\delta+r} + \frac{g(f,1)f}{1-\delta+r} \leq w - \frac{p}{1-\delta+r}\left(1 - \frac{\frac{f}{2}}{1-\delta+r}\right) \end{aligned} \tag{21}$$

It is obvious from the two problems above, that if brides were free, a man would always choose the age-gap marriage, but such a choice would not clear the market. Define the value of marrying young but having the same number of kids as a man who marries when old as

$$\begin{aligned} \tilde{V}^{sa}(p) &= \max_{c^y, c^o} \ln(c^y) + \beta \ln(c^o) + \gamma \ln(f^{ag}) \\ & c^y + \frac{c^o}{1-\delta+r} + g(f^{ag},1)f^{ag} \leq w - p\left(1 - \frac{\frac{f^{ag}}{2}}{1-\delta+r}\right) \end{aligned}$$

It it sufficient to show that there exists a price p s.t. $\tilde{V}^{sa}(p) \geq V^{ag}(p)$ since this implies $V^{sa}(p) \geq V^{ag}(p)$ immediately. To show this, it is sufficient to find a p such that present discounted consumption in the $\tilde{sa}$ case is higher than in the ag case. This reduces to

$$-p(1-\frac{\frac{f^{ag}}{2}}{1-\delta+r}) > g(f^{sa},1)f^{sa}$$

It is easy to show that k^{ag} increases in p, and hence as long as $f^{ag}(p=0) < 2(1-\delta+r)$ the left-hand side goes to infinity as p goes to minus infinity, while the right-hand decreases. By continuity, a price $p < 0$ s.t. the LHS and the RHS are equal has to exist. At this price $\tilde{V}^{sa} = V^{ag}$ and hence $V^{sa} \geq V^{ag}$. It remains to be verified that $f^{ag}(p=0) < 2(1-\delta+r)$ is indeed true. Solving for f^{ag} analytically gives $f^{ag}(0) = \sqrt{\frac{(1-\delta+r)w\gamma}{\epsilon(\gamma+2\beta+2}}$. Therefore, $\frac{w\gamma}{\epsilon(\gamma+2\beta+2)} < 4(1+r-\delta)$ guarantees that the equilibrium number of kids is small enough for the argument to work.

F Robustness

This section looks at robustness of the results regarding the details of the calibration. I find that the qualitative results are very robust. I have done sensitivity analysis along the following dimensions: depreciation rate, capital share of output, calibrating to the monogamous data instead, matching population growth rates instead of fertility rates, and calibrating to the gross national savings rate instead of the investment-output ratio.[42] All of the experiments show the following qualitative difference between polygyny and monogamy: fertility is always significantly higher under polygyny and the capital-output ratio and output per capita are always much lower under polygyny.

Quantitatively, results are somewhat sensitive to changes in the parameters. Ignoring changes in α for a moment, for all experiments I have computed, fertility differences range from 1.2 to 1.8. Investment rates range from being 1.4 times higher under monogamy to being up to 2.3 times higher. Per capita output under monogamy ranges from 2.5 times the polygynous output to almost 4 times the polygynous output.

To be more concrete, calibrating the model to the monogamous steady state instead gives almost identical results along all dimensions. A second exercise I have done is to match population growth rates instead of fertility rates. This leads to a decrease in the investment rate differential from about 100% in the original calibration to only 43% in this experiment. These results may be more realistic than the original calibration since it

[42] Along some dimensions only small changes in parameters are possible because steady states may cease to exist for too big changes.

Table 8: Changes in α (Model calibrated to match data under monogamy)

	$\alpha = 0.5$	$\alpha = 0.4$	$\alpha = 0.35$
ϵ	2.3	0.5	0.13
Pol $\frac{P}{\frac{Y}{L}}$	0.038	0.014	0.005
Pol $\frac{I}{Y}$	0.085	0.16	0.18
Pol $\frac{K}{Y}$	0.05	0.06	0.06
Pol Ypc	30	42	41
Pol TFR	4.4	6.0	7.1

leaves more room for other factors to explain differences in investment rates. For example, the current model ignores growth in GDP per capita. If differences in growth rates across countries were taken into account, countries with a higher growth rate would have a higher incentive to save, which ceteris paribus would lead to even higher investment rates under monogamy. The annual depreciation rate in the benchmark calibration was set at 7%. Increasing the depreciation rate leads to a higher investment rate (and output) differential, while it does not affect fertility rates. Similarly, decreasing the investment rate has the opposite effects.

The choice of the capital share parameter, α, seems to matter most. Small changes can lead to big differences in the investment rate as shown in the table below. The table shows numerical results for the polygynous model for a calibration that matches fertility and investment rates under monogamy. It shows that investment rates are particularly sensitive to changes in α. However, despite big differences in investment rates, the capital stock remains surprisingly constant. This is because fertility also adjusts, which changes the way of how current investment translates into tomorrow's capital stock.

To summarize, changes in the details of the calibration are not completely innocuous quantitatively. The reason is that small changes in α require relatively large changes in the cost of child-rearing parameter ϵ to still match the fertility and investment rates. These changes in ϵ can then have a big impact on how the two regimes compare to each other. The differences in ϵ also imply large differences in the fraction of GDP spent on child-rearing and the magnitude of the brideprice (dowry). To better evaluate the performance of the model, it would thus be interesting to compare data on child-rearing costs and on marriage payments to the predictions of the model. Since this data is not easily available, this is left for future research.

G Alternative Model (Women only child-producers)

Women do not make many choices in the model presented in this paper, since fertility and marriage decisions are made by men. One may therefore wonder what role women play in this economy. The only choice left to women in the current model are savings decisions. Some people argue that this is not a reasonable assumption for many developing countries, in which women are not allowed to own property. To address these concerns and to assess the role women play in this framework, I consider an alternative model in which the only role women play is to bear children. For men, the model is identical to the original model. Women are now reduced to their role as an input into child production. They do not have a labor endowment, and they do not have a utility function.

This alternative specification does not change any of the qualitative results, all propositions are true in this new environment. Qualitatively, as pointed out in Section 6, the model can no longer be calibrated to match the average polygynous country. However, it is possible to calibrate it to the average monogamous country. Results are shown in Table 9. It can be seen that this alternative model also does well in accounting for the differences between polygynous and monogamous countries. Allowing for multiple wives leads to a large drop in GDP per capita, a decrease in the investment rate, as well as to an increase in fertility.

Compared to the results for the benchmark model, two things are worth pointing out. The predicted decrease in GDP per capita when going from monogamy to polygyny is almost identical to the differences in the data; compared to an over-prediction in the benchmark model. This better fit, however, comes at the price of a worse fit along other dimensions. The implied fertility and investment rates under polygyny are both too high.

Table 9: Results when women are only child-producers

	Monogamy	Polygyny	
	Model & Data	Model	Data
surviving fertility	3.56	6.08	5.04
$\frac{I}{Y}$	16%	14%	8.5%
Y per capita	2,587	955	1,029