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OVERLAPPING GENERATIONS MODELS OF AN AGE-GROUP SOCIETY: THE RENDILLE OF NORTHERN KENYA*

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ABSTRACT

This paper makes five contributions to the modeling of societies organized primarily according to age. First, it models the social rules adhered to by a particular *age-group society*, the Rendille of Northern Kenya. Second, it shows that their age-group rules are well represented by the standard overlapping generations (OLG) model. Third, we develop a genealogical OLG model that closely captures lifecycle transitions and lineages. Fourth, despite heterogeneity in the timing of marriage and birthing, the model can be calibrated using standard aggregate demographic data. Fifth, the model permits an analysis of institutions that reveals the intergenerational conflicts between the lineages in changing the social rules.

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1. **Introduction**

Anthropologists have identified a number of societies, in various parts of the world, where social and economic life are regulated closely by synchronized transitions through the various stages of life. The rules governing these transitions are closely linked to chronological age and/or age relative to that of the person's father. Ethnographers call societies with these homogenous lifecycle characteristics *age-group societies*.[1] The definitive work in this area is Stewart's *Fundamentals of Age-Group Systems* (1977).

In a recent paper, Engineer and Welling (2004) show that a *standard overlapping generations system* can exactly represent the transitions of Stewart's *standard graded age-set system*, the simplest type of age-group system. The overlapping generations (OLG) structure captures both the generation dimension (age-set affiliation) and the lifecycle dimension (age grades that assign social roles) of males by age. Where Engineer and Welling (2004) provide set-theoretic equivalence results between age-cohort systems, they do not develop a dynamic model nor do they examine genealogical systems.

This paper develops a dynamic model of a particular age-group society, the Rendille tribe of Northern Kenya. The analysis is of interest to economists because we show that the age-group rules followed by the Rendille imply standard and genealogical OLG models. Paying careful attention to the evidence, the rules are modeled in three parts. First, the paternal age-group rules are shown to imply what Engineer and Welling (2004) term a standard OLG system. Second, the marriage rules are shown to incorporate women by age and lineage into the OLG system. Third, the rules restricting fertility are described. From these foundations, the OLG models are derived.

The genealogical OLG model implies restrictions on standard demographic variables and we are able to calibrate it using limited aggregate data on marriage timing and net reproductive rates. The simulations capture population proportions, track lineages, and permit the historical analysis of institutions. A particular marriage institution termed *Sepaade* is shown to dramatically affect the demographics in favor of one of the lineages. A simple voting analysis reveals the different interests of the generations in the recent decision to eliminate *Sepaade.*

An outline of the Rendille social rules quickly reveals the stylized OLG structure of the society. In Rendille society, similar aged males are assigned to an *age set*. Age sets span 14 years and we model individuals as potentially 6-period lived (where each period is the duration of an age-set). At the beginning of the third period of their lives, males are initiated into the *warriorhood* grade. At the end of this period, all warriors marry *en masse* and then become *elders* and can have children. (The lifecycle of father's and sons is illustrated in Figure 1 in Section 2.)

Men typically marry younger women. These *women-marrying-young* marry at the end of their second period of life. They give birth to early-born children in the third period of their lives and late-born children in their fourth period of life. A peculiar feature of the Rendille age-group system is that daughters of every third age set have a special designation as *Sepaade*. By convention, the marriage of early-born *Sepaade* is delayed by one period. These *women-marrying-old* only give birth to children in the fourth period of their lives. (The timing of marriage is shown in Figure 2 in Section 2.)

The fact that *Sepaade* have lower fertility has been much commented on in the anthropology literature as an example of an institution for population regulation. The OLG model captures the heterogeneity in the timing of birthing and marriage and reveals that *Sepaade* dramatically reduces the level and the growth rate of the population. The model also reveals that *Sepaade* dramatically favors one of the lineages, the *Teeria*, consistent with evidence that this is the most populous and well-off lineage.

A fascinating aspect of Rendille society is their paternal age-group rules governing lineage. Among the Rendille, *age-set lines* represent a well-ordered

[1] Spencer (1997) describes the overarching premise of such societies as the respect for age. This contrasts with premises such as honor, associated with integrity of kinship, and purity, linked to status and caste.

genealogical lineage that relate father's age set and the eldest son's age set to the same age-set line. The fact that three age sets separate the birth of fathers and eldest sons, indicates that there are three age-set lines and the length of a *generation group* is 42 years.[2] The *Teeria*, or "first born" lineage, is the age-set line (line X) that starts a *fahan*, a new generation group. The daughters of *Teeria* men are *Sepaade.* The models reveal how the interaction of lineage and *Sepaade* rules act to benefit the paternal *Teeria* age-set line. (The OLG progression of age sets and age-set lines is illustrated in Figure 3 in Section 3.)

The model is used to examine the intergenerational political economy around the institution of *Sepaade*. We start with a counterfactual analysis of the origin, persistence and recent dissolution of this institution. Our analysis is consistent with Rendille oral history that *Sepaade* arose in 1825 as a reaction to external threat: it mobilized women's labor for camel herding while the men battled marauders. We speculate that *Sepaade* persisted because it favoured the *Teeria* age-set line and the dominant position of the *Teeria* allowed them to block attempts to reverse it. *Sepaade* was recently discontinued in 1998. Our analysis suggests this might have happened for two reasons. First, the society was becoming too demographically lopsided towards the *Teeria* line to the substantial detriment of the overall fitness of the society. Second, the institution became unviable as women disadvantaged by the tradition found it easier to emigrate in recent times.

We are aware of no direct precedents for our analysis. In the economics literature, only recently have economist been able to operationalize the OLG model due to computational complexity and data limitations. The few attempts have concentrated on modeling macro variables rather than accurately capturing the heterogeneous transitions of agents through life cycle stages by modeling marriage, fertility and tracking lineages.[3] The analysis in this paper is supported by the anthropological analysis in Engineer, Roth

[2] The word "generation" is often confused in two uses -- as a measure of time associated with a cohort of individuals versus genealogical distance between parent and child. In the OLG literature, the term "generation" most often corresponds to an age set versus a generation group.

[3] Applications of the OLG model that include considerable demographic detail include Auerbach and Kotlikoff (1987), Gokhale et. al. (2001), and the related work on generational accounting and social security. Huggett (1996) calibrates an OLG model to describe the U.S. wealth distribution. Greenwood et. al. (2003) calibrate an OLG model that includes marriage and fertility to the wealth distribution.

and Welling (2005). Kang and Engineer (2005) derive the analytical solution to our genealogical OLG model paper using mathematical methods used in population ecology.

The paper proceeds as follows. Section 2 outlines the social rules of the Rendille age-group society. Section 3 models the social rules and develops a standard OLG model. Section 4 develops the genealogical overlapping generations model, which is calibrated in Section 5. Section 6 develops a simple voting analysis of the decision to abolish *Sepaade.* Section 7 concludes.

2. **The Age-Group System of the Rendille**

The Rendille are a Cushitic–speaking people with a population of approximately 30,000, who live in Northern Kenya. In the northern Kenyan lowlands the land is too dry for farming; nomadic pastoralism is the most efficient - and possibly the only - way to sustain life in this environment. For descriptions of Rendille society see Beaman (1981), and Roth [(1993), (1999), (2001), (2004)].

Our focus is on Rendille age-group organization which goes back well before 1825 when the institution of *Sepaade* was introduced. The key social rules in the Rendille system are summarized in 15 rules by Beaman (1981, p380-423). For brevity we list in Table 1 only those rules that pertain to our model. For a complete list of Beaman's rules and a fuller description of Rendille society with references to further evidence supporting our modeling choices see Engineer et. al. (2005).

(Table 1 here)

2.1 The Paternal Age-Group System

The rules in Table 1 relate to the paternal age-group system, marriage, and fertility. Rules (i)-(ix) describe the lifecycle of men, and the assignment of men and their sons to age groups or "age sets". The circumcision of a group of boys marks the beginning of a new age-set and the transition from boyhood to warriorhood. The group of warriors initiated in period t is then identified as age-set t. The next circumcision occurs 14 years later, at which point age-set t+1 forms. After 11 years as warriors, men become eligible for marriage and elderhood (following the *nabo* ceremony). After 3 years adaptation to new roles, the next age-set is opened; thus, during the transition there are technically no warriors. These men are putative elders and, if need be, the effective warrior group.

The timelines for a father and his son are described in Figure 1, using 14-year periods. The father is of age-set t, the period during which he is a warrior. Suppose he is born at the beginning of period t-2. After two periods in boyhood, this male enters warriorhood at age 28 and marries when he is aged 39 to 42.[4] Rule (iv) requires that males can only claim paternity of children from marriage.

(Figure 1 here)

Now consider sons. Rule (vi) restricts the minimum age distance between the inaugurations of fathers' and "early-born" sons to be three age sets or 42 years. Thus if the father is inaugurated into age-set t, the early-born sons are inaugurated into age-set t+3. By rule (viii), every third age set belongs to the same *age-set line* so that age-set t and t+3 belong to the same age-set line. Age-set lines preserve the generation-group relationship between fathers and the eldest sons (who receive all the family wealth, primogeniture). "Late-born" sons (born after period t+1) join later age sets and change their age-set line accordingly.

