Demographics and Institutions*

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> The population of approximately six hundred was divided into rather sharply divided age grades with the old gray-haired men constituting a governing body. They were promoted to the office on the basis of age, relieved of physical labor, provided with food from the common stock, and placed in control of the distribution of food. Consequently, the choicest diet was often reserved for them...(Simmons, 1945: 31).

1. Introduction

Douglass North transformed his field. He first encountered economic history as a branch of economics; his work has reconstituted it as a branch of political economy. Economic historians focus on endowments, technologies, preferences and the operations of markets, and seek, among other things, to explain rates and patterns of economic growth. North introduced another factor -- the society's endowment of institutions. In a variety of studies, he argues that societies with similar economic endowments would vary in their economic performance, should their institutions differ. Societies with institutions that safeguarded property rights; equated the social and private returns to productive effort; reduced the costs of transacting; or facilitated the making of credible commitments would elicit higher rates of economic growth, all else being equal, than would societies lacking such institutions. It is governments that create institutions, or that provide the legal framework that empowers them. Thus did North's insight encourage those trained as political scientists — Barry Weingast, Margaret Levi, Jean-Laurent Rosenthal, and others — to turn to economic history, or to the adjacent field of development.

In his most famous books, Douglass North looks at economic history in *le longue durée.* In *The Rise of the Western World,* written with Robert Paul Thomas, he addresses the history of the west from the time of the fall of the Roman Empire (North and Thomas, 1973). In *Structure and Change in Economic History,* he reaches even further back, addressing the political economy of societies that existed before even the ancient civilizations (North 1981). As with the British historians centered in Cambridge, most notably Postan (1966) (more recently, Wrigley and Schofield 1981), and the *Annalistes* working in France (see Bloch 1970; Ladurie 1974; Braudel

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1969), North adopts a demographic approach to the study of economic change over the long duration. The growth of population, he argues, leads to the spread of people into regions possessing diverse natural endowments; the growth of markets promotes specialization and trade; and per capita incomes therefore rise as people reap the benefits of exchange. Population growth helps to account not only for increased incomes, but also for the distribution of income. This is evident in the classic analysis of the changing terms of labor markets, or the theory of serfdom, that Postan (1937) pioneered and that North and Thomas (1973) perfected, drawing on the work of Cheung (1969).

While building on the work of the demographic historians, North broke sharply with them. Their analysis, he argued, was incomplete, for it omitted the role of institutions. Exchange could occur only when transaction costs were reduced to the point where markets could form; investment would take place only where property rights were enforced; and the incentives to promote trade and enforce property rights varied, depending upon the political interests of governments, and, in particular, upon their need for revenues.[1] This error of omission, he argued, led to an error of commission, since societies experiencing similar changes in their economic endowments, e.g. similar changes in the ratio of people to land, experienced *different* rates of economic growth. And they did so because of differences in their institutions, such as their system of property rights. In this respect he contrasts Spain on the one hand, where rent seeking by producers and the revenue needs of monarchs led to the inefficient use of resources in the production of wool, and England on the other, where property rights equated the private with the social return in the use of resources, such that private agents made private decisions that were consistent with the maximization of the returns to society (see chapters 10 and 12 in North and Thomas, 1973).

In his criticism of the demographic approach to economic history, North was joined by others, most notably Robert Brenner (1976). Focusing on the same stylized facts as North, Brenner saw the variation in the rates and patterns of economic growth in societies experiencing the same demographic transition as reason to reject the neoclassical approach. North did not,

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[1] To quote:

"The most important causal factor in the development of new property rights was that the government created them only when it was in its fiscal interests. ...[T]he granting of the alienability of land (a key step in the development of fee-simple absolute ownership) was accomplished in England, France, Anjou, Poiters, and other areas to ensure that the Crown would not lose existing feudal revenues. ... For identical reasons, counter-productive actions, such as the multiplication of tolls, arbitrary confiscation, forced loans, and many other similar devices, were taken, which made for greater uncertainty with respect to property rights. The direction the government took depended upon its fiscal interests" (North and Thomas, 1973, pp. 69-70).

and instead turned to such theorists as Coase (1960), Cheung (1969), Barzel (1989), Demstez (1988) and others for neoclassical foundations for his theory of non-market institutions.

