Equality's fate: toward a natural history[1]

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1. Introduction

Differences among people (and among peoples) in talents, strength, and other capacities are seemingly minor by comparison with the often-observed vast and historically persistent between-group and individual differences in economic fortunes, reproductive success, status, rights, and power. The same may be said of many non-human primates and other animals. *What processes translate seemingly small differences in individual capacities into social hierarchies characterized by large and persistent differences in access to valued resources and power over others*? And, *what accounts for the dramatic differences in the degree of social hierarchy and economic inequality that have been observed across time and space?*

The structures of social interactions associated with these inequalities exhibit substantial differences across societies and through time. Included are unequal bargaining power in competitive markets, the use of state power to advance group interests, bonded labor and other forms of coercive resource transfers, racial and ethnic exclusion, hierarchically ordered or assortative mating systems and other forms of positive assortation, and many others. Do these processes share a common causal structure? Can the evolutionary success of hierarchically ordered societies in the past 10 millennia be traced to a common underlying

[1] What follows is an overview of an on going and as yet speculative research project. I would like to thank the MacArthur Foundation, the Russell Sage Foundation and the Behavioral Sciences Program of the Santa Fe Institute for support of this project. I draw upon joint work with Jung-Kyoo Choi and Astrid Hopfensitz (Bowles, Choi, and Hopfensitz (2003) and Bowles and Choi (2005a)) and Suresh Naidu (Naidu and Bowles (2004)) as well as material presented in chapters 12 and 13 of Bowles (2004). I have also benefitted from contributions by Chris Boehm, Hillard Kaplan, Suresh Naidu, Ugo Pagano, Rajiv Sethi, Polly Wiessner, Elisabeth Wood, Peyton Young and participants in the Santa Fe Institute working group on inequality as an emergent property of social interactions, the September Seminar, and the working group on biology and the human behavioral sciences at the Central European University.

dynamic?

Analogously, what accounts for the limited inequality and muted hierarchy observed in many societies? The proximate causal processes that reduce inequality in these societies are seemingly unrelated across time and among different societies. For example reproductive leveling, the formation of coalitions of subordinates to limit the power of dominants, the sharing of some foods and information and other forms of within-group variance reduction were probably common among our forager-ancestors as they are among foragers in the ethnographic and historical record. But these processes appear to have little in common with the extension of formal political rights to all citizens and the enlargement of these rights to claim resources, as in modern-day social democracies. Do these processes have common elements? Why have such egalitarian societies emerged and persisted over long periods?

Answering these questions requires an account of the dynamics of hierarchical structures. What accounts for major transitions between economically egalitarian and more unequal social orders such as occurred with the emergence of possession-based property rights and private storage of wealth associated with the domestication of plants and animals, or with the demise of Communist-ruled societies in the former Soviet Union and Eastern Europe, or the market reform of the Chinese economy?

Correspondingly, are there common processes underlying movement toward more equal outcomes such as the dramatic reduction in the income shares of the very rich during of the 20th century in countries as diverse as the U.S., Japan India, Germany, France, and the UK (Piketty and Saez (2003), Moriguchi and Saez (2005), Dell (2003)) . Are the causes underlying these trends also at work in the mid- to late-20th century land reforms in Taiwan, Korea, and West Bengal (Fei, Ranis, and Kuo (1979), Banerjee, Gertler, and Ghatak (2002)). Do these episodes have anything in common with the processes that have on occasion reined in the political, juridical, social, and sexual privileges associated with wealth? Examples include the emergence of jury trial in some European judicial systems, rights to privacy and civil liberties, the accountability of political leaders to inclusive electorates, and what has been called by Herlihy and Klapische-Zuber (1985) "the great social achievement of the early Middle Ages" in Europe, namely "the imposition of the same rules of sexual and domestic conduct on both rich and poor."

I assume that the types of social relationships referred to generically as unequal and hierarchical have enough in common that it makes sense to attempt a common explanation of the entire suite of vertically ordered relationships. The most plausible justification of this assumption is that many of the distinct dimensions along which inequality is measured are causally related in ways that insure that wealth, reproductive success, political influence and so on are highly correlated. We know this to be untrue in numerous settings, from the substantial political authority exercised by Mae Enga big men who do not enjoy correspondingly disproportional material resources (Wiessner and Tumu (1998), see also Kelly (1993)) to the reverse situation characterizing the extraordinarily rich Swedish economic elite, to the many modern populations in which wealth and reproductive success are uncorrelated (Kaplan, Lancaster, Block, and Johnson (1995))or even inversely correlated ({Vining, 1986 #12203}). But even where the dimensions are not highly correlated, the causes contributing to dispersion along one dimension may be similar to the causes generating differences along another. Accounting for reproductive skew in an agrarian kingdom, for example, may draw upon the some of the same causal mechanisms that account for the concentration of political power in a big man social system, or wealth inequality in a capitalist economy.

I also assume that neither genetically transmitted individual differences in capacities nor genetically transmitted predispositions toward social dominance or hierarchical living provide an adequate explanation of the inequalities under study. That genetic differences among people cannot explain observed differences in command over material resources and other valued goods is suggested by three sets of facts.
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First, substantial alterations of hierarchical and economically unequal structures often take place at a pace fare exceeding that of genetic evolution. The most dramatic of these changes is the emergence of hierarchically ordered states and the displacement of egalitarian foraging bands following the domestication of plants and animals beginning about ten millennia ago (e.g. Allen (1997), Marcus and Flannery (1996).) There are plentiful modern examples as well (some of them mentioned above) including the dramatic increase in income inequality following the liberal reforms of the Chinese economy (Ravallion and Chen (2004).)

