Altruism and Climate

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Abstract

Recognizing that individualism, or weak family ties, may be favorable to economic development, we ask how family ties interact with climate to determine individual behavior and whether there is reason to believe that the strength of family ties evolves differently in different climates. For this purpose, we develop a simple model of the interaction between two individuals who are more or less altruistic towards each other. Each individual exerts effort to produce a consumption good under uncertainty. Outputs are observed and each individual chooses how much, if any, of his or her output to share with the other. We analyze how the equilibrium outcome depends on altruism and climate for *ex ante* identical individuals. We also consider (a) "coerced altruism," that is, situations where a social norm dictates how output be shared, (b) the effects of insurance markets ,and (c) the role of institutional quality. The evolutionary robustness of altruism is analyzed and we study how this depends on climate.

Keywords: altruism, family ties, individualism, moral hazard, evolution.

JEL codes: D02, D13

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"Here, then, is an admirable specimen of an English life: left early to fend for oneself; marriage to a woman with no fortune; a large family of children; income all spent, no savings; work very hard and place one's children under the necessity to do likewise." (Hippolyte Taine, *Notes on England)*

1 Introduction

As is well-known the wealth and productivity in the world's most advanced economies exceed those of the least advanced ones by far. Disparities in physical endowments and constraints (see, e.g., Landes, 1999, and Diamond, 1997), as well as differences in human capital (Glaeser et al, 2004) may partly explain this persisting pattern.[1] Other researchers have pointed out that institutions, such as the protection of property rights (North, 1990), matter, and several empirical studies provide support for this view (Mauro, 1995, Hall and Jones 1999, Acemoglu, Johnson and Robinson, 2001). Yet others have devoted attention to the effect of culture and beliefs, such as trust (Fukuyama, 1995, Knack and Keefer, 1997, La Porta et al., 1997), religion (Barro and McCleary, 2003), respect for others, and confidence in self-determination (Tabellini, 2005).[2] In fact it has been argued that individualism was an important force behind the industrial revolution in England. Thus, Max Weber (1951), as cited by Lipset and Lenz (2000, p.119), thought that "the great achievement of [...] the ethical and ascetic sects of Protestantism was to shatter the fetters of the sib [the extended family]." In his view, a strong sense of solidarity among members of the extended family and their friends, coupled with a hostile attitude towards strangers, promotes a culture where nepotism may thrive and counter the efficient development of markets. Likewise, Banfield (1958) thought that the "amoral familism" that he observed in certain parts of Italy was an impediment to economic development.[3]

The fact that institutions and cultural values seem to matter for economic development

[1]Several works, including Nordhaus (1994), Theil and Chen (1995), and Ram (1997), have provided evidence of a correlation between the distance to the equator and various measures of economic development. More recently Masters and McMillan (2001) show that an increase in the number of frost days has a favorable impact on economic outcomes.

[2]The political scientists Banfield (1958) and Putnam (1993) had previously emphasized the possible importance of cultural values. See also Guiso, Sapienza and Zingales (2006).

[3]The potential effects of other cultural traits or values, such as trust and religion, on economic outcomes have been investigated elsewhere. See, for instance, Huntington (1996), Landes (1999), Knack and Keefer (1997), Inglehart and Baker (2000), and Barro and McCleary (2003).

raises many important questions. First, a systematic study of how institutions and cultural values affect economic outcomes could seek to answer questions such as: How sensitive is economic growth to changes in institutions and values? Are some institutions and/or values substitutes? A second line of inquiry, to which this paper belongs, would aim at enhancing our understanding of the institutions and values themselves. For instance, are some institutions or values more stable than others? And why do cultural values and institutions differ among countries in the first place—is this a mere accident, or can we identify some underlying forces that enable us to gain some predictive power regarding the evolution of values and institutions? In this paper we seek to provide some partial answers to the last question. Our focus is on the importance of the family.

