Preliminary, comments welcome

MODELING SOCIAL RULES AND HISTORY:
The Impact of the *Sepaade* Tradition on the Rendille of Northern Kenya

by

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ABSTRACT

This paper models the age-group social rules followed by the Rendille of northern Kenya and develops a simple simulation model (available to the reader) for experimenting with the history induced by those rules. Rendille society is well described as a *graded age-group society* with *negative paternal linking*. This age-group demography is elegantly captured by an *overlapping generations* model, arguably the paradigm theoretical model for macroeconomic analysis. We use the model to examine a prominent and unique institutional feature of the Rendille age-group system, termed *Sepaade*. *Sepaade* involves women from every third age group marrying unusually late. The model shows that *Sepaade* reduces the level and the growth rate of the population, induces periodicity in the age-group demographics and dramatically favours one of the age-group lineages. We examine the impacts of the introduction of *Sepaade* in 1825 and its dissolution in 1998. This method of examining history is valuable because it both provides answers to existing questions and suggests additional important questions. The relevance of both answers and questions is confirmed by the emic test of asking Rendille elders.

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 well established, and frequently closely linked to chronological age and/or age relative to that of the person's father. Anthropologists call societies with these homogenous lifecycle characteristics *age-group societies*.[1] The definitive integrative work in this area is Stewart's *Fundamentals of Age-Group Systems* (1977). Stewart develops an empirically relevant prototype model and analytically describes other age-group societies as varying from this prototype.

In a recent paper, Engineer and Welling (2004) show that a prototype *overlapping generations* (OLG) structure can exactly represent the transitions of Stewart's prototype *graded age-group system*.[2] The OLG structure captures both the generation and the lifecycle stages of all individuals. The generational dimension captures the age-group affiliation; while, the lifecycle dimension captures the grades of individuals in the prototype graded age-group system. Where Engineer and Welling (2004) provide results on classes of demographic structures, they do not actually model a particular age-group society.

This paper develops an OLG model of a particular age-group society. Because the distinguishing feature of the analysis is the group and grade structure, we concentrate on demography. The model accurately tracks births, marriages, deaths, by age group, *given* the age-group rules, initial population and fecundity. The analytical solution to the model reveals the demographic dynamics

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

[2] The OLG model specifies a well-defined temporal sequence of interactions between agents. Many economists view the OLG model as the paradigm general equilibrium model because it allows for incomplete markets and provides a realistic lifecycle analysis for agents. See Engineer and Welling (2004) for an extensive list of references to the literature.

inherent in the rules governing the age-group society. Simulations of the model using reasonable parameters give a sense for the magnitudes of the variables and the transition dynamics of the society. We invite the reader to use the Excel simulation package provided to get a sense for the dynamics of the society.

The particular application is to the Rendille of northern Kenya. Each age group represents a generation in the usual sense of an age-cohort. Among the Rendille age-set lines represents a distinct genealogical lineage relating fathers to eldest sons. The fact that every third age group is in the same lineage indicates the length of the genealogical generation is 42 years. The lineages are named. The *Teeria*, or "first born", is the lineage that starts a *fahan*, a new genealogical generation.

A prominent feature of the Rendile age-group system is the institution of "*Sepaade*", whereby women of the *Teeria* age-set line marry unusually late. *Sepaade* delays marriage for women in a particular lineage called the *Teeria age-set line*. This delay results in *Sepaade* women marrying back into the *Teeria* line, whereas non-Sepaade women marry out of their fathers' lineage. This asymmetry in marriage rules dramatically increases the population of the *Teeria* age-set line relative to the population of the other age-set lines. Overall, *Sepaade* reduces the level and the growth rate of the population, and induces periodicity in the demographics.

Sepaade favours the men of the *Teeria* age-set line in two ways. *Sepaade* requires daughters to work for fathers longer than they would if they were married young. The delay in marriage also shifts these women (who would ordinarily marry older men from another age-set line) to marrying men of their own age, in their own age-set line. Thus, *Sepaade* provides another source of mates for the young male warriors (moran) of the *Teeria* line. Men of the *Teeria* line have more wives, and consequently become more numerous and wealthier. Thus, *Sepaade* has the effect of increasing the population of the *Teeria* age-set line while reducing the population of the other age-set lines. Moreover, with *Sepaade* bride wealth is kept within the *Teeria* age-set line. Therefore, in our model the *Teeria* are the most populous and well-off age-set line, consistent with Rendille beliefs.

Our model provides counterfactual analysis for investigating the origin, persistence and recent dissolution of the institution of *Sepaade*. 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 engaged neighboring tribes in battle. 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 happen for two reasons. First, the society was becoming too demographically lopsided towards the *Teeria* line. Second, the institution became unviable as women disadvantaged by the tradition found it easier to emigrate in recent times. We ask Rendille elders for their views on the reasons for discontinuing *Sepaade* and whether the factors suggested by the model were important considerations.

In the context of the anthropological literature our paper can be thought of following in the footsteps of the pioneering work of Hallpike (1972) and Legesse (1973). These works are ground breaking because they are the first serious attempts to simulate the history implied by the social structural rules governing whole societies. The works are also striking in their vast scope and innovative blend of methodologies. Legesse's analysis seeks to understand the demographic history of the Borana from when they adopted the Gada system in 1623. Hallpike's analysis examines 180 years of Konso demographic history. Legesse (1973) explicitly starts with structural analysis, then generative simulations, followed by statistical analysis and finally emic views. Hallpike (1972) is less explicit but carefully describes the structure of the social rules in the context of emic rationales before doing simulation analysis. We believe Hallpike's and Legesse's works set an ambitious and high standard for social science. Unfortunately, though often cited, these works have been neglected as evidenced by the few similar studies.

This paper seeks to emulate Legesse's general approach and incorporate modern computational techniques to make the analysis more accessible and transparent. As in Legesse, we start with an analysis of the structure of society. We are fortunate that the rules of Rendille society have been studied thoroughly. We have conducted our own field research to fill the gaps in our knowledge. Rendille society is a graded-age set society. It turns out that this structure is systematic and fairly straightforward. In its macro broad outlines it lends itself to the modeller dream of a model that is both understandable and accurate. We apply Occum's razor to deliberately make the analysis as parsimonious as possible.

The straightforward social structure and simple model allows us to simulate the experimental history on any PC using a simple spreadsheet like Excel. Here our methodological contribution is modest, transparency. We have taken pains to make this program elegant and straightforward. We welcome readers to play with the program to get a sense for how structural and other parameters affect the history. In this sense, the reader is readily able to test the sensitivity of the experimental history to variants on the structure and to the inevitable numerous auxiliary assumptions. Indeed our exposition attempts to educate the reader in properties of the model and how they affect the solution.

The paper proceeds as follows. The next section summarizes the social rules of the Rendille age-group society. Section 3 models the social rules and develops the overlapping generations model for Rendille demography. Section 4 describes the solution and simulations. Section 5 discusses the implications of the simulation results. Section 6 concludes by summarizing and outlining directions for future research. The Appendix contains documentation for the simulation program.

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. The Rendille have camel herds, with some additional smallstock. Wealth among the Rendille is measured by the camel herds, owned by the (male) elders in the tribe. These herds are passed on to the eldest son in a family. The Rendille rely upon camels as a tradeable good, as a means for transporting their communities and water, and as a source of food (milk most importantly, blood, and occasionally meat). Until recent times, interaction with agricultural and industrial economies was limited to the trade of skins or livestock itself for tea, sugar, maize, tobacco, cloth, etc. (Beaman p. 29). For more complete description of Rendille society see Beaman (1981), and Roth [(1993), (1999), (2001)].

Our focus is on Rendille age-group organization which The goes back well before 1825 when the institution of *Sepaade* was introduced (Roth (1993), p601). Beaman (1981) provides the most comprehensive analysis of the system. We organize our description by first listing Beaman's on rules for the age-group organization and then detail important aspects of the rules relating to the paternal age-group system, marriage, and fertility.

Beaman's (1981, p380-423) 15 rules governing the Rendille age-group society are listed in Table 1.

Table 1:

BEAMAN'S RULES ON

RENDILLE AGE-GROUP ORGANIZATION

1. 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).

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

3. Only one age-set occupies the warrior grade at a time.

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

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

6. 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.

7. A late born son, too young for circumcision with third age-set after his father's, may by special prearrangement "climb" into it after circumcision with the succeeding set. He then has a form of dual membership, sharing the restrictions on member of both sets, but acquiring the rights of the older, in particular the right to marry without further delay; his primary membership is in the older set. As the right to "climb" if not used by the eligible son, is passed down to his own sons.

8. 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.

9. 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.

10. 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.

11. Every person belongs to one of two alternations called a *marad*, and membership alternates with each generation such that a father and son will belong to opposite *marad*, and a grandfather and grandson always belong to the same *marad*. Interactions between individuals is dependent on their respective *marad* affiliations, ….

12. *Marad* tends to alternate with age-set as well as generation, such that most of the members of any age-set line are members of one *marad, …*

13. Three successive age-sets, starting with a *Teeria* age-set, constitutes a *fahan*, and are similar to an institutionalised generation. A *fahan* is opened with the circumcision of the *Teeria* age-set, and closed with marriage of the second set to follow the *Teeria* set. Ideally, generations of men should progress in line with the progression of *fahano*, such that all the sons of any man in an *fahan* would be members of the next succeeding *fahan* ….

14. *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.

15. 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.

2.1 The Paternal Age-Group System

Rules 1-9 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 of readjustment and adaptation to new roles, the next age-set is opened; thus, during the 3-year gap before the next initiation there are technically no warriors.

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. If he lives to the end of period t+2 (or beginning of period t+3), he would be 70 years old when he dies. After two periods in boyhood, this male enters warriorhood at age 28 and marries when he is aged 39 to 42.[3] Rule 4 requires that males can only claim paternity of children from marriage.

Figure 1
Father and sons

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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
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Now consider sons. Stewart (p 108) states: "Fundamentally, the Rendille operate a *negative paternal-linking system*." A negative paternal-linking system restricts the minimum number of age sets separating the inauguration of father and son into their respective age sets and organizes fathers' and early-born sons' age sets into age-set lines. Beaman's rules 6 and 8 sketch the operation of this system among the Rendille.