Figure 1 depicts early-born sons as born in the interval starting one year after the period t *nabo* ceremony and extending through period t+1. Typically most sons are born in this 16-year interval. These "early-born" sons are between ages 14-30 at the beginning of period t+3 and are old enough to be initiated into age-set t+3. Sons born in period t+2, "late-born" sons, are too young to be circumcised at t+3 and are circumcised at the same time as their "age mates" at the beginning of t+4.[5]

[4] The oldest males in an age set are those "first-born" sons born one year after the *nabo* ceremony of their fathers (at age -2 in the figure). They enter warriorhood at age 30. In contrast, an age-set t male born at the end of the period t-2 enters warriorhood at age 14 and marries when he is 25-28.

[5] The minimum "enrolment age" into an age set is 14. Beaman (p389) states: "…boys younger than fourteen are seldom among the initiates". Sons sired by age-set t fathers in period t+3 are initiated into age-

Rule (viii) specifies that every age set is assigned to one of three age-set lines in rotation. For example, consider the *Teeria* line, identified in Rule 9 as the senior age-set line. If age-set 0 is in the *Teeria* line then so are age sets 3, 6, 9, … . As early-born sons are normally enrolled in the third age set following their fathers', they are in the same line as their fathers. Late-born sons are usually enrolled in the subsequent line.

2.2 Marriage

Traditionally, all men are strongly encouraged to marry as soon as possible, and most men of a given age-set marry in a mass ceremony shortly after their *nabo* ceremony. Poor men who cannot raise bridewealth cannot marry at the *nabo* ceremony but instead do 2-3 years of bride service for their prospective in-laws before marrying. Thus, almost all men marry by the end of the three year period to elderhood.

The Rendille permit polygyny. However, the vast majority of marriages were monogamous. If a man took a second wife it would typically be years after the first marriage, in a separate ceremony. Roth (1993) states that the chief reason for taking a second wife was to have a son if there was no male issue from the first marriage.

(Figure 2 here)

Figure 2 illustrates the timing of marriage for males of age-set *t*. These men marry shortly after the *nabo* ceremony at the end of period *t*. In the absence of *Sepaade*, the usual practice is for men to marry younger women one age-set their junior. We denote these women as *women-marrying-young.* In the figure, such a women born at the beginning of period *t*-1 (age 0 in the figure) would be 25 when she marries. "First-born" daughters born one year after their father's *nabo* ceremony (age –2 in figure), would be 27 when they marries.[6] In contrast, females born (well after their father marriage) in the last two years of period *t*-1 would be 11-13 at the time of the next *nabo* ceremony. Since

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set *t*+ 5. However, the number of such sons is likely to be very small. First, Rule (xi) requires that no women with sons circumcised in period *t*+3 shall raise sons in that period or later. Second, husbands and wives are often being too old to have children.

[6] There are two reasons to believe this is the case. First, "first-born" daughters are valuable to the families for the work they do. Second, Roth's (1993, 1999) data has few married women in the age range of 14-18.

girls are typically not eligible for marriage until age 14, such girls usually marry a few years later to men doing bride service (or wealthy men taking second wives).

Women whose marriage is delayed by a full *nabo* ceremony we term *women-marrying-old.* In the figure, women-marrying-old to age-set t men are born in period t-3. Thus, women-marrying-old marry into the age-set of their same-aged brothers and will be as old as 41 at the time of the *nabo* ceremony. Most women-marrying-old do so because they are held back from marrying by the institution of *Sepaade*.

Rule (x) indicates that all daughters of *Teeria* men (age-set line *X*) are designated *Sepaade.* The social rules on *Sepaade* delay marriage and in its place assign special work. Typically, the rules delay the marriage of early-born *Sepaade* daughters by one age-set so that they become women-marrying-old as described above (see Figure 2).[7] *Sepaade* women delayed in marriage do the same work as sons, herding camels for their fathers. For the work they do and the fact that they marry back into the *Teeria* lineage, *Sepaade* are considered by the Rendille as the main reason why the *Teeria* are more numerous and wealthy than the other age-set lines.

2.3 Reproduction

Rule (xi) requires that a women-marrying-young in period t and bearing an early-born son in period t+1 can not have a very late-born son in period t+3. Beaman mentions several additional important restrictions on fertility that she does not list as rules. First, unmarried women are forbidden to bear children. Second, polygyny is allowed. This implies the shortage of men will not affect the timing of marriage. Third, widows cannot remarry but can continue to bear children. Fourth, any children born to widows are assigned as if they were the husband's. Thus the husband's death does not interrupt the usual passing down of lineage and does not restrict fertility. These restrictions indicate that only the females age at time of marriage matters for lifetime fertility.

3. Modeling the Age-Group Rules and the Standard OLG Model

Almost all Rendille demography can be naturally and parsimoniously represented relative to the initiation of age sets as described in Figures 1 and 2.

Assumption 1 (Time and Period Length). Time is partitioned into discrete 14-year periods. The period begins with the initiation of an age set and ends with the initiation of the subsequent age set. Periods are indexed by whole numbers.

This assumption allows us to trace the life passages of cohorts by their period of birth and their age in periods. However, there is one obvious feature that is "out of joint" with the period increment. Not all early-born children are born in the same period. Early-born children of men age-set t in Figure 1 are born over a 16-year interval that straddles the last two years of period t and extends for all of period $t+1$. The children born in the last two years of period t are *first-born* children. These first-born children do not pose a problem for the analysis because, as discussed in Section 2, the social rules treat all early-born children the same (the age-set designation and marriage timing is determined by their father's age set). Thus, there is no loss of generality in technically lumping the first-born children in the period following the marriage of their parents.

Simplifying Assumption (Early-born children). All early-born children are born in the period immediately following the marriage of their parents.

3.1 *Modeling the Paternal Age-Group System*

Rendille paternal demography can be almost exactly modeled using 14-year periods.

[7] Anthropologists accounts suggest this timing. An exception is Roth (2001, p1017) who interprets the *Sepaade* rule as potentially further delaying marriage for a small fraction of daughters. As shown in Engineer et. al. (2005) this leads to similar results with slightly lower growth rates.

Assumption 2 (Individuals and Age Sets). The lifespan of an individual potentially spans six contiguous 14-year periods. Males born in period t-2 are inaugurated into *age-set t* at the beginning of period t; this period defines the age-set number for that cohort.

In Assumption 2 age-set assignment is by age whereas it is by paternity in rule (vi). The two coincide under the Simplifying Assumption. The role of males is determined by their age-grade assignment.

Assumption 3 (Age-Grades). Age grades are assigned to males in a way that coincides with periods. The period of his birth and the following period are *Boyhood*. The third period of life is *Warriorhood*. The remaining periods of life correspond to *Elderhood*.

The lifecycles of males is illustrated in Figure 3. Consider age-set j males. These males are boys in periods j-2 *and* j-1, warriors in period j, and elders in periods j+1, j+2, and j+3. The number of boys is denoted $B_1(j\text{-}2)$ and $B_2(j\text{-}1)$, where the subscript indicates their age in periods. Similarly, warriors are denoted $Wr_3(j)$, and elders are $E_4(j+1)$, $E_5(j+2)$, and $E_6(j+3)$. Since births of individuals (who are recruited into any cohort) occur throughout the period, the variables count people at the end of the period. This captures the extant population in the age-set.

(Figure 3 here)

Figure 3 is typical of depictions in the OLG literature and exactly corresponds to what Engineer and Welling (2004) define as a *standard OLG system.*[8] The system describes both the generation and the lifecycle stages of individuals. The generational dimension captures the age-set affiliation; while, the lifecycle dimension captures the grades (social roles) of males by age.[9] The figure illustrates the complete cross-section of

[8] The definition includes six elements: time, agents and generations, endpoints, period length, lifecycle stages, and stationarity. Stationarity refers to the unique mapping from age to lifecycle stage that is independent of the time period. Figure 3 satisfies all of these elements for a "perpetual economy" with no endpoints. The proof is straightforward but tedious and therefore is omitted.

[9] Conversely, Assumptions 2 and 3 satisfy what Stewart defines as a *graded age-group system*. In fact, because initiations are at the beginning of periods and all periods are of equal length, it describes a particularly well-behaved system that Engineer and Welling (2004) term a *standard graded age-set system*. Engineer and Welling (2004) show that this system is equivalent to a *standard OLG system.*

males in different grades for period *j*+3. Figure 3 depicts one feature not found in economic depictions. Every third Rendille age set belongs to the same age-set line.

Assumption 4 (Age-Set Lines). The three Rendille age-set lines follow a cycle as follows: *age-set line X* includes age-sets $j = 0, 3, 6, 9, 12, 15\ldots$; *age-set line Y* includes age-sets $j+1 = 1, 4, 7, 10, 13\ldots$; and *age-set line Z* includes age-sets $j+2 = 2, 5, 8, 11, 14, \ldots$. Age-set line *X* is the *Teeria* age-set line.