In searching for a neoclassical theory of institutions, we feel, North may have jumped too far. An alternative lay far closer at hand embedded, implicitly to be sure, in the demographic approach from which he so strikingly departed. At the core of the demographic theory is the birth and death of individuals. The individuals are finitely lived. The objective of the economic historian is to explain how such finitely lived individuals can generate social outcomes that endure over long durations, indeed longer than individual lifetimes. To address this issue, North introduces institutions. We instead attribute longevity of social practices to a second demographic fact: that not only are people born and not only do they die, but that they also progress through a life course (Eisenstadt, 1956). Quite simply, they age, passing from junior to middle aged and then to elder status. Within this simple demographic framework, we locate the capacity of societies to provide the kinds of outcomes North attributes to institutions; the preservation of stable outcomes over long durations and the provision of public goods.

2. A Theoretical Approach to Intel-temporal Institutions

To motivate our discussion, imagine the following stylized setting. There is a group consisting of T generations, each of which has N members. At each time period t, the oldest generation dies and a new generation is born. Thus, at any time period there are NT members alive.[2] Members of the oldest generation at time t, born t-T+1 periods ago, each have only the current period of "life" remaining; the members of the youngest generation have T-l periods remaining after the current one. Their interactions in each period comprise a game in which each member of each generation must decide whether to contribute to the production of a public good, such as defense.

This setting, which may be generalized or specialized in any number of ways (some of which we pursue shortly), is modeled by Cremer (1986) as a multiperiod prisoners' dilemma involving overlapping generations of players. To provide the reader with intuition, however, we present an especially clean version crafted by Cooper and Daughety (1989), hereafter "CD." The CD model is of a public good with production linear in member contribution, hereafter "effort."

2 Most of the insights of our argument are conveyed in the setting in which every generation is of the same size -- N -- though our qualitative conclusions go through with generations of different population size. Indeed, as a comparative statics exercise below, we examine what happens when there is a demographic "shock" (a baby-boom generation, a cohort of Watergate or Gingrich babies in a legislature, an unexpected yield in graduate admissions recruitment, etc.).

So, let $e_t^{i,\tau} \in \{0, 1\}$ be the effort choice by member i of generation τ at time t. Thus, the amount of public good provided at time t is $\Sigma_{k=0, T-1}\Sigma_{j=1,N}\ e_t^{j,t-k}$. Effort is costly; in particular, in units of the public good in question, effort costs α. Consequently, for any member of generation τ, his or her *period t payoff* is:

$$\Pi_t^{i,\tau} = \Sigma_{k=0, T-1}\Sigma_{j=1,N}\ e_t^{j,t-k} - \alpha\ e_t^{i,\tau}. \qquad (1)$$

For $\alpha > 1$, the cost of effort exceeds the benefit to its contributor, so that it is not rational to contribute in any stage game with payoff function (1). However, for $\alpha < NT$, it would be desirable for everyone to "do the irrational" and contribute, since $\Pi_t^{i,\tau} > 0$ for all i in this case. Thus, for $1 < \alpha < NT$, equation (1) gives the payoff function of an n-person prisoners' dilemma in which $e_t^{i,\tau} = 0$ is a dominant strategy that, if pursued by everyone, produces a Pareto-inferior result.

This structure of repeated interactions among members of overlapping generations "fits demographic reality" (Cooper and Daughety, p. 4) better than conventional finite and infinite horizon repeat-play formulations. In the literature on comparative politics, the standard manner of resolving the prisoners' dilemma is repeated play by infinitely lived individuals. But people are not infinitely lived; we therefore cannot assume that punishment strategies will induce cooperation in the provision of public goods. The finitely lived framework adopted by Cremer (1986) and Cooper and Daughety (1989) provides an alternative specification. In such a framework, an individual clearly possesses incentives to "defect" in the last period of her life, since there is no way to punish her. Moreover, she would prefer to free ride on the contributions of fellow group members in other periods of her life. Nonetheless, Cremer (1986) and Cooper and Daughety (1989) find that societies of rational individuals partitioned into overlapping generations can provide positive levels of public goods as a subgame perfect equilibrium of repeat play in an "ongoing organization" (Cremer, 1986).

