POPULATION GROWTH AND CUSTOMARY LAW ON LAND:

the case of Cordillera villages in the Philippines

by

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ABSTRACT

This paper examines how a traditional village deals with the consequences of population growth. The increase in population demands more intensive use of the land which requires the transformation of commonly-owned land into privately-owned land. Customary law contains clear prescriptions about the circumstances under which a couple can privatize land. We estimate this land accumulation rule using data from two villages in the Cordillera Region of the Philippines. In order to study the evolution of the distribution of land, we model the inheritance practices of the community which constitutes another aspect of customary law. Finally, we use the model to show that despite the flexibility of the customary law on land, the present rapid growth of the population given the limited availability of land leads to its breakdown. This could be avoided only if seven out of ten children are able to make a living from occupations other than farming.

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1. INTRODUCTION

Recently, several economists have studied the interaction between property rights, population pressure and technology. Migot-Adholla, Hazell, Blarel and Place (1991) claim that population pressure has induced an automatic evolution within the system of indigenous land tenure systems in Sub-Saharan Africa from communal property towards private individual rights. We find that a similar process has been at work in the Cordillera Region of the Philippines. Our paper attempts to model this process in that region. As such, the approach differs from that adopted by Feder and Feeny (1991). They stress the role of public infrastructure with regard to the certification and registration of the ownership of land for an effective land rights system. In the context of small villages in which land and credit markets have emerged only recently and in which the former is still of minor importance as a means to acquire land, we look at how the customary law on land copes with the changes wrought by increased population pressure.[2] This reaction is embodied as part of customary law and we refer to it as the land accumulation rule.

In order to describe the dynamic evolution of the distribution of land, we need to describe another aspect of customary law: the set of rules which define inheritance practices. The more familiar inheritance rules are those of Equal Division and Primogeniture. In the former all property is divided equally among the children. In the latter, all property goes to the first-born child (General Primogeniture). Primogeniture may be restricted to the first-born son (Male Primogeniture) or the first-born daughter (Female Primogeniture). Assuming that each family has exactly two children, Blinder (1973) and Atkinson (1980) have analyzed the influence of these inheritance rules on the distribution of wealth. Cowell (1991) introduces differences in household size in the analysis of general equal division. Van de gaer (1997) makes similar assumptions as Cowell regarding differences in household size and focuses on a comparison of different inheritance rules and the importance of marriage patterns. This paper adopts the latter 's framework to deal with the traditional inheritance practices in the Cordillera villages.

Now imagine an agricultural community settled in a mountainous region. Rice is one of the staple crops that the people want to grow. In order to grow rice, land has to be

[2] Feder and Feeny (1991: 147) recognize that "...in areas where credit and land markets are not yet developed, an investment in titling and land registration may entail an excessive cost in comparison with the benefits, and security of tenure can be enhanced by cheaper methods such as legalizing the authority of local institutions."

irrigated. This requires that irrigation canals are built and given the nature of the terrain that terraces are also constructed. Wet-rice cultivation, thus, requires the input of a lot of labor. People are more willing to undertake these investments if they can individually reap the benefits from these investments (see Feder and Noronha, 1987; Feder and Feeny, 1991; Migot-Adholla, et. al., 1991). Irrigated rice fields will therefore be private property which couples can own and pass on to their offspring. In many societies, there are clear rules which describe who inherits what from whom. We will analyze the inheritance rules applicable in parts of the Cordillera in the Philippines in section 3.

Other land which is not improved upon in the way described above can be used for growing root crops, pasturing of animals, or as forests from which people collect wood for fuel and lumber. These types of land are more likely to be common property. Even here, clear rules prescribe who may have rights to these uses since a misuse of the land by one individual will affect what everyone else gets out of it. Since the communities which we study are fairly small, the enforcement of these rules poses no major problems.

As long as the population remains stable, there is no incentive to convert common land into private land. Once the population starts to increase, a further intensification of agriculture and an increase in rice production becomes necessary (see e.g. Boserup, 1976). These can only be done by transforming common land into private land, i.e. irrigated rice fields. There are two reasons why the village will regulate this process. First, the land which can be converted is common land, and its use has been delimited by rules upheld by all members of the community. Transforming common property rights into private individual rights is therefore subject to community approval. Second, an unregulated transformation of common land into private land can have disadvantageous effects on all people of the community using the land. In addition, some people will be affected more than others. Those who have little of privately-owned land might be deprived of their means of subsistence. As a consequence, the village will prescribe when a family can increase its land holdings, and how much a family is allowed to take out of the commons and turn it into privately-owned land. We will model this process of land accumulation in section 4 and use data on two villages to estimate the parameters of this process.

Then due to improvements in public health measures the population increases drastically. The previous arrangements for transforming common land into private land may no longer be sustainable. In view of the mountainous nature of the terrain, not all common land can be suitably turned into irrigated rice fields: springs cannot be found everywhere and it is costly to transport the water from the river to rice fields located along the higher slopes of the mountain. We will investigate whether the institutional arrangements for transforming common land into privately-owned rice fields do break down. Finally, the whole set of traditions and customs described above such as inheritance practices and the land accumulation rule, might be maintained even when the population increases dramatically provided a substantial part of the younger generation emigrates or finds employment outside the agricultural sector. We will calculate how big a fraction of the younger generation should take this outside option.

We begin in section 2 with a description of that part of the customary law on land in some villages in the Cordillera which deals with the issues raised above.

2. ACCESS TO LAND AND CUSTOMARY LAW

In Cordillera villages, the customary law on land recognizes both common and individual property rights. These rights define the use, access, and transfer of land. There are two types of common property: *communal* and *corporate* (see, e.g., Prill-Brett, 1993: 1). In the former, rights to use belong to each member of the village. In the latter, usufruct rights are restricted to members of a descent group. The most restrictive rights apply under private individual ownership. Forest and pasture lands are communal, swiddens are corporate, and irrigated rice fields (*payew*) are private.

Table 1 shows how couples can have access to agricultural land in two Cordillera villages.

Table 1: MEAN SIZES OF LAND BY TYPE OF ACCESS (in sq. m.)

TYPES OF ACCESS		Village 1		Village 2	
		N=29	Mean*	N=48	Mean*
By inheritance					
Irrigated	W	7	4507	24	1295
	M	10	4482	24	1611
Other	W	7	2855	22	422
	M	11	5750	20	1311
By usufruct rights					
Irrigated	W' clan	1	10000	4	588
	M' clan	0	-	4	1018
Other	W' clan	3	550	4	2105
	M'clan	4	2207	2	135
	Com'nty	0	-	4	122
By Sharecropping		4	4966	3	257
By Rental		2	7500	11	2536
By Purchase		2	2166	4	562

*This refers to the conditional mean; i.e. for values above zero.

Access to land is by inheritance, by usufruct rights, by sharecropping, by renting and by purchase. The land may be irrigated or not. As the table shows, access to land by inheritance through either the husband (M) or the wife (W) is quite important. The access to both kinds of land, irrigated or not, is very similar. There does not appear to be any discrimination between men and women regarding land ownership as far as the distribution of inherited irrigated land is concerned. However, the other land appears unevenly distributed between men and women and this results in an unequal distribution of their total land.[3] Non-irrigated land consists of forests, pastures or swiddens. Although the traditional means of access to land through inheritance and usufruct continue to remain dominant, access to land through purchase and rental has recently become more common. Renting occurs more frequently in Village 2 while sharecropping is more frequent in Village 1.