Second, the genetic variance between the ancestral sub-populations of the people of the world is *an order of magnitude* less than the genetic variance among individuals within groups; but something like three quarters or more of global income inequality is between rather than within these ancestral groups.[2]

Third, while there may be a non-trivial role for genetically transmitted traits in explaining income differences within national economies, the evidence is not very robust (Bowles and Gintis (2002)), and the effects are not large. For example, the correlation among the logarithm of the wages of brothers in the U.S. exceeds one half, indicating that more than half of the variance in this measure of economic success is associated with influences that brothers have in common, such as family educational and economic status, and community of

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[2] Rosenberg, Pritchard, Weber, Cann, Kidd, Zhivotovsky, and Feldman (2002). About three quarters of the global inequality in income is between countries (depending on which inequality measure one uses (Milanovic (2005)), from which it may safely be inferred that not less than this amount is between the (for the most part smaller) groups used in the Rosenberg et al study.

upbringing. Virtually none of this correlation is explained by one of the best measured and (to a substantial extent genetically) heritable determinants of wages: IQ and height (Bowles and Gintis (2002), Mazumder (2004).)

An important role of genetically transmitted predispositions towards dominance and subordination cannot be excluded, but the counter evidence is substantial. Humans share with our closest genetic relatives (chimpanzees and bonobos) a suite of counter-dominance behaviors suggesting a strong aversion to being bossed (Boehm (2004)); and some non-human primates appear to exhibit forms of inequality aversion in laboratory experiments (Brosnan and De Waal (2003)). Moreover, among humans (including those in foraging groups and other small scale societies), experimental and other evidence suggests that many (perhaps most) humans are motivated by some form of inequality aversion and strong reciprocity (Falk, Fehr, and Fischbacher (2003), Henrich, Boyd, Bowles, Fehr, and Gintis (2004)).

The pages that follow identify a series of causal mechanisms consistent with the familiar idea that the degree of hierarchy and inequality in a population is powerfully influenced by the technologies available for producing the livelihoods of its members and reproducing life and the social institutions governing these processes of production and reproduction. The approach is evolutionary in that it studies inequality and hierarchy in an explicitly dynamic framework, asking why plausible evolutionary processes might favor the long term persistence of more or less unequal outcomes.

In the next section I survey the formidable processes tending to generate persistent income polarization (or even runaway inequality), raising the question: why do we nonetheless observe substantially egalitarian and non hierarchical systems as common human forms of social organization? Section 3 reports on models and agent based simulations that provide two possible answers to this question: within-group leveling may contribute to a group's ability to survive environmental challenges and intergroup competition, and highly unequal conventions may not be evolutionarily robust by comparison to less unequal conventions. The final section is a speculation about inequality in the very long run and how the evolutionary processes accounting for it might be modeled.

2. Cumulative Advantage: technology, social interactions and runaway inequality

The persistence of a particular configuration of inequality is commonly explained by its status as an asymptotically stable equilibrium in some plausible dynamical system. Dynamical systems typically support high and or increasing levels of inequality when they are characterized by cumulative advantage, that is, when small advantages at one time contribute to greater advantages at later periods. The positive feedbacks that contribute to cumulative advantage may result from winner- take-all reward systems (like tournament based pay, or mating systems with high male reproductive skew, as with gorillas), positive assortation and other advantageous sorting opportunities in marriage, coalition formation, residence, and co-production, and increasing returns to scale in production, coercion, and other processes. When these and other aspects of cumulative advantage are operative, small individual differences occurring by chance are magnified and may become persistent over long periods.

To explore this idea, suppose that an individual's wealth, that is his or her income-generating capacity is acquired directly from parents (considered as a single individual, in the form of material bequests, skills, genotype, connections, and so on) and from randomly selected others in the population (in the form, say, of equal access to common resources, knowledge, public education and such). We summarize these two influences on one's wealth by expressing the expected wealth of individual i as $\beta w_{ip} + (1-\beta)\underline{w}$, where wealth, w, is measured in natural logarithms, $\beta \in (0,1)$, and w_{ip} is the income level of individual i's parent and $\underline{w}$ is the average wealth level (assumed to be the same across generations). The value $(1-\beta)$ represents regression to the mean as introduced by Francis Galton (1889).

In each generation, the realized wealth of an individual, w_i, is his expected wealth plus a disturbance term, λ, that over time is independent of past values of wealth and independent and identically distributed with mean zero and variance σ_λ^2:

(1) $$w_i = \beta w_{ip} + (1-\beta)\underline{w} + \lambda_i$$

This stochastic process is a first-order auto regression with a steady state expected (logarithm of) wealth, $\underline{w}$. For values of β less than one the steady state variance of the logarithm of wealth (a standard unit-free measure of inequality) is:[3]

(2) $$\mu = \sigma_\lambda^2 / (1- \beta^2).$$

The steady state level of wealth inequality may be interpreted as the effect of stochastic shocks, blown up by the inter-generational transmission multiplier $(1- \beta^2)^{-1}$ which is increasing in the extent of intergenerational transmission of wealth. The stationary distribution is thus the result of both chance (the numerator) and social structure (the denominator). For β exceeding one there is no steady state and the inequality will increase from year to year.

Why is it plausible to restrict the value of β to be less than one? Because it is the elasticity of one generation's wealth with respect to parental wealth, β measures the

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[3] To see this write μ_t, the variance in period t, as

$$\mu_t = \beta^2\mu_{t-1} + \sigma_\lambda^2$$

Setting $\mu_t = \mu_{t-1}$ to get the steady state variance μ we get (2).

cumulative advantage of having a higher-wealth parent.[4] However, there is no reason why this derivative cannot exceed unity, and as we will see presently, some reason to think that it might.

To see this, we need to make the income-generating process explicit, and allow individuals to accumulate or consume income-earning capacities. Suppose that income is generated by combining human and material capital (h and m respectively) according to the following income-generating function

(3) $w = w(m,h)$

Human capital is all culturally and genetically transmitted influences on one's capacity to earn income. Equation (3) need not be interpreted as a production function; it merely describes the ways that individuals may combine their capacities to generate income, including through the use of coercion of others. Equation (3), the income generating equation, captures the causal relationships between assets and income, while (1), the intergenerational transmission equation, is a summary of the relevant statistical relationships arising from the dynamics that follow from (3) and similar causal relationships.