Consider a putative equilibrium in which members of each generatiion contribute effort for T* periods, and then shirk thereafter; a member from generation τ contributes in periods τ, $\tau+1$, ... , $\tau+T^*-1$, and then shirks from period $\tau+T^*$ until she dies after period $\tau+T-1$. We claim that this pattern of behavior can be sustained by the (credible) threat of banishment: if any agent younger than T* shirks, she is banished from the group, a circumstance yielding a utility of zero.[3] CD prove the following proposition:

> ***Proposition 1 (Cooper and Daughety):*** **For the game with period t payoff function (1) in which $1 < \alpha < NT$, if (i) $(T\text{-}T^*)T^* = (\alpha\text{-}1)/N$ and (ii) $T^2 / 4 \geq (\alpha\text{-}1)/N$, then there exists a T* such that the intertemporal strategy in which each generation contributes for its first T* periods and shirks thereafter is a subgame perfect equilibrium.**

A sketch of the proof begins by noting that an agent from generation τ would not wish to defect when he reached age τ+T*-1, his last period of contribution. If he continues to follow the stipulated equilibrium behavior in this period by contributing effort, then he receives NT* - α this period followed by (T-T*) periods in which he receives a payment of NT* (assuming in all these periods that everyone else contributes who is supposed to). This amounts to a total payoff from this point on of (T-T*+1)NT* - α. If, on the other hand, he defects by failing to contribute, and is banished from the next period of his life until its end, his payoff is NT* -1, followed by zero thereafter. These payoffs are equal when condition (i) is satisfied, so that an agent exactly T* periods old is indifferent between following and deviating from the equilibrium path. However, an agent one period younger will definitely contribute since, if she doesn't, the punishment period will be a period more and the periods of reward from social cooperation will be one period less. (By parallel argument, an agent one period older will definitely shirk). So, if a T* exists satisfying (i) in Proposition 1, social production of the public good can be sustained. Condition (ii) of the proposition gives the requirement for such a T* to exist.[4]

From (1) above it is straightforward, albeit notationally inelegant, to compute the lifetime utility of any group member from generation τ as $\Sigma_{t=\tau,\ \tau+T-1} \Pi_t^{i,\tau}$, appropriately discounted if necessary. It is easy to see that this is a (weakly) monotonic function of N. Monotonicity results from two effects. First, for the given equilibrium number of contribution periods, T*, more

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3 CD argue that trigger strategies sustain this equilibrium -- so that if any one person shirks before he or she is T* periods old, *everyone* stops working thereafter and the group effectively disbands. Banishment, with group interaction minus the "banishee" continuing, is *a fortiori* credible.

4 The proof is found in Cooper and Daughety (1989). In effect, condition (ii) gives the requirement for the graph of the function defined on the left-hand side of (i) to intersect the graph of the (constant) function on the right-hand side.

individuals are contributing. Second, T* increases with N (the value of T* that solves (i) in Proposition 1 is monotonic in N, and (ii) holds *a fortiori*). Thus we have the following corollary:

> ***Corollary to Proposition 1*: Suppose that the generation born at τ is of size $N_\tau > N$. The equilibrium level of production of the public good remains an equilibrium (indeed, higher levels may now be sustainable), and lifetime utility of every generation alive during τ's lifetime, is increased.**

3. Intertemporal Institutions in Practice

It is useful to return at this point to the work of the economic historians. The demographic approach to economic history emphasizes that when the birth rate exceeds the death rate and population increases, so too do the opportunities for increased personal incomes. Population spreads to new territories; as people occupy diversely endowed territorial niches, they can exploit gains from trade; and the growth of trade can generate increases in welfare not attainable in the absence of markets. As North and others have argued, however, the capacity to reap benefits from the exchange of private goods is premised upon the provision of public goods, such as security for trade and the defense of rights in property. To explain economic growth, North therefore turns to the analysis of institutions. *What we are suggesting is that the same demographic framework that accounts for the just-noted growth of private markets can be used to explain the provision of public goods as well.*

Let us make the point slightly differently. When pressed to define what they mean by the new institutionalism, practitioners tend to equivocate. When describing empirical realities, they tend to point to examples of formal institutions, such as the police, the court system, or the bureaucracy. When seeking to communicate the conceptual meaning of the term, they tend to be far more abstract and to refer to enduring and self-enforcing patterns of behavior. Like the rest of us, North seeks to discuss the role of institutions at a high level of generality; but, when illustrating their significance for economic history, he tends to revert to the discussion of formal institutions. We would argue that the demographic approach provides a way of understanding how societies could secure the provision of public goods *even before* the creation of such institutions.