Rule 6 restricts the minimum age distance between fathers' and "early-born" (i.e. eldest) sons' inaugurations 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 8, 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

[3] An age-set *t* male born at the end of the period *t*-2 enters warriorhood at age 14 and marries

generation-group relationship between fathers and the eldest sons (who receive all the family wealth, primogeniture). Late-born (i.e. younger) sons join later age sets and change their age-set line accordingly. This is called a negative paternal-linking system because of these features. Rule 7, however, specifies an exception to this normal practice called "climbing " which we describe below.

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 interval. It implies that sons of between ages 14-30 at the beginning of period *t*+3 are initiated into age-set *t*+3. Beaman (p.388) states: "As the majority of sons are not first born, the majority of initiates at circumcision are younger than thirty." Except for first-born sons (born at the end of period *t*), the figure uses an enrolment age of 14.[4] Thus, sons born in period *t+2,* late-born sons, are too young to be circumcised at *t*+3 and are circumcised at same times as their "age mates" at the beginning of *t*+4.[5]

Rule 8 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. In the model we describe the Teeria line as age-set line X and the subsequent two lines as age-set line Y and age-set line Z. Thus early-born sons of fathers in age-set line X are normally enrolled in age-set line X; whereas late-born sons are normally enrolled in age-set line Y.

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when he is 25-28. If he lives to the end of period *t*+3 he would be 70 years old.

[4] Beaman (p389) states: "…boys younger than fourteen are seldom among the initiates". Stewart (1977) cites Baxter as observing a son of about 12 being initiated. Adamson (1967) interviews with the Rendille indicated no sons younger than 14 being initiated. Our discussions with Rendille elders confirm that except for first-born sons one age-set (i.e. 14 years) is the usual minimum interval between the birth and inauguration of a son. This historical practice has been violated recently with younger sons being circumcised.

[5] Sons sired by age-set *t* fathers in period *t*+3 would be initiated into age-set *t*+ 5. However, the number of children this applies to is likely to be small for two reasons. First, Rule 15 requires that no women with sons circumcised in period t+3 shall raise sons in that period or later. Second,

Rule 13 describes a *fahan* as an epoch that encompasses a rotation through the three age-set lines. A *fahan* starts with the initiation of the next *Teeria* age set and takes 42 years to complete. In term of our notation, the *fahan* starts with age-set line X. After 14 years the age-set corresponding to age-set line Y is initiated, and 14 years after that the age-set corresponding to age-set line Z is initiated. The *fahan* ends with the start of the next. As Rule 13 indicates, normally, fathers are in one *fahan* and sons are in the next. If the fathers from age-set *t* (see Figure 1) are in *fahan n* all early-born sons in age-set *t*+3 are in *fahan n*+1. (The exception is late-born sons of age-set Z; they are initiated with their age mates in age-set line X in *fahan n*+2.) Rule 14 describes alternative fahans as suffering good and ill. The Rendille believe their society follows a six-period cycle and label a pair of alternating fahans a *fahano*. Interestingly, our simulations do not produce fluctuations corresponding to *fahano*, but they do produce regular cycles over the length of a *fahan.*

Climbing

The Rendille system deviates from the norm of negative paternal linking by a unique institution called *climbing*. According to Rule 7, by special prearrangement, a late-born son of an age-set *t* father may "climb" into age set *t+3*. If the late-born son is considered too young to climb then the right can be transferred to the grandson and so on.[6] In all cases climbing involves circumcision with one's age mates, then proceeding immediately to elderhood (skipping warriorhood), with the right to marry without delay.

Elders report that historically only one or two persons climb in any clan, which would put the proportion that climb below 5%.[7] Climbing is relatively rare

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period t+3 corresponds to husbands being between 56-84 years old. It is likely that many of these husbands are already dead or too old to sire.

[6] Though Beaman's rule is ambiguous on this point, Stewart (1977, p?) and Roth (1993, p602) describe climbing as a right that in principle is extended in perpetuity.

[7] Elders views on climbing were gathered by Engineer in interviewed in May 2001. Beaman's (1981) census of 136 men finds that only 2.4% of men are initiated early, i.e. two age sets after

because it usually occurs when a father has only late-born sons and tries to preserve at least one son in the family's historical age-set line. [8] In Section 3 we chose not to model climbing partly because climbing is infrequent and also because we argue that it does not essentially affect the long-run population trends.

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. Marriage involves the husband paying bride wealth of 4 cattle to the wife's family. This is a substantial payment that the eldest son usually acquires from his father (or inheritance) by the time of the *nabo* ceremony. The Rendille subscribe to primogeniture so that by custom only the oldest son receives the family wealth, livestock.

Younger sons, who work for their father or older brother during warriorhood in the *fora*, have a moral right to, but are not assured of, cattle for bridewealth. This often gives rise to conflicts between brothers. Poor men who cannot raise bride wealth cannot marry right after the *nabo* ceremony but instead do 2-3 years bride service for their prospective in-laws before marrying. Almost all poor men are usually married by the end of the three-year transition period to elderhood. Alternatively, faced with the prospect of not receiving cattle, younger

their father's. In a smaller census Spencer as reported in Stewart (1977) found around 10% of men climb.

[8] The fact that climbing is uncommon is supported by several additional considerations. First, the main reason put forward for climbing is to secure an heir in the father's line. However, primogeniture results in the family wealth being inherited by the oldest son. Thus, the presence of early-born sons precludes the need for late-born sons to climb. A late-born son will climb only when there are no sons born in the first 17 years following the *nabo* ceremony. Second, climbing is not in the economic interest of the father: it precludes the son from warriorhood and hence from working for the father in the *fora* during that period. Also, it puts the onus on the father to give up cattle early so the son can pay bride wealth. Lastly, elders report in interviews with Engineer in 2001that very young sons do not want to climb but would rather be in their age mates' age set .

sons often emigrate before or during warriorhood to the neighbouring Samburu where doing bride service is less onerous.

The Rendille permit polygyny. However, Spencer (1973) reports that when he observed the Rendille in the early 1970s, 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. Recently, there appears to be a large increase in polygyny, a puzzle we attempt to explain.

Figure 2 illustrates the traditional timing of marriage for males of age-set *t*. These men marry 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, sisters of men one age-set their junior. We denote these women as *women-marrying-young*. In the figure, such a female born at the beginning of period *t*-1 would be 25 when she marries. Females born in the last two years of period *t*-1 would be 11-13 at the time of the next *nabo* ceremony. Since 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). The exception is if these girls are the first-born daughters of age-set *t*-1 fathers, in which case they are usually forced to delay their marriage to the following *nabo* ceremony. Similarly, first-born females of age-set *t*-2 fathers who are born in the last two years of age-set *t*-2 marry age-set *t* men, in which case they may be as old as 27 when they marry.[9]

Figure 2
Husbands and Wives

[9] 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, our data contains surprisingly few married young women in the range of 14-18. Thus, it is unlikely that they marry in the transition period following the *nabo* ceremony to age-set *t*-1 men.

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

                                                               Fatherhood
         Male age-set t:    /--/----------/----------/------\---/----------/----------/---------/
                  Age:    -2  0        14        28    39  42       56        70        84

                                                     Marriage and Motherhood
                                                           ny1      ny2
Women-marrying-young:       /--/----------/-------\---/---------/----------/----------/---------/
                  Age:              -2  0        14     25 28       42        56        70        84

Women-marrying-old:                                        no
                           /--/----------/----------/------\---/----------/----------/---------/
                   Age:   -2  0        14        28    39  42       56        70        84
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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. Like their brothers they will be between ages 28-44 at the time of the relevant *nabo* ceremony. Many women-marrying-old do so because they are held back from marrying by the institution of *Sepaade*.

Sepaade

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). *Sepaade* women delayed in marriage do the same work as sons, herding camels for their fathers.[10] They are viewed as very valuable to their

[10] This tradition is also interesting because it arguably defines a third gender where *Sepaade* perform a hybrid role. Beaman (1981, p.435) believes that *Sepaade* is an ecologically adaptive control on population growth in a restrictive environment. This raises the intriguing possibility of viewing *Sepaade* as a gender response to ecological adaptive control.

father's household and the main reason why the *Teeria* are more numerous and wealthy than the other age-set lines.

The origin (in 1825), role, and the recent end (in 1998) of the *Sepaade* tradition are detailed in Roth (2001). An emic view of the origin of *Sepaade* institution is that during a period of warfare in the 19th century women took on a portion of the responsibility of watering and herding camels. 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 (and continue to be) beneficial to the community, it constrains women's fertility and thus is considered disadvantageous to *Sepaade*. Originally, 6 of the total 9 clans followed the *Sepaade* tradition. However, for the last 7 age-sets all clans have participated. Some elders also reported that an additional line to the *Teeria* in the distant past had *Sepaade* but were not specific.

Beaman's Rule 10 states that *Sepaade* "… are not allowed to marry until their brothers have become eligible to do so." There is some ambiguity about what Beaman means by "brothers". According to Sato (1980, p7), "… *Sepaade* must wait until those of the third age-set after that of their fathers marry. In other words, *Sepaade* cannot marry before their eldest brothers". Spencer's (1973, p35) definition also corresponds to the same timing: *Sepaade* marry eleven years after the initiation of the subsequent Teeria age set. This is the age-set of their early-born brothers. On the other hand, Roth (2001, p1017) states that *Sepaade* cannot marry until *all* their brothers wed. Both interpretations agree in normal circumstances: when a family has only early-born sons or all late-born sons climb or emigrate. Indeed, Roth (2001) places early-born *Sepaade* as marrying no sooner than their early-born brothers. Thus, the existing anthropologists' accounts all suggest we adopt an *early-born brother interpretation of Rule 10*: *Sepaade* are not allowed to marry until their *early-born brothers age-set* have become eligible to do so.

However, as we shall see, the early-born brother interpretation produces startling results in our model. This prompted us to make further inquires. Engineer's (2001) interviews with Rendille elders revealed that *Sepaade* were sometimes too old to bear children and a few were 50 or older when they married. This is consistent with an "all brothers interpretation" of the rule where it is the marriage of late-born brothers that are holding up *Sepaade* from marrying. However, Roth's (1999) data reveals this is clearly not true in all families but rather in a small subset of families with late-born sons. Roth's (2004) interviews with elders reveal that this practice is usually conducted in families that (have no early-born sons and) only have late-born sons who are too young to climb. Rendille practice primogeniture and it is the eldest son who gets the family's cattle, usually upon marriage and elderhood. *Sepaade* prevented from marrying could continue to work for the family and manage their herds. This suggests an *youngest brother interpretation of Rule 10*: *Sepaade* are not allowed to marry until the youngest brother in the family is eligible to do so.