Customary law prescribes how and when members of the village can segregate land out of commonly-owned property and thereby transform its ownership. When permanent improvements are made on land such as building of irrigation canals, or terracing; and there is occupation and cultivation for a prolonged period of time (i.e. five years) without interruption[4], the land becomes privately-owned. In this manner a couple can increase its land holdings during its existence. Since land is passed on when a child is married, the family land at such time will consist of each spouse's inherited land. Land to which a couple has only use rights can become exclusive to them under the above-mentioned conditions. Such acquired land together with the individual spouse's inherited land are devolved to the couple's heirs as their exclusive private property. The land acquisition function describes the process by which couples can acquire land under this customary law. Since improving the land requires a lot of labor, it is limited by the number of labor hands of family members. If a family attempts to improve more land than it actually needs, its action will merit village disapproval. Given these, we can suppose that the amount of land a family can obtain depends upon the number of children in the family.

The way irrigated land is devolved combines bilateral primogeniture with equal division. Bilateral primogeniture[5] is applied to the part of the property which is inherited and 'equal division' is applied to that which is acquired. We can formalize bilateral primogeniture as follows. Let k stand for the number of children in the family. Given k, land is devolved to its heirs in the following manner:

> *k=1*: If the child is a boy, he gets his father's inherited land. If it's a girl, she gets her mother's inherited land.
>
> *k>1 and there is at least one boy and one girl*: The eldest son gets his father's land, the eldest daughter gets her mother's land.
>
> *k>1 and all children are of the same sex*: The eldest child inherits the land of the same-sexed parent. The second child receives the land of the other parent.

The children who inherit land in this way will be called primary heirs. Those who inherit the acquired land, we shall label secondary heirs. A fraction $(1-q)$ of families is

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[3] Davies and Zhang (1995), using Quisumbing's (1994) data find evidence of a fairly strong pure sex preference for males. Perhaps a similar mechanism is at work for the other type of land. Since customary law is less rigidly applied to this other type, there is more room for parental sex preference.

[4] As Prill-Brett (1993: 14) puts it: "Another condition under which common land transforms into individual property with restricted rights of use, is the construction of irrigated rice fields ... The channeling of water from a nearby water source, the construction of an irrigation canal to transport water to the field, the construction of retaining stone walls, the transporting of soil nutrients into the constructed pond field, and the sustained production of rice through continuous cropping, transforms the land use system."

allowed to accumulate land which they can devolve to the other children who do not have claims on either parent's inherited land. Note that it is not necessarily an advantage to be a primary heir. This will be the case when the inherited land of the parent is smaller than the acquired land which is given to the secondary heirs[6].

Two further remarks complete our description of this inheritance rule. First, if the heir assigned by the rule does not exist, then the land becomes common land. This happens when a couple is childless or when they have only one child such that there is no heir to either the father or mother's fortune[7]. Second, a fraction *l* of those who own land might lose their land. Land can be lost when it is given as payment for a fine for personal offenses such as theft[8]. Or due to adverse circumstances, one is forced to sell the land, usually to one's kinsmen. In these cases, the heir assigned by the rule will receive no land at all. We will now analyze the customary law just described formally.

3. THE CONSEQUENCES OF CUSTOMARY LAW ON LAND

(a) Evolution of the distribution of land

Let the probability that a couple has *k* children be given by p_k [9] and a family can have *K* children at most, such that $\sum_{k=0}^{K} p_k = 1$. The number of boys is on the average equal to the number of girls. We assume that the population can be represented by a continuum of individuals. At time zero, we normalize the total male or female population such that they are represented by the interval $[0,1]$.[10] $H_t^i[x]$, *i*=*m* or *w*, is a measure of the number of men or women having land smaller than or equal to *x* at time *t*. From the normalization

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[5] The inheritance rule analyzed here (also referred to as homoparentalism) has to be distinguished from the rule of General Primogeniture which most wet rice agricultural societies in the Central Cordillera traditionally practiced (personal communication with June Prill-Brett, 15 October 1996).

[6] In our sample, the mean land size inherited by first born children, who are primary heirs, was not different from the mean land size inherited by later-born children.

[7] We adopt this interpretation in consonance with the idea that 'should a couple fail to produce an offspring, and one of the spouses dies, the property of the deceased reverts to his/her natal family, to be reassigned to another heir' (see, Prill-Brett, 1993: 20). In our model, we assume that the procedure by which the land is reassigned follows that by which a family is allowed to acquire land.

[8] See Prill-Brett, 1993: 19.

[9] We follow Cowell (1991) in assuming that fertility is independent of the amount of land owned by each family and that the distribution of the couples on the basis of the number of children remains constant. For a traditional economy, this assumption is not unreasonable (see, e.g., Boserup, 1976). Pryor (1973) simulates among others the influence of differences in fertility between rich and poor people under General Primogeniture and Equal Division.

[10] The large population assumption has the advantage that the number of men is equal to the number of women. The fraction of men and women which do not get married are included in p_0 , the fraction of couples that do not produce children.

above, it follows that $H_t^i[\infty] = (1+n)^t$, where n is the growth rate of the population such that $n = (1/2)\sum_{k=1}^{K} p_k k - 1$ and $n > -1$. Of greater interest than the evolution of the absolute number is the evolution of the relative number of women or men who own no more than x. This is captured by the cumulative distribution function $F_t^i[x]$. Where defined, $f_t^i[x]$ is the corresponding density. We have that $H_t^i[x] = (1+n)^t F_t^i[x]$

Assuming that $K \geq 3$, there are three ways in which a male child can inherit land.[11] He could be the first born son and inherit his father's land. Such an heir will exist with probability $\tilde{a}_1 = 1 - p_0 - \sum_{k=1}^{K} (1/2)^k p_k$, which is 1 minus the probability that there are no children and the probability that there are only daughters. He could be the second son and, in the absence of a sister, inherit his mother's land. The probability for this event is $\tilde{a}_2 = \sum_{k=2}^{K} (1/2)^k p_k$. In these two cases, he will inherit the land provided his parents did not lose it. The probability of land loss is l. Finally, he could have been one of the children in a large family $(k \geq 3)$, and get his share from the land which his parents acquired during their marriage. The probability that his parents are allowed to acquire land is $(1-q)$. If his parents bequeath land of size x to their children through the third way, on average *(1/2) (k-2)* boys will inherit this size of land. As a consequence of all these, the number of male children inheriting land size x at time t, $h_t^m[x]$, depends on the number of men and women who inherited the same amount of land in the previous period, $h_{t-1}^m[x]$ and $h_{t-1}^w[x]$ respectively, and the number of families with k children that bequeath x to their children, $h_{t-1}^k[x]$

$$h_t^m[x] = (1-l)\tilde{a}_1 h_{t-1}^m[x] + (1-l)\tilde{a}_2 h_{t-1}^w[x] + (1-q)\sum_{k=3}^{K} \frac{1}{2}(k-2) h_{t-1}^k[x]$$

Our main interest is in the distribution of land. We can divide the equation above by $(1+n)^t$, the total number of men at time t to get an equation describing the evolution of the frequency distribution of land:

[11] The problem for the evolution of women's land is symmetric. For now we focus on the problem of men's land.

$$f_t^m[x]=\frac{1}{1+n}\left((1-l)\tilde{a}_1 f_{t-1}^m[x]+(1-l)\tilde{a}_2 f_{t-1}^w[x]+(1-q)\sum_{k=3}^{K}(1/2)(k-2)p_k f_{t-1}^{uk}[x]\right)$$

where $f_t^m[x]$ is the density of men which, at time t, own an amount of land equal to *x*, given that the family has acquired a positive amount of land. $f_t^w[x]$ denotes the corresponding density for women, and $f_{t-1}^{uk}[x]$ is the density of the inheritance *x* coming from the land acquired by a family with *k* children. Since $n\equiv(1/2)\sum_{k=1}^{K}kp_k-1$ and using the fact that the p_k add up to 1, it is easy to verify that the weights attached to the densities at the RHS of the equation sum to 1.