Empirical research indicates that family ties are weaker in some cultures than in others, as suggested by Weber's observation above. Intrafamily transfers provide a measure of the strength of family ties. These transfers, which may be monetary or in kind, may indeed be viewed as "the very fabric of families" (Laferrère and Wolff, 2006). Recent data reveals significant differences between developing and developed countries. In their survey, Cox and Jimenez (1990) conclude that in developing countries 20-90% of households receive (private) transfers, compared to 15% in the US. Moreover, whereas intrafamily transfers represent only 1% of household income on average in the US, it can reach 20% in parts of the developing world. One obvious explanation is that intrafamily transfers are common where publicly provided insurance mechanisms are absent. However, research by economists, anthropologists, sociologists and historians suggests that there are other, more fundamental, differences that may also explain the differences in transfer behavior.

Bentolila and Ichino (2000) analyze unemployment and consumption data from five different countries. They find that the drop in consumption due to a prolongation of unemployment is significantly smaller in the South (Italy and Spain) than in the North (UK and Germany), while the unemployment insurance is more generous in the North than in the South. They argue that the smaller consumption drop in Italy and Spain is due to intrafamily help.[4]

Various studies point out that Mexican immigrants and white Anglo families in the US display significantly different behaviors and attitudes related to the family. Thus, data collected by Keefe et al (1979) indicates that second and third generation Mexican American

[4]In an essay on Africa, Etounga-Manguelle (2000), a former member of the World Bank's Council of African Advisors, claims that people with a regular income in today's Africa are not only expected to provide help in emergency situations; they are also expected to finance the studies of younger members of the extended family, and to contribute to the many lavish celebrations dictated by social rules.

families have stronger kin ties than Anglo families, even after controlling for variables such as education, occupation, and the number of years of residence in the same city. Moreover, Anglos are more likely than Mexican Americans to include neighbors and friends in their support networks, and less likely to view support from the family as being superior to other types of support. Keefe (1984) further finds that Mexican Americans attach a larger value than Anglos to the physical presence of family members. Using another dataset, Gonzales (1998) finds that Mexican Americans (people of Mexican descent but born in the US) tend to live closer to and have more contact with kin than Anglos, even after several generations in the US. Her analysis further shows that both Mexican Americans and Mexican Immigrants are significantly more sympathetic to the idea that parents (adult children) should let their adult children (parents) live with them if in need.

Reher (1998) suggests that one can measure the strength of a society's family ties by studying the age at which a child would leave his/her parents' home. In 1995, the average age of children living with their parents was 15 in Spain, 18 in Italy, 9 in the UK, 11 in the US, and 13 in Germany (Bentolila and Ichino, 2000). Of course these differences may be due to differences in economic opportunities, availability and cost of housing, and the extent of publicly provided insurance. However, data from pre-industrial Europe reveals a similar pattern. Hajnal (1982) reports data on servants in northwestern Europe during the 17th-19th centuries; approximately half of all youngsters served outside the parental home at some point, some leaving the parental home at the age of 10. Thus, in 17th century England, "the unit of production was the husband and the wife and hired labor, not children" (Macfarlane, 1978). By contrast, in southern and eastern Europe hired labor would be scarce, and children would work on the parental farm; several related couples and their children would constitute the more widespread type of household.

Differences in the legal systems provide further insights into the strength of family ties. In England parents had the right to bequeath or sell their assets to anyone; according to Macfarlane (1992) this right may be traced back to the thirteenth century. By contrast, in France the heirs must be given the opportunity to purchase the assets (Macfarlane, 1992).