Indeed, in our analysis, we take direction from the work of anthropologists. Many, particularly those working in Africa, study the sources of order in societies that lack states (Falk-Moore, 1993). In such societies, order does not result from the operation of bureaucracies or public authorities, but rather from the operation of kinship groups. Family relations encompass not only the social and cultural domain but also that of the economy and polity. Production as well as consumption takes place within the household, where age, kinship, and descent organize the patterns of cooperation and conflict that make up the political life of kin-based polities.

As long ago argued by Meyer Fortes (1958), one of the leading students of kin-based societies, the domestic domain is dominated by the fact of time. A given family in different periods of time will be composed of a different distribution of people, for it will, with the passage of time, change the numbers and proportions of young, middle aged, and senior persons. Families organize the relationships between generations; the rules of descent structure the transmission of wealth and property. They also structure the transmission of authority in societies in which kinship organizes the distribution of power as well. Examples of these truths abound in the anthropological record. Simmons (1945) draws illustrations from Oceana, North America, Central America, and Africa. Most relevant for our argument, however, are the more detailed investigations from Africa.

In both Eastern and Southern Africa, as well as in other societies, the public good that appears to be of greatest value is defense. In many societies — the Zulu, the Nyakusa, the Gusi, the Nandi, the Pokot, the Samburu, and the Maasai, to mention but a few (see Baxter and Almagov, 1978) — the young men specialize in military arts. Indeed, the societies are organized into age grades, with the young men serving as warriors. Prior to their induction, they first serve as herdsmen for their families. When the young men reach the appointed age, the elders conduct initiation rites in which the youths pass from workers for their families into servants of the tribe. In some societies, they move into military camps — into *manyatas,* in the case of the Maasai (Spencer 1988) — from which they defend the tribal territory against encroachment by man and beast, thereby defending the wealth and livelihood of other members of the polity.

The young men serve as warriors. With the passage of time, they seek to move on to the next age-grade: that of elderhood. Elderhood is marked by the accumulation of status, power, and wealth (see headnote). Age elicits deference and respect. The elders dominate the decision making of the tribe. And they accumulate cattle, wives, and children — the socially sanctioned forms of wealth in their societies. In elderhood, they thus turn from community service to the reaping of the private rewards that tribal life has to offer. As Spencer (1965) recounts for the Samburu: "the voiced ambitions of... elders are to build up herds, to marry several times, and to have direct control over a large and growing family, to have cordial friendships with a large number of clansmen, age mates, and others ..."(p. 84).

4. Theory and Evidence Revisited

To see how this demographic framework provides a sustainable means of providing public goods,[5] consider the case in which life expectancy is three periods (T=3) -- young, middle-aged, and old. Suppose further that the steady state in this tribe is one in which each generation consists of a single individual (N=1).[6] Thus, at any time t there are three generations alive (of one person each), as displayed in Table 1. This on-going situation is picked up there at t = -3 when the young, middle-aged, and old generations are G_{-3}, G_{-4}, and G_{-5}, respectively. At the beginning of period t = -2, G_{-5} dies and is replaced by G_{-2}. A similar replacement occurs at t = -1. The first three rows of Table 2 display a possible equilibrium. It is the CD equilibrium of Proposition 1 in which each member's lifetime utility is 6-2α, derived from working while young and middle-aged and shirking while old; this payoff is positive for $\alpha < 3$, and it may be shown that no generation has an incentive to defect from this pattern. Even in the absence of formal political institutions, then, a "demographic structure" -- one based upon birth and death, with persons progressing through generations -- will yield the provision of public goods.

Tables 1 and 2 here

Let the demographic process proceed, precisely in the manner analyzed by the demographic historians. That is, let population increase. We already know that normal incentives will generate specialization and trade and the consequent gains in welfare from the consumption of private goods. What is striking, however, is that with the gains in population, in societies organized in overlapping generations, increased population leads as well to the *strengthening* of incentives to provide public goods.