Concomitantly, a son will not inherit land in the following cases. He is the primary heir of his father (or mother) who has no land to give since he (she) has none. A parent will have no land to pass on to an heir because either he did not inherit any land or if he did, has lost it. Alternatively, he is the secondary heir of couples who did not accumulate any land. Therefore, the density of zero land holdings is given by

$$f_t^m[0]=\frac{1}{1+n}\left(\tilde{a}_1 f_{t-1}^m[0]+\tilde{a}_2 f_{t-1}^w[0]+l\tilde{a}_1\left(1-f_{t-1}^m[0]\right)+l\tilde{a}_2\left(1-f_{t-1}^w[0]\right)\right)$$
$$+\frac{1}{1+n}\left((1/2)q\sum_{k=3}^{K}(k-2)p_k\right)$$

This yields:

$$f_t^m[0]=\frac{1}{1+n}(1-l)\left(\tilde{a}_1 f_{t-1}^m[0]+\tilde{a}_2 f_{t-1}^w[0]\right)+\frac{1}{1+n}\left(l(\tilde{a}_1+\tilde{a}_2)+(1/2)q\sum_{k=3}^{K}(k-2)p_k\right)$$

The above equations describe the evolution of the densities of land owned by men and women as a system of first order difference equations. Therefore, the density of the distribution of land at each point $[x]$ and at each point in time is a weighted average of the corresponding densities of the initial and final distribution of land (see proposition 1 in the appendix). The weights given to the initial distribution decline as time passes by, while the weights attached to the equilibrium distribution increase. The steady state distribution will be completely independent of the initial distribution.

Because of the symmetric treatment of men and women by both the inheritance and the accumulation rules the steady state distribution of men and women's land is the same. Moreover, if the initial distribution of land of men and women is the same, then the distribution of land for both sexes will be equal. In that case the distribution of land will be discrimination-free at each point in time.

The literature analyzing the dynamics of wealth distribution pays a lot of attention to the speed at which the steady state distribution is approached and to the latter's properties. The comparative static properties of the steady state distribution and of the speed at which the steady state distribution is approached are fairly straightforward (see corollary 1).

The higher the probability that a parent loses his land, the faster the steady state distribution is approached. The higher l is, the sooner the initial wealth holdings disappear. If the size of the population increases, then the equilibrium distribution is approached more rapidly. n increases when the number of small families decreases and the number of large families increases. In larger families relatively more children inherit acquired land. Since the distribution of acquired land determines the steady state distribution, the increase in the number of large families will increase the speed of convergence to the steady state distribution. At the same time the relative number of primary heirs (i.e., the heirs to the parents' inherited land) may decrease due to a decrease in p_0 or p_1. And this diminishes the importance of the initial distribution.

The equilibrium distribution of land is completely determined by the demographic composition of the population, as reflected by the p_k, and the amount of land acquired by a family during its existence. This is not surprising since, with $p_k \neq 0$ for at least one value of $k < 2$ all initially private land holdings will become common land sooner or later. Then the future generations remain landless until the family is allowed to acquire land. A dynasty is allowed to do so sooner or later provided $p_k > 0$ for some $k \geq 3$. In summary, each family's land becomes acquired land and is transferred to the next generation through the rule that applies to this type of land.[12]

[12] More specifically, the equilibrium density of land at each point $x > 0$ is a weighted linear average of the densities of the $K\text{-}2$ distributions of acquired land at that same point. The relative weights of each of the densities depend on $\left((k-2)/2\right)p_k$, the expected number of male/female secondary heirs of a family with $k>2$ children. The similarities are striking when we compare this result with the one obtained for equal division by Cowell (1991). In his framework, the distribution of the younger generation's wealth is a linear weighted mean of K values of wealth in the older generation. Here saving is proportional to the older generation's wealth. In our context, saving is equivalent to the amount of acquired land. Cowell's result comes quite close to the result obtained here for our system of bilateral primogeniture for primary heirs and equal division among secondary heirs. This is expected since the rule of equal division among the secondary heirs applied to acquired land determines our steady state distribution completely.

The form of the equilibrium distribution depends on the p_k and $f^{uk}[x]$ exclusively. q and l only blow up the form of the equilibrium distribution. If q and l would both be zero, everybody will own land eventually. If $q = 1$ nobody is allowed to acquire any land and asymptotically nobody owns any land. Then, all land will be common. When $l = 0$ and $q = 1$, we get a version of our inheritance rule where only primary heirs exist. Also then, nobody will own any land in the steady state, since every sequence of primary heirs will terminate at some point.

The number of landless individuals is increasing in *l*, *q*, and $\tilde{a}_1 + \tilde{a}_2$ and decreasing in *p* (see corollary 2). The latter is the average number of men or women who inherit from the land acquired by the family. The larger *p* is, the greater the relative number of children inheriting a positive amount of land. $(\tilde{a}_1 + \tilde{a}_2)$ is the probability that there is a primary heir to a parent's fortune. If a parent has lost his inheritance, then there will be on average $\tilde{a}_1 + \tilde{a}_2$ heirs who inherit nothing. The comparative static properties for positive land sizes mirror these results.

(b) Amount of arable land and population growth

We have now derived the steady state distribution of land, assuming that the process can be repeated indefinitely. Implicitly it was assumed that the amount of land that could be made suited for wet-rice cultivation was unlimited. Generally this type of land would be limited even when villagers could, as they did, begin new settlements when land in the original village sites became scarce. The relationship between the land accumulation rule, the probabilities to acquire or to lose land, the size distribution of families, and the growth of the total amount of irrigated land is described in this section and proposition 2 in the appendix.

The more generous the accumulation rule and the higher the probability that a family can accumulate land, the more land is claimed. Therefore the faster the total amount of irrigated land has to grow. The greater the possibility that a family loses its land, *l*, and the greater the proportion of families without direct heirs, $p_0 + (1/2)p_1$, the more private land becomes common, and hence the smaller the growth of the total amount of irrigated land.

It is clear that when the population grows fast, the pressure on the amount of land increases. To assume a stable size of the population cannot be justified given the recent experience in the region, nor by our data. Yet, the assumption need not be objectionable if we redefine the p_k in the model as the distribution of the number of children who take up farming. Suppose that there are many children who do not take up farming. And let us also assume that these children do not receive any land but may instead receive something else as their inheritance. This could be money to finance a college education, or to purchase farm land in another part of the country or to start a small business. Then everything might go on exactly as described here. Provided that the number of farmers remains constant, a steady state amount of irrigated land for the community will exist.

4. EMPIRICAL RESULTS

a. The villages[13]

The two villages we consider are Cudog (Village 1), located in the municipality of Lagawe, province of Ifugao and Sagada[14] (Village 2), located in the Mountain Province. In 1992 there were 174 households in Cudog and 290 households in Sagada. We have a sample of 29 and 48 families for the two villages, respectively. Our sample indicates that village 1 is more agriculturally based than village 2. In the former, all households had farm work as a means of livelihood. Sixty-four per cent of households relied only on farm work while 36 per cent combined farm with off-farm work as sources of livelihood. In village 2, a smaller 46 per cent of households relied only on farm work while a larger 40 per cent relied on both farm and off-farm work for their livelihood. About 15 per cent of households compared to none in village 1, were completely engaged in off-farm work In Village 1, 52 per cent of the households planted rice as their primary crop while 14 per cent planted rice and cash crops compared to a smaller 44 per cent and 8 per cent, respectively, in Village 2.

Table 2 presents some characteristics for the sample of couples in the two villages. Individuals have received more education in village 2 compared to village 1. The average family size is larger in village 2 than in village 1. Given the standard deviation around the mean however, these differences are not statistically significant.