Taken together these pieces of evidence suggest that family ties are weaker in some parts of the world than in others, and that such differences may predate the industrial revolution. As noted above, and as suggested by the following excerpt from Adam Smith's *The Theory of Moral Sentiments* (1790), an explanation is that the family is more important where formal institutions are lacking: "extensive regard to kindred is said to be taking place among the Tartars, the Arabs, the Turkomans [...]. In commercial countries, where the authority of law is always perfectly sufficient to protect the meanest man in the state, the descendants of the same family, having no such motive for keeping together, naturally separate and disperse." (VI.ii.1.13) Empirical evidence for this "supply-side" explanation exists (Inglehart and Baker, 2000). However, there may also exist a causal link in the other direction: the strength of family ties may vary for exogenous reasons, and this may be expected to result in different levels of *demand* for formal institutions. This is a hypothesis that we explore in this paper. More precisely, we investigate whether exogenously given conditions, such as climate, may provide some clues regarding possible evolutionary forces that shape the strength of family ties.

Our idea is quite simple. Consider a pre-industrial society. In such a society a typical household would seek to produce most of the goods needed for survival within the family farm. The lack of formal insurance and low degree of diversification of income sources would however expose the household to substantial risks, which may lead them to form informal insurance arrangements with, say, a brother of the husband.[5] Intuition would suggest that intrafamily insurance or the lack thereof may in turn affect the incentives to produce. Now imagine two unrelated (extended) families living in the same region, and suppose that one family has a higher degree of intrafamily insurance than the other. Is one of the families more likely to be successful? If so, which one, and how does this depend on the exogenously given climate? Assuming that the behavior patterns in the family that is more successful are likely to spread in the population, this type of analysis may yield predictions regarding the strength of family ties as a function of the climate or of other aspects of the environment that may interact with the strength of the family ties to affect the welfare of the family.

We analyze these issues as follows. We model the interaction between two individuals, which we may think of as siblings. An individual's total utility is taken to be a weighted sum of both individuals' material utility, which in turn is determined by each individual's work effort and consumption. The weight put on the other individual's material utility is assumed to be non-negative and not greater than the weight put on one's own material utility. This weight can be interpreted in terms of altruism, or, alternatively, in terms of the esteem derived from others who observes and evaluates one's behavior, such as members of one's extended family, village or society at large. The siblings invest effort in production, and output may be low or high. Once the outputs have been realized, these are observed by both individuals, and each individual may share some of his or her output with the other. Consumption is taken to equal the final amount of the output available to the individual. We interpret the low output as a base-line output provided by nature without human effort,

[5] See, e.g., Caldwell et al. (1986), Lucas and Stark (1985), and Rosenzweig (1988) for evidence regarding the extended family as a source of insurance in developing countries.

and the high output as being the joint result of human effort and nature ("luck"). The two output levels, high and low, represent the exogenously given environment, or climate, in which the individuals operate. A climate will be said to be more favorable if both output levels are higher, and we will say that a climate is more forgiving if the ratio of the high to the low output is lower.

We solve this two-player game by backward induction, focusing mostly on the case of individuals with the same Cobb-Douglas preferences over own consumption and effort, potentially differing in their degree of altruism towards each other. This game has a unique subgame-perfect equilibrium. Its qualitative features are as follows. In equilibrium, transfers are never given if both individuals' outputs are equal (both high or both low). If they are distinct, however, the "rich" individual transfers some of his or her output to the other, "poor" individual, granted the potential donor is sufficiently altruistic. The anticipation of receiving a transfer when poor has a negative effect on an individual's incentive to exert effort. This free-rider effect is well-known from other analyses of altruism.[6] However, altruism also has a positive effect on an individual's incentive to exert effort: an altruist may exert more effort in order to have more to give the other individual, an effect we call the "empathy effect" of altruism on effort.

We find that in a society with equally altruistic individuals, the free-rider effect outweighs the empathy effect when altruism is of intermediate strength: the equilibrium effort decreases as a result of an increase in altruism from low to intermediate. By contrast, if the common degree of altruism is strong, the empathy effect is more pronounced, and the equilibrium effort is then increasing in altruism. Depending on the climate, the empathy effect may or may not outweigh the free-rider effect at high levels of altruism, that is, effort may then be smaller or larger than if the individuals were selfish.[7] Despite the non-monotonicity of effort in the common degree of altruism, the expected material utility is always the highest for fully altruistic individuals—in particular, higher than for fully selfish individuals. The intuition

[6] For models with one-sided altruism, see Becker (1974), Bruce and Waldman (1990), and Chami (1998). Lindbeck and Weibull (1988) analyze the effect of two-sided altruism on savings.