Figure 3
Brothers and Sisters

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Period:                t       t+1      t+2      t+3      t+4     t+5      t+6     t+7

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

Early-born daughter:  /--/----------/----------/------\---/------\---/----------/---------/
             Age:       -2  0         14         28     39 42  53 56        70        84

             Late-born daughter: /----------/-------\---/------\---/----------/----------/--------/
                    Age:           0         14      25  28     39 42        56        70       84
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The timing of marriage under the different interpretations is described using Figure 3, which outlines the time lines of early and late-born sons and daughters of age-set *t* fathers. Early-born sons (and late-born sons who climb) of age-set *t* fathers are eligible to marry at the end of period *t*+3. If age-set *t* are *Teeria* so are age-set *t*+3. As described above, in normal circumstances, *Sepaade* cannot marry until their early-born brothers' age-set marries at the end of period t+3. Thus early-born *Sepaade* are women-marrying old between ages 28-44, and late-born *Sepaade* are women-marrying young between ages 14-28. Both early and late-born *Sepaade* marry at the same time as their brothers and presumably into the *Teeria* line.

A different timing arises under the youngest brother interpretation when a father only has late-born sons too young to climb. Then the *Sepaade* daughter would be held back until the fourth age set following their fathers. Under this scenario early-born *Sepaade* would be as old as 42-58 when they marry; late-born *Sepaade* become women-marrying-old between 28-44. Who do these early-born *Sepaade* marry? Beaman (1981, p. 402) reports that many (older) *Sepaade* are second wives of older men. This description fits with these older *Sepaade* marrying *Teeria* men but in the period following their first marriage.[11] Men of age-set *t*+1 are unlikely to marry these older women. The remaining question is: whom do the late-born *Sepaade* marry? Since their marriage is delayed until after the *nabo* ceremony in period *t*+1, it is likely they marry age-set *t*+1 men. Thus, the eldest son interpretation results in substantial further delays in marriage and some women marrying out of the *Teeria* line (in a small proportion of families).

2.3 Child Rearing Rates

[11] Because of their age and low fertility very old *Sepaade* are not viewed as valuable marriage partners [Engineer (2001)]. Nevertheless, the elders insisted that the full bride price (of 4 cattle) was always paid for *Sepaade*. The marriage of very old *Sepaade* would net a loss of cattle without reciprocal marriages between *Teeria* families.

The delays in marriage caused by *Sepaade* clearly will reduce their fertility. The only other related rule that Beaman lists is rule 15: "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." Under this rule, a women-marrying-young in period *t* and bearing a 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 (Beaman p. 104). 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. The rules and restrictions all indicate that only the timing of marriage matters for fertility. This suggests Rendille demography might be well captured with a maternal model.

3. Modeling Rendille Demography

This section develops a model for examining how the social rules of Rendille society impact major trends in the demography. Ideally, the model should capture key features of the society without becoming unnecessarily complicated. Three observations suggest simplifications of the Rendille system that yield a parsimonious model, appropriate for our focus on the impact of the *Sepaade* rules. First, the Rendille paternal age-group rules closely resemble a graded age-set system. This implies that the paternal rules can be modeled as a *standard overlapping generations system*. Second, the marriage rules match men and women systematically according to age in the graded age-set system. This means that the maternal structure of the model can be described by an overlapping generations system. Third, fertility seems to depend only on the timing of marriage. This means that a relatively simple "maternal" OLG model can describe the underlying population dynamics of the society. The three subsections below correspond to each of these observations and simplifications.

Before detailing the specifics, we describe the time grid for the model. Rendille society is naturally described in term of 14-year periods marked by the initiation of age sets as described in Figures 1 and 2.[12]

<u>Assumption 1 (Time and Period Length)</u>. 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.

Almost all Rendille activities can be parsimoniously described in discrete 14-year periods. This allows us to trace the life passages of cohorts by their period of birth and age in periods.

However, there is one feature that is "out of joint" with the period increment. Not all early-born children are born in the same period. Consider early-born children of men age-set *t* in Figure 1. These children are born over a 16-year interval. The interval extends over all of period *t*+1. It also extends over the last two years of period *t*. These are first-born children. It greatly simplifies the analysis to count these children as having been born in the next period with the bulk of their brothers and sisters. It is possible to do this in the model by assigning fertility rates for the 16-year interval to early-born children in period *t*+1. We later show that this adjustment captures the right numbers for early-born children and is appropriate in a macro model in which we are concerned with population averages.

[12] The Rendille calendar is in lunar years and isn't completely synchronized with the Julian calendar. However, the period length is roughly the same in both calendars as described by Beaman (1977). Roth (?) traces Rendille initiations back to using 14-year periods in the Julian calendar.

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

With this simplification Rendille demography can be nearly exactly modeled using 14-year periods.

3.1 Modelling the Paternal Age-Group System

Assumption 2 (Individuals and Age Sets). The lifespan of an individual (not emigrating) 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.[13]

It can be shown that this assumption satisfies all of Stewart's (1977, 28-29) criteria for his *age-set model* when the enrollment age is 14.[14] This is because the assumption produces a regular structure (without the anomalies ruled out by Stewart's criteria).

Every third Rendille age set is linked into the same age-set line.

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

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[13] In Assumption 2 age-set assignment is by age whereas it is by paternity in Beaman's Rule 6. The two coincide under the simplifying assumption for early-born children. Engineer and Kang (2003) solve the model using Rule 6 and find that it makes no practical difference to the simulations.

[14] Without the simplifying assumption on early-born children, the Rendille system violates the "no overlapping" requirement of the age-set model. Sons of fathers' *t, t*-1 and *t*-2 born in the last two years of period *t* are assigned to different age sets even though they have the same chronological age.

Age-set lines are part of the Rendille *negative paternal-linking system*, which preserves lineage from fathers t to their sons t+3. According to Assumption 2, sons born in period t+1 are initiated into age-set t+3, whereas sons born in t+2 are initiated into age-set t+4. From Figure 1 we note that if these are sons of fathers t, then they are respectively early and late-born sons. Thus, these early-born sons are in the father's line, whereas the late-born sons are in the subsequent line. As Stewart (1977, 104) notes, negative paternal linking does not preclude the society from adhering exactly to the age-set model.[15]

The role of males is determined by their age-grade assignment.

<u>Assumption 4 (Age-Grades)</u>. 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*.

This assumption satisfies Stewart's (1977; 130-131) *age-grade definition*, because the grades are well-ordered and contain no gaps.[16]

Stewart defines a *graded age-group system* as one that satisfies both the age-set model and the age-grade definition. Since our description fits both criteria, it describes a graded age-group system. In fact, it describes a particularly well-behaved system that Engineer and Welling (2004) term a *standard graded age-set system*. This system is well behaved because initiations are at the beginning of periods and all periods are of equal length. Engineer and Welling

[15] This is only true of negative paternal-linking systems, like the Rendille, where marriage takes place after initiation. This qualifier is to prevent "overaging" that arises from sons being too old to join the age-set in their father's line.

[16] Assumption 4 specifies that the warriorhood grade occupy the third period of life whereas in actuality it only occupies the first 11 years. During the three-year transition (to elderhood) at the end of the period, there are technically no warriors. This violates the grade-filling constraint in the age-grade definition. This simplification might be worrying if we were concerned with the number of extant warriors *per se*. However, it is inconsequential for our purposes of tracking long-term population trends from the impact of *Sepaade*,

(2004) show that a standard graded age-set system is equivalent to a *standard overlapping generations system.*[17]

This system is illustrated in Figure 4. Time is along the horizontal axis whereas the vertical axis lists age set, line and *fahan*. Within any age-set, grades occupied correspond to the period. Boyhood is described by periods B_1 and B_2. Warriorhood, denoted M_3, is when males become men. Elderhood is M_4, M_5, and M_6 (not drawn). This is a typical depiction in the OLG literature (e.g. ?) except for the genealogical line and *fahan*. Since births of individuals (that are recruited into any cohort) occur throughout the period, the variables count people at the end of the period to capture the extant population in the age-set.

Our construct ignores climbing. Climbing violates Assumptions 2 and 4; climbers do not join the age-set of their age mates but rather skip warriorhood and join the senior age-set. This puts them in the age-set line of their forefathers. Our analysis ignores climbing for three reasons. First, as explained in Section 2.1, climbing only applies to a small proportion of sons so that fundamentally Rendille society conforms to the negative paternal-linking system. This interesting broader system has never been modelled. Second, the model without climbing is far less complex than the model with climbing, and modelling the paternal dynamics of climbing is not essential to capture the maternal effects of *Sepaade*, which is our focus. We are interested in long-term population trends and not the number of extant warriors, climbing is not particularly relevant to our analysis of the impact of *Sepaade*. Third, in a maternal model, the population distortion from a climber does not affect the future population. Whereas the

[17] Interestingly, Assumptions 1 and 2 also correspond to the criteria for the “bare bones” standard OLG model defined in Engineer and Welling (2004). The bare bones version leaves out a description of the lifecycle (i.e. grade structure). Assumption 1 corresponds to criteria 1 (Time), 3 (Endpoints) and 4(Period Length) in Engineer and Welling. Assumption 2 corresponds to criterion 2 (Agents and Generations). As Assumption 1 specifies no definite endpoint, we are implicitly modeling a “perpetual” system. The simulations start at an arbitrary date, in which case it is strictly speaking an “ongoing” system.

climber is younger than this cohort, he starts to sire children as the same time as others. Climbing only affects the proportion of males in the lines.[18]

3.2. The Marriage Model

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.

Failure to marry is greatly frowned upon and the Rendille allow *polygyny* (multiple wives). All women marrying is feasible as polygyny implies there need not be a shortage of husbands. As the usual pattern is for a man to have either one or two wives, we make the assumption that "no man has more than one more wife than any other man". This assumption allows us to derive simply the distribution of polygynous marriages. For example, if the *polygyny ratio* R of married women to men is R=1.1, 10% of males will have 2 wives and 90% will have 1 wife. The polygyny ratio exceeds 1 with population growth or child rearing practices that favour girls over boys.