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[13] The data described here is part of a larger data set collected through a survey of rural households from two villages in the Cordillera Region. Based on community census data (1992) and field work done by the Natural Resource Management Research Program (NRMP) of the Cordillera Studies Center, UP College Baguio, a structured questionnaire was constructed with which interviews were conducted in April and May of 1994. This data set was collected for the dissertation research of the second author.
[14] We use the term to refer to the two barangays of Patay and Suyo and not to the whole municipality.

Table 2: SOME CHARACTERISTICS OF THE SAMPLE

	Village	Mean	Std Dev	Min	Max	N
years of schooling of husband	1	5.59	4.29	0.0	14.0	29
	2	7.88	4.48	0.0	14.0	48
years of schooling of wife	1	5.86	4.57	0.0	14.0	29
	2	7.79	5.46	0.0	14.0	48
family size	1	6.34	2.61	2.0	11.0	29
	2	7.62	2.43	3.0	13.0	48

Differences in family size were crucial for our framework. In order to take this into account, we needed data on the number of children in families which have reached their full size. The second and fifth columns of Table 3 give the distribution of families according to the number of children for those in the sample where the youngest child is at least five years old. Although the distribution has the expected feature of a few large families, it looks a bit erratic. This is probably due to the small number of observations. In addition, assuming that everybody gets married, this distribution of family sizes implies a population growth of 189 per cent from one generation to the next[15]. It is difficult to maintain these p_k, particularly if it would reflect the constant distribution of the number of farmers generated by couples. In order to test the sensitivity of our results to the values for family sizes, we replicated the analysis with the Belgian distribution of household sizes in 1910. The data are given in the third and sixth columns of the table and imply a population growth of 31 per cent between successive generations[16].

[15] The population growth in the Cordillera region was 2.53 per cent per year in 1994 (National Statistics Office, Manila). If you take one generation to be 30 years, this amounts to about 112% per generation. Because of the emigration out of the small villages, and their traditional nature, population growth in these villages might be a lot higher, however.

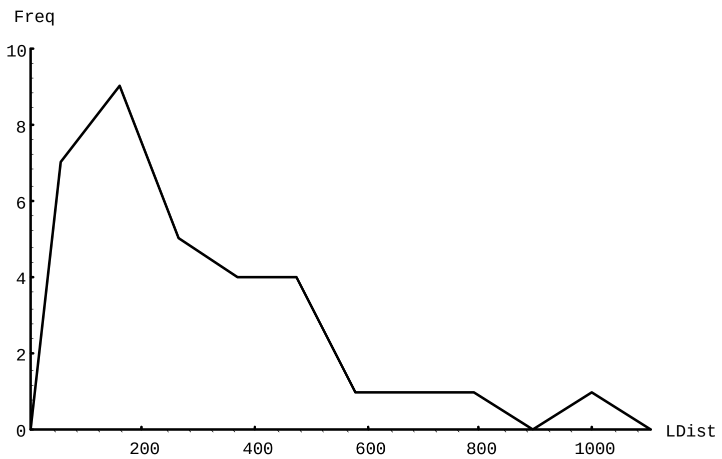
[16] This number is more in line with Boserup's (1976) contention that "the most reasonable assumption about past demographic trends seems to be that some unfortunate peoples, decimated by disease and war, had negative rates of population growth and disappeared, while other more fortunate ones had positive, but fairly low, rates of growth over long periods." (p.23)

Table 3: DISTRIBUTION OF FAMILIES BY NUMBER OF CHILDREN

Number of children	Village Data[17] N = 37	Belgian Data[18] N=1370878	Number of children	Village Data N= 37	Belgian Data N=1370878
0	0.027	0.190	6	0.217	0.048
1	0.081	0.230	7	0.162	0.033
2	0.054	0.185	8	0.054	0.020
3	0.027	0.130	9	0.135	0.012
4	0.081	0.094	10	0.027	0.009
5	0.108	0.067	11	0.027	0.006

We have already discussed the characteristics of the distribution of land in section 2. To get some idea about the distribution of inherited irrigated land, we depict the frequency distribution of the distribution of men and women's land in village 2. With very few observations from village 1 we cannot do the same for that village. Since for land sizes of more than 1000 square meters the observations are spread too far apart, we limit the range to land sizes smaller than 1000 m². There are 33 observations in this range.

FIGURE 1: Frequency Distribution of Small-Sized Irrigated Land in Village 2



The distribution has the familiar hump-shape and one might recognize a lognormal distribution, which is not unfamiliar in the literature on the distribution of wealth (see, e.g. Gibrat, 1933; Brown, 1988).

[17] Since the family with no children has the wife aged over 40, we included this case.
[18] See NIS (1965).

b. Estimation of the accumulation rule

Now, we consider the specification for the amount of land which a couple, say couple *s* from village *i*, can acquire and bequeath to their secondary heirs. This amount of land, $L_{i,s}(k_s, \varepsilon_s)$, depends on k_s, the number of children in the family, a stochastic term, ε_s, and the village where the family lives, *i* (*i=1* or *2* for villages 1 and 2, respectively). The stochastic term can be interpreted as reflecting differences in the quality of land. The following specification has been chosen:

$$L_{i,s}\left[k_s, \varepsilon_s\right] = \alpha_i \left(k_s - 2\right)^{\beta_i} \varepsilon_s \qquad \forall k_s > 2$$ [19]

where α_i and β_i are parameters, and ε_s is lognormally distributed with mean 1.[20] The elasticity of the amount of land acquired by a family with respect to the number of children minus two is β_i for Village *i*.[21]

If we had observations on the amount of land acquired by each family, then we could estimate the parameters of the land acquisition function with linear regression techniques. For, let S_i be the set of all observations we have on village *i*,

$$\ln\left[x_s\right] = \ln\left[a_i\right] + \left(\beta_i - 1\right)\ln\left[k_s - 2\right] + \ln\left[e_s\right] \qquad \forall i \in S_i$$

where $\ln\left[\varepsilon_s\right]$ is normally distributed with mean zero.

These data were not available however, and we had to follow a different procedure. What we do not know is whether the irrigated land inherited by a spouse is part of his parent's inherited property, or it was his share in the land acquired by his parents. We do have data on the birth order of the spouses, o_s, and the number of children in their family of origin, k_s. This allowed us to calculate the likelihood that his inherited land was part of that acquired by the previous generation. We can then construct the loglikelihood for our sample $S_1 \cup S_2$. This is done in proposition 4 in the appendix.

Maximization of the likelihood function yielded the following estimates shown in Table 4. Standard errors are given in parentheses.

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[19] The specification of the land acquisition function for $k_s \leq 2$ is not relevant to our problem. Since families with less than three children have no secondary heirs, they cannot pass on the accumulated land. If they accumulate land, it becomes the couple's land, but it will never be individually owned. When the spouses are dead, the land becomes common again, or a new heir is assigned on the basis of the procedures by which the village determines who is allowed to accumulate land.

[20] This assumption is necessary to identify α_i and can be maintained without loss of generality.

[21] Proposition 3 describes the distribution of inherited land out of a couple's acquired land using this specification (see appendix).