[7] Despite the previous strong emphasis in the literature on the possible moral hazard effect of intrafamily altruism, there seems to be a limited number of empirical studies on this topic. Using data on farmer output in Mali, Azam and Gubert (2005) find that remittances from emigrated relatives have a negative impact on agricultural output. By contrast, Kohler and Hammel (2001) show, using census data for Slavonia from 1698, that the number of different crops grown by a family tended to *increase* as the nearby extended family increased. The authors were expecting the opposite effect, namely that as a result of insurance a family would invest less in risk-reducing planting strategies. However, our results suggest that there exists an intuitive explanation for this pattern: when a family expects to help another family out, the expected benefit of the risk-reducing planting strategy is increased.

is straightforward: an individual who attaches the same weight to the other' material utility fully internalizes the external effects of his or her effort.

Climate has an unambiguous effect on effort: for given preferences, the equilibrium effort increases as the climate becomes less forgiving—then the marginal return to effort is higher. This effect may be so strong that the expected output increases as the climate becomes both less favorable and less forgiving. However, due to the higher disutility of effort, the expected material utility will then be lower: the expected material utility always increases as the climate becomes more favorable, irrespective of whether it becomes more or less forgiving. In addition to studying the effects of climate upon behavior, we briefly analyze the effect of income taxation and of the quality of the institutional framework surrounding the interacting individuals, in particular, the effect of private property protection.

In an extension of the model we consider situations in which an individual's degree of altruism differs from that enforced by society. More precisely, we here suppose that the interacting individuals live in a society with a social norm that dictates a larger transfer than the individuals' own altruism suggests. If the degree of such *coerced altruism* is strong, individuals feel forced to help each other out.[8] We focus on selfish individuals in a society with a high degree of coerced altruism. Such coercion entails a free-rider effect but no empathy effect. Hence, the equilibrium effort decreases as the degree of coerced altruism increases. However, while coerced altruism induces "involuntary" transfers ex post, such coercion may be efficient *ex ante* in the sense that the equilibrium expected utility is higher than it would be in the absence of coercion. In such situations, it is as if social norms play the role of compulsory but informal insurance.

In another extension of our basic model we introduce a perfectly competitive insurance market in a large population of pair-wise interacting selfish individuals. By way of numerical simulation, we show that the ranking, from the best to the worst in terms of expected material utility, may be as follows: first, informal insurance by way of full altruism, second, actuarially fair insurance of selfish individuals, third, informal insurance of selfish individuals by way of coerced altruism, and finally, selfish individuals without access to formal or informal insurance. Effort is lowest in a society with selfish individuals with access to actuarially fair insurance, highest in a society with selfish individuals without insurance possibility. Moreover, effort is lower among selfish individuals under coerced altruism than among fully altruistic individuals without formal insurance possibilities.

[8]Many individuals are willing to pay in order to avoid situations where they feel coerced to behave altruistically, even in the absence of potential social sanctions. For recent laboratory studies showing this, see Dana et al. (2006) and Broberg et al. (2006).

We apply insights from the analysis of the basic model (that is, without coerced altruism and without formal insurance) to ask whether evolutionary forces would tend to select for or against altruism. Would a population consisting of fully altruistic individuals, who always share total output equally among themselves, resist a small-scale "invasion" of selfish individuals, who never share any or their output? Would the opposite be true? When analyzing such questions, we define a degree of altruism, α, to be *evolutionarily robust* against another degree of altruism, α', if it satisfies the following two-fold condition. First, an α-altruist should do at least as well, in terms of material welfare, against an α-altruist as an α'-altruist does against an α-altruist. Secondly, if an α'-altruist does equally well against α-altruists as these do against themselves, then an α-altruist should do strictly better against an α'-altruist than these do against themselves. We study such evolutionary robustness in three informationally and behaviorally distinct setups.