Age-set lines organize fathers and their early-born sons in the same lineage. By Assumption 2, sons are initiated two periods after their birth. Early-born sons of fathers *t* are born in *t*+1 and are initiated into age-set *t*+3 which is in their father's age-set line; whereas, late-born sons of father's *t* are born in *t*+2 and are initiated into age-set *t*+4 and fall into the subsequent line. In Figure 3, fathers *j* are in line X and so are their early-born sons, age-set *j*+3. Late-born sons *j*+4 fall into line Y.[10]

3.2. *Modeling Marriage*

In Rendille society polygyny is allowed, implying there need not be a shortage of husbands. The usual pattern is for a man to have either one or two wives.

Assumption 5 (Marriage, and Polygyny) All women marry. All men marry (if possible), and no man has more than one more wife than any other man.

The distribution of marriages is easily derived. For example, if the *polygyny ratio R* of married women to men is R=1.1, 10% of males have 2 wives and 90% have 1 wife.

Males of age-set *t*, $Wr_3(t)$, marry after the *nabo* ceremony near the end of period *t.* Under the Simplifying Assumption, they marry females who are either *women-marrying-young* born in period *t*-1, or *women-marrying-old* born in period *t*-2.

[10] Stewart (1977, 104) notes that negative paternal linking does not preclude the *age-set model*. Engineer and Welling (2004) show that the age-set model is consistent with the *standard OLG system.*

Assumption 6 (Marriage Timing) All men of age-set t marry at the end of period t. They marry to women-marrying-young born in period t-1 and to women-marrying-old born in period t-2. These are the only groups of women from whom they draw marriage partners.

The factors that determine whether a female marries young or old are the lineage of her father and whether she is early- or late- born. In particular, *Sepaade* restricts most early-born daughters of Teeria men to be women-marrying-old. The following definition develops notation for modeling the timing of marriage.

Definition. Let p_X, p_Y and p_Z denote the proportions of *early-born* daughters in lines X, Y, and Z respectively that are women-marrying-young. Similarly, let p_X', p_Y' and p_Z' denote the proportions of *late-born* daughters in lines X, Y, and Z respectively that are women-marrying-young.

Sepaade implies that p_X is small or, equivalently, that 1-p_X is large. That is, most early-born daughters in line X are women-marrying-old. Complete *Sepaade* is p_X=0.

Assumption 7 (Marriage Proportions by Line) *Sepaade* restricts most early-born daughters of Teeria men to be women-marrying-old, $p_X \leq 0.4$. The vast majority of early-born daughters in other lines are women-marrying-young, $p_Y = p_Z = p \geq 0.8$. Almost all late-born daughters are women-marrying-young $p_X' = p_Y' = p_Z' = p'$, and $p \leq p'$.

We state the assumption this way to give a sense for the magnitudes consistent with the evidence (in Section 5). Our analysis of *Sepaade* maintains $p_X < p \leq p'$. As we have no evidence to the contrary, we equate the proportions in the other lines: $p_Y = p_Z = p$; also $p_X' = p_Y' = p_Z' = p'$. The analysis isolates *Sepaade* as the key asymmetry.

The lifecycle of females depends on their birth order and timing of marriage. Girlhood in the period of birth is denoted G_1, if the female is early-born and G_1' if she is late-born. Females who marry at the end of the second period of their lives are called women-marrying-young. They are denoted WMY_2 if they are early-born, and WMY_2' if they are late-born. Females that are women-marrying-old go through another grade denoted G_2 or G_2' in the second period of their lives. They marry at the end of the third period of their lives and are denoted WMO_3 if early-born and WMO_3' if late-born.

There are potentially four groups of women who marry men of age-set *t*, $Wr_3(t)$: early- and late-born women-marrying-young, WMY_2(t) and WMY_2'(t), and early- and late-born women-marrying-old, WMO_3(t) and WMO_3'(t). Recall from Assumption 6 that women-marrying-young in period *t* are born at *t*-1 and that women-marrying-old in period *t are* born at *t*-2. Thus, we can track the women groups back through their lifecycle to the new-born girl groups from which they are drawn. This is done is Table 2 (ignoring attrition). As in Figure 3, men marrying in period *j*, $Wr_3(j)$, are from line X.

(Table 2 here)

Table 2 extends the OLG system to incorporate females. A sense for how *Sepaade* impacts the dynamics is revealed by the polygyny ratio for age-set *j* men from line X:

$$R(j) = [WMO_3(j) + WMY_2(j) + WMY_2'(j) + WMO_3'(j)]/ Wr_3(j). \quad (1)$$
$$= [(1-p_X)G_1(j-2) + p_Y G_1(j-1) + p_X' G_1'(j-1) + (1-p_Z')G_1'(j-2)]/ Wr_3(j).$$

Sepaade benefits line X men -- a reduction in p_X increases the number of line X girls $G_1(j-2)$ marrying into line X. Consider an extreme case with "Complete *Sepaade*", where p_X =0 and $p=p'$=1. Then the number of women that line X men $Wr_3(j)$ marry is $WMO_3(j) + WMY_2(j) + WMY_2'(j) = G_1(j-2) + G_1(j-1) + G_1'(j-1)$. In contrast, line Z men $Wr_3(j-1)$ marry only $WMY_2'(j-2) = G_1'(j-2)$ women. This *Sepaade* induced asymmetry shows up in the difference equations derived below and can result in line Z dying out.

3.3 *Modeling Reproductive Rates*

The next assumption specifies female net reproductive rates.[11] For each female reared, we assume that g=1 males are reared, as that is consistent with Roth's (1993, 1999) data.

Assumption 8 (Net Reproductive Rates). No children are reared before marriage. Women-marrying-young each rear n_1^y daughters born in the first period after marriage, and rear n_2^y daughters born in the second period after marriage, where $n_1^y \geq n_2^y > 0$. Women-marrying-old each rear n^o daughters born in the first period after marriage. Lifetime net reproductive rates are restricted: $n^y \equiv n_1^y + n_2^y \geq n^o$ and $n^o \geq n_2^y > 0$.

We restrict $n^y \geq n^o$ because women-marrying-young bear children for two periods (roughly 28 years) following marriage whereas women-marrying-old only bear for one period (roughly 14 years) following marriage. The period net reproductive rates are declining with the number of periods following marriage, $n_1^y > n_2^y$. These fecundity rates and intervals roughly match Roth's (1993, 1999) data.

The reproductive rates are conditional only on the female's age at time of marriage.[12] This type of female-based fecundity assumption is often made in anthropological demography. We believe that if there is any society that fits this assumption the Rendille are an excellent candidate. Recall, in Rendille society child rearing is only permitted after marriage. All children born of a married woman are brought up as if they were the husband's (even well after the husband is deceased).

3.4 *The Standard OLG Model*

The OLG system described in Table 2 can be combined with the net reproductive rates to derive the dynamic equations of the OLG model. The equations relate mothers to

[11] The net reproductive rate is the number of surviving daughters per mother. The simulation program allows for gross reproductive rates and a schedule of mortality rates as well as various values of g.

[12] Rearing rates are independent of the presence of the husband, number of other wives, or whether mothers were early- or late-born. Even if these factors are important (and we have no evidence that they are), it is not clear that they would affect the population proportions, unless they impacted the lines asymmetrically.

daughters through time. Consider all daughters born in period t+1. Early-born daughters, $G_1(t+1)$, are daughters of $E_4(t+1)$ men. Suppose these men belong to age-set j and line X. From Table 2, we know that these men in the previous period, $Wr_3(j)$, married four groups of women: women-marrying-young $WMY_2(j)=p_Y G_1(j-1)$ and $WMY_2'(j)= p_X' G_1'(j-1)$, and women-marrying-old $WMO_3(j)= (1-p_X)G_1(j-2)$ and $WMO_3'(j)= (1-p_Z')G_1'(j-1)$. Hence, ignoring attrition early-born daughters born to line X fathers are:

$$G_1(j+1) = n_1^y \{p_Y G_1(j-1) + p_X' G_1'(j-1)\} + n^o \{(1-p_X)G_1(j-2) + (1-p_Z')G_1'(j-2)\} .$$

Late-born daughters born in j+1 are from women-marrying-young in period j-1: $WMY_2(j-1)$ and $WMY_2'(j-1)$. Hence, late-born daughters born to line Z fathers, $E_5(j+1)$, are:

$$G_1'(j+1) = n_2^y \{p_X G_1(j-2) + p_Z' G_1'(j-2)\}.$$

Similarly we can derive the girls born in periods j+2 and j+3.

$$G_1(j+2) = n_1^y \{p_Z G_1(j) + p_Y' G_1'(j)\} + n^o \{(1-p_Y)G_1(j-1) + (1-p_X')G_1'(j-1)\}$$
$$G_1'(j+2) = n_2^y \{p_Y G_1(j-1) + p_X' G_1'(j-1)\}.$$
$$G_1(j+3) = n_1^y \{p_X G_1(j+1) + p_Z' G_1'(j+1)\} + n^o \{(1-p_Z)G_1(j) + (1-p_Y')G_1'(j)\}$$
$$G_1'(j+3) = n_2^y \{p_Z G_1(j) + p_Y' G_1'(j)\}.$$

This completes the rotation through lines X, Y, and Z, after which the system repeats.