Males age-set t marry after the *nabo* ceremony near the end of period t. They marry females from two daughter groups: women-marrying-young of fathers t+1, and women-marrying-old of fathers t. These daughter groups are born in periods t-1 and t-2 respectively, under the simplifying assumption.

Assumption 6 (Marriage Timing) All men of age-set t marry at the end of period t (or equivalently, at the beginning of period t+1). 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.

[18] Engineer (2003) models climbing and demonstrates this result. The simulation program allows for climbing and the reader can experiment with the effects of different rates of climbing. The full documentation for this part of the program is in Engineer (2003).

Figure 5 describes this timing. Males marry after being inaugurated, M_3, in the third period of life. Girlhood in the period of birth is denoted G_1. Females that are women-marrying-young are denoted W_2, as they marry at the end of the second period of their lives. Females that are women-marrying-old go through another grade denoted G_2 in the second period of their lives before marrying. They marry at the end of the third period of their lives and are denoted W_3.

The factors that determine whether a female marries young or old are the lineage of her father and whether she is early-born. In particular, *Sepaade* restricts most early-born daughters of Teeria men to be women-marrying-old. Here we detail the early-born brother interpretation of *Sepaade* (and leave the more involved youngest-brother interpretation until later). The following definition develops notation for capturing the extent of the import of the restrictions on the various cohorts.

Definition. Let p_X, p_Y and p_Z denote the proportion of *early-born* daughters in line X, Y, and Z respectively that are women-marrying-young. Similarly, let p_X', p_Y' and p_Z' denote the proportion of *late-born* daughters in line 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 $p_X=0$. The following assumption specifies conditions capturing the relative import of the restrictions on the various cohorts.

<u>Assumption 7 (Marriage Proportions by Line)</u> *Sepaade* restricts almost all early-born daughters of Teeria men to be women-marrying-old, $p_X \leq 0.1$. The vast majority of early-born daughters in other lines are women-marrying-young, $p_Y = p_Z = p \geq 0.9$. Almost all late-born daughters are women-marrying-young $p_X' = p_Y' = p_Z' = p' \geq p$.

We state the assumption this way to give a sense for the magnitude of the differences suggested by our limited evidence. Our analysis relaxes these restrictions but our work on *Sepaade* maintains $p_X < p \leq p'$. As we have no evidence to the contrary, the proportions in the other lines are set equal to each other $p_Y = p_Z = p$; also $p_X' = p_Y' = p_Z' = p'$.

Assumption 6 and the proportions marrying by line enable us to identify all marriages by line in Table 2. Consistent with Figure 4, men marrying in period *t*, $M_3(t)$, are from line X.

Table 2

Marriages of Daughters by Line to Men by Line

Men's Line, Men	Daughters of X	Daughters of Y	Daughters of Z
Z, $M_3(t-1)$	$p_X W_2(t-1)$	$(1-p_X')W_3'(t-1)$	$(1-p_Z)W_3(t-1)$, $p_Z'W_2'(t-1)$
X, $M_3(t)$	$(1-p_X)W_3(t)$, $p_X'W_2(t)'$	$p_Y W_2(t)$	$(1-p_Z')W_3'(t)$
Y, $M_3(t+1)$	$(1-p_X')W_3'(t+1)$	$(1-p_Y)W_3(t+1)$, $p_Y'W_2(t+1)'$	$p_Z W_2(t+1)$
Z, $M_3(t+2)$	$p_X W_2(t+2)$	$(1-p_X')W_3'(t+2)$	$(1-p_Z)W_3(t+2)$, $p_z'W_2'(t+2)$
X, $M_3(t+3)$	$(1-p_X)W_3(t+3)$, $p_X'W_2'(t+3)$	$p_Y W_2(t+3)$	$(1-p_Z')W_3'(t+3)$

Table 2 extends the OLG system to organize all females by period of marriage. Four groups of women potentially marry into each line. For example, consider line X men, $M_3(t)$. They marry two groups of early-born daughters: line X women-marrying-old, $(1-p_X)W_3(t)$, and line Y women-marrying-youngy, $p_Y W_2(t)$. They marry two groups of late-born daughters: line X women-marrying-young,

p_X'W_2'(t), and line Z women-marrying-old, (1-p_Z')W_3'(t). Notice that this same pattern is repeated for the next group of line X men, M_3(t+3). Thus, the pattern over a *fahan* (a rotation through lines X, Y, Z) captures the matching function of women to men. The polygyny ratio for age-set t men measures the average number of wives per man:

$$R(t) = [(1-p_X)W_3(t) + p_Y W_2(t) + p_X' W_2'(t) + (1-p_Z')W_3'(t)]/ M_3(t). \quad (1)$$

As is evident from the Table 1, *Sepaade* benefits line X men -- a reduction in p_x increases the number of women marrying into line X at the expense of line Z. Consider an extreme case with complete Sepaade, where p_X =0 < p=p'=1. Then the number of women that line X men M_3(t+3) marry is W_3(t)+ W_2'(t) + W_2(t), whereas line Z men M_3(t+2) marry only W_2'(t+2) women. This *Sepaade* induced imbalance shows up in the equations derived in the next subsection. We later show that when there are few late-born daughters, line Z dies out.

3.3 Modeling Child Rearing Rates

<u>Assumption 8 (Children Reared)</u>. Women-marrying-young each rear n_1^y children in the first full period of marriage, and n_2^y children from the second full period of marriage, where $n_1^y \geq n_2^y$ > 0. Women-marrying-old each rear n_1^o children in the first full period of their marriage, where $n_1^y + n_2^y \geq n_1^o$ > 0. Of the children reared, the proportion of males is denoted *g*. No children are reared before marriage.

The rearing rates are only conditional on the timing of marriage and not on a host of other considerations. This type of female-based fecundity assumption is often made in demographic research to simplify the analysis. We believe that if there is any society that fits this assumption the Rendille are an excellent candidate. Recall from Section 2.3, in Rendille society child rearing is only permitted after marriage. Rearing rates are independent of the presence of the husband or number of other wives. Children born of married women are brought up as if they were the husbands' even well after the husband is deceased.[19] Finally, rearing rates are independent of whether mothers were early- or late-born.[20] We have no evidence to the contrary(?)

We pick n_1^y to represent the true rearing rate over the 16-year child bearing interval following marriage. Under the simplifying assumption all early-born are counted in the period after marriage. Thus, first-born children in the two-year interval at the end of the period of marriage are effectively counted in the period following marriage with the bulk of their brothers and sisters. This adjustment captures the right numbers for early-born children once they reach initiation and is appropriate in a macro model in which we are concerned with population averages.

Roth (1999) empirical study of fecundity roughly supports this pattern: women-marrying-young bear children for an average of less than 28 years after marriage; whereas, early-born *Sepaade* women bear children for an average of about 14 years following marriage. He finds rearing rates (net of attrition) of non-Sepaade women to be $n_1^y + n_2^y$ =2.88 and rearing rate for *Sepaade* of 1.76. The

[19] Even if these considerations were important (and we have no evidence that they are), it would not affect the results of the macro model, unless the considerations impacted the different lines asymmetrically.

[20] There are several special cases in which this is true. It follows if the rearing rate for these women does not depend on age at marriage. If it does we then have to compare the density functions of rearing rates. First, observe that the age range at marriage differs between the groups: early-born wed between 14-27 whereas late-born wed between 14-25. Some early born are older, 26-27, when they marry. If they have lower rearing rates then *ceteris paribus* early born would have a lower rearing rate. However, there is an offsetting consideration. We have to look at the density of the number of women at each marrying age. This depends on the timing of their birth. Late-born daughters are most likely to be born in the first half of the period (when rearing rates are declining in age). Thus, when they wed they tend to be older than the midpoint of the range, 19.5 and tend to have lower rearing rates. This offsetting consideration supports the assertion.

delay in marriage forced by *Sepaade* lowers the rearing rate. To identify the rearing rates n_1^y, n_2^y, and n_1^o …

The fraction of males reared, g, may differ from one-half because of infanticide (see rule 15) or child neglect.[21] However, an imbalance in gender proportions isn't prominent in Roth's data so we set *g* =.5 in all the simulations.

3.4 The Overlapping Generations Model

Combining the rearing rates and the OLG system described by Table 2 yields the dynamic equation system of the OLG model. These equations relate mothers to daughters through time. Given initial conditions for females, the equations yield a dynamic path for the maternal demography. The paternal demography can be easily calculated from this solution.

Consider all daughters born in period *t*+1. Early-born daughters born in period *t*+1, $G_1(t+1)$, are daughters of $M_4(t+1)$ men. Suppose these men belong to line X consistent with Table 2. To trace their mothers note that these men in the previous period $M_3(t)$ married four groups of women: women-marrying-young $p_Y W_2(t)$ and $p_X' W_2'(t)$, and women-marrying-old $(1-p_X)W_3(t)$ and $(1-p_Z')W_3'(t)$. Hence, early-born daughters born to line X fathers are:

$$G_1(t+1) = (1-g)[n_1^y\{p_Y W_2(t) + p_X' W_2'(t)\} + n_1^o\{(1-p_X)W_3(t) + (1-p_Z')W_3'(t)\}].$$

Late-born daughters born in period *t*+1 are from women-marrying-young in period *t*-1: $p_X W_2(t-1)$ and $p_Z' W_2'(t-1)$. Hence, late-born daughters born to line Z men are:

$$G_1'(t+1) = (1-g)\, n_2^y\{p_X W_2(t-1) + p_Z' W_2'(t-1)\}.$$

These equations relate mothers to daughters. To express them as difference equations in daughters we must identify the daughter groups from which the mothers derived using the lifecycle described in Figure 5. For example, early-born women-marrying-young in period *t* were girls in the previous period, $W_2(t) = G_1(t-1)$. Making these identifications we get:

$$G_1(t+1) = (1-g)[n_1^y\{p_Y G_1(t-1)+p_X' G_1'(t-1)\}+ n_1^o\{(1-p_X)\, G_1(t-2)+(1-p_Z')\, G_1'(t-2)\}]$$

$$G_1'(t+1) = (1-g)\, n_2^y\{p_X G_1(t-2) + p_Z' G_1'(t-2)\}.$$

To complete the difference equation system we must similarly derive the girls for periods *t*+2 and *t*+3.