If individuals are naïve in the sense of believing that the other individual is equally altruistic (or selfish), then full altruism is evolutionarily robust against selfishness in certain environments, in particular in less forgiving climates. By contrast if individuals know each other's degrees of altruism, then this effect disappears and only pure selfishness is evolutionarily robust. A third possibility is that individuals know each other's degree of altruism and that this is discriminatory: altruists behave altruistically only against other altruists. In this case, full altruism is evolutionarily robust but full selfishness is not (a population of selfish individuals can be invaded by discriminating full altruists who informally insure each other).

We finally extend the evolutionary robustness analysis to a setting where altruism is biologically inherited in sexual reproduction.[9] In such a setting, the interacting siblings' degrees of altruism are positively correlated, by way of their common parents, and therefore altruists are more likely to be matched with altruists, and likewise for selfish individuals. We apply results due to Bergstrom (1995, 2003) for such settings to the special case of our model when individuals are naïve, as described above. Then evolutionary forces tend to select for altruism and against selfishness, thanks to the mentioned correlation. In particular full altruism among siblings always resists a small-scale mutation to selfishness. Nonetheless, pure selfishness is robust against full altruism when output variability is high, as it is in less forgiving climates: then a naïve altruist stands to lose much from interacting with a naïve selfish sibling. Even though an altruistic mutant has a high chance of interacting with an

[9] There is some evidence that altruistic behavior may be affected by genes. Bachner-Melman et al. (2005) studied a group of 354 families, and found a correlation between the occurrence of two specific genes and the degree of assessed selflessness. Warneken and Tomasello (2006) detected a strong willingness to help strangers among very young children. However, the model may also be interpreted in terms of cultural inheritance (Richerson and Boyd, 2005).

altruistic sibling (probability one half) and then enjoy the benefits of mutual insurance, when output variability is high the cost of having a selfish sibling (also approximately probability one half) is sufficiently large to outweigh the mutual insurance benefit.

Early proponents of evolutionary theory, including Darwin, were puzzled by the occurrence of altruism in nature: if behavior and traits maximize the individual's likelihood of survival and reproduction, how could a behavior/trait whereby the individual gives up resources for the benefit of others survive? Ever since this puzzle was highlighted biologists, as well as social scientists, have proposed evolutionary theories of altruism, and more generally of cooperation. One now widely accepted explanation is "kinship selection," proposed by Hamilton (1964): an individual's children, siblings, and cousins all share the individual's genes to some extent; being altruistic toward kin therefore promotes the survival of the genes. The above-mentioned analysis falls into this category.

Starting with Becker (1976) economists have also made contributions. Bergstrom and Stark (1993), and Bergstrom (1995, 2003) have enriched the kinship selection theory by allowing for more complex strategic interactions between kin; in Hamilton's original theory the cost and benefit arising from an altruistic action by, say, a sister towards her brother, did not depend on the brother's action. More recently Weibull and Salomonsson (2005) use a revealed-preference argument in a biological context to suggest an explanation of how social preferences, with altruism as an important special case, can emerge from natural selection even in the absence of kinship. Other theories of cooperation have often relied on the idea that people interact repeatedly, which allows for the evolution of reciprocal altruism among non-kin (Trivers, 1971, Axelrod and Hamilton, 1981); see Sethi and Somanathan (2003) for a survey. This argument has then been extended to indirect reciprocity (surveyed by Nowak and Sigmund, 2005), whereby an individual may be punished for not cooperating even though he may never interact with the same individual more than once, because an individual may have some information about his/her co-player's past behavior; Bowles and Gintis (2004) provide a recent contribution. Our theory makes a contribution to the literature on the evolution of altruism by drawing a link between exogenously given conditions, such as climate, and the survival value of altruism.