What do we know about the shape of such income generating functions? Studies of the U.S. and South African labor markets, suggest that the rate of return to schooling (the derivative of the logarithm of earnings with respect to years of schooling) is rising in years of schooling (Ashenfelter and Rouse (2000), Keswell (2004),Hertz (2003), see also Hauser, Warren, Huang, and Carter (2000).) A similar pattern appears to be at work concerning the returns to capital: Yitzhaki (1987) found that the appreciation of the value portfolios of corporate stocks (on the New York Stock Exchange) held by high-income individuals exceeded by a considerable margin the appreciation of portfolios held by less wealthy individuals.[5] Studies in low-income countries show that net worth strongly affects farm investment, and low wealth entails lower returns to independent agricultural production (Rosenzweig and Binswanger (1993).)[6] This evidence suggests that the wealthier farmers

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[4] The correlation between parental and offspring wealth, ρ is of course restricted to the unit interval, but $\beta = \rho\sigma/\sigma_p$ where σ and σ_p are the standard deviation of the logarithm of wealth in the current and parental generation, respectively. Thus if β exceeds 1, inequality must be rising.

[5] Bardhan, Bowles, and Gintis (2000) and Bowles (2004) present models in which this result obtains for risk-neutral individuals due to the credit market disabilities faced by the less wealthy. It could occur for many other reasons, including decreasing absolute risk aversion.

[6] Rosenzweig and Wolpin (1993) showed that poor and middle-income Indian farmers could substantially raise their incomes if they did not confront credit constraints: not only did

pursue riskier strategies with higher expected returns. The lack of insurance and restricted access of the poor to credit not only reduces incomes, it also increases the level of income inequality associated with a given level of wealth inequality.

These data do not establish any general properties of income generating functions, of course, but they do suggest the importance in some settings of both increasing marginal returns and complementarities among assets. Let us then consider a case in which the income generating function exhibits (over some relevant range) the following characteristics: the return to both human and material capital is rising in the amount of capital acquired ($w_{hh} > 0$, $w_{mm} > 0$), and the return to each form of capital is increasing in the amount of the other ($w_{mh} > 0$).

The last assumption expressing asset complementarity is consistent with the data just mentioned: the higher-income stock owners in Yitzhaki's study are surely also better educated, and those with more schooling in the U.S. labor market are also wealthier. The rate of return to schooling may increase in the wealth of the individual because wealth reduces the costs of job search and supports more nearly risk neutral occupational and geographical choices. Schooling may raise the rate of return to wealth for analogous reasons.

We return to the inheritance process, but instead of the intergenerational transmission described in equation (2), suppose that upon coming of age each individual acquires from the previous generation a level of both h and m, and then either accumulates or uses up both (material wealth can be consumed, and we assume that the knowledge, skills, physical capacities, health status and the like captured in h also depreciate unless renewed). Individuals will accumulate wealth if the marginal return on the investment (the derivative of the income generating function, given the individual's current holdings) exceeds the individual's rate of time preference. To simplify matters I normalize the amount of both types of capital that an individual may have so that $\forall i$, $h_i \in [0,1]$ and $m_i \in [0,1]$.[7] For simplicity, assume that individuals differ only in their inheritance, and that those owning no assets have no incentive to accumulate, while those endowed with the maximal amounts of both have an incentive to dis-accumulate (or $w_m(0,0)$, $w_h(0,0)$, $w_m(1,1)$ and $w_h(1,1)$ are all less than the (common)

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they under invest in productive assets generally, but the assets they did hold were biased towards those they could sell in times of need (bullocks) and against highly profitable equipment (irrigation pumps) which had little resale value. Similarly, Rosenzweig and Binswanger (1993) found that a standard deviation reduction in weather risk (the timing of the arrival of rains) would raise average profits by about a third among Indian farmers in the lowest wealth quartile, and virtually not at all for the top wealth holders, suggesting that risk reduction strategies adopted by the poor reduced their expected incomes.

[7] Limiting the amount of material wealth an individual can have is arbitrary, but it does not affect the results, given the assumptions that immediately follow.

individual rate of time preference.)

Consider the investment (or disinvestment) strategy of an individual with a limited amount of human capital h^-, facing the rate of return to material capital schedule $w_m(m, h^-)$ and a rate of time preference δ as depicted in figure 1. If the individual's assets are less than m^- the individual will consume her wealth, while for values of between m^- and m^+ the individual will accumulate material wealth. Consider a second individual with more human capital, h^+, and, recalling that increased human capital raises the marginal effect of material capital ($w_{hm} > 0$), notice that the lower critical value (below which the individual will not accumulate) is reduced, while the upper critical value is increased as a result of the higher human capital endowment.

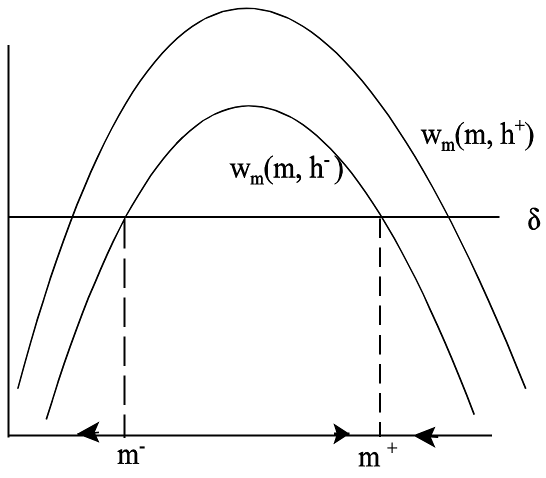

Figure 1. Optimal accumulation of material wealth, m, with differing levels of human wealth h.