4. The Genealogical OLG Model and Dynamics

The above OLG model is cast in age-set periods of 14 years and describes a three-period rotation through lines X, Y, and Z that relates one fahan, generation-group, to the next. This section recasts the analysis into a genealogical OLG model with generation-group periods of 42 years (see Figure 3). The recast model not only reveals the relationship between fahans but also more closely fits the rules and can be solved analytically.

The OLG model is readily recast because age-set lines are well-ordered X, Y, and Z in 14-year intervals within each generation-group period and the age-group rules relate father's and early-born sons age-sets to the same age-set line. Specifically rule (vi) requires that early-born sons of fathers age-set *j*, fahan *n,* lineage X are initiated into age-set *j*+3, fahan *n*+1, lineage X. The standard OLG model makes this linkage by age rather than paternity. Assumption 2 counts two age-sets between birth and initiation; those born in period *j*+1 are initiated in *j*+3. However, "first-born" sons are out of joint with this time. In particular, the Simplifying Assumption is invoked to shift these early-born sons that are actually born at the end of period *j* into period *j*+1 (see Figure 1).

The genealogical OLG model uses two indexes, lineage and fahan. Thus, it maps early-born sons of fathers, fahan *n,* lineage X, directly to fahan *n*+1, lineage X. Early-born sons are identified as those sons born before their fathers enter their second period of elderhood (here, before the initiation of age-set, lineage Z, fahan *n*), and late-born sons are born thereafter. Early- and late-born daughters are similarly related to their fathers. The Simplifying Assumption is not needed to sort out the temporal overlap in birthing across age-sets. Thus, the genealogical model exactly captures Beaman's rules (i)-(xiii).[13] The following table describes how generation groups marry and rear children.

Men of generation-group …	… Are eligible to marry women-marrying-old (women-marrying-young) from groups:	… Rear daughters belonging to groups:
X_n	Z'_{n-1}, X_n (X'_n, Y_n)	X_{n+1}, X'_{n+1}
Y_n	X'_n, Y_n (Y'_n, Z_n)	Y_{n+1}, Y'_{n+1}
Z_n	Y'_n, Z_n (Z'_n, X_{n+1})	Z_{n+1}, Z'_{n+1}

The first two columns of the table transform of the marriage matrix Table 2 into the new variables. The transformation of the standard model in our new notation is:

[13] The model does not capture a rule (omitted in Table 1) where by special prearrangement a late-born son can "climb" an age-set so as to be in their father's age-set line. As discussed in Engineer et. al. (2005), this rule is an exception that applies to about 5% of sons. It does not affect the dynamics of the maternal model. In simulations it only slightly changes the proportions of males in age-set lines.

$$X_{n+1} = n^o \{(1-p_{Z'})Z'_{n-1} + (1-p_X)X_n\} + n_1^y \{p_{X'}X'_n + p_Y Y_n\}$$
$$X'_{n+1} = n_2^y \{p_{X'}X'_n + p_Y Y_n\}$$
$$Y_{n+1} = n^o \{(1-p_{X'})X'_n + (1-p_Y)Y_n\} + n_1^y \{p_{Y'}Y'_n + p_Z Z_n\}$$
$$Y'_{n+1} = n_2^y \{p_{Y'}Y'_n + p_Z Z_n\}$$
$$Z_{n+1} = n^o \{(1-p_{Y'})Y'_n + (1-p_Z)Z_n\} + n_1^y \{p_{Z'}Z'_n + p_X X_{n+1}\}$$
$$Z'_{n+1} = n_2^y \{p_{Z'}Z'_n + p_X X_{n+1}\}$$

Using matrix population methods from mathematical ecology, Kang and Engineer (2005) are able to prove the existence of a unique globally stable dynamic path that converges to a (periodic) steady-state growth path. They find necessary and sufficient conditions for growth of the age-set lines under realistic restrictions $n_2^y \leq n^o$ and $n_2^y p' \leq 1$.[14] As might be expected when marriage rates are symmetric across age-set lines, all lines are the same size and grow at the same rate in the steady state. In contrast, the sepaade rule, $p_X < p$, induces both a negative level and growth rate effect on the population. There is also a pronounced composition effect where line X dominates. In the extreme case of "complete sepaade", $p_X = 0$, the other lines tend to die out quickly and the growth rate of line X will be negative for the historically relevant case $n^o < 1$. Technically, in this case, age-set line X becomes an absorbing lineage. The following simulations describe the transition dynamics to these steady states.

4.1 Symmetry

Symmetry among the age-set lines requires $p = p_X = p_Y = p_Z$ and $p' = p_X' = p_Y' = p_Z'$. As might be expected, when $n^y = n^o = 1$ (each mother rearing one daughter) the steady state population is constant, and when $n^y \geq n^o > 1$ the steady state displays growth. The level of the steady state population path increases when more children are born early and less late, i.e. increasing p, p' or n_1^y (holding $n^y = n_1^y + n_2^y$ constant).

[14] Engineer et. al. (2005) examine the available data and find that the upperbound for n^o is 0.8 so that the later restriction follows from the former.

This is because the average lag between birth and bearing children is reduced. Interestingly, both population growth and more early-born daughters increase polygyny.[15]

More relevant to our data, population growth occurs when $n^y > 1$ is sufficiently large even if $n^o < 1$.[16] This is illustrated in Simulation 1, which uses the same parameters (except for p_X) derived in the calibration analysis of Section 5.

(Simulation 1 here)

Though $n^o < 1$, population growth occurs because $n^y = 1.286$ is sufficiently large. The age-set lines are symmetric except for being in different phases. (every third period each line includes two groups of women, one just married and women about to die). The steady state net average growth rate of the population is 16.36% per (14-year) period, and R= 1.1455. Increasing p or p' increases the growth rate and R.

4.2 A Compete Sepaade Shock

The effects of the institution of *Sepaade* can be examined by "shocking" the pre-existing symmetric steady state by lowering $p_X = p$ to $p_X < p$. The dynamic impact of this asymmetry is most clearly revealed by examining the extreme case $p_X = 0$, what we call a Complete *Sepaade* Shock. In this case, the *Teeria* population (line X) often comes to completely dominate the population, as illustrated in Simulation 2.

(Simulation 2 here)

Apart from $p_X = 0$, Simulation 2 uses the same parameters as Simulation 1. After the shock in period 5, line X initially dramatically grows and the other lines (Y and Z) dramatically fall off. The other lines essentially disappear by period 20 and the *Teeria*

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[15] With $p=p'$ and g=1, the polygyny ratio described in (1) reduces to $R(t) = (1-p) + p*r(t)$, where $r(t)$ is the growth rate of women. When $r(t) > 1$, $R(t) > 1$, even though there is gender balance, g=1.

[16] With $p=p'$ the model reduces to two difference equations in $G_1(t+1)$ and $G_1'(t+1)$. In the zero growth steady state, $G_1(t+1) = G_1(t)$ and $G_1'(t+1) = G_1'(t)$ for all t. Solving yields $pn^y + (1-p)n^o = 1$. Engineer and Kang (2005) prove that the steady state population grows if and only if $pn^y + (1-p)n^o > 1$.

line comprises the entire population but rapidly declines. The steady state growth rate converges to $(n^o)^{1/3} - 1 =$ -37.34%. Below we show this is a general pattern.

The startling result that lines Y and Z disappear is due to line X becoming an "absorbing state". Introducing Complete *Sepaade* at the beginning of period 5 results in all early-born daughters of line X fathers (age-set 3) working in period 5 rather than marrying young to line Z men (age-set 5). Instead, they become women-marrying-old and marry line X men (age-set 6) in period 6. With Complete *Sepaade*, all early-born X daughters marry back into line X, and most late-born X daughters also marry into line X (as the *Sepaade* rule only applies to early-born daughters). In addition, most early-born daughters in line Y marry into line X. Thus, there is a net drain of women into line X and the other lines retain women at a rate that is well below replacement and die out.

In the steady state, all line X daughters are *Sepaade* and marry back into line X as women-marrying-old. Thus, the steady state net growth rate, $(n^o)^{1/3} - 1$, is negative as long as $n^o < 1$. This result is conditional on the other lines dying out, a sufficient condition for which is that $n^y < 2$. In the next section we show that historically $n^y < 2$ and $n^o < 1$. Thus, these results are applicable to the Rendille under Complete *Sepaade*. But, the evidence suggests that *Sepaade* rule has been incompletely applied, $0 < p_X < p$. With incomplete *Sepaade* the other lines do not disappear. Nevertheless, the Complete Sepaade results are indicative, as the steady state line proportions are continuous in p_X.[17] The next section explores the incomplete *Sepaade* case.

5. Data and Calibration of the OLG Model

5.1 Demographic Data

[17] These results are developed in Engineer and Kang (2005). They identify both a negative growth effect as well as a negative level effect from the introduction of *Sepaade*.