Our focus here on a simple two-stage game that is not repeated is not because we think repetition—allowing for threats, punishments and reciprocity—is unimportant, but because we think (a) that many individuals do have social preferences, in the revealed-preference sense, (b) that such preferences may be altruistic towards others, in particular towards close relatives and friends, and (c) that repetition, with its potential plethora of equilibria, may blur rather than clarify the picture when trying to lay bare possible causal links from climate to altruistic behaviors. Phrased differently, our aim is to clarify how altruistic preferences, individually held and/or socially coerced, interact with the physical and institutional environment in the formation of income, welfare and altruism in society, while admitting that repetition may add another important layer to explanations of observed behaviors.

Our model is similar to that in Lindbeck and Nyberg (2006), who analyze altruistic parents' incentive to instill a work norm in their children. The incentive stems from parents' inability to commit not to help their children if in financial need. If the children feel a strong social norm to work (hard), then this reduces the risk that the children will be in need, which is good for the altruistic parents. On the other hand, the parents will suffer with the children if their work ethic is very demanding and the children fail. The parents instill just enough of the social work norm in their children so that that these two effects are optimally traded off. While their model is asymmetric—parents are altruistic and move first and children are selfish—our model is symmetric—the two siblings move simultaneously and may be equally altruistic towards each other. Nevertheless, the issues dealt with are related, the models similar in structure and the Cobb-Douglas parametrization of preferences over consumption and effort identical.

The remainder of the paper is organized as follows. We present the basic game in the next section and prove, in section 3, that this game has a unique subgame-perfect equilibrium. Section 4 is devoted to a comparative-statics analysis of the equilibrium outcome with respect to altruism and climate, but we also briefly discuss the effects of income taxation as well as institutional quality (represented by a crude measure of the degree of protection of private property). Section 5 extends the basic model to allow for socially coerced altruism, that is, interactions where individuals feel socially coerced to behave more altruistically than they themselves feel an inner motivation for. Section 6 compares the informal insurance that altruism, voluntary or coerced, brings with the insurance that a competitive insurance market would deliver. Section 7 elaborates on the evolutionary robustness of altruism and selfishness, and section 8 concludes by summarizing our main results and by pointing to directions for future work.

2 The model

We analyze a strategic interaction between two individuals, each of whom faces an investment decision with uncertain returns. There are two time periods. In the first period, each individual chooses to invest some effort. This effort in turn determines the probability distribution over the possible returns, or outputs, that accrue at the end of the first period.

Let y_i denote the output of individual $i \in \{1, 2\}$: it may be either low, $y^L > 0$ or high, $y^H = \beta y^L$, where $\beta > 1$. The two outputs are statistically independent random variables.[10]

For many kinds of agricultural production, both y^L and y^H are arguably lower in harsher climates (say, Scandinavia) than in milder climates (say, Southern Europe). Hence, in a *more favorable* climate both y^L and y^H are higher. In parts of the comparative statics to follow we will compare climates A and B where not only $y^L_A < y^L_B$ and $y^H_A \leq y^H_B$ but also $\beta_A > \beta_B$. In other words, as one moves from climate A to the more favorable climate B, not only are both out levels higher but y^L relatively more than y^H as one moves from A to B. This is often the case, we argue. Tomatoes grown in Scandinavia, when properly cared for, can be just as tasty as those grown in Southern Europe, but in the absence of effort they are much worse (if they grow at all) in Scandinavia than in Southern Europe. When discussing such comparative statics, we will say that climate B is more favorable and *forgiving* than climate A.