Figure 1 illustrates the wealth accumulation dynamics of this population, the arrows on the horizontal axis indicating the movement of m in response to the accumulation or dis-accumulation incentives. The accumulation dynamics for human capital are similar. We model the joint dynamics of the two accumulation processes by

(4) $dh/dt \equiv \dot{h} = H\{w_h(m, h) - \delta\}$

(5) $dm/dt \equiv \dot{m} = M\{w_k(m, h) - \delta\}$

where H and K are positive constants indicating the speed of adjustment of the two accumulation processes.

These equations give the stationarity conditions $\dot{h} = 0$ and $\dot{m} = 0$, when respectively $\{w_h(m, h) - \delta\}$ and $\{w_m(m, h) - \delta\}$ equal zero. For other states, the direction of change implied by equations (4) and (5) is given in the vector field shown in figure 2. The functions $\dot{h} = 0$ and $\dot{m} = 0$ in the lower left portion of figure 2 are downward sloping due to the complementarity of the two determinants of wealth illustrated in figure 1: the critical value below which accumulation of one type of capital will not take place is lower, the better endowed is the individual with the other type of capital.

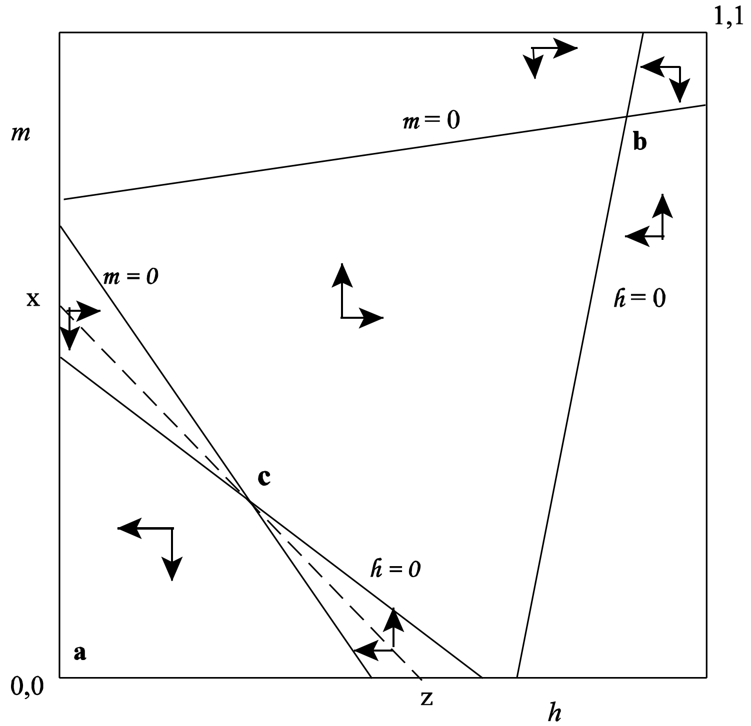

Figure 2. Joint accumulation of material and human capital. Points **a** and **b** are asymptotically stable equilibria, **c** is a saddle.

There are three equilibria in this system, **a**, **b** and **c** in the figure: individuals inheriting any combination of h and k will over time approach one of these states.. The point **c** is a saddle and will be reached (with vanishingly small probability) only by individuals inheriting assets along the dashed line xz. Those whose inheritance places them above xz will move to **b**, while those falling below xz will move to **a**. The line xz is therefore the boundary between the basin of attraction of the two stable equilibria.

It is clear from figure 2 that as long the population of individuals inherit assets placing some of them on each side of *xz*, the population will over time bifurcate into two classes, those with the minimum assets (**a**)and those with the assets described by point **b**. In the world described by this model, starting from a distribution of assets in the neighborhood of the locus *xz*, inequality would grow over time until the population were sorted into the two classes just mentioned. Until it reached this stationary state, the system would exhibit the opposite of regression to the mean (analogous to β in equation (1) exceeding unity).

Of course the deterministic assumptions of this model are unrealistic (the inheritance is modified only by a deterministic dynamic given by (4) and (5).) And the income generating assumptions abstract from relations of employment and borrowing between those with substantial and limited assets. But the model serves to illustrate a second way that cumulative advantage may work: small differences in individual endowments may be magnified by the individuals' optimal path of accumulation or dis-accumulation.

This dynamic suggests an extension of the intergenerational transmission model introduced above. Suppose the value of β depends on the level of assets inherited and hence on parental wealth, as illustrated in figure 3 so that we have:

(1') $w_i = \beta(w_{ip})w_{ip} + (1-\beta(w_{ip}))\underline{w} + \lambda_i$

This model exhibits runaway inequality for middling levels of inheritance (those in the neighborhood of the boundary between the two basins of attraction, xz) and convergence of expected wealth to two distinct levels at the extremes. For example, those with very wealthy parents would have endowments in near the maximum, and their wealth (in the absence of shocks) would converge downward to point **b**. For appropriate parameters this process produces a bimodal steady state distribution of wealth with substantial polarization ((Gardiner (2004):342-344).

The bifurcation in the dynamical system just presented arises because the income generating function exhibits two characteristics: *complementarity* of the two types of capital in generating income, and *increasing marginal returns* to each type of capital over some ranges.

A further, well studied contributor to income inequality is *positive assortation*, namely, the tendency of those with substantial income-earning assets to be paired with similarly well endowed individuals in marriage and other productive activities(Fernandez, Guner, and Knowles (2001), Kremer (1997)).