$$G_1(t+2) = (1-g)[n_1^y\{p_Z\, G_1(t)+p_Y' G_1'(t)\}+ n_1^o\{(1-p_Y)\, G_1(t-1)+(1-p_X')\, G_1'(t-1)\}]$$

$$G_1'(t+2) = (1-g)\, n_2^y\{p_Y G_1(t-1) + p_X' G_1'(t-1)\}.$$

$$G_1(t+3) = (1-g)[n_1^y\{p_X\, G_1(t+1)+p_Z' G_1'(t+1)\}+ n_1^o\{(1-p_Z)\, G_1(t)+(1-p_Y')\, G_1'(t)\}]$$

$$G_1'(t+3) = (1-g)\, n_2^y\{p_Z G_1(t) + p_Y' G_1'(t)\}.$$

This completes the rotation through line X, Y, and Z, after which the system repeats. The system relates daughters of men in one *fahan* to daughters of men in the next *fahan.*

Technically, this is a linear six-equation fifth-order difference equation system. Though such systems are very difficult if not impossible to solve analytically, they are easy to simulate. The Appendix contains documentation for a simple Excel spreadsheet that simulates the model. The spreadsheet allows

[21] While a first son is highly valued, having more than one son may result in conflict because of primogeniture. In contrast, daughters earn the father bride price and domestic labour. Thus, there would appear to be an incentive for $g<0.5$.

the reader to pick values for all parameters and initial conditions and analyze the maternal and paternal demography from several perspectives. As might be expected of a linear model, it is not chaotic. The dynamics are smooth and always converge to a three-period periodic steady state growth path. This is consistent with Engineer and Kang's (2003) analytical solution and characterization of the model. [22]

4. Basic Simulations and Results

This section explores the properties of the model by using simple simulations to identify key features of the model that generate our general results. With the symmetric treatment of age-set lines, population growth depends in a straightforward way on rearing rates. *Sepaade* introduces an asymmetry into the age-set lines that increases the level and possibly growth rate of line X. We explore how the results vary with the different interpretations of *Sepaade*.

4.1 Symmetric treatment of all age-set lines

Symmetry among the age-set lines requires $p= p_X=p_Y=p_Z$ and $p' =p_X'=p_Y' = p_Z'$. Full symmetry is the further requirement that $p = p'$ and g=0.5. The following result describes the growth of all our variables describing population series and aggregates (eg. men in age-set lines and total population).[23]

[22] Engineer and Kang (2003) analytically solve a model that has a more general characterization of the social rules using *fahan* time units for periods. With the simplifying assumption on early-born children, this *fahan* can be expressed as the above system. The transformation and solution are lengthy and mathematically advanced and hence are not included here.

[23] The exceptions are aggregates that fluctuate over duration of a *fahan.* For example, the number of women by age-set line varies with the period. Every third period it includes two groups, one just married and women about to die; whereas, in other period it includes just one group of women.

Results (Full Symmetry): (a) $n^y = n_1^o$ =2; the model converges to a steady state with zero population growth and *R*=1. The steady state population is increasing in p and in n_1^y (holding $n^y = n_1^y + n_2^y$ =2).

(b) With $n^y > n_1^o \geq 2$, the model converges to a steady state with population growth and polygyny, *R*>1. The steady state population growth rate and polgyngy ratio are increasing in n^y, n_1^o, and p. The population level is increasing in p and in n_1^y holding $n^y = n_1^y + n_2^y$ constant.

With equal gender proportions and each mother rearing two children, each mother rears one daughter and one son on average. Thus, there is no polygyny and the steady state population is constant. The steady state population level is larger when more children are born early and less late, because the average lag between birth and bearing children is reduced.

More generally, population growth occurs when n^y is sufficiently large or n^y > $n_1^o \geq$ 2.[24] Population growth induces polygyny as long as there are some women-marrying-young, p>0. Then the pool of marriageable women is larger than men. From (1) we can derive

$$R(t) = [(1-g)/g]*\{(1-p) + p*[G_1(t-1)+G'_1(t-1)]/[G_1(t-2)+G'_1(t-2)]\}.$$

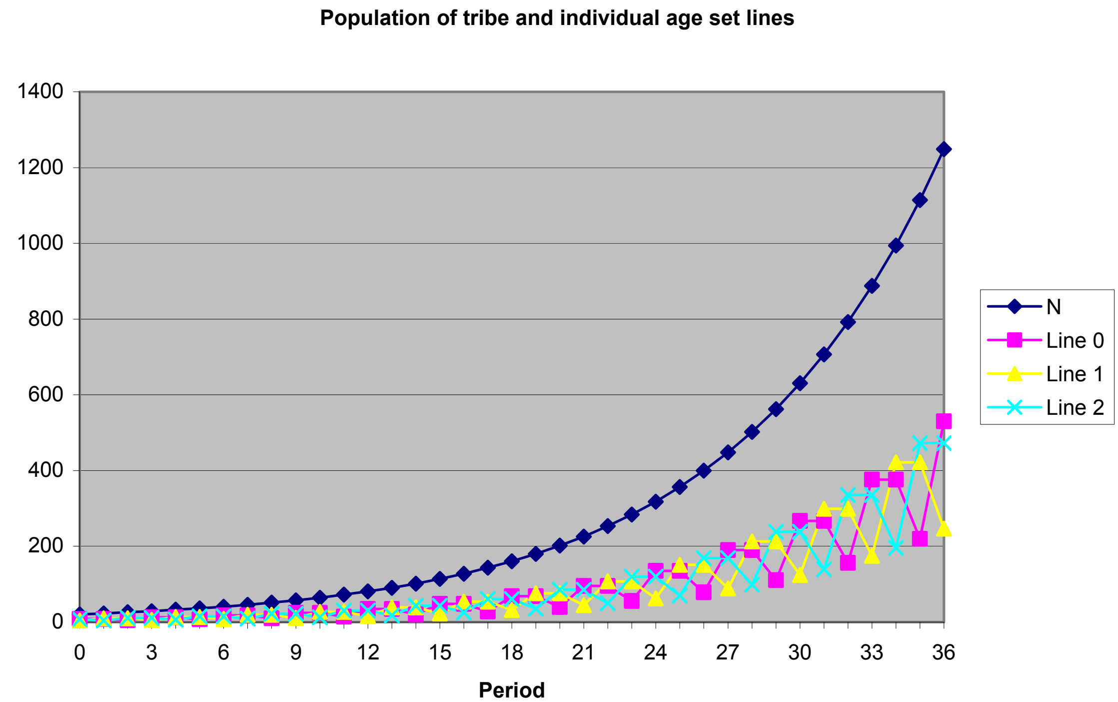
In the steady state $[G_1(t-1)+G'_1(t-1)]/[G_1(t-2)+G'_1(t-2)]$ yields the gross rate of population growth. Polygyny arises with growth even with gender balance, *g=.5.* Initial conditions do not affect the steady state growth rates but of course affect the population level.

[24] With full symmetry the dynamical system can be expressed by with two difference equations in G(t+1) and G'(t+1). In the zero population steady state, G(t+1) = G(t) and G'(t+1) = G'(t) for all t. Solving yields a condition for zero population growth, p n^y +(1-p) n^o =1/(1-g). Engineer and Kang (2003) prove that population grows if and only if p n^y +(1-p) n^o >1/(1-g).

An example with somewhat realistic parameters is given in Simulation 1.

Simulation 1: Symmetric age-set lines

p=.9, n_1^y =1.75, n_2^y =1, n_1^o =1.5, and g=.5



(In the figures Lines 0, 1, and 2 are respectively Lines Z, X, Y in the text.)

Though n_1^o < 2, population growth occurs because n^y =2.75 is sufficiently large. The age-set lines are symmetric except for being in different phases. The steady state net growth rate of the population is 12.07% per (14-year) period, and *R*= 1.1086.[25] Increasing p=.9 to p=1 increases the growth rate to 14.52% and *R* =1.1452.

[25] The simulation converges quickly, typically by period 15, with a variety of initial conditions. The diagram uses initial conditions K(-9)=2 and G_2(-9)=1. As discussed in the Appendix, these two initial conditions are sufficient to generate all the other cohorts.

Consider departures from full symmetry: p < p' and $g \neq .5$. In the above example suppose p = .9 and p' = 1. As more late-born daughters marry young, the growth rate and polygyny ratio respectively increase to 12.86% and *R* =1.12. Changing the gender proportion g has growth consequence. Increasing g reduces the proportion of children that are girls and hence reduces the growth rate; with $n^y = n_1^o$ =2 and g >.5 growth is negative.

4.2 *Sepaade, the Early-Born Brother Interpretation*

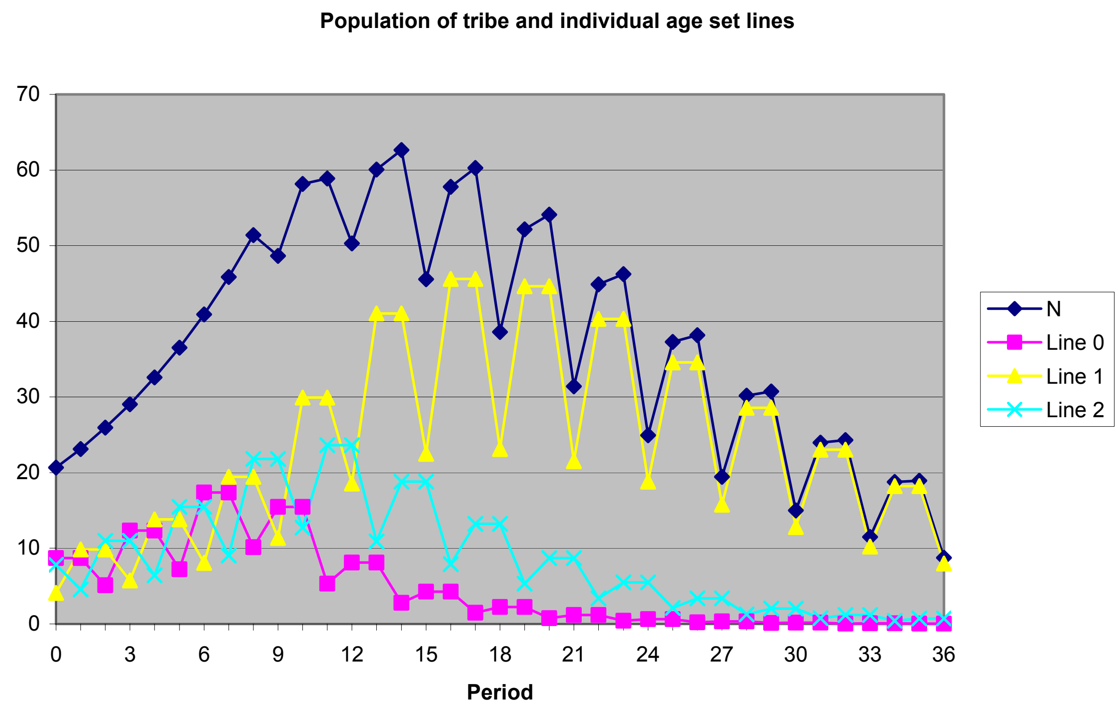
We examine the effects of introducing *Sepaade* by "shocking" the steady state of the symmetric simulation by suddenly lowering $p_X = p$ to $p_X < p$. The shock only takes effect in line X because *Sepaade* only effects *Teeria* daughters. Under the "early-born brother interpretation", *Sepaade* only delays early-born daughters from marrying early.