We assume that the probability of high output is strictly increasing in effort. Since the effort level and this probability thus are in a one-to-one relationship, we economize on notation by letting each individual i directly choose the probability for the high output level. Thus, in the first period the two individuals simultaneously choose probabilities $p_1, p_2 \in [0, 1]$ of obtaining the high output. The output y_i of each individual i is realized at the end of the first period. Write $\mathbf{y} = (y_1, y_2)$. We assume that the vector $\mathbf{y} \in Y = \left\{y^L, y^H\right\}^2$ is public information at the beginning of the second period and will call $\mathbf{y}$ the *state* in period two. By contrast, we assume that an individual's effort is not observed by the other individual. This assumption turns out to be innocuous: given the (separable) preferences that we focus on in the subsequent analysis, the results are identical for the case when efforts are observed. Having observed the state, both individuals independently choose whether to make a transfer to the other, and if so, how much to transfer. Each individual's consumption therefore equals his output plus any transfer received from the other individual, minus any transfer given to the other individual.

If individual i, for $i = 1, 2$, chooses probability p_i in the first stage and consumes c_i in the second stage, then his or her *material utility* is $u(c_i, p_i)$, where $u : [0, +\infty) \times [0, 1) \to \mathbb{R}$ is continuously differentiable, concave, strictly increasing in its first argument, consumption, and strictly decreasing in its second argument, effort-*cum*-probability. Although some results hold more generally, we will restrict the analysis to additively separable functions u. The individuals are altruistic in the sense that each cares about the material utility of the other.

[10] This independence simplifies the analysis but is not necessary. We believe that the results for the correlated case are similar.

Letting $\alpha_i \in [0,1]$ represent the *degree of altruism* of i for j, the *welfare* of i is defined as

$$U_i(\mathbf{c},\mathbf{p}) = u(c_i, p_i) + \alpha_i u(c_j, p_j) \tag{1}$$

where $\mathbf{c} = (c_1, c_2)$.[11] An individual i with $\alpha_i = 0$ will be called *selfish* and an individual with $\alpha_i = 1$ *fully altruistic.*[12]

We analyze this interaction as a two-stage game of perfect information, denoted G, in which a pure strategy for individual i is a pair $s_i = (p_i, \tau_i)$, where $\tau_i : Y \to \left[0, y^H\right]$ is a function specifying what transfer i gives to j in each state $\mathbf{y}$, where transfers are restricted by own output: $\tau_i(y) \leq y_i$ for all $\mathbf{y} \in Y$. Together with the state $\mathbf{y}$, a strategy profile $\mathbf{s} = (s_1, s_2)$ thus determines the resulting welfare levels, or game payoffs, as follows:

$$\pi_i(\mathbf{s},\mathbf{y}) = u(y_i - \tau_i(\mathbf{y}) + \tau_j(\mathbf{y}), p_i) + \alpha_i u(y_j - \tau_j(\mathbf{y}) + \tau_i(\mathbf{y}), p_j).$$

We note that, for each state $\mathbf{y} \in Y$, the second stage of the game forms a subgame, $G(\mathbf{y})$, in which a pure strategy of individual i is the transfer $t_i \in [0, y_i]$ to individual $j \neq i$ (conditional upon the observed state $\mathbf{y}$). As solution concept when analyzing the two-stage game G, we will use *subgame perfect equilibrium.*

Most of the subsequent analysis is focused on the analytically tractable special case of Cobb-Douglas material utility:[13]

$$u(c_i, p_i) = \ln c_i + \gamma \ln(1 - p_i), \tag{2}$$

where we interpret

$$x_i = -\ln(1 - p_i)$$

as *effort* and hence $\gamma > 0$ as representing the individual's *disutility from effort.* Under this interpretation, the probability for high output is an increasing, differentiable and strictly concave function of effort, running from zero at zero effort towards unity as effort goes to plus infinity: $p_i = 1 - e^{-x_i}$ (see section 4.4 for a slight generalization).

[11] For $\alpha_1\alpha_2 < 1$, this is equivalent with U_i being proportional to $u_i + \alpha_i U_j$ for $i = 1, 2$ and $j \neq i$. Hence, for such parameter combinations, the current formulation is consistent with "pure," or "non-paternalistic," altruism.