Roth (1993, 1999) analyzes survey data on daughters of men from three adjacent age-sets that span the age-set lines. These age sets correspond to age-set 10 from line Y initiated in 1895, age-set 11 in line Z initiated in 1909, and age-set 12 in line X (*Teeria*) initiated in 1923. The sample contains 101 *Teeria* daughters (*Sepaade*) and 107 *non-Teeria* daughters (*non-Sepaade*). Though Roth makes no claims for this being a representative sample, it is the best evidence we have of the cross-section of daughters by line. We use the data ratio of *non-Sepaade* to *Sepaade*, 107/101 = 1.06, as a final touchstone in the calibration. The predominance of *Sepaade* in the sample lends credence to the idea that the *Sepaade* rule leads to the dominance of the *Teeria* line.

Roth (1999) presents strong direct evidence that the *Sepaade* rule reduces fertility and delays marriage. The female net reproductive rate for *Sepaade* is $NRR_X = .76$, whereas for *non-Sepaade* it is much higher, $NRR = 1.39$. Roth's data on age at marriage is presented in 5-year intervals. Among *Sepaade*, 34% marry before they are 25 and 52% before they are 30. Among *non-Sepaade*, 78% marry before they are 25 and 92% before they are 30. For purposes of the model, we are interested in the proportion of women-marrying-young (28 years and younger). One issue is how to divide those in the 24-29 year age cohort. We use two benchmarks. Extrapolation, using the weights in the adjacent cohorts, yields the proportion of women-marrying-young among *Sepaade* as $P_X = .40$ and among *non-Sepaade* as $P = .89$. In contrast, the "strictest adherence" to rules consistent with the data gives $P_X = .34$ and $P = .92$. In the analysis below we concentrate on ranges: $0.34 \le P_X \le 0.4$ and $0.89 \le P \le 0.92$.

5.2 Ranges for the Model's Parameters

From the demographic data we can uncover ranges for the model parameters. First, consider the following decompositions:

$$NRR = n^y P + n^o(1 - P)\ ,$$
$$NRR_X = n^y P_X + n^o(1 - P_X).$$

Here the average net reproductive rate is decomposed into the net reproductive rates of women-marrying-young, n^y, and women-marrying-old, n^o. These two equations can be solved for the unknowns n^y and n^o, given our data for NRR, NRR_X, P, and P_X. The following table explores how ranges of (P, P_X) impact (n^y, n^o).[18]

P	P_X	n^y	n^o
0.92	0.34	1.477	0.391
0.92	0.4	1.487	0.275
0.9	0.34	1.503	0.378
0.9	0.4	1.516	0.256

The first row describes the "strictest adherence to *Sepaade*" case (largest ratio $P/P_X =$ .92/.34). This case gives the largest n^o and smallest n^y, and hence we can bound the ratio $(n^o/n^y) \leq 0.391/1.477 = 0.265$. The delay in marriage reduces the net reproductive rate by about 75% or more.

Now consider the decomposition $n^y = n_1^y + n_2^y$ and ratio (n_1^y/n^y). The restriction $n^o \geq n_2^y$ requires $n_1^y \geq n^y - n^o$. The "strictest adherence to *Sepaade*" case gives the smallest difference $n^y - n^o = 1.086$. Thus, $n_1^y \geq 1.086$, and we can bound the ratio $(n_1^y/n^y) \geq$ 1.086/1.477 =.735. Women-marrying-young predominantly rear children that are born in the first period after marriage. If the restriction does not bind, $n^o > n_2^y$, then we get a higher lower bound on n_1^y/n^y. For the reason that a higher bound seem less plausible and for the reason that the binding restriction identifies parameter values, we assume $n^o = n_2^y$ in the following analysis.

The proportions P and P_X can be decomposed into early-born and late-born daughters who are women-marrying-young:

$$P = pw + p'(1 - w)$$

[18] The calculations are rounded to 3 decimal places. For extreme value $P_X = 0$, the net reproductive rate for women-marrying-old in line X is equal to the net reproductive rates for Sepaade, $n^o = NRR_X = .76$. This is

$P_X = p_X w_X + p'(1 - w_X)$,

where w and w_X are the proportions of early-born daughters in the respective cohorts. It can be shown that $w_X \geq w \geq n_1^y / n^y \geq 1.086/1.477 = .735$.

First consider p_X, the proportion of *Sepaade* who are women-marrying-young. Since $p_X \leq p \leq p'$, it follows that $p_X \leq P_X \leq 0.4$, consistent with Assumption 6. Realistic values of p_X are likely smaller than this upper bound. For example, if $p' = .9$ and $w_X = .82$, then late-born Sepaade who are women-marrying-young account for (.9)(1-.82) =.162 of women. If the total women-marrying-young is $P_X = .4$, it follows that $p_X = .290$. The value of p_X is increasing in P_X and w_X, and decreasing in p'. Thus, using values $P_X = .34$, $p' = 1$ and $w_X = 0.735$, we can establish a lower bound, $p_X > 0.10$. The data is inconsistent with Complete *Sepaade.*

Similarly, consider the lower bound for p. The value of p is increasing in P and w, and decreasing in p'. If $P = .89$, $p' = 1$ and $w = .7353$, then $p = .85$. This is well within the lower bound of $p \geq .8$ specified in Assumption 6. In contrast, the highest value of p corresponds to $p = p' = P = .92$.

5.3 Calibration

Using standard demographic variables, the model can be calibrated to find the extent to which the *Sepaade* rule applies. The marriage timing parameter p, p_X and p' depend on w and w_X, the proportions of daughters that are early born. In turn, w and w_X are generated from the simulation and depend on all the model parameters. Since our data does not correspond to the steady state, w and w_X also depend on the initial conditions. As described above, *Sepaade* is analyzed as a shock from the symmetric steady state. The following table presents calibration results for various (P, P_X) combinations under the assumption that $n_2^y = n^o$.

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the extreme upper bound for n^o. Conversely, when $P = 1$, $n^y = NRR$=1.39. This is the lower bound for n^y.

(*Table* 3 here)

As described before, each (P, P_X) pair uniquely yields a (n^y, n^o) pair. Given (n^y, n^o), the model is calibrated by finding values of p, p' and p_X that generate (P, P_X) output over the sample (periods 10-12) consistent with the inputted (n^y, n^o). Given (n^y, n^o), for each p' there is a unique solution for p and p_X. The polar cases $p' = p$ and $p'=1$ are reported. The lowerbound for p', $p' = p = P$, corresponds to the upperbound for p, $p = P$. The values of p' and p move inversely, so that $p'=1$ corresponds to p being at its lowerbound. Similarly, all the simulations display an inverse relationship between p' and p_X and between p' and *NSR* (the Non-*Sepaade* to *Sepaade* Ratio).

The first four (P, P_X) pairs in the table are the cases discussed in the data Section 5.1. None of these entries give calibrations with $NSR = 1.06$, the ratio of Non-*Sepaade* to *Sepaade* found in the data. However, the "base case" $(P, P_X) = (.9, .4)$ comes surprisingly close, and $(P, P_X) = (.89, .40)$ yields ratios $1.048 \leq NSR \leq 1.075$. With $(P, P_X) = (.89, .40)$, the unique calibration that exactly matches $NSR = 1.060$ has $p = .88$, $p' = .945$, and $p_X = .3125$. As $p_X = .3125$, the calibration indicate a substantial level of non-compliance with the *Sepaade* rule. Simulation 3 illustrates the dynamics.

(*Simulation 3* here)

After the shock the total population continues to grow and converges to a (average) growth rate of 4.2% per period. This is in stark contrast to the Complete *Sepaade* case (Simulation 2 which has the same except for $p_X = 0$), where the total population starts to falls by period 13 and converges to a very negative (average) growth rate of –35.0%. Nevertheless, the incomplete adherence to the *Sepaade* rule does reduce the growth rate very substantially from the 16.4% that would arise in the absence of the rule (see Simulation 1). Also, in contrast to the Complete *Sepaade* case, lines Y and Z exist in the steady state where the ratio of Non-*Sepaade* to *Sepaade* daughters in the steady state is 1.078. Thus, in the transition, this ratio overshoots its steady-state level.

Of course, this is not the only possible exact calibration. The follow chart shows that by varying P and P_X together there is a substantial region of plausible (P, P_X) parameters for which we can generate calibrations with NSR =1.06.

(*Figure 4* here)

The lowerbound in the chart corresponds to simulations with $p = p' = P$; whereas, the upperbound has $p < P < p'=1$. Overall these parameters range $p \in [.82,.92]$ and $p' \in [.85, 1]$. In contrast, the calibrations provide a much narrower range for $p_X \in [.293, .327]$. Thus, for calibrations with *NSR*=1.06, we can conclude that slightly less than a third of early-born *Sepaade* marry young in violation of the rule. Generically, all of these calibrations have similar features to Simulation 3: there is positive population growth and lines Y and Z produce about half the total daughters.