Table 4: ESTIMATION RESULTS[22]

	Village Data				Belgian Data			
		v1	v2	v3		b1	b2	b3
	Free Model	$\beta_1=\beta_2$ $\sigma_1=\sigma_2$	$\alpha_1=\alpha_2$ $\sigma_1=\sigma_2$	$\alpha_1=\alpha_2$ $\beta_1=\beta_2$ $\sigma_1=\sigma_2$	Free Model	$\beta_1=\beta_2$ $\sigma_1=\sigma_2$	$\alpha_1=\alpha_2$ $\sigma_1=\sigma_2$	$\alpha_1=\alpha_2$ $\beta_1=\beta_2$ $\sigma_1=\sigma_2$
α_1	14576	19715			12691	14828		
	(19445)	(16171)	5598	7073	(12309)	(9503)	3875	8234
α_2	4005	3559	(3369)	(6326)	3139	2894	(2789)	(2904)
	(3674)	(2698)			(2330)	(1784)		
β_1	0.44		1.09		0.39		1.39	
	(0.86)	0.31	(0.43)	0.33	(0.80)	0.36	(0.62)	0.01
β_2	0.25	(0.50)	0.02	(0.60)	0.33	(0.46)	0.16	(0.20)
	(0.61)		(0.37)		(0.56)		(0.52)	
σ_1	1.27				1.24			
	(0.23)	1.34	1.34	1.54	(0.25)	1.33	1.33	1.45
σ_2	1.37	(0.12)	(0.12)	(0.14)	1.36	(0.13)	(0.13)	(0.15)
	(0.15)				(0.15)			
-LnL	545.86	545.95	546.21	554.51	545.93	546.04	546.38	553.66

Although Table 3 showed a substantial difference between the distributions of couples according to the number of children they have when based on village or Belgian data, the estimates are quite robust with respect to the choice of a particular distribution of family sizes. Testing the restrictions which are imposed when we move away from the free model[23] using a log-likelihood test, it is easy to verify that only the most restrictive version of the model is rejected by our data. This confirms what was already obvious from an inspection of Table 1: the distribution of land sizes are quite different between the two villages and cannot have been generated by completely identical mechanisms.

We based the simulation exercises that follow on the estimates of the *b1* column for the following reasons. First, there is only a very small decline in the likelihood when we impose the restrictions $\beta_1 = \beta_2$ and $\sigma_1 = \sigma_2$. Second, a value of $\beta > 1$ (though not significantly different from 1) is more difficult to maintain. It would mean that secondary

[22] The estimates where obtained using Gauss with the help of Denis Fougères.
[23] We also tested the restrictions separately. None of them had to be rejected.

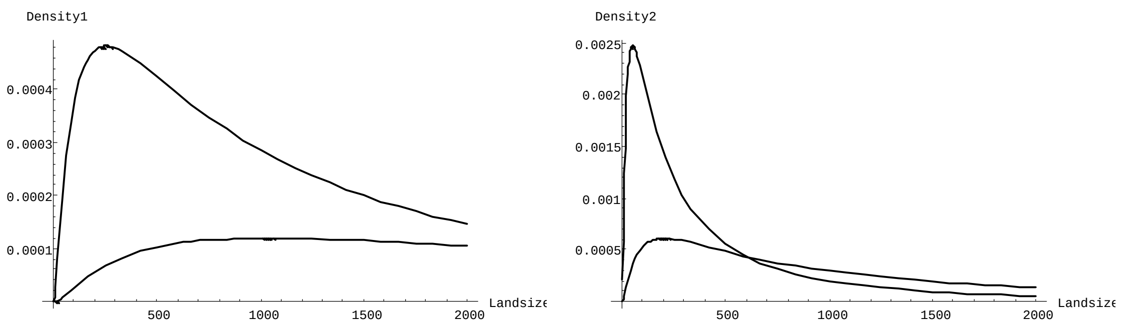
heirs of large families will get a larger plot of land than those coming from small families. This occurs in columns *v2* and *b2*. Third, the a_i reflect circumstantial land characteristics which are different in the two villages, raising doubts about the hypothesis that $a_1 = a_2$. Finally, we preferred the estimates in the *b1* column to those of *v1* because the village distribution of family sizes with its rapid population growth is implausible as a steady state distribution for the past. Note, however, that using *b1* or *v1* estimates do not change our qualitative results.

(c) Equity aspects of customary law

The estimated value for $b = 0.36$ indicates that couples are partly compensated for the number of children they have. Provided that a couple is allowed to accumulate land, the amount of land they can accumulate increases with the number of children. The compensation is far from complete, however. As a consequence, it is a big advantage to be born in a small family in the sense that, on average, secondary heirs in large families will get a smaller amount of land than secondary heirs in small families. This finding is illustrated in Figure 2 which shows the distribution of inheritances out of acquired land for families of different sizes. The distribution of inheritances resulting from the land acquired by large families has more probability mass to the left than the distribution for small families. The distribution of inheritances out of acquired land for small families dominates[24] the distribution of inheritances out of acquired land for large families.

FIGURE 2: The Distribution of Inheritances from the Acquired Irrigated Land for Different Household Sizes, (k = 3,11)

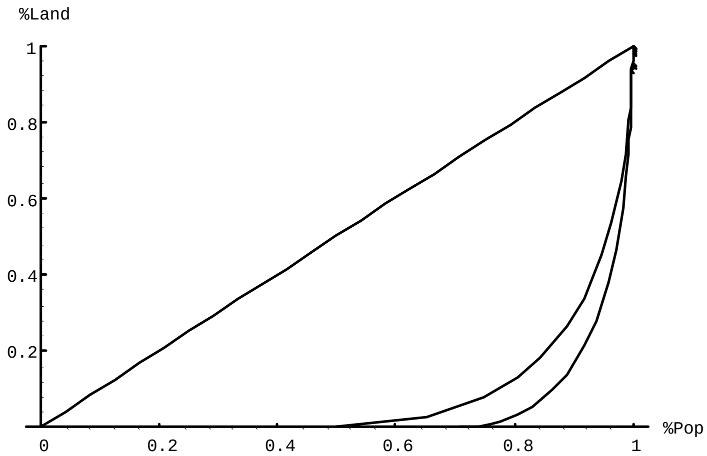
Village 1 Village 2



[24] In the sense of first-order stochastic dominance -see, e.g. Atkinson (1970).

Now we have the necessary components to calculate the steady state distribution of irrigated land which follows from the application of the inheritance rule and the land accumulation rule embodied in this customary law of the Cordillera villages. Taking the observed frequencies of zeros as the steady state number of zeros in the two villages, the expression for the steady state number of zeros (see corollary 2) implies a restriction between the values of *q* and *l* for each village. Assuming *l* to be the same in both villages, and setting *l=0.05*, we can calculate the values of *q* for both villages ($q_1 = 0.69$ and $q_2 = 0.47$). Then, we can compare the Lorenz curves of the steady state distribution of irrigated land for the two villages. The Lorenz curve for village 1 lies everywhere below the Lorenz curve for village 2.[25] Therefore, land is more unequally distributed in village 1 than in village 2.

FIGURE 3: The Lorenz Curve for the Steady State Distribution of Irrigated Land



(d) Population growth and the land constraint: some simulations

As was noted in section 3b, our model can only reach a steady state when the total amount of irrigated land grows as fast as the population. Given the dramatic increase in the population (see also Table 3) and the natural and geographical[26] limits to the amount of land which can be made suitable for intensive cultivation, this assumption is hard to maintain. Therefore, we will consider the following scenarios.

[25] This conclusion is not sensitive with respect to the particular value chosen for *l*.

[26] Remember that these villages have a mountainous and rugged terrain. Where the slopes become less steep, the landscape remains hilly and sloping.

Suppose that the population dynamics was described by the Belgian p_k and that land was abundantly available. There were no problems for the model reaching a steady state. Then, at a certain point in time the geographical limits to the amount of land which can be transformed into irrigated rice fields are reached. How can customary law adjust in the next period to deal with the limited availability of land suited for intensive cultivation? This is described in the first simulation exercise. The second scenario also starts from a steady state, but in addition to the land constraint, the population starts to grow much faster: the Belgian p_k are replaced by the Village p_k. The second simulation exercise describes how customary law can adapt to these simultaneous changes.

Given the structure of our model, there are four ways in which customary law might adjust: *q* or *l* might increase, or a or b might decrease. An increase in *q* or *l* increases the number of landless people without changing the sizes of land holdings of those who are able to acquire land. As a result, for each change in *q*, there exists a change in *l* which has exactly the same effect on the Lorenz curve for the distribution of irrigated land provided *q* and $l \in [0,1]$. The way this shift occurs in the Lorenz curve will be very different depending on whether this change is brought about by *q* or *l*. An increase in *q* allows less people to acquire land, while an increase in *l* increases the fraction of land holding families that lose their land.