[12] Under separable material utility u, the analysis would be unaffected if each individual instead cared only about the other's subutility of consumption, and not, as here, about the other's total material utility (also including effort).

[13] This parametization of preferences was also chosen in Lindbeck and Nyberg (2006).

3 Equilibrium

We begin the analysis by solving for the transfers in the second stage, when outputs already have been realized, whereafter we turn to the determination of efforts-*cum*-output probabilities in the first stage.

3.1 Transfers

In the second stage, individual i can increase his welfare by making a transfer to j if and only if, given efforts made and outputs obtained, his marginal material utility is smaller than that of j, weighted by his altruism parameter α_i, *i.e.*, if and only if $u_c(y_i, p_i) < \alpha_i u_c(y_j, p_j)$. If $u_c(y_1, p_1) \geq \alpha_1 u_c(y_2, p_2)$ and $u_c(y_2, p_2) \geq \alpha_2 u_c(y_1, p_1)$, then neither individual 1 nor individual 2 can increase his or her own welfare by making a transfer to the other. Formally, let $\tau_i^* : Y \to \left[0, y^H\right]$ be the function that defines, for every state $\mathbf{y} \in Y$, the transfer that individual i would like to make to j if the latter makes no transfer to i. The above assumptions imply that $\tau_i^*(\mathbf{y}) > 0$ if and only if $u_c(y_i, p_i) < \alpha_i u_c(y_j, p_j)$, in which case $\tau_i^*(\mathbf{y})$ solves

$$u_c(y_i - \tau_i^*(\mathbf{y}), p_i) = \alpha_i u_c(y_j + \tau_i^*(\mathbf{y}), p_j). \tag{3}$$

Otherwise, $\tau_i^*(\mathbf{y}) = 0$. It is straightforward to prove the following lemma, which says that unless both individuals are fully altruistic ($\alpha_1 = \alpha_2 = 1$) there exists a unique Nash equilibrium for every subgame $G(\mathbf{y})$, in which at most one individual makes a positive transfer to the other. Should both individuals be fully altruistic equilibrium is not unique, although for every state $\mathbf{y}$ the consumption levels are the same in every equilibrium.

Lemma 1 *For every $\mathbf{y} \in Y$, $\boldsymbol{\tau}^*(\mathbf{y}) = (\tau_1^*(\mathbf{y}), \tau_2^*(\mathbf{y}))$ is a Nash equilibrium of $G(\mathbf{y})$. If $\alpha_1\alpha_2 < 1$, then this equilibrium is unique. If $\alpha_1 = \alpha_2 = 1$ then there is a continuum of Nash equilibria, but in each state $\mathbf{y}$ both individuals consume the same amount.*

In the special case of Cobb-Douglas utility (2), the transfer from i to j is positive if and only if i obtains the high output and j the low, and, moreover, i is sufficiently altruistic in the precise sense that

$$\frac{1}{y^H} < \frac{\alpha_i}{y^L}.$$

Hence, the lower bound on altruism for a transfer from i when “rich” to j when “poor” is $\alpha_i > \hat{\alpha}$, where $\hat{\alpha} = 1/\beta$. We note that this lower bound is independent of the identity of the potential donor and receiver.

Moreover, if a transfer is given by i to j, then this transfer t_i satisfies the first-order condition (3), which in the Cobb-Douglas case boils down to

$$\frac{1}{y^H - t_i} = \frac{\alpha_i}{y^L + t_i},$$

Hence:

$$t_i = \max\left\{0, \frac{\alpha_i y^H - y^L}{1 + \alpha_i}\right\}. \tag{4}$$

This defines the *conditional transfer* t_i, conditional upon i being rich and j poor, as a function of α_i, y^H and y^L. As intuition suggests, the conditional transfer, when positive, is increasing in the giver's altruism and "wealth" and decreasing in the recipient's "wealth." The transfer, when positive, is such that the recipient ends up with the share $\alpha_i / (1 + \alpha_