This is displayed in Table 1 in which a perturbation occurs at t = 0, disturbing the steady-state demographic pattern of exact population replacement. The new generation, G_0, consists of

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[5] For an earlier study of the sustainability of such systems, see Chapter 5 of Legesse (1973).

[6] Purists may quibble about how generations of size one can reproduce. We leave this as a homework exercise.

two individuals. Thereafter, the earlier population pattern reemerges, with one person per generation in subsequent periods. The generation born in t = 5 is the first to be born into a society in which no generation had been alive when the population-blip (baby-boom?) generation lived. In Table 2 it may be seen that the baby-boomer generation produces a *positive* externality of one extra unit of defense per period during the periods it contributes, while consuming the public good at no cost to the tribe throughout its lifetime (since its enjoyment of the public good is non-rivalrous). Thus, the lifetime utility of the generation old at t = 0 is $7-2\alpha$, of the generation middle-aged at t = 0 is $8-2\alpha$, and of the baby-boomer generation is $8-2\alpha$, all exceeding the lifetime utility of generations born during steady-state circumstances. It is easy to check that at no point along the equilibrium path does it pay one of these generations alive with the baby boomers to defect if it did not pay for a generation alive during steady-state (non-baby boom) circumstances to defect.[7]

It is possible to show that this overlapping generations characterization of public goods production may be generalized to alternative demographic distributions. Thus, if $\{N_\tau\}$ is the series of parameters characterizing generational size (that is, N_τ need not equal a fixed constant N in every generation), then if public goods production is sustainable in some fashion, it will also be sustainable if one of the N_τs is replaced by $N_\tau' > N_\tau$. Unexpected increases in population *always* have the effect of making it easier to sustain intergenerational cooperation (and perhaps to increase the amount of intergenerational cooperation); they also always increase the lifetime utility of all agents.

It should be noted that Proposition 1 and its corollary generate testable hypotheses. In particular, the corollary to Proposition 1 suggests that the provision of public goods is positively correlated with group size. Public goods should become more apparent, more likely, and more substantially supplied the larger the number of people in a group. In an earlier study, Bates,

[7] An old person never deviates from the equilibrium, whether alive during steady-state times or baby-boom times (since she never contributes to the public good). A middle aged person in steady-state times sticks to the equilibrium path if his expected payoff in his two remaining periods ($2-\alpha$ and 2, respectively) exceeds his defection payoff of 1 (only the young generation of size one contributes in this circumstance), i.e., if $\alpha < 3$. A middle-aged person alive when there are baby-boomers working, on the other hand, will defect if the expected payoff in her two remaining periods ($3-\alpha$ and 3, respectively) exceeds her defection payoff of 2 (only the young baby boomers contribute in this circumstance), i.e., if $\alpha < 4$. Hence baby-boom time middle-agers will not deviate if their steady-state counterparts did not deviate. Finally, young generations in steady-state times will not deviate from the equilibrium if their lifetime payoff of $6-2\alpha$ exceeds the defection payoff of 1, i.e., if $\alpha < 5/2$. Baby-boomers when young will not defect if their lifetime payoff of $8-\alpha$ exceeds their defection payoff of 1, i.e., if $\alpha < 7/2$. Again, baby-boomer youngsters will not defect if steady-state youngsters don't.

using African data drawn from the Human Relations Area Files, found empirical support for this hypothesis; population size, density, and the capacity to provide public goods appeared to go together (Bates 1983, Chapter 2). And Proposition 1 suggests that as the costs of banishment rise, the conditions for eliciting contributions to the public good relax, becoming easier to fulfill. This implication too finds support in Bates's research, where the capacity to provide public goods proved greater in societies that possessed specially fertile endowments of land, water, or ecological variation (Bates 1983, Chapter 2). Indeed, archeologists have coined the term "environmental circumspection" in reference to the tendency of organized societies, in the early history of mankind, to arise in regions with especially valuable endowments, such as fertile river bottoms (Carneiro 1970).