Changes in a or b do not affect the number of landless individuals. Instead, changes in these parameters alter the average amount of land available to land holding families. For example, a decrease in their values will lower the average amount of land which a family allowed to claim land, can actually obtain. But though both parameters will decrease this average amount of land, the way they bring this about differs. A decrease in a decreases the amount of land for all families in the same proportion, while a decrease in b will accomplish this decline at the expense of larger families.

Assuming that only one of the parameters adjusts, the expression in proposition 2 allows us to calculate the exact adjustment necessary for each parameter in each of the two scenarios we consider.[27] Since the necessary adjustments are similar for both villages, we only give the results for Village 2. The values and their effects on the number of landless individuals are given in the first four rows of Table 5a and 5b.

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[27] A Mathematica program was used to calculate the roots of this equation.

Table 5: SIMULATION RESULTS

(A) LAND CONSTRAINT

Parameter	Base case values	New parameter values	frequency of zeros	Conditional mean land size
q	0.47	0.72	0.61	1391
l	0.05	0.46	0.61	1391
α	2894	1481	0.5	1078
β	0.36	-0.34	0.5	1078
η	1.00	0.74	0.56	1233

(B) LAND CONSTRAINT AND POPULATION EXPLOSION

Parameter	Base case values	New parameter values	frequency of zeros	Conditional mean land size
q	0.47	0.97	0.83	1063
l	0.05	2.08		
α	2894	157	0.5	367
β	0.36	-1.98	0.5	367
η	1.00	0.29	0.86	1327

It is clear that customary law, with regard to the devolution of inherited land and the acquisition of land from the commons for restricted private use and control, has a hard time to deal with the scenarios we considered. The first scenario already implies dramatic changes in customary law. The number of families allowed to accumulate land needs to be halved, the probability that a family looses its land has to be multiplied by a factor of nine, the amount of land that a family is allowed to accumulate needs to be halved or large families have to be severely punished. Matters are even worse in the second scenario. Let us take the value of *l*, which becomes greater than 1. This indicates that, even if we could expropriate all present land holdings and use this to give to those families which could acquire land, the amount will not be sufficient. The values of the other parameters indicate a similar conclusion. If only 3 percent of the households are allowed to acquire land, or if the amount of land a couple can acquire is only one fifteenth of what it used to be, or if large families are severely punished such that they are able to acquire much less land than small families, customary law as it has been practiced in the past ceases to be applicable. Combinations of parameter changes will not alter this conclusion.

In the preceding discussion we assumed that customary law adjusted. This leads to an increase in the number of landless farmers, or a decrease in the size of the plots of those who own land. One might wonder whether these scenarios were at all sustainable. At this point, it must be stressed that if the total amount of land remains fixed, then any inheritance rule deals with a trade-off between the number of landless individuals on one hand and the average size of plots of landowners, on the other. Indeed, when the size of the population grows, equal division of inheritances will lead to a decrease of the size of the plots of those who have land. Primogeniture, on the other hand, either decreases or keeps the absolute size of the landowning class constant. In the presence of population growth, primogeniture increases the relative number of landless people. What may be remarkable about this inheritance rule practiced in Cordillera villages is that it allows a certain flexibility for the community to find a compromise within this trade-off. It is as if, by changing a particular parameter rather than another, the village could choose whether to change the number of landless people and/or the average size of land of the landowning individuals.

To close our discussion, we look at a final variant of our scenarios where there is population growth given a limited amount of arable land. The prescriptions of customary law can still be followed when we limit the reference of heirs to the children of farmers who would like to become farmers themselves. Let there be a certain probability that a child will not take up farming. Taking this into account, the inheritance rule will now be as follows. The eldest of the sons (daughters) who takes up farming inherits his (her) father's (mother's) land. The other children who take up farming get an equal share out of the land acquired by their parents. The total amount of land which a couple can acquire is based upon how many of their children will take up farming. For our analysis, this implies that the distribution of families according to size has to be adjusted. Let η be the probability that a child will take up farming. Formally, the p_k will have to be redefined in the following way:

$$\hat{p}_k = \sum_{i=k}^{K} \binom{i}{k} \eta^k (1-\eta)^{i-k} p_i \qquad \forall k = 1,\dots,K$$

Indeed, the probability that there will be exactly *k* farmers in a family with i $(i \geq k)$ children is binomially distributed. Multiplying this binomial probability with p_i and summing over all *i* results in the expression above. We can now insert the resulting $\hat{p}_k$ in the equation of Proposition 2 and search for the value of η such that $g_t = 0$. The result is given in the last row of Table 5. We interpret this result as indicating that if customary law is maintained as it is, but is only applicable to the children who farm, then, given the present rate of population growth and the geographical limits, seven out of ten children cannot become farmers in their village of origin. If the village were only confronted with the land constraint, one out of four children cannot farm in its village of origin. These children will either have to migrate, or take up a non-farming job. Given the poor performance of the Philippine economy with respect to job creation outside of farming (see, e.g., Balisacan, 1993), this constitutes a considerable challenge for government policy. Finally, note that the transformation of probabilities described above makes families where many children become farmers less frequent. Since compensation for family size is incomplete, this increases the average plot size inherited by secondary heirs, thereby increasing the conditional mean land size.

5. CONCLUSION

Customary law responds to changes in the environment. This observation stands out clearly in the case of Cordillera villages. Population pressure necessitated an intensification of agriculture thereby requiring the transformation of common land into privately-owned land. The land accumulation rule is an institutionalized arrangement to transform common unimproved land into private irrigated rice fields. Since we wanted to study the evolution of the distribution of irrigated land, we needed to look into the inheritance rules practiced in the locality. Here, the inheritance rule applies bilateral primogeniture for the couple’s inherited land and applies equal division among the other children for the couple’s accumulated land. It does not discriminate among offspring on the basis of sex. The distribution of land at each point in time is a weighted average of the initial and steady state distribution. This unique, globally stable steady state distribution is itself a weighted average of the distribution of the inheritances which result from the land acquired by families of different sizes. Hence, the land accumulation rule is crucial for the steady state distribution of land.

We used data on two villages to estimate the land acquisition function. We attempted to investigate whether families with more children as compared to families with fewer children are more able to increase the number of their rice fields through transforming parcels from commonly-owned land. Although far from conclusive, our results indicate that some compensation for the number of children takes place, though compensation is far from complete. It is important to stress that though irrigated land is most valued, it constitutes only part of the total amount of land to which family members have access. There are other mechanisms in the property rights system, (i.e., usufruct rights to communal or corporate land) that provide for the matching of family resources and family needs. And the transformation of commonly owned land into private ownership will influence the role of these channels.

Now that the geographical limits to the land transformation process have been reached and with the population rapidly growing, one does wonder how the traditional property system can adjust to these new circumstances. Customary law in these villages has more channels of adjustment than the inheritance practices traditionally analyzed by economists such as Primogeniture and Equal Division. One way is that more people are made landless. In the present system, this can be achieved by allowing less people to acquire land or by increasing the fraction of people who lose their land. Another way is that the land holdings of those who have land can be decreased. Again there are two ways to achieve this. It can be done by decreasing proportionately the amount of acquired land by all families, or by decreasing the compensation provided for large families. We have used the estimation results to investigate how customary law might adapt to population pressure. These options will have different distributional effects within the class of landowning families. Unfortunately, our simulation results suggest that with the present rapid growth of population, these theoretical possibilities will not suffice.