4.2.1 *A Complete Sepaade Shock*: $p_X = 0$

When all early-born daughters of the *Teeria* age-set line become women-marrying-old, the *Teeria* population often comes to completely dominate the population. Introducing Complete Sepaade in the above example yields this dramatic result, as illustrated in Simulation 2.

Simulation 2: Complete *Sepaade* shock starting in period 6

$p_X = 0$, $p = .9$, n_1^y =1.75, n_2^y =1, n_1^o =1.5, and g=.5



Starting in the symmetric steady state, the shock is introduced in period 6. After the shock, the Teeria population (line X) initially dramatically grows and the other lines dramatically fall off. The other lines (lines Y and Z) essentially disappear by period 30 and the *Teeria* line comprises the entire population. The steady state growth rate converges to $(n_1^o/2)^{1/3} - 1$ (= -9.14% here). Below we show that is a general pattern. To identify the features that generate the pattern, we first examine Complete *Sepaade* when rearing rates are at replacement levels.

Results: When $n^y = n_1^o$ =2, introducing Complete *Sepaade* results in only the *Teeria* age-set line (line X) existing in the steady state. The *Teeria* population doubles in size so that the average population is 2/3 of the steady state level before the shock.

The startling result that lines Y and Z disappear is due to line X becoming an absorbing state. With complete *Sepaade*, all females reared in line X marry back into line X. In contrast, women marry out of the other lines into line X, leading to the increase in the *Teeria* population. Thus, there is a net drain of women into line X and the other lines retain women at a rate that is below replacement.[26]

The *Sepaade* shock has the level effect of reducing the average population by 1/3. This negative level effect is not due just to the delay in marrying, per se. Without *Sepaade* and with $p_X = p = 0$ (and equal initial conditions), the population is 1/3 larger. Nor can the decline be attributed to women not marrying, or a change in rearing rates. Rather the decline is from the loss of lineages. Having all the women marrying into one age-set line doubles the population of that age-set line. Instead of one group of females reproducing each period, as in the symmetric pre-shock state, *Sepaade* has two groups of females producing every third period. Thus, it is the combination of the delay in reproduction and the elimination of lines that yields the negative level effect.

Another channel by which *Sepaade* can reduce population is through a negative growth effect that arises when young mothers rear more children than old mothers, $n^y > n_1^o$.

Results: The steady state after the shock behaves as follows:

[26] The disappearance of the other lines is immediate when n_2^y =0. Age-set line Z males either marry daughters who are "women-marrying-old" from age-set line Z or women-marrying-young from age-set line X. But with *p* =1, all the women in line Z marry into line Y when young, so there are no women-marrying-old in age-set line Z. As for age-set line X, this is the Teeria age-set line so there are no "women-marrying-young". Thus, line Z men have no mates and produce no children. Line Y disappears two periods later because there are no women-marrying-young coming from line Z.

(i) When $n_1^y = 2$, $n_2^y < 2$ and $n^y > n_1^o = 2$, only the *Teeria* age-set line (line X) survives. After the shock, the periodic steady state has no population growth; whereas, before the shock, population growth was positive.
(ii) With $n_1^y \geq n_2^y \geq 2$ and $n_1^o = 2$, all age-set lines survive and grow at the same average rate. The *Teeria* line has the largest population and line Z the smallest.

The results in (i) show that *Sepaade* can reduce the net growth rate of the population from a rate approaching 2 to 0. The dramatic drop in growth is related to the complete *Sepaade* shock eliminating the other lines. More generally, with the other lines gone, the net average growth rate of the population is determined solely by n_1^o and is $(n_1^o/2)^{1/3} - 1$.

The results in (ii) indicate that when the rearing rates are sufficiently high, all lines survive in the steady state. Then the growth rate of the population is determined by all the rearing rates. The other lines survive because women marrying into those lines rear enough children for the lines to reproduce. This occurs despite *Sepaade* preventing women from marrying outside of line X. Line Y is larger than line Z because it marries young women from line Z.

Historically (as we discuss later), $n^y < 3$ and $n_1^o < 2$. Thus, generically, the results in (i) are the ones applicable to the Rendille.

Simulation 2 displays the typical transition dynamics. There is a dramatic decrease in polygyny in line Z in period 6 and a dramatic increase in polygyny in line X in period 7. This increase is a one-time event. Introducing *Sepaade* at the beginning of period 6 results in young women from line X working in period 6 rather than marrying. These women marry old in period 7 to men from age set X. Thus, the shock results in these men enjoying extra wives at the expense of age set Z men. The polygyny ratio does not stay high in line X because that line is now producing as many men as women in each generation.

4.2.2. An Incomplete *Sepaade* Shock: $p_X > 0$

Results: All three lines exist in the steady state after the shock. The *Teeria* line has the largest population. There is a three-period steady state cycle in the aggregate population.

(i) When $n^y = n_1^o = 2$, the level of the average population is constant and is larger than 2/3 of the level found with no *Sepaade*. Lines Z and Y are the same size and the *Teeria* line size is larger by the factor p/p_X.

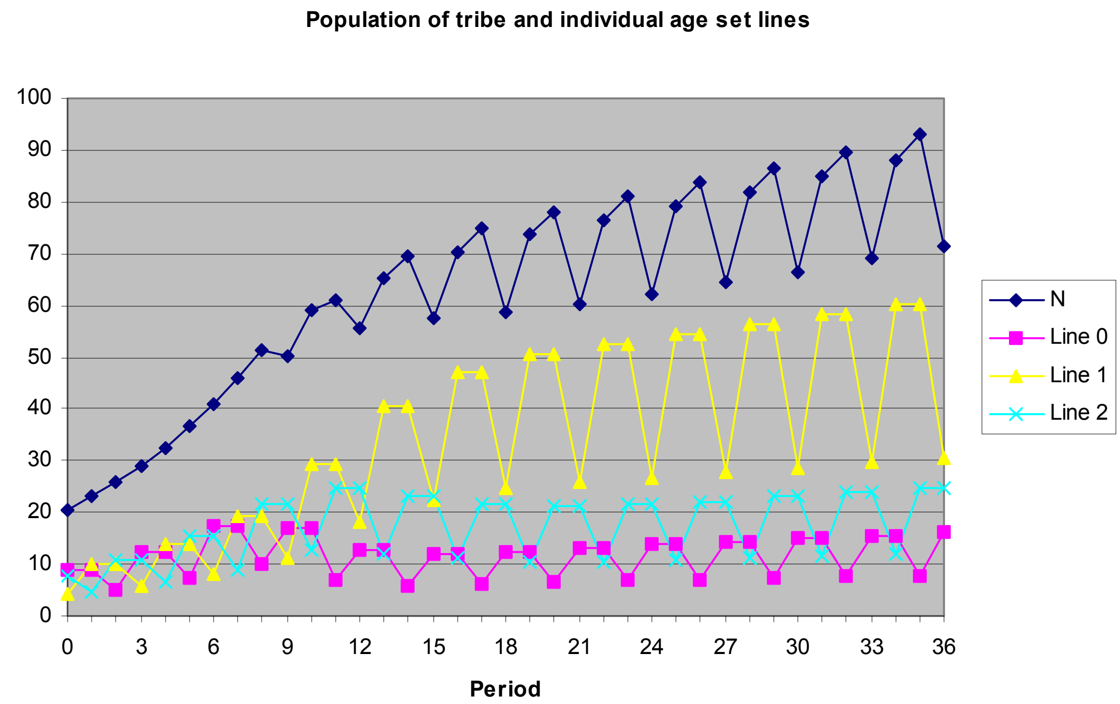
(ii) When $n^y > 2$ and $n_1^o = 2$, the population grows and the growth rate is between that found with Complete *Sepaade* and no *Sepaade*. The population of line Y is larger than that of line Z.

When $p_X > 0$, the *Teeria* line is not a completely absorbing state. Young women marrying out of the *Teeria* line provide a constant source of young wives for line Z. Thus, line Z survives. Since it supplies young wives to line Y, that line also survives. The population size and growth rate of these lines and the aggregate population is increasing in p_X: the negative level and growth effects on the population are not as pronounced with incomplete *Sepaade*. The factor p/p_X indicates that there can be a dramatic difference in the size of the *Teeria* line relative to the other lines when there is zero growth.

To illustrate, Simulation 3 introduces an incomplete *Sepaade* shock into the example.