Taken together, the two propositions suggest that the key stylized facts of early economic history — the growth of private trade and the provision of public goods — can both be treated as natural outcomes of demographic phenomena. Increased trade and the provision of security can both be supplied by societies that possess family structures (overlapping generations), even while lacking formal political institutions. Moreover, in such societies, the supply of both private benefits and public goods *increases* with the growth of population. Our results thus cast light upon the way in which human populations figuratively "bootstrap" themselves, achieving an increased capacity to provision themselves with public and private goods as they increase in size.[8]

While rich in implications, the model is as yet Spartan and highly unrealistic. In the next section we therefore seek to complicate it in ways that render it more applicable to early societies, where simple demographic structures rather than formal institutions govern the provision of public goods.[9]

5. Theory Extended: The Old and the Young as Dependents

In most societies, the young and the old are dependent. They fail to contribute not because they don't want to but because the cannot. This age-specific contribution of effort is particularly characteristic of warfare. In the context of our example, where residents must be protected from the predatory behavior of other tribes, it is entirely realistic to think of the burdens of public-

[8] The reader should *contrast* our theoretical conclusion about group size and public good provision with Olson's (1965). In the intertemporal setting of overlapping generations, large groups are "privileged."
[9] Technically interesting enhancements have been provided by a number of game theorists, including Cremer, 1986; Kandori, 1992; Salant, 1991; and Smith, 1989; also see Shepsle and Nalebuff, 1990.

good production falling entirely on "middle-aged" warriors. The young and the old are dependents in the sense that there is an initiation age, $T^y > 0$, below which, and a retirement age, $T^o < T$, above which, contribution to the public good of defense is zero. We want now to explore the conditions under which the intertemporal production of a public good is sustainable when there are age-related dependencies of this sort. Before doing so we take up the example developed earlier to provide some intuition.

Example (revisited). We begin as before with T=3 periods of life per generation -- youth, warrior, and elder. Again assume there is one person per generation, though this does not restrict generality much. Finally, let us assume that the young are dependent. Thus, it is stipulated that $e_t^y = 0$, i.e., the young cannot be warriors. Is intergenerational cooperation -- the production of defense of the common wealth as a public good -- desirable or sustainable?

Claim 1. *Sustainability* requires $e_t^o = 0$ whenever $\alpha>1$. The threat of banishment is insufficient to induce an elder to contribute to public-good production, unless the benefit to the elder from her contribution exceeds its cost.

Claim 2. If $e_t^\tau = 1$ for some τ, then "social welfare" at time t is at least $3-\alpha$. Thus, the provision of each unit of the public good is *desirable* at t if $\alpha<3$.

Claim 3. But $e_t^y = 0$ by stipulation and $e_t^o = 0$ by sustainability, so the middle-aged generation must provide the public good, if it is provided at all.

Claim 4. $(e_t^y, e_t^m, e_t^o) = (0, 1, 0)$ is a subgame perfect equilibrium if and only if $\alpha<2$:

- $\tau = y$ cannot defect from the putative equilibrium (she is constrained not to contribute)
- $\tau = o$ will not defect from the putative equilibrium (obvious!)
- $\tau = m$ will not defect since his lifetime utility "on the equilibrium path" is $(1-\alpha)$ while a warrior and 1 while an elder, or $(2-\alpha)$. His payoff if he defects is 0 (since no one else is contributing). So long as $\alpha<2$, m will not defect.
- Therefore, intergenerational cooperation to provide the public good is both desirable and sustainable, with dependency as specified, if $\alpha<2$.

Generalizing the Example. To generalize this example we consider once again the payoff function defined in (1). We can simplify CD's representation by writing the period t payoff to a member of generation τ as:

$$\Pi_t^\tau = \sum_{j=1,T} e_t^j - \alpha\, e_t^\tau \qquad (1')$$

where, as before, $e_t^j \in \{0, 1\}$. So, each generation lives for T periods, {1, ..., T}; and, as the change from (1) to (1') reflects, we are assuming one person per generation. Generation τ receives a per-period payoff equal to the number of other contributors net of his own effort (priced in terms of the public good). We stipulate the following

***Dependency Assumption*: There exist numbers, T^y and T^o, with $0 < T^y < T^y+1 < T^o < T$, such that $e_t^\tau = 0$ if $\tau \le T^y$ or $\tau \ge T^o$.**

Under the circumstances described in this paragraph, the question becomes one of whether a society that is constrained by age-based dependency can nevertheless produce public goods. Will the middle-aged generations[10] -- $T^y+1, T^y+2,\ldots,T^o-1$ -- contribute to this enterprise? To answer this question, we will determine whether (0,0,...,0,1,1,...,1,0,0,...,0), where there are T^y zeros followed by T^o-T^y-1 ones followed by $T-T^o+1$ zeros, is a subgame perfect equilibrium of the intergenerational public goods game described above.