There is a final scenario where customary law may be maintained in exactly the way it has been practiced. This requires an increase in the opportunities offered for the children of farmers. It also requires the reformulation of the inheritance rule such that only children who choose to be farmers can inherit land from their parents. Given the recent demographic developments in the region and the exhaustion of the amount of land suited for intensive cultivation, we estimated that 71 per cent of the children should find a non-farm job or emigrate. Here is a considerable challenge for public policy at both the regional and national levels.

APPENDIX: PROPOSITIONS AND COROLLARIES

PROPOSITION 1 : Provided that the way land is accumulated by families remains unchanged, the evolution of the densities of men's and women's land can be expressed as

$$f_t[x] = E\langle b\rangle^t E^{-1} f_0[x] + \left(I - E\langle b\rangle^t E^{-1}\right) f_\infty[x] \qquad \forall x \geq 0$$

where $A = (1-l)\begin{bmatrix} \tilde{a}_1 & \tilde{a}_2 \\ \tilde{a}_2 & \tilde{a}_1 \end{bmatrix} \equiv \begin{bmatrix} a_1 & a_2 \\ a_2 & a_1 \end{bmatrix}$, $E = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$, $\langle b\rangle = \begin{bmatrix} b_1 & 0 \\ 0 & b_2 \end{bmatrix}$, $\mathrm{i} = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$

$b_1 = (1+n)^{-1}(a_1 + a_2)$ and $b_2 = (1+n)^{-1}(a_1 - a_2)$,

$\forall x \geq 0$, $f_t[x] = \begin{bmatrix} f_t^m[x] \\ f_t^w[x] \end{bmatrix} \quad t = 0,1,\ldots\infty$

$$f_\infty[x] = \left(I - (1+n)^{-1} A\right)^{-1} (1+n)^{-1} f^u[x] \qquad \forall x \geq 0$$

and $f^u[.]$ is defined as follows:

if $K \geq 3$, $f^u[x] = (1-q)\left(\sum_{k=3}^{K} (1/2)(k-2) p_k f^{uk}[x]\right)\mathrm{i} \qquad \forall x > 0$

if $K < 3$ $f^u[x] = 0 \quad \forall x > 0$

if $K \geq 3$, $f^u[0] = \left(l(\tilde{a}_1 + \tilde{a}_2) + (1/2)q\sum_{k=3}^{K}(k-2)p_k\right)\mathrm{i}$

if $K < 3$ $f^u[0] = l(\tilde{a}_1 + \tilde{a}_2)$

Δ **Proof**:

For $x > 0$ we know from the preceding discussion that the following system of difference equations describes the distribution of inherited land:

$$f_t[x] = (1+n)^{-1}\left(A f_{t-1}[x] + f_{t-1}^u[x]\right)$$

Assuming that $f_{t-1}^u[x]$ remains unchanged over time this equation is just a system of first order difference equations, a particular solution of which is given by $\left(I - (1+n)^{-1} A\right)^{-1}(1+n)^{-1} f^u[x]$. In order to find the complementary functions, we have to find the roots of the equation $\left|bI - (1+n)^{-1} A\right| = 0$. This characteristic equation has two roots, b_1 and b_2. Hence, the complementary function can be written as $z[t] = E\langle b\rangle^t c$. c is a vector of arbitrary constants, which has to be determined by the initial conditions of the system. Then we get $c = E^{-1}\left(f_0[x] - (I - (1+n)^{-1} A)^{-1} f^u[x]\right)$. The solution to the system of difference equations can be written as[28]

[28] Keeping in mind that $AE = E\langle b\rangle$, it is straightforward to verify that this is indeed the solution to our system of difference equations.

$$f_t[x] = E\langle b\rangle^t E^{-1} f_0[x] + \left(I - E\langle b\rangle^t E^{-1}\right)\left(I - (1+n)^{-1} A\right)^{-1}(1+n)^{-1} f^u[x]$$

Note that $0 < b_2 < b_1 < 1$. Both roots are positive and smaller than one and therefore there exists a globally stable asymptotic solution for each density; a solution which does not depend on the initial conditions of the system. Hence, as t goes to infinity, $\langle b\rangle^t = 0$ and the asymptotic or equilibrium distribution is given by $f_\infty[x] = \left(I - (1+n)^{-1} A\right)^{-1}(1+n)^{-1} f^u[x]$. The solution can be rewritten in terms of the initial and the asymptotic distribution:

$$f_t[x] = E\langle b\rangle^t E^{-1} f_0[x] + \left(I - E\langle b\rangle^t E^{-1}\right) f_\infty[x].$$

For $x = 0$, note that, given the definition of $f^u\ [0]$, the equation for $f_t\ [0]$ has exactly the same form as the equation we started from above. Δ

COROLLARY 1: The speed at which the equilibrium distribution is approached is increasing in *l* and *n*.

Δ **Proof:**

It is immediate from the facts that $b_1 = (1+n)^{-1}(1-l)\left(1 - p_0 - (1/2)p_1\right)$,

$b_2 = (1+n)^{-1}(1-l)\left((1/2)p_1 + \sum_{k=2}^{K}\left(1 - 2(1/2)^k\right)p_k\right)$ and that increasing the population size requires an increase in p_k accompanied by a decrease in the frequency of smaller families p_l with *l*<*k*. Δ

COROLLARY 2:

The steady state distribution has the following comparative static properties:

$$\frac{\partial f_\infty^z[0]}{\partial q} > 0,\ \frac{\partial f_\infty^z[0]}{\partial l} > 0,\ \frac{\partial f_\infty^z[0]}{\partial p} < 0,\ \frac{\partial f_\infty^z[0]}{\partial(\tilde{a}_1 + \tilde{a}_2)} > 0$$

where $p \equiv \sum_{k=3}^{K} \frac{k-2}{2} p_k$, the expected number of male/ female secondary heirs per family

$$\forall x > 0:\ \frac{\partial f_\infty^z[x]}{\partial q} < 0,\ \frac{\partial f_\infty^z[x]}{\partial l} < 0,\ \frac{\partial f_\infty^z[x]}{\partial p_k} <> 0,\ \frac{\partial f_\infty^z[x]}{\partial(\tilde{a}_1 + \tilde{a}_2)} < 0\ ,\ (z=m,w)$$

Δ **Proof:**

The proof follows from Proposition 1 and noting that

$$\left(I-(1+n)^{-1}A\right)^{-1}(1+n)^{-1}\mathrm{i} = \left(p+l(\tilde{a}_1+\tilde{a}_2)\right)^{-1}\mathrm{i} \ ,$$

such that we can rewrite the steady state densities as $f_\infty^z[x] = \dfrac{(1-q)}{p+l(\tilde{a}_1+\tilde{a}_2)}\sum_{k=3}^{K}\dfrac{k-2}{2}p_k f^{uk}[x]$, $\forall x>0$ and $f_\infty^z[0] = \dfrac{l(\tilde{a}_1+\tilde{a}_2)+qp}{p+l(\tilde{a}_1+\tilde{a}_2)}$.