Simulation 3: Incomplete *Sepaade* shock starting in period 6

$p_X = .15$, $p = .9$, $n_1^y = 1.75$, $n_2^y = 1$, $n_1^o = 1.5$, and g=.5



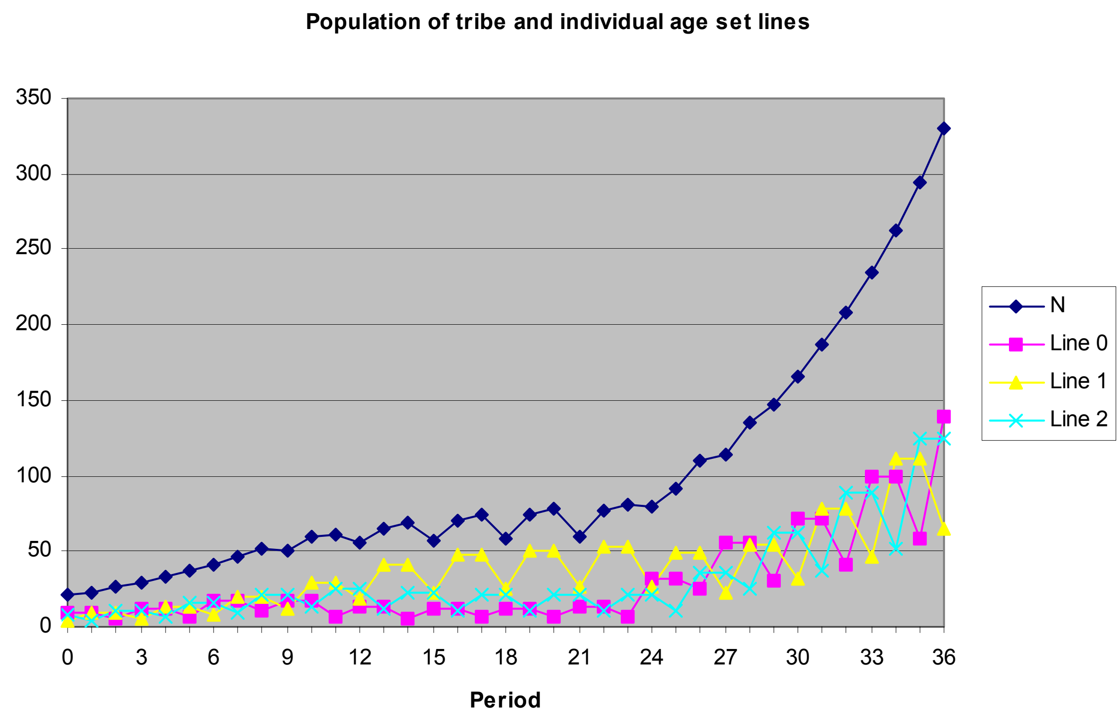
After the shock, the population growth is no longer negative because with incomplete *Sepaade* some *Teeria* women are marrying young, and their higher rearing rates increases the average population growth rate. The average steady state net growth rate is 1.2%, an order of magnitude less than the value before *Sepaade*. The transition dynamics indicate a long convergence to the steady state. The population in line Z falls abruptly, since they cannot marry as many young women from line X as before the shock. In the steady state, the *Teeria* line is roughly three times the size of each of the other lines. With an incomplete *Sepaade* shock, the polygyny ratio retains the pattern of the complete shock but is less dramatic.

4.3 Abolishing *Sepaade*

To examine the effects of abolishing *Sepaade*, we introduce a shock into the previous simulation. *Sepaade* is removed 15 periods after its introduction, to mimic its historical duration. Simulation 4 illustrates this shock.

Simulation 4: Incomplete *Sepaade* shock between periods 6 and 21

$p_X = 0$, $p = .9$, $n_1^y = 1.75$, $n_2^y = 1$, $n_1^o = 1.5$, and g=.5



Results. The steady state after the abolition of *Sepaade* yields the same results as the symmetric treatment of age-set lines detailed in Section 4.1.

The abolition of *Sepaade* restores the symmetric treatment of age-set lines. The steady state consequences of the abolition of *Sepaade* are the opposite of introducing *Sepaade*: an increase in population growth and polygyny, and the disappearance of cycles.

The transition dynamics are marked by a massive spike in the polygyny ratio followed by a dramatic fall and a second large spike. The initial spike, in line Z in period 21, is from women-marrying-young from the large line X population into the very small line Z male population. In period 22, the polygyny ratio for line X is less than one because population of women-marrying-young from line Y is much smaller than the line X population of men. In period 23, the polygyny ratio for line Y greatly exceeds two because line Z has a large number of young daughters.

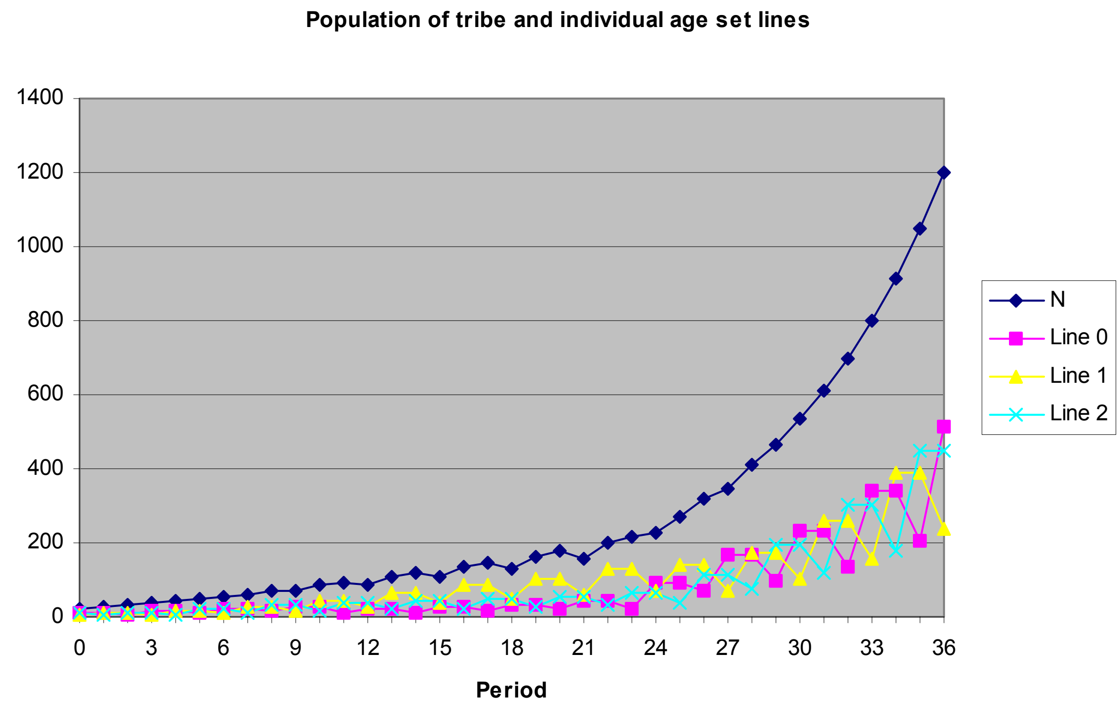
5. Discussion

Our model is highly stylized and omits many important factors. It is unrealistic to believe that the parameters of our analysis are constant through time, and fail to behaviorally respond to the shocks. Nevertheless, the analysis reveals dramatic demographic features implied by the Rendille age-group system. These features obtain across a wide range of parameter values.

The partial *Sepaade* shock illustrated in Simulation 4 is our most “realistic” case. The parameters in that simulation are close to, though lower than, numbers found in Beaman (1981) and Roth (1993). Beaman finds that approximately one quarter of all eligible women do not follow the *Sepaade* role, so p_X=.24. Roth finds higher fertility among women who marry young, n^y = 2.88 versus n^o =1.76. Simulation 5 reproduces the analysis with these numbers, specifying *p*=.9, and n_1^y =1.75 (so n_2^y =1.13). Not surprisingly, the larger values (rearing rates and larger proportion of women not following *Sepaade*) yield larger growth in Simulation 5.

Simulation 5: Incomplete *Sepaade* shock between periods 6 and 21

p_X = .24, *p* = .9, n_1^y =1.75, n_2^y =1.13, n_1^o =1.5, and g=.5



The parameters used in Simulation 5 are likely on the high side. As Beaman comments, the institution of *Sepaade* was already under stress in the last *fahan* (from emigration). The rearing rates in Roth are for 1990, and are probably higher than historic rates due to improved access to medicine and the settling of the Rendille.[27] Simulation 4 uses p_X=.15, n^y=2.75, and n^o=1.5, with the rearing rates of women-marrying-young divided as n_1^y=1.75 and n_2^y=1. The value p =.9 captures the fact that some daughters marry late in the other lines.

5.1 Comparison of Steady States

The net population growth rates generated from simulations 4 and 5 probably bracket the realistic range. In Simulation 4 the steady state net population growth before *Sepaade* is 12.1% per period; after *Sepaade* it is 1.2%.

[27] Nomadic life leads to fewer children reared as spacing of children is important for mobility reasons. According to elders interviewed by Engineer (2001), in earlier times *Sepaade* women

By comparison, Simulation 5 yields 14.4% before *Sepaade* and 6.75% after. In both cases, *Sepaade* acts to decrease population growth substantially. Both simulations give fairly low annual population growth rates. 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.

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.

The steady state also has the dramatic feature that the *Teeria* population is substantially larger than that of the other two lines. 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 (Engineer (2001)).

Finally, the steady state displays a marked three-period population cycle 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 termed *fahano*. 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 then war. The three period demographic cycles would provide the natural building block of a six-period cycle.

5.2 The Transition Impact of Introducing *Sepaade*

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often had no surviving children. This was their greatest fear, as they had no daughters to help them with housework or sons to care for them in old age.

The origin and rationale for the institution of *Sepaade* is obscure. The simulation offers us a sense of the dynamic impact of the institution's creation.

Introducing *Sepaade* at the beginning of period 6 prevents women of line X from marrying young to men of line Z.[28] Instead, these women marry when old, in period 7, to men from line X. Thus, the shock results in these latter men enjoying extra wives at the expense of line Z men. This shows up in the simulation with a dramatic decrease in polygyny in line Z in period 6 and a dramatic increase in polygyny in line X in period 7.[29]

Introducing *Sepaade* has implications for work and wealth. *Sepaade* keeps women from line X working 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.

5.3 The Transition Impact of Abolishing *Sepaade*

Sepaade was abolished 15 age-sets after it was introduced. In the simulations the *Sepaade* is abolished in period 21, 15 periods after it is introduced in period 6. It is clear from the simulations that when *Sepaade* was abolished the dynamics had not settled into a steady state. Nevertheless, at the time of abolition, the *Teeria* line in both simulations is twice the size of line Y and

[28] Roth (1993) describes *Sepaade* as an institutional response to prolonged heavy warfare with Somali neighbours. 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. A war starting when line Z men were moran and ending when line X men were moran would preclude women-marrying-young to line X men.

[29] The impact is muted if men of age set line Z can marry late in period 7, at the end of the fourth period of their lives. An exception might have been made for such men as former active warriors

three times the size of line Z. This is consistent with anecdotal accounts that the *Teeria* are as populous as the other two lines together (Engineer 2001).