Because of the dependency structure in which neither the old nor the young can contribute to the public good, the maximum number of "working" generations is T^o-T^y-1. If they all contribute, as indicated in the proposed equilibrium, then the period t payoff to generation τ is

$$\Pi_t^\tau = \begin{cases} (T^o - T^y - 1) - \alpha & \tau \in M \\ (T^o - T^y - 1) & \tau \in Y \cup O \end{cases}$$

where $Y = [1, T^y]$, $M = [T^y + 1, T^o - 1]$, and $O = [T^o, T]$.

If any generation were to defect from this arrangement, it would be the *youngest* middle-aged generation (since older middle-aged generations are closer to receiving the benefits of retirement). Call this generation *. Its lifetime utility from age T^y+1 onward under the putative equilibrium is

$$LU^*(e) = \sum_{t=T^y+1,T} \Pi_t^* = (T^o - T^y - 1)\,[(T^o - T^y - 1) - \alpha] + (T - T^o + 1)\,[T^o - T^y - 1] \qquad (2)$$

The first term is the payoff from working (in brackets) if all middle-aged group members work, multiplied by the number of periods of work. The second term is the payoff from retirement (in

[10] Since the Dependency Assumption requires $T^y+1 < T^o$, there is at least one middle-aged generation.

brackets) if all middle-aged group members work, multiplied by the number of retirement years. Equation (2) simplifies to

$$LU^{*}(e) = (T^{o} - T^{y} - 1)(T - T^{y} - \alpha) \tag{3}$$

Since the first factor of (3) is positive by the Dependency Assumption, it follows that lifetime utility is positive if $\alpha < T - T^{y}$, *independent of* T^{o}. If, on the other hand, generation * defected from the arrangement, then it would enjoy one period of public-good production produced by the other middle-aged generations, followed by zero payoff for the rest of its life, or

$$LU^{*}(d) = (T^{o} - T^{y} - 2) = (T^{o} - T^{y} - 1) - 1 \tag{4}$$

Equation (3) exceeds equation (4) if $\alpha < T - T^{y} - 1$, again independent of T^{o}.[11] We have thus established:

> ***Proposition 2:*** **For societies with age-grading as defined by the Dependency Assumption, public goods production in which every middle-aged generation contributes is a subgame perfect equilibrium if $\alpha < T - T^{y} - 1$.**

There is a deceptive simplicity to this result. But it cuts deep, defining the conditions under which societies which draw upon demographic structures for the creation of public goods can sustain their creation.

The proposition suggests, for example, that were α to increase, then to sustain the same level of public goods, all else being equal, T^{y} would have to decline. Should, for example, the effort required for military defense increase, then, to achieve the same level of defense, the society would have to lower the age of initiation into the warrior class. Anthropological accounts suggest the existence of this response. As Spencer (1988) writes:

> [C]eremony is in the hands of the elders and this gives them the power to control the rate at which new generations mature. In orchestrating ceremony, they defend their position and control their society. ... Delay and denial of maturity are built into this system.(p. 63).

[11] This is a sufficient condition. Arithmetically, $LU^{*}(e) > LU^{*}(d)$ if $(T^{o} - T^{y} - 1)(T - T^{y} - \alpha - 1) > -1$. A fortiori this hold if the left hand side is positive. The first factor on the left hand side is positive from the Dependency Assumption. Thus, the left hand side is positive if $(T - T^{y} - \alpha - 1)$ is positive, which is true if the condition in the text holds.

By the same token, the proposition suggests that should T^y increase, then, all else being equal, the social order would be threatened, for the conditions under which the warriors would contribute effort would become more tightly constrained. This proposition too finds support in the anthropological literature. Social order is threatened by the delay of initiation ceremonies, with tension and anxiety mount with the passage of time (increase of T^y) (Baxter and Almagov 1978; Legesse 1983; Spencer 1965, 1988).