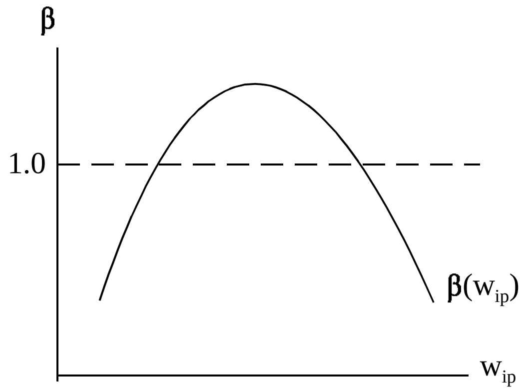

Figure 3. A state-dependent intergenerational transmission coefficient

On the basis of these intergenerational transmission and factor accumulation models, it seems likely that plausible values of the relevant parameters would generate high and in some circumstances increasing levels of wealth dispersion, even among individuals with substantially similar initial endowments.

While rapidly increasing inequality is sometimes observed (in the last quarter of the

20th century in the U.S., China, India, Canada and the UK for example) the long term stability of the income distribution in most nations and historical periods is remarkable. The models above thus serve to invert the "why inequality?" question and instead ask why we do not commonly see runaway inequality or persistent polarization, and why egalitarian and counter-dominance outcomes are as common as they are. A possible interpretation is that the institutions that regulate the distribution of wealth attenuate inequality in ways that do not appear in the above models.

3. Does the arc of history bend toward justice?

My collaborators and I have proposed two models that support affirmative answers to this question in recent work (Bowles, Choi, and Hopfensitz (2003)), Naidu and Bowles (2004) and Bowles (2004)). I here provide sketches of the underlying causal mechanisms.

The first concerns the way that within-group variance reduction contributes to the evolutionary success of a group. Inter-group competition may favor egalitarian institutions if those institutions contribute to the survival of groups and thereby allow the proliferation of their institutions. Some have suggested, for example, that success in warfare is favored by both universal suffrage and monogamy (meaning potential wives are not monopolized by the elite), providing an explanation of the spread of these leveling institutions. Others have suggested that the information sharing and flexible job assignments that contribute to the competitive success of many large Japanese firms are made possible by the relatively egalitarian pay and employment policies adopted by these firms. Here I develop a variant of this idea.

That the suppression of within-group competition is a strong influence on evolutionary dynamics has been widely recognized in eusocial insects and other species (Smith and Szathmary (1995), Frank (1995), Frank (2003), Michod (1996), Buss (1987), Ratnieks (1988)). Christopher Boehm (1982) and Irenaus Eibl-Eibesfeldt (1982) first applied this reasoning to human evolution, exploring the role of culturally transmitted practices which reduce phenotypic variation within groups. Examples of such variance-reducing practices are leveling institutions such as monogamy, food sharing among non-kin and other practices that reduce within-group differences in reproductive fitness or material well-being. Such structures may have attenuated within-group selection operating against individually-costly but group-beneficial practices, resulting in higher group average fitness or material success. If so, groups adopting these variance-reducing institutions would have had advantages in coping with climatic adversity, intergroup conflicts and other threats. According to this view, the evolutionary success of variance-reducing social institutions may be explained by the fact that they retard selection pressures working against in-group-beneficial individual traits, coupled with the fact that high frequencies of bearers of these traits reduces the likelihood of group extinctions and increases the likelihood that a group will expand and propagate new groups.

Beginning with Darwin (for example Darwin (1873):156 and other passages), a number of evolutionary theorists (J.B.S.Haldane (1932), William Hamilton (1975)) have suggested that human evolution might take place under the influence of multi-level selection along these lines. Among the distinctive human characteristics which may enhance group selection effects on genetic or cultural variation is our capacity for the suppression of within-group phenotypic differences in reproductive or material success and the frequency of intergroup conflict. The variance reducing institution modeled here is the commonly observed human practices of resource sharing among group members including non-kin, but the model could easily be extended to study other group level institutions that, like resource sharing, reduce the within-group variance of material and hence reproductive success. Included are information sharing, consensus decision making, and monogamy.

We simulated the coevolution of altruistic individual behaviors and sharing at the group level, using parameters that may describe some ancestral human populations and their environments (Bowles, Choi, and Hopfensitz (2003).) We represented group competition as infrequent lethal conflict in which the groups with more altruists have a higher probability of winning, and in which winners extend their institutions to the losers' territory. We introduced a rising marginal and average cost of resource sharing to capture the incentive effects and administrative costs of sharing systems. The results confirm the above expectations. We found that for sufficiently small group size, frequent intergroup conflicts and limited between-group migration, the simulated population sustains high frequencies of altruists and significant levels of resource sharing within groups. For plausible parameters, altruism does not evolve in the absence of group level resource sharing institutions.

The second model that may shed light on the evolutionary success of egalitarian institutions concerns within-group class conflict rather than between-group conflict. Are institutions that implement substantial inequalities between highly polarized classes more vulnerable to being overturned than more egalitarian institutions? A Marx-inspired answer to this question would explore the way that polarized economies contribute to the conditions under which successful collective action might overturn the status quo in favor of a more egalitarian alternative.

We use formalize this reasoning using an adaptation of stochastic evolutionary game theory in which the stochastic influences on the evolutionary process (that is, idiosyncratic or non-best-response play) take the form of intentional collective action rather than mutation-like errors (Bowles (2004)). We model institutions as conventions such that conformity to the behaviors specified by the institutions is best response as long as most members of the population also conform. Populations experience institutional transitions when sufficient numbers of one of the two classes adopt some strategy other than a best response. In this model two characteristics of institutions affect the likelihood of successful oppositional collective action: the payoffs to the two classes under each of the institutions and the size of the sub-populations in each class. Payoffs and class size affect the fragility or robustness of institutions because they jointly determine both the minimum numbers of collective action participants required to induce a transition from one institutional convention to another, and the likelihood that stochastic events combined with the intentional pursuit of class interests will produce the required numbers. Egalitarian institutions are indeed favored in this setup, but very unequal institutions may persist for long periods even when they are less efficient (produce a smaller joint surplus) than an alternative more egalitarian institution.