The results follow from a differentiation of the above formula. Δ

PROPOSITION 2 : Let L_t be the amount of irrigated land at time t. $g_t \equiv (L_t - L_{t-1})/L_{t-1}$ is the rate of growth of L_t . Then

$$1+g_t = (1-q)\frac{(1+n)^{t-1}}{L_{t-1}}\sum_{k=3}^{K}(k-2)p_k\int_0^\infty f_{t-1}^{uk}[x]x\,dx - l - (1-l)\left(p_0+(1/2)p_1\right)$$

Δ **Proof**:

The amount of privately-owned irrigated land can decrease for two reasons. First, some persons may lose their land. This will diminish the area of privately-owned land in period *t* by lL_{t-1}. Second, some will have no heirs. This will also decrease the amount of privately-owned land in period *t* by $(1-l)\left(p_0+(1/2)p_1\right)L_{t-1}$. At the same time, the amount of irrigated land increases since some families will acquire land. Therefore, the amount of privately-owned irrigated land increases by $(1-q)N_{t-1}\sum_{k=3}^{K}(k-2)p_k\int_0^\infty f_{t-1}^{uk}[x]x\,dx$, where N_{t-1} is equal to the total number of couples at time *t-1*. The expression following the integral sign is the average amount of land left to each of the secondary heirs of families having *k* children. There will be $(1-q)p_k N_{t-1}$ such families, bequeathing on average this amount to $(k-2)$ children. The equation describing the evolution of the total amount of irrigated land can be written as

$$L_t = \left(1-l-(1-l)\left(p_0+(1/2)p_1\right)\right)L_{t-1} + (1-q)N_{t-1}\sum_{k=3}^{K}(k-2)p_k\int_0^\infty f_{t-1}^{uk}[x]x\,dx$$

Deriving the condition in the proposition is now straightforward when we use the fact that $N_{t-1} = (1+n)^{t-1}$. Δ

COROLLARY 3 : Provided that the way land is accumulated by families remains unchanged, the steady state growth rate of the total amount of irrigated land is equal to the growth rate of the population.

Δ **Proof:**

The last equation in the proof of proposition 2 can be written in the form

$$(L_t/N_t)(N_t/N_{t-1}) = \kappa\,(L_{t-1}/N_{t-1}) + c$$

where $\kappa = (1-l)\left(1-p_0-(1/2)p_1\right)$. Since $N_t/N_{t-1} = 1+n$ and we have that

$$\kappa/(1+n) = (1-l)\left(\left((1/2)p_1 + \sum_{k=2}^{K} p_k\right) \Big/ \left((1/2)p_1 + \sum_{k=2}^{K} p_k k\right)\right) < 1\,,$$

a steady state solution for (L/N) exists, which implies that, in steady state, L and N grow at the same rate. Δ

PROPOSITION 3 : Let $\varepsilon \approx LN\left[1, \exp\left[\sigma_i^2\right] - 1\right]$. Then

$$f_i^u\left[x_s, k_s; \alpha_i, \beta_i, \sigma_i\right] = \frac{1}{\sqrt{2\pi}\sigma_i} \exp\left[\frac{-1}{2\sigma_i^2}\left(v\left[x_s, k_s; \alpha_i, \beta_i\right] + \left(\frac{\sigma_i^2}{2}\right)\right)^2\right] \left[\frac{1}{\exp\left[v\left[x_s, k_s; \alpha_i, \beta_i\right]\right]}\right]\lambda_{i,s}$$

where $\begin{cases} v\left[x_s, k_s; \alpha_i, \beta_i\right] = \ln\left[x_s\right] + \ln\left[k_s - 2\right] - \ln\left[\alpha_i\right] - \beta_i \ln\left[k_s - 2\right] \\ \lambda_{i,s} = \dfrac{\left(k_s - 2\right)^{1-\beta_i}}{\alpha_i} \end{cases} \qquad \forall k_s > 2\,.$

Δ **Proof**:

The amount of land x_s, inherited by a child in village i, is related to the realized value of the stochastic term ε_s in the following way:

$$x_s = \alpha_i \left(k_s - 2\right)^{\beta_i - 1_i} \varepsilon_s$$

The distribution of land sizes is therefore a monotone increasing transformation of the distribution of the stochastic term ε_s which is lognormally distributed with parameters γ_i and σ_i. The density of ε_s is given by

$$g_i\left[\varepsilon_s\right] = \exp\left[-\frac{\left[\ln\left[\varepsilon_s\right] - \gamma_i\right]^2}{2\sigma_i^2}\right] \frac{1}{\sigma_i\sqrt{2\pi}} \frac{1}{\varepsilon_s}$$

The mean[29] of ε_s is $\exp\left[\gamma_i + \left(\sigma_i^2/2\right)\right]$. Since we assumed that this mean is 1, $\gamma_i = \left(-\sigma_i^2/2\right)$. To obtain the density of the distribution of land, we have to multiply this density with $\left[\dfrac{\partial x_s}{\partial \varepsilon_s}\right]^{-1}$. This factor is equal to $\lambda_{i,s}$. Then, using the relationship between x_s and ε_s to define $\ln\left[\varepsilon_s\right] \equiv v\left[x_s, k_s; \alpha_i, \beta_i\right]$ the proposition follows. Δ

PROPOSITION 4 : The loglikelihood is given by

$$\sum_{i=1}^{2} \sum_{s \in S} \ln\left[f\left[x_s, k_s, o_s; \alpha_i, \beta_i, \sigma_i\right]\right]$$

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[29] The variance of the distribution is given by $\exp[2\gamma]\left(\exp\left[2\sigma^2\right] - \exp\left[\sigma^2\right]\right)$, which in our case reduces to $\exp\left[\sigma^2\right] - 1$.

where

$$f[x_s, k_s, o_s; \alpha_i, \beta_i, \sigma_i] \equiv p^a[o_s, k_s] f_i^u[x_s, k_s; \alpha_i, \beta_i, \sigma_i]$$
$$+ (1 - p^a[o_s, k_s]) \sum_{k=3}^{K} \left(\frac{k-2}{2p} \right) p_k f_i^u[x_s, k; \alpha_i, \beta_i, \sigma_i]$$

$$p^a[o_s, k_s] = 0 \text{ if } o_s = 1$$

$$p^a[o_s, k_s] = 0 \text{ if } o_s = k_s = 2$$

$$p^a[o_s, k_s] = (1/2) - (1/2)^{k_s - 1} \text{ if } o_s = 2 \text{ and } k_s > 2$$

$$p^a[o_s, k_s] = 1 - (1/2)^{o_s - 1} \text{ if } o_s > 2$$

Δ **Proof**:

If $o_s = 1$, then the land was definitely inherited by the parent. When $o_s = 2$ there are two possibilities. If $k_s = 2$, then again the land was definitely inherited by a parent. If $k_s > 2$, then the land was part of the parents' inherited land when this child is of a different sex from that of the first born child, or has the same sex as all his siblings (i.e., they are all boys or all girls). The former happens with a probability of 1/2, the latter with a probability of $2(1/2)^{k_s}$. Otherwise, the land comes from the parents' acquired land. The probability of the latter event is $(1/2) - (1/2)^{k_s - 1}$. For $o_s > 2$, the probability that the land was part of the parents' inherited land equals the probability that all previous children are of the same sex and the o_s -th child is of the other sex. This probability is $(1/2)^{o_s}$ and there are two cases in which this might occur: one where all previous children are boys followed by a girl and the other, where all previous children are girls followed by a boy. Hence, in this case, the probability that the land comes out of the acquired pool is $1 - 2(1/2)^{o_s}$. We can now reformulate the likelihood to take this into account. Define $p^a[o_s, k_s]$ as the probability that individual *s*, being the o_s-th child out of k_s, inherited his land from the acquired pool. These probabilities are given in the proposition.

As we have already noted, all land is acquired land, and, therefore drawn out of one of the distributions of $\{f_i^u[x_s, k; \alpha_i, \beta_i, \sigma_i] | k = 3, \ldots, K\}$. If the land is not acquired by the parents in period *t-1*, then it must have been acquired by one of the more distant ancestors. Reconstructing this tree, it is easy to see that the probability that the land came out of $f_i^u[x_s, k; \alpha_i, \beta_i, \sigma_i]$ given that the land is not acquired in *t-1*, equals $((k-2)p_k / 2p)$. We now have established $f[x_s, k_s, o_s; \alpha_i, \beta_i, \sigma_i]$.

Estimation of the parameters of the land acquisition function can now be done by a maximisation of the likelihood of our sample S, with respect to the parameters α_i, β_i and σ_i. The sample contains those observations for which $x_s > 0$. Hence the loglikelihood.

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