Abolishing *Sepaade* results in a large increase in polygyny in line Z from women-marrying-young from the large *Teeria* line (line X). *Teeria* men due to marry after the shock lose, as the pool of available wives is smaller. The other impact is on population. Since ours is a maternal model, the impact is a large increase in children reared in the next two periods, as women rear more children when they marry young versus old. The growth rate of the population actually overshoots the new higher steady state level.

Apart from inducing a population explosion, the abolition of *Sepaade* quickly restores the fortunes of line Z, and the imbalance in population between the age-set lines. This suggests that perhaps a motivating factor in abolishing *Sepaade* at this time was the clear awareness that the inherent dynamic with *Sepaade* was increasing dominance of the *Teeria* line.

6. Conclusions and Extensions

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 can be described by an overlapping generations (OLG) model. Simulations of the OLG model give a sense of the dynamic implications of the social rules. This is used to explore Rendille history. In particular, we examine the demographic implications of a particular tradition among the Rendille, called *Sepaade. Sepaade* delays the marriage of a group of women and according to our simulations has dramatic effects on the population. The model informs historical accounts of *Sepaade* regarding its origin, role, development and demise.

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that were precluded from marrying. Changing this initial specification does not change the steady state impact of *Sepaade*.

A number of extensions remain to be attempted. The key exogenous variables in our model are p_X, p, n_1^y, n_2^y, n^o, g. We would like to introduce simple plausible behavioral descriptions that endogenize these variables. We would like to consider other variables. For example, emigration is likely to be a function of the ordering of male children. The first male child receives the full inheritance. Thus, subsequent male children receive no inheritance and may be better off emigrating. Various rules regarding emigration by birth order could be explored.

More ambitiously, we would like to introduce preferences, production, prices and equilibrium into the model. Preferences over number of children and for wealth (partly for status) are often mentioned by authors. For example, Roth provides a rational choice model of marriage among the Rendille. Such a model might be expanded to derive behavioral specifications for the parameters. 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.

In this paper we have tried to carefully show how social rule can be modeled and their implications analyzed.[30] We hope that this exercise will help expand the usefulness of the OLG model as a demographic framework, as well as generate additional insights/questions about the workings of age-set societies.

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[30] We do not address the more fundamental questions of why social rules arise. However, our analysis reveals that certain rules are more likely to be stable than others. RITTER [1980] surveys anthropologists' attempts to answer this question with regard to age-set rules. In the economics literature, ENGINEER AND BERNHARDT [1992] look at the incentive compatibility conditions between

APPENDIX: GUIDE TO THE SIMULATION PROGRAM

This appendix explains how to use the Excel program used for generating the simulations in this paper.[31] The program is divided into several spreadsheet pages -- Parameters and ICs, Maternal model, and Paternal model -- and a series of output graph pages – in both period and fahan time. The parameters and initial conditions on the first spreadsheet page are used in the second page to solve the maternal model difference equation system (described in Section 3.4) for the number of kids born in each period *t*. These children's lifecycle passages evolve as described in Table A. The maternal and paternal models are implemented by associating each period with a row and each demographic category with a column and then rewriting Table A in terms of relative cell references and parameters.

Table A: Key formulae used in the simulation program

Demographic category	Variable	Formula*	Life-cycle
Early-born (EB) kids	K(t)	$n_1^y \cdot[W_2(t-1)+W_2'(t-1)]+ n_1^o \cdot[W_3(t-1)+W_3'(t-1)]$	1
Late-born (LB) kids	K'(t)	$n_2^y \cdot[W_2(t-2)+W_2'(t-2)]$	1
EB girls	$G_1(t)$	$(1-g)\cdot K(t)$	1
LB girls	$G_1'(t)$	$(1-g)\cdot K'(t)$	1
EB women-marrying-young	$W_2(t)$	$p(t-1)\cdot G_1(t-1)$	2
LB women-marrying-young	$W_2'(t)$	$p'(t-1)\cdot G_1'(t-1)$	2
EB girls to marry old	$G_2(t)$	$[1–p(t-1)]\cdot G_1(t-1)$	2
LB girls to marry old	$G_2'(t)$	$[1–p'(t-1)]\cdot G_1'(t-1)$	2
EB women-marrying-old	$W_3(t)$	$G_2(t-1)$	3
LB women-marrying-old	$W_3'(t)$	$G_2'(t-1)$	3
Boys	$B_1(t)$	$g\cdot[K(t) + K'(t)]$	1
Boys to be initiated	$B_2(t)$	$B_1(t-1)$	2
Warriors	$M_3(t)$	$B_2(t-1)$	3
New elders	$M_4(t)$	$M_3(t-1)$	4

Table A summarizes the demographic formulation. Early-born (EB) children K(t) are reared by women who married in the previous period; late-born (LB) children K'(t) are reared by women who married young two periods prior. Kids are divided into boys and girls according to the gender ratio, *g*. Respecting birth order, girls (G_1,G_1') split into two cohorts, one marrying young in the next period (W_2,W_2')

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two-period lived generations and ENGINEER, ESTEBAN AND SÁKOVICS [1997] examine the core of a simple OLG to examine the stability of age-based social rules.

[31] The program also permits analysis of features of Rendille society not stressed in this paper, like the effects of climbing and *fahans.* More advanced documentation that explains the use of these extra features as well as a detailed discussion of methodology is available at http://… .

and the other marrying old in the following period ($G_2 \rightarrow W_3$, $G_2' \rightarrow W_3'$). Boys, on the other hand, remain in one cohort as they evolve into men. The variables used in the program are the same except for the notational difference that superscripts and subscripts are not possible in Excel and so are listed together on the mainline.

The only substantive difference from the account in the text is that the parameters for the proportion of women-marrying-young are related to the period instead of lineage. In the program we use (p(t), p'(t)), where p(t) is the proportion of EB women-marrying-young born in period t and p'(t) is the proportion of LB women-marrying-young born in period t. This formulation take advantage of the fact that the age-sets regularly cycle through the lineages X, Y, and Z (a *fahan*) every three periods:

$$p(t) = x(t)\cdot p_X + y(t)\cdot p_Y + z(t)\cdot p_Z$$
$$p'(t) = x(t)\cdot p_{Z'} + y(t)\cdot p_{X'} + z(t)\cdot p_{X'}$$

where: x(t) = 1 if X fathers sire EB children in period t, x(t) = 0 otherwise
y(t) = 1 if Y fathers sire EB children in period t, y(t) = 0 otherwise
z(t) = 1 if Z fathers sire EB children in period t, z(t) = 0 otherwise

p_X, p_Y, p_Z – proportion of EB women marrying young for lines X, Y, Z
$p_{X'}$, $p_{Y'}$, $p_{Z'}$ – proportion of LB women marrying young for lines X, Y, Z.

(Our analysis restricted the parameters: $p_X < p_Y = p_Z = p \leq p' = p_{X'} = p_{Y'} = p_{Z'}$. The program however leaves the parameters unrestricted.)

Simulation parameters and initial conditions

Child rearing: g, n_1^y = ny1, n_2^y = ny2, and n_1^o = no1.

Marriage: The model parameters (p_X, p_Y, p_Z) and ($p_{X'}$, $p_{Y'}$, $p_{Z'}$) can be effectively chosen using three progressive settings.

Default: (p_X, p_Y, p_Z) = (pX, pY, pZ)
($p_{X'}$, $p_{Y'}$, $p_{Z'}$) = (pX', pY', pZ')

Sepaade (EB brother interpretation): (p_X, p_Y, p_Z) = (qX, qY, qZ)
from T_begin to T_end

Sepaade (youngest-brother interpretation): λ_X = lamdaX < 1,
n^{vo} = nvo

The default setting gives the values for the parameters when the other two "*Sepaade* settings" are off. (qX, qY, qZ) specifies the line-specific proportion of women who marry young over the *Sepaade* interval. The parameters T_begin and T_end determine how long the *Sepaade* interval lasts. Eg. To match the history in the simulations, we start *Sepaade* in period 6, T_begin = 6, and end it in period 21, T_end = 21. (To shut *Sepaade* off set T_begin =81; our program only goes as far as 80 periods.)

The last setting, lamdaX, specifies the version of *Sepaade* we are examining. The default, lamdaX = 1, gives the EB brother interpretation of *Sepaade.* The youngest-brother interpretation of *Sepaade* has lambdaX < 1, i.e. proportion (1 – lambdaX) families in line X are subject to the constraint that daughters cannot marry until the late born sons have married. This variable delays the marriage of these Teeria daughters by one further period (in addition the delay implied by qX). In this case, there is the possibility of some EB daughters marrying when they are very old. Their rearing rate is set at nvo.

Initial conditions: These fix the initial population numbers in all demographic categories at t = -9. Setting the first two initial conditions nonzero, K(-9) and W2(-9), is sufficient to generate a dynamic path that converges to the unique steady state growth rate. It is possible to choose initial conditions so that the program begins on a steady state growth path. First, identify the steady state grow rate over a *fahan* (available in the last panel of the program). Second, identify a period in which the variables have effectively converged to the steady state. Lastly, use the growth rate to extrapolate backwards to find the value of the initial conditions in t = -9.

Flexible Features

The program has several features we did not discuss in the text and we invite the reader to experiment with them.

Fertility shock: The program allows for the rearing rates to be multiplied by a factor for a chosen interval.

Attrition: To change the cycle length from 5 periods to 6 periods set the rate of survival to period 6 to 1. The code allows for gender-neutral attrition through the entire life cycle. (In the paper attrition is zero because we use rearing rates that implicitly incorporate attrition. However, if we knew attrition rates we could interpret the parameters ny1, ny2, and no1 as fertility rates and work from there.)

Marriage Shift: For generality, the program includes a lamdaY and lamdaZ variable that produce marriage shifts analogous to lamdaX.

Other Institutional Features

The program allows the analysis of Rendille institutions not stressed in this paper but developed in other papers.

Fahan Analysis: In additional to the output pages, the spreadsheets contain a breakdown of the model in *fahan* time. The links between the period and *fahan* model are detailed in Engineer and Kang (2003).

Climbing: The model permits a detailed analysis of climbing. See Engineer (2003) for a detailed analysis of climbing and documentation for programming.

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