Of course, these conclusions are based on fitting the model to *NSR* = 1.06. But as mentioned in the data section, this data ratio is suspect (as representative of a random cross-section). The natural question is: How robust are the conclusions to all plausible (P, P_X) pairs? In particular, are there any (P, P_X) pairs that give negative growth and highly skewed population proportions? Consider the first entries in the table, (P, P_X) = (.92, .34). This corresponds to the "strictest interpretation of *Sepaade*". Not surprisingly, these entries have the highest values of p and p' and lowest values for p_X. The entry with the smallest p_X has the lowest *NSR* value and a growth path with the smallest population and the lowest growth rates. The growth path is illustrated in Simulation 4.

(*Simulation* 4 here)

The growth path is similar to Simulation 3 but with less growth converging to a steady state growth rate of 1.5%. Thus, even with the "strictest adherence to *Sepaade*, growth is positive and lines Y and Z exist in the steady state (the ratio of Non-*Sepaade* to *Sepaade* in the steady state is 0.793, also indicating overshooting). This contrasts with a steady state growth rate of –23.9% that results when $p_X = 0$ and a growth rate of 15.5% when $p_X = p$, *ceteris paribus*.

5.4 Discussion

The candidate values of (P, P_X) consistent with the data, yield calibrations with quite different growth rates and proportions. Nevertheless, several strong conclusions emerge. First, the *Sepaade* rule is incompletely adhered to: it holds back the majority but not all early-born *Sepaade* daughters from marrying young, $0.15 < p_X < 1/3$. Second, though the *Sepaade* rule is incompletely adhered to, it substantially reduces the growth rate of the population from high rates (15.5 % and 16.4%) to low rates (1.5% and 4.2%). Third, the *Sepaade* rule results in the *Teeria* line being about as populous as the other two lines together (*NSR* about 1).

Other evidence supports these conclusions. Beaman (1981) survey of *Teeria* age-set 12 finds that approximately one quarter of all eligible women do not follow the *Sepaade* role, so p_X =.24. Though there is no good historical data, it would appear that the Rendille population has been growing fairly slowly. In 1990 they numbered at about 30,000.[19] Rendille elders report that the *Teeria* is by far the largest and most powerful line, as large and as powerful as the other two lines combined.[20]

The analysis also reveals other interesting features. After the shock the total population displays a marked three-period population cycle, which persists in the steady state. This cycle is the same length as a *fahan* (a rotation through the age set lines). The steady state of our model does not produce the six-period cycles of boom and bust believed to exist among the Rendille and termed termed *fahano*.[21] If this cycle is to show up in the demographics it must come from another source (e.g. war, disease, ecology). Indeed, the progression of *fahano* is usually associated with alternating periods of peace

[19] By lowering the steady state population growth, *Sepaade* also lowers the steady state polygyny ratio on average. Our analysis probably underestimates the extent of polygyny because we do not allow for the emigration of sons who receive no inheritance because of primogeniture. Nevertheless, the historical observation is that most men had one wife and very few had more than two wives.

[20] Information revealed in interviews taped by Merwan Engineer in 2001.

[21] Beaman's rule 14 is "Fahano influence history for good or ill in alternating periods of 42 years for a cycle of 84 years. Thus, every age-set is associated with a period of historical influence characterized by either peace or war which alternates every 42 years as predictably as the seasons."

then war. The three period demographic cycles would provide the natural building block of a six-period cycle.

6. The Political Economy of *Sepaade*

The origin, role, and the recent end of the *Sepaade* tradition are detailed in Roth (2001). An emic view is that *Sepaade* was an institutional response to prolonged heavy warfare with Somali neighbours in the early 19th century. Young women of marrying age were recruited to take care of the camels when the warriors engaged the enemy. This precluded them from marrying. It also made the nomadic Rendille more mobile, not having to carry young children when relocating. According to this account, the institution results from a cultural group selection arising as an emergency response to a crisis. While the institution may have been beneficial to the community, it seriously constrained women's fertility and thus is considered disadvantageous to *Sepaade*.

The institution of *Sepaade* was introduced in years 1825-1839, period 5 in the model. The impact of the institution was to prevent women of line X from marrying young to men of line Z in 1836. Instead, these women marry when old to men from line X in 1851, period 6 in the model. The, *Sepaade* shock results in line X men enjoying extra wives at the expense of line Z men. This shows up in the simulations with a dramatic increase in polygyny in line X in period 6. There is a dramatic decrease in polygyny in line Z in period 5, but if many line Z men had died in battle the actual polygyny ratio may not have fallen.[22]

Sepaade has major implications for work and wealth. *Sepaade* keeps women from line X doing hard work for their fathers for an extra period rather than marrying when young. Thus, the institution generates an immediate and ongoing increase in labour from women of line X. Furthermore, *Sepaade* keeps wealth within the *Teeria* line -- the bride wealth of four camels is paid to a *Teeria* father. (Men in line X eventually inherit their wealth from their *Teeria* fathers.) Thus, introducing *Sepaade* unambiguously benefits men of the *Teeria* age set line. Conversely, it is disadvantageous to men in the other lines.

Why did the *Sepaade* institution persist, well after the external threat had pasted? This is puzzling for at least two reasons (ignoring population regulation). First, the dynamics reveal that the composition effect from *Sepaade* makes the lineages unbalanced. Thus, the Rendille are increasing at a disadvantage for wars breaking out in periods in which line Y and Z men are warriors. The second reason is that Y and Z men were at least initially in the majority and their self-interest would have been to abolish the institution.

In fact, there was at least one earlier attempt to abolish the institution. Engineer in interviews with Rendille elders in 2001 was told that the Rendille had convened a council to consider the abolition of *Sepaade* in 1966 (period 15). In that council, all elders but those from two senior *Teeria* families were for abolition. Nevertheless, they were able to block abolition. In 1998 (period 17) they relented and the institution was abolished. The interviews revealed that Rendille collective decision-making normally requires a very high plurality. Further, the *Teeria* elders, as powerful members of the "first-born" lineage, have extra clout in decision-making. This would explain why *Sepaade* persisted. But the dynamics would suggest that the *Teeria* with time would be in an even stronger position. So a puzzle remains: if the *Teeria* were able to block abolition in the past they should be to block it in 1998.

An answer to this puzzle was provided in interviews, which included a key elder from the most powerful *Teeria* family that blocked the move in 1966. The elders confirmed that the *Teeria* stood to gain substantially from *Sepaade* and for that reason had blocked the change in 1966. However, all the *Teeria* had agreed to abolition in 1998 because the early-born *Sepaade* daughters were already starting to escape in anticipation

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[22] The impact is somewhat muted if men of age set line Z can marry late in period 6, at the end of the fourth period of their lives. Sons unless they climb join line X. Daughters on the other hand are married to line Z.

of being forced to hard work (instead of being allowed to marry in 2004). Apparently, *Sepaade* escaping to neighbouring tribes, including traditional enemies, had occurred in 1966. However, the exodus was forecast to be worse this time, perhaps because of the ability to escape to the cities. Faced with the inability to keep their young daughters from running away the *Teeria* elders agreed to the abolition. Thus, it would appear that it is a change in the participation constraints facing *Sepaade* that explain abolition.

7. Conclusion

In this paper, we draw on anthropologists' reports to model the social rules of a particular age-group society, the Rendille of northern Kenya. We show that the social rules are surprisingly well captured by a standard overlapping generations (OLG) model. More interesting, we develop a genealogical OLG model that almost exactly captures the ways males are incorporated into age-sets, transit the lifecycle, and are joined in intergenerational lineages.

The age-group rules of the Rendille are naturally and parsimonious modeled using individuals who are potentially six-period lived. This permit us to captures the essential heterogeneity in the timing of marriage and birth. The Rendille provide a particularly good case study because their age-group system has lineages integrated with their age-set system. This allows us to track lineages and examine the intergenerational political economy behind the social rules. As far as we are aware, there are no applied OLG models that are structurally exact, capture marriage and birth timing heterogeneity, or track lineages.

Another novel feature of the paper is that the OLG model can be calibrated out of the steady state using standard (time and group aggregated) cross-section demographic data. The calibration allows us to derive parameters that correspond to specific individual lifecycle transitions: period fertility rates conditional on age at marriage and marriage

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Changing this initial specification does not change the steady state impact of *Sepaade*.

timing probabilities conditional on birth order. The parameters can also be derived according to age groups.

In our application, we examine the marriage timing parameters by lineage groups, and the asymmetry implied by the *Sepaade* rule. Strict application of the *Sepaade* rule requires that no early-born daughters of a particular lineage (the *Teeria*, line X) marry early, $p_X = 0$, whereas it is the usual practice in other lineages, $p > 0.8$. Our calibration analysis finds $0.15 < p_X < 1/3$ and $p > 0.85$ implying that the rule is incompletely applied. Nevertheless, the implied delay in marriage dramatically lowers the path of the population, leading to almost zero population growth. Interestingly, the Sepaade rule favours line X as this line quickly becomes almost as populous as the other two lines combined. These effects are much more pronounced if the rule is strictly followed. Then the population falls after 7 periods and converges to negative growth; line X quickly comprises the entire population as the other lines disappear.