It is easy to show that if the groups are of equal size, the population will spend most of its time at the more equal convention. The reason is as follows (Naidu and Bowles (2004)) By comparison with some relatively equal "benchmark" convention, increasing the degree of inequality of an alternative convention makes the unequal convention more persistent (requiring more idiosyncratic play to dislodge it). But this effect is more than offset by a counter effect: increasing the inequality of the alternative makes the benchmark even more persistent. So the effect of greater inequality in the alternative convention is to slow down the process of transition in an asymmetrical way, disproportionately retarding the transitions from the equal to the unequal convention. For this reason, the more unequal is the alternative contract, the greater the amount of time the population spends at the equal (benchmark) contract. The evolutionary advantages of equal conventions are enhanced if the rate of idiosyncratic play (ε) is made state-dependent. Reflecting our interpretation of idiosyncratic play as participation in class-based collective action we let ε be increasing the degree of class polarization at each state using a measure due to Esteban and Ray (1994). In this case highly unequal conventions provoke high levels of idiosyncratic play, thus reducing their expected persistence.

The evolutionary success of unequal and inefficient conventions benefitting the smaller of the two classes is readily explained. As long as rate of idiosyncratic play is less than the critical fraction of the population required to induce a transition (which I assume), smaller groups will more frequently experience "tipping opportunities" when the realized fraction of the population who are "called" by chance exceeds the expected fraction (ε itself). The theory of sampling error tells us that the class whose numbers are smaller will generate more "tipping" possibilities. Small size does not facilitate collective action if more than the critical number are "called": recall that in this case, all of those called will choose the risk dominant strategy, and this is independent of their numbers.

4. Fugitive Resources

From a very long run perspective, two big facts about inequality stand out. First, humans descended (and are not very different genetically) from an animal (the common ancestor of us, chimps, bonobos and gorillas) that almost certainly lived in a society of marked dominance hierarchies. Second, for perhaps the first 90 percent of the entire time that modern humans have existed (since about 100 thousand years ago) most humans lived in foraging bands that were strikingly egalitarian in access to valued resources and power, at least when compared to the substantial inequalities of the agrarian autocracies and capitalist economies that were to follow and the societies of non-human primates (with the possible exception of bonobos) that had preceded our foraging ancestors. What explains this great U-turn? And what does an answer to this question suggest about the future of equality?

The causal mechanisms operative in the models above (cumulative advantage, between-group competition, within-group class conflict) have been presented ahistorically, as if they were time-invariant. But to explain the U-turn we need to take account of the changing nature of human livelihoods. The forces at work over this very long run concern (at least) four aspects of production, reproduction, and distribution.

The first is the nature of stochastic shocks to which humans have been exposed, and the opportunities for insuring against these shocks given the mode of livelihood and the organization of reproduction of the groups in question. The thrust of this argument is that the ecology and livelihood of the typical foraging band entailed substantial individual uncertainty primarily because hunting success is very sporadic (Hawkes (2000)). Because the main sources of nutrition were difficult to store, self-insurance over time (through saving and accumulating reserves) was ineffective. As a result, within-group contemporaneous consumption smoothing was widely adopted. The domestication of plants and animals made storage effective, allowing self-insurance (by the more productive) to displace co-insurance (Bowles (2005)).

The second is that our foraging ancestors (unlike non-human primates) were substantial meat eaters who often acquired their nutrition in huge packages, the marginal benefits to which (in fitness or other benefits) were sharply diminishing beyond a small fraction of the package size. As a result that the opportunity cost of sharing was quite limited, and the cost of not sharing with needy competitors was substantial (Blurton-Jones (1987)). By contrast, post-domestication livelihoods are often acquired in highly divisible pieces, the returns to which (over the relevant scale) are not so sharply diminishing.

The third aspect is that the life cycle of learning, productivity and consumption among foragers differs greatly from our primate ancestors in that the costs of child rearing are substantially greater, creating a large net deficit for most families when their children are past infancy but not yet productive hunters and gathers. Resource sharing among families within groups facilitates the long learning times associated with human (but not other primate) development (Kaplan and Gurven (2004)). This is but an early example of the socialization of the costs of reproduction a more recent example of which is the Nordic welfare state.

The fourth dimension, and the one I would like to explore here, concerns the nature of the technology by which livelihoods are produced, and especially the degree to which the forms of wealth involved generate cumulative advantage and are privately appropriable and hence may be transmitted within families across generations.[8] Suppose that livelihoods are produced and the next generation are reproduced using three kinds of wealth: material capital, somatic wealth, and knowledge. By *somatic wealth* I mean (following Kaplan) the individual's bodily capacities and condition, including health, mental acuity, strength and learning abilities. *Knowledge wealth*, by contrast is a stock of information to which one may have access (through the traditions, lore, technical manuals, libraries, and other information sources available to members of a group.) (I am here treating somatic and knowledge wealth as components constituents of human capital appearing in equation (3).)

Production and reproduction typically require some of all three kinds of wealth. Scientific and technical knowledge must often be embodied in material wealth in order to be effective. Access to knowledge wealth requires at least minimal levels the learning and information processing capacities that are elements of somatic capital. As these examples suggest, the three inputs are often (but not always) complementary, the effectiveness of one increasing in the level of the other. One could take account of these and other complementarities among the types of wealth by adopting a generalized Cobb-Douglas or CES income generating function. In the former case we would have

(6) $w = Am^{\alpha m}s^{\alpha s}k^{\alpha k}$

where w, as before is wealth defined as income making capacity, A is a positive constant and α_m , α_s , α_k measure the relative importance of material, somatic and knowledge wealth in the production proces. For positive levels of all three inputs, each exponent measures the elasticity of output with respect to the type of wealth concerned. For example a one percent increase in material wealth will increase output by α_m per cent.