And what if T — life expectancy ~ falls? Proposition 2 suggests that, all else being equal, in societies governed by demographic structures, the provision of public goods declines. The logic implies that in such societies threats to longevity constitute threats to public order. Famine or plague could weaken the incentives to provide public service; and when the public order itself collapses, further driving down life expectancy, then the collapse becomes complete. The foreshortening of the expected life span leads to a violation of the conditions that makes the defense of public order sustainable. In the words of Hobbes (1661), it is the "continual fear, and danger of violent death" that renders the "life of man, solitary, poor, nasty, brutish, and short" (p. 368) ~ i.e. that plunges mankind into the state of nature.

Lying behind Proposition 2 is another factor: the costs of exclusion. These costs support the provision of effort as an equilibrium strategy. Were the experience of banishment to become less costly, then defection would become relatively more attractive, and the equilibrium could break down. An example is provided by the outbreak of violence in the West African nations of Liberia and Sierra Leone, in societies in which kinship and family systems continue to structure political and economic life. Those studying violence in that area stress the disintegrative impact of the incomes that can be earned from the widespread smuggling of drugs and alluvial diamonds — activities that provide an alternative source of benefits and lead to the defection of youths who might otherwise provide public service to their communities (Richards 1994).

To complete the analysis of this richer model, we consider once again the impact of a demographic shock. Imagine that the generation born at time t is larger than any others (which we have normalized to one). During the time this baby-boom generation is younger than initiation age, as well as when this generation retires, it will have no effect on the incentives of others to contribute (since, as we have stipulated, they constitute no burden and the territory is no more or less difficult to defend as population size changes). When this generation "comes of age," it will, however, contribute to the group's well being. It is. thus easy to demonstrate that any generation alive after $t + T^y + 1$ -- alive, that is, after the baby-boomers come of age — will have a higher lifetime utility as a consequence of the demographic blip than they would have had with steady-state population. Conversely, a "baby-dearth" generation will threaten the equilibrium by tightening the inequality on a; the production of some public goods may no longer be possible to sustain.

This argument re-emphasizes the relationship between demographic decline and public disorder, discussed above. Demographic decline can reduce the incentives to provide public goods in societies governed by generationally defined social structures. It also re-emphasizes that in such societies, the incentives necessary for the provision of public goods become easier to fulfill as populations increase in size. Our argument may therefore help to illuminate the manner in which human societies create the conditions that initially facilitate economic growth ~ even prior to the creation of formal institutions. It also suggests a striking contrast, as noted earlier, with the arguments of Mancur Olson (1965) and others that the capacity to provide public goods declines with the size of the group. In an overlapping generations framework, the more persons that potentially may contribute, the more willing are all members of society to adhere to strategies that underpin the provision of public goods. Public goods provision becomes far less problematic than Olson's arguments would suggest. Indeed, we have shown their provision can be a normal part of social life, even in the absence of means of policing free riding; and that the incentives to contribute to their formation will strengthen the larger the group.

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Table 1. Cross-sectional and Longitudinal Display of Generations

	Time (t)								
	-3	-2	-1	0	1	2	3	4	5
Generations									
Y	G_{-3}	G_{-2}	G_{-1}	<u>G_0</u>	G_1	G_2	G_3	G_4	G_5
M	G_{-4}	G_{-3}	G_{-2}	G_{-1}	<u>G_0</u>	G_1	G_2	G_3	G_4
O	G_{-5}	G_{-4}	G_{-3}	G_{-2}	G_{-1}	<u>G_0</u>	G_1	G_2	G_3

Table 2. Equilibrium Strategies and Payoffs

	Strategies			*Payoffs*		
Time (t)	e_t^y	e_t^m	e_t^o	Π_t^y	Π_t^m	Π_t^o
-3	1	1	0	2-α	2-α	2
-2	1	1	0	2-α	2-α	2
-1	1	1	0	2-α	2-α	2
0	2	1	0	3-α	3-α	3
1	1	2	0	3-α	3-α	3
2	1	1	0	2-α	2-α	2
3	1	1	0	2-α	2-α	2
4	1	1	0	2-α	2-α	2
5	1	1	0	2-α	2-α	2