Our results are consistent with the view in the anthropology literature that the *Sepaade* rule strongly regulates constant population.[23] However, our analysis reveals that it is the incomplete application of the rule that maintains constant population. This raises questions about how the rule is regulated and questions about the intergenerational political economy supporting the rule. The *Sepaade* institution was shown not only to favour the *Teeria* by increasing their numbers but also by increasing their wealth. Both factors added to their political clout in blocking attempts to abolition the institution by the other lines.

The model throws up the possibility that the institution was abolished in 1998 because it was leading to a society which was too lopsided and hence vulnerable to attack. However, interviews with Rendille elders suggest the more plausible reason that it was the increased ability of *Sepaade* daughters to escape to the neighbouring tribes and

[23] Roth (1993) reviews this literature, which argues that *Sepaade* prevents overpopulation and thereby helps achieve homeostasis with the environment.

the cities that explains the recent abolition. Thus, a change in the participation constraints of the *Sepaade* appears to be decisive factor in limiting the power of the *Teeria* men.

Whereas we have explored the rich dynamic implications of the structural rules of Rendille society, our analysis falls substantially short of a full account. The gold standard in economics is to specify an environment and preferences and then examine the equilibrium behavioral choices for consumption, production and reproduction.[24] In future work we hope to acquire more data and knowledge to model important aspects of individual choice in a general equilibrium framework.[25] Nevertheless, we believe that the structural analysis shows that the OLG model is a powerful tool for investigating the nature and dynamics of actual societies. We hope that this exercise helps points the way to modifying the OLG model as an applied framework for societies that less exactly fit the standard model.

REFERENCES

Auerbach A. and L. Kotlikoff (1987), *Dynamic Fiscal Policy*, Cambridge University Press: New York.

Beaman, A.W. (1981), "The Rendille Age-Set System in Ethnographic Context: adaptation and integration in a nomadic society", unpublished Ph.D. dissertation, Department of Anthropology, Boston University.

Engineer, M. H. and D. Bernhardt (1992), “Endogenous Transfer Institutions in Overlapping Generations”, *Journal of Monetary Economics*, 29, 445-74.

[24] A full account would address the more fundamental questions of why social rules arise. Our analysis reveals that certain rules are more likely to be stable than others. In the economics literature, Engineer and Bernhardt (1992) look at the incentive compatibility conditions between two-period lived generations and Engineer, Esteban and Sakovics (1997) examine the core of a simple OLG to examine the stability of age-based social rules.

[25] Roth’s (1999) work on marriage choice points to specifying preferences over cattle and camels for wealth and also the probability of a surviving male heir. Production mainly involves camels, and there is surprisingly detailed information available about camels in the region. Perhaps not surprisingly, camels appear to have a lifecycle that coincides with the 14 year age-set period. Droughts and human cycles may induce cycles in the environment that have their own “deep-ecology” dynamic. From this perspective, the institutions of age-sets and *Sepaade* may be viewed as intriguing ecological control mechanisms.

Engineer, M. H., Esteban, J. and Sakovics (1997), “Costly Transfer Institutions and the Core in Overlapping Generations”, *Journal of Economic Behavior and Organization*, 32, 287-300.

Engineer, E. Roth and L. Welling (2005), “ Modeling Social Rules and Experimental History: The Impact of the *Sepaade* Tradition on the Rendille”, mimeo Department of Economics, University of Victoria.

Engineer, M. H., and L. Welling (2004), "Overlapping Generations Models of Graded Age-Set Societies", *Journal of Institutional and Theoretical Economics*, 160(3), 454-476.

Gokhale, J. L., J. Kotlikoff, J. Sefton, and M. Weale (2001), “Simulating the Transmission of Wealth Inequality via Bequests”, *Journal of Public Economics,* 79, 93-128.

Greenwood, J., N. Guner, and J. Knowles (2003), “More on Marriage, Fertility, and the Distribution of Income.” *International Economic Review*, 44, 827-662.

Huggett, M. (1996), “Wealth Distribution in Life-Cycle Economics”, *Journal of Monetary Economics*, 38, 469-494.

Kang M. and M. Engineer (2005), “A Linage Matrix Population Model of the Rendille of Northern Kenya”, mimeo, Department of Economics, University of Victoria.

Roth, E. (1993), "A Re-examination of Rendille Population Regulation", *American Anthropologist*, 95:597-611.

_______(1999), Proximate and Distal Variables in the Demography of Rendille Pastoralists”, *Human Ecology*, 27. 4: 517-36.

_______(2001), "Demise of the Sepaade Tradition: Cultural and Biological Explanations", *American Anthropologist*, 103.4: 1014-1024.

_______(2004), *Culture, Biology and Anthropological Demography,* Cambridge University Press.

Spencer, P. (1997), *The Pastoral Continuum*, Oxford University Press.

Stewart, F.H (1977), *Fundamentals of Age-Group Systems*, Academic Press.

Table 1:

BEAMAN'S RULES ON

RENDILLE AGE-GROUP ORGANIZATION (ABRIDGED)*

(i) There are three grades: boyhood (from birth to initiation; this may be termed a pre-grade); warriorhood (from initiation to marriage); and elderhood (from marriage until death).

(ii) A new age-set is formed every fourteen years upon the initiation, by circumcision, of all eligible boys into warriorhood.

(iii) Only one age-set occupies the warrior grade at a time.

(iv) Warriorhood confers the right to engage in sexual relations but not the right to claim paternity in any child, which comes only from marriage.

(v) Warriors remain unmarried for eleven years after initiation, and then all members of set become eligible for marriage and elderhood at one time.

(vi) A son is normally circumcised into the third age-set to follow that of his father; late-born sons may join later sets, but no son may be circumcised with an earlier set.

(vii) The age-sets are organized into three lines of descent as a result of Rule No. 6, such that every third set is composed largely of sons of the first. Fathers and sons thus tend to fall into the same age-set lines. One set in each line is inaugurated before any line recurs.

(viii) One age-set line is named *Teeria*, and is considered the senior line of the three. The sons of any *Teeria* man, if they are initiated into the third set after their father's, will be *Teeria* themselves.

(ix) Daughters of *Teeria* men are called *Sebade* (or *Sepaade*), and in most lineages they are not allowed to marry until their brothers have become eligible to do so.

(x) No son born to a woman after her eldest son has been circumcised may be raised, and such a son should be killed at birth.

*From Beaman (1981); a complete list of the rules is found in Engineer et. al. (2005).

Table 2
Marriages of Daughters by Line to Men by Line

Line, Men	Daughters of X (*Teeria*)	Daughters of Y	Daughters of Z
X (*Teeria*), $Wr_3(j)$	$WMO_3(j)=(1\text{-}p_X)G_1(j\text{-}2)$ $WMY_2'(j)=p_X'G_1'(j\text{-}1)$	$WMY_2(j)=p_YG_1(j\text{-}1)$	$WMO_3'(j)=(1\text{-}p_Z')G_1'(j\text{-}1)$
Y, $Wr_3(j+1)$	$WMO_3'(j+1)=$ $(1\text{-}p_X')G_1'(j\text{-}1)$	$WMO_3(j+1)=(1\text{-}p_Y)G_1(j\text{-}1)$ $WMY_2'(j+1)=p_Y'G_1'(j)$	$WMY_2(j+1)= p_ZG_1(j)$
Z, $Wr_3(j+2)$	$WMY_2(j+2)=p_XG_1(j+1)$	$WMO_3'(j+2)=(1\text{-}p_Y')G_1'(j)$	$WMO_3(j+2)=(1\text{-}p_Z)G_1(j)$ $WMY_2'(j+2)=p_z'G_1'(j+1)$

Table 3
Calibrations by (P, P_X) holding $n_2^y = n^o$

(P, P_X)	n^y	n^o	p	p'	p_X	*NSR*
(0.92, 0.34)	1.477	0.391	.92	.92	.189	.795
			.892	1	.168	.774
(0.92, 0.4)	1.487	0.275	.92	.92	.302	1.008
(0.9, 0.34)	1.503	0.378	.9	.9	.315	.825
(0.9, 0.4)	1.516	0.256	.9	.9	.315	1.051
			.88	1	.30	1.023
(0.89, 0.39)	1.529	0.269	.89	.89	.303	1.030
(0.89, 0.40)	1.531	0.246	.89	.89	.322	1.075
			.87	1	.305	1.048
			.88	.945	.3125	1.060
(0.89, 0.41)	1.534	0.222	.872	1	.325	1.095

Figure 1
Father and sons

Period: *t*-2 *t*-1 *t* *t*+1 *t*+2 *t*+3 *t*+4 *t*+5 *t*+6

Boy Warrior Elder

Father: /--/----------/----------/------\---/----------/----------/---------/

Age: -2 0 14 28 39 42 56 70 84

Early-born son /--/----------/----------/------\---/----------/----------/---------/
Age: -2 0 14 28 39 42 56 70 84

Late-born son: /----------/----------/------\---/----------/----------/--------/
Age: 0 14 28 39 42 56 70 84