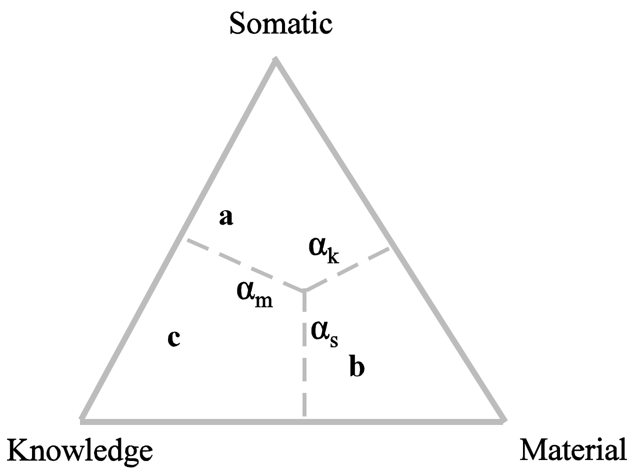

Figure 4: Technology. Each point in the simplex represents the relative importance of the three types of wealth in production.

A convenient way to represent

[8] An aspect of this process – the extent a technology permits the clear definition of property rights – is the explanation for the emergence of possession-based individual property at the time of the domestication of plants and animals advanced in Bowles and Choi (2005b)

the relative importance of each type of wealth is illustrated in figure 4. Each point in the simplex gives the exponent as indicated (disregard points **a**, **b**, and **c** for the moment). The sum of the exponents is a measure of the extent of economies of scale: increasing all inputs by one percent will increase output by $\alpha_m + \alpha_s + \alpha_k$ per cent. The function exhibits complementarity among all three inputs: the derivative of w with respect to each type of wealth is increasing in the levels of the other types.

The three types of wealth exhibit the properties in the table below.

	Material	Somatic	Knowledge
Cumulative advantage	Yes	No	Yes
Privately appropriable and transmissible	Yes	Somewhat	Effectively no

Characteristics of Three Types of Wealth

These properties are not entirely determined by the technical nature of the wealth, of course: with confiscatory inheritance laws, for example, material wealth may not be transmissible across generations, and with well defined and aggressively enforced intellectual property rights knowledge may be privately appropriable and the its benefits intergenerationally transmissible. But the technical features of the category of wealth greatly influence the extent to which it exhibits the properties listed.

Now consider the intergenerational transmission of wealth as before, and let us as in equation (1) collapse the transmission-across-generations process with the accumulation process so that we write $w_{j\,t}$ as the wealth of type j {material, somatic, knowledge} of the t th generation at the time that they pass on their wealth to the next generation (namely having inherited wealth from the previous generation as in the first model in section 2 and having then accumulated or dis-accumulated, as in the second model). Assume (contrary to the accumulation model for h and m) that the accumulation and transmission processes for these three types of capital are independent (the level of one type of wealth not affecting the transmission or accumulation of the other). This assumption may be particularly inappropriate for the case of knowledge wealth, for the productivity of free information may depend critically on access to material and somatic capital.[9] Then we can write

[9] If the production function has the Cobb Douglas form (above) the variance of the logarithm of wealth can then be expressed as the sum of the variances and covariances of the (logarithm) of the three types of capital, weighted by coefficients reflecting the relative contributions of the three to income generation, the degree of economies of scale, and the

(7) $w_{j\,t} = \beta_j\, w_{j\,t-1} + (1-\beta_j)\underline{w}_j \;\; + \lambda_j \quad j \in [m, s, k]$

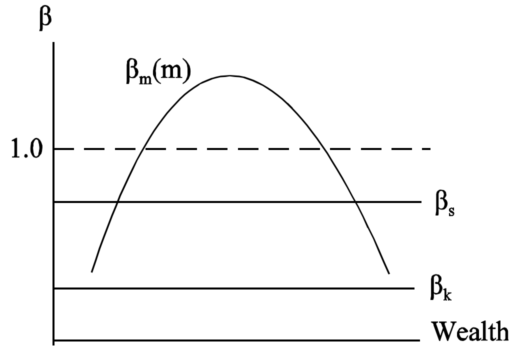

Figure 5 Intergenerational persistence for three types of wealth: material, somatic, and knowledge

where $\underline{w}_j$ is the societal mean of wealth of type j, and λ_j is a mean-zero disturbance term with standard deviation σ_j (and like λ in equation (1), it is independent and identically distributed and is uncorrelated with $w_{j\,t-1}$). Call this an intergenerational persistence (rather than transmission) process as it includes both the literal transmission ('handing down' from parent to offspring) and the process of accumulation or dis-accumulation taking place over the life course. The β's are persistence coefficients.

Given the entries in the above table, and the reasoning in section 2, it is plausible to suppose that the values of β are as they appear in figure 5. The intergenerational persistence process for material wealth gives an inverted-U persistence coefficient for the cumulative advantage reasons presented in section 2.

The persistence process for somatic wealth exhibits significant regression to the mean ($\beta_s < 1$) over its entire range. The reason is that cumulative advantage in accumulating somatic capital is quite limited (due to the limited nature of the necessary site of the investment, the body) and the inheritance process for the traits that are essential to generating income is characterized by limited heritability and limited assortative mating on the relevant traits.

Finally β_k is characterized by strong regression to the mean because, despite positive feedbacks in the process of knowledge generation, the zero-cost copying aspect of knowledge its substantially public good nature makes its inheritance within families very weak (most of the knowledge to which one has access is based on the stock of knowledge enjoyed by any member of one's group.)

Recall that a persistence process characterized by regression to the mean at the extremes and movement away from the mean over intermediate ranges (like β_m) will (for appropriate parameters) generate a stationary (ergodic) distribution of wealth that is bimodal, that is, polarized. By contrast, if regression toward the mean characterizes the persistence process, as we have seen, the stationary distribution is uni-modal and its variance is given by

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degree of complementarity among the three types of capital:

$$\mathrm{var}(w) = \alpha_m^2\,\mathrm{var}(m)+\alpha_s^2\mathrm{var}(s) + \alpha_k^2\mathrm{var}(k) + \alpha_m\alpha_k\mathrm{covar}\,(mk) + \alpha_m\alpha_s\mathrm{covar}(ms) + \alpha_k\alpha_s\,\mathrm{covar}(ks)$$

(2). Thus the three persistence processes given in figure 5 could sustain the stationary distributions given in figure 6.

A possible interpretation of the U-turn is the following. Our foraging ancestors produced their livelihoods (and reproduced themselves) relying primarily on somatic capital and knowledge, their technology represented by point **a** in figure 4. This, along with the group-survival advantages of within-group variance-reduction and the other contributors to hunter-gatherer egalitarianism mentioned above, provided the economic underpinnings for a culture and political process that discouraged the emergence of social dominance hierarchies and persistent differences in wealth.

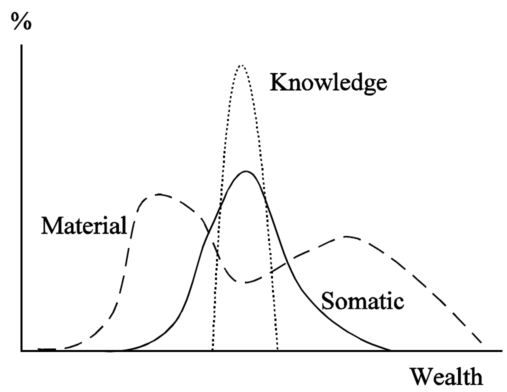

Figure 6. Stationary distributions (steady state frequency distribution) for three types of wealth.

Agriculture (and later machine-assisted industry) greatly enhanced the importance of material wealth, and reduced the relative importance of somatic capital, and probably also reduced the importance of knowledge capital (corresponding to point **b** in figure 4). The result was a class division characterized by substantial polarization. The essential role of material capital in income generation and its polarized distribution along with increasing returns in the effective use of coercion further contributed to social dominance hierarchies and economic inequality. Inequality may have been somewhat attenuated by the vulnerability of highly unequal conventions to insurgent collective action demonstrated in the previous section. Material wealth remains important today, but the importance of knowledge and other so-called 'fugitive resources' (Arrow (1999)) is rapidly increasing (moving our technology toward point **c** in figure 4.).

5. Equality's fate

Whether current attempts to enclose the 'knowledge commons' can 'domesticate' these fugitive resources, so that their persistence coefficients come to resemble those of material wealth is one of the major political and economic questions of the coming decades. If these efforts fail, as there is good reason to expect (and to hope) that they will, the increasing economic importance of knowledge may contribute to the realization of a more egalitarian future.

I have identified major epochs in the evolution of inequality according to ways that people interacted with nature and one another to produce their livelihoods and to reproduce life itself. But the precarious future of the knowledge commons suggests that the persistence coefficients which drive the above model are socially as well as technologically determined. Groups occupying identical ecologies and adopting similar technologies often exhibit durable differences in learned behaviors and group level institutions; and these often support group level differences in the extent of unequal access to resources and political power.

Surprisingly this is true of many primate species. Among the twenty species of macaques, for example, there exist substantial differences in social organization, including dominance styles between females. But a recent study concludes that “available data ...does not indicate species specific features of known ecological conditions that appear to be correlated with characteristic dominance styles”(Menard (2004):258.) Sapolsky and Share (2004) report a remarkable natural experiment tragically occurring with olive baboons (*Papio anubis*). An epidemic spread by contaminated food acquired in contests with a neighboring troop eliminated the most aggressive males (about half of all adult males in the troop under study). The less aggressive survivors inaugurated a “pacific culture” exhibiting higher rates of affiliative behaviors and less aggression toward and subordination of low ranking males by those of higher rank. Ten years after the epidemic none of the initial males remained (they typically disperse to other groups), so the new culture had been transmitted to the entirely new population of males.

Among humans, the case of storage is instructive. The relationship between domestication, storage, and inequality is uncontroversial, but it is also true that storage has been used among hunters and gatherers (Soffer (1989)) and electively *not* used even when the technology is known and feasible (Cashdan (1980) describes extensive meat storage among the //Gana in Botswana while the practice is absent in neighboring groups.)

The stochastic evolutionary game model of the evolution of conventions governing the distribution of income between classes (described in section 3) highlights the role of intentional choices in the evolution of inequality, with many distinct outcomes being consistent with the same underlying technology. In similar vein, Chris Boehm (1993):226 sees equality as a deliberate outcome: “intentional leveling linked to an egalitarian ethos is an immediate and probably wodespread cause of human societies failing to develop authoritative or coercive leadership.” James Woodburn (1982):431 refers to the “politically assertive egalitarianism” of some hunter gatherer groups as a constraint on technical innovation: “the value systems of non-competitive egalitarian hunter gatherers limit the development of agriculture because the rules of sharing restrict the investment and savings necessary for agriculture.” Deliberate egalitarianism may explain the many groups in which sedentism and domestication did not produce hierarchical political systems and substantial economic inequality or did so only after a very long delay.

The importance of politics extends to the present. The studies of long term income distribution in France, U.S., and Japan mentioned at the outset indicate that most of the long term decline in inequality that took place in those countries over the 20th century coincided with either the Great Depression or the Second World War. A plausible account of these shifts would seem to require attention to the particular political conjunctures generated by these two events.

Thus while the long term evolution of the forms of livelihood of peoples has powerfully shaped the trajectory of hierarchy and inequality, the cases mentioned suggest that a given ecology and technology may support (as stable equilibria) a multiplicity of distributional outcomes, the selection of which depends on deliberate choices that people make.

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