Figure 2
Husbands and Wives

Period: *t*-2 *t*-1 *t* *t*+1 *t*+2 *t*+3 *t*+4

Marriage and Fatherhood
Male age-set *t*: /--/----------/----------/------\---/----------/----------/---------/

Age: -2 0 14 28 39 42 56 70 84

Marriage and Motherhood

Women-marrying-young: /--/----------/-------\---/---------/----------/----------/---------/
Age: -2 0 14 25 28 42 56 70 84

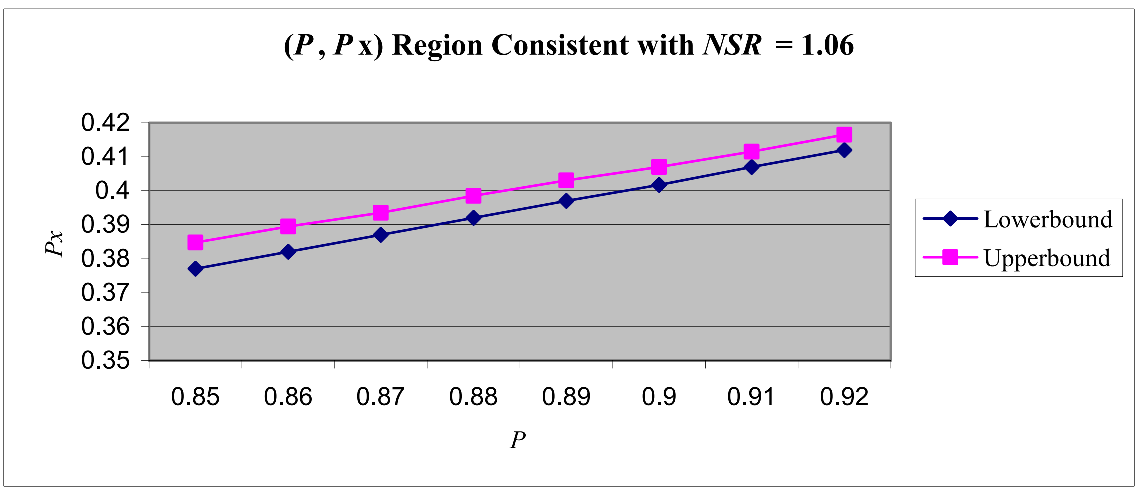
Women-marrying-old:
/--/----------/----------/------\---/----------/----------/---------/
Age: -2 0 14 28 39 42 56 70 84

Figure 3
Paternal Graded Age-Set System

Line	Age Set / Time	*j*-2	*j*-1	*j*	*J*+1	*j*+2	*j*+3	*j*+4	*j*+5	*j*+6	*j*+7
X	*J*	B_1	B_2	Wr_3	E_4	E_5	E_6				
Y	*j*+1		B_1	B_2	Wr_3	E_4	E_5	E_6			
Z	*j*+2			B_1	B_2	Wr_3	E_4	E_5	E_6		
X	*j*+3				B_1	B_2	Wr_3	E_4	E_5	E_6	
Y	*j*+4					B_1	B_2	Wr_3	E_4	E_5	E_6
Z	*j*+5						B_1	B_2	Wr_3	E_4	E_5

Note: B refers to Boyhood, Wr to Warriorhood, and E to Elderhood; the subscript refers to the period of life.

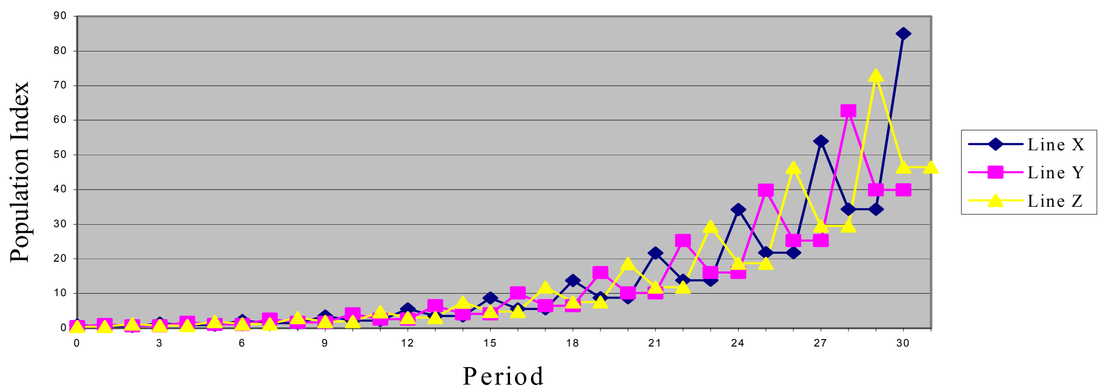
Figure 4
Non-Sepaade and Sepaade Proportions Marrying Young Consistent with Sample Population Ratio



Simulation 1: Symmetric age-set lines

$p_X = p = .88,\ \ p' = .945,\ \ n_1^y = 1.286,\ \ n_2^y = n^o = .246$

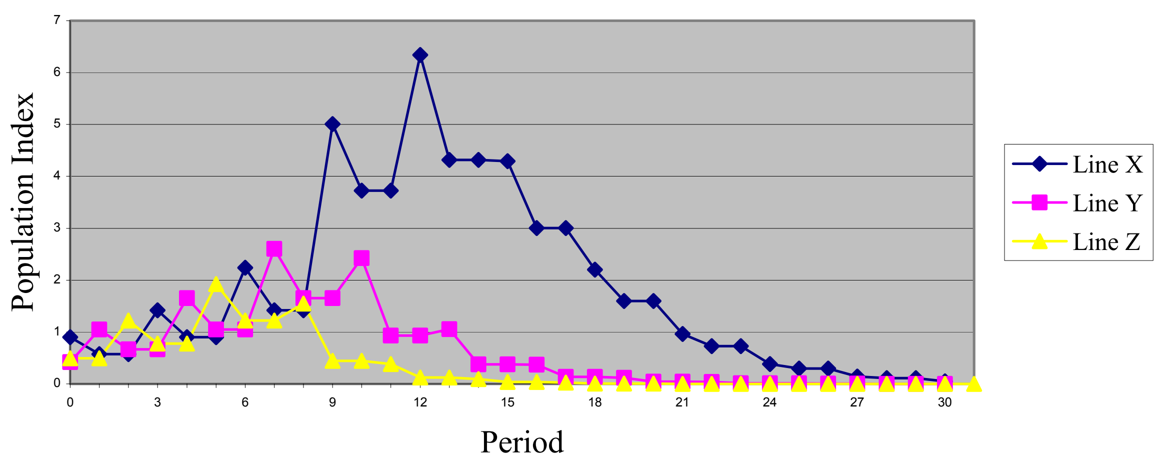
Populations of Women by Line



Simulation 2: Complete *Sepaade*
Shock starting in period 5

$p_X = 0,\ p = .88,\ p' = .945,\ n_1^y = 1.286,\ n_2^y = n^o = .246$

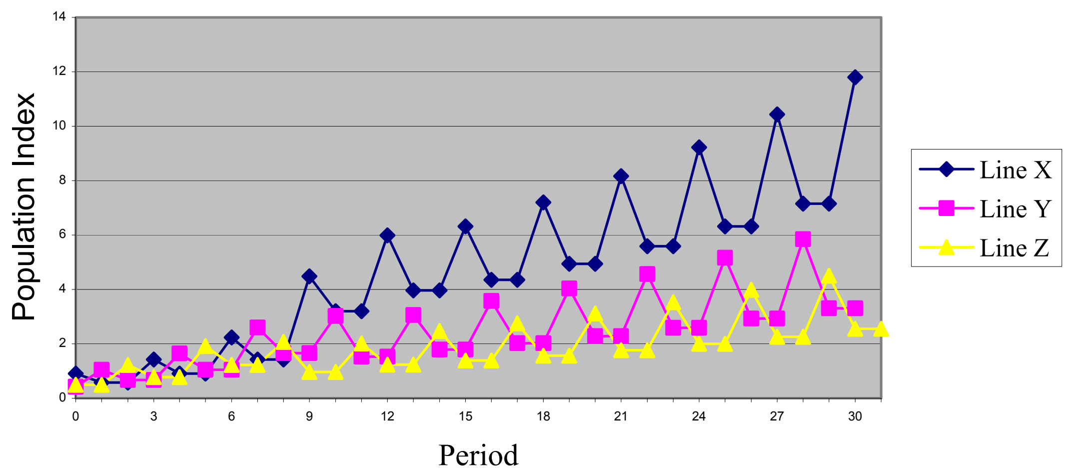
Populations of Women by Line



Simulation 3: Calibration to *NSR* =1.06
Shock starting in period 5

p_X= .3125, p = .88, p'=.945, n_1^y=1.286, $n_2^y = n^o$ =.246

Populations of Women by Line



Simulation 4: Strictest Adherence to *Sepaade*

Shock starting in period 5

p_X= .168, p = .892, p'=1, n_1^y=1.477,
$n_2^y = n^o$ =0.391

Populations of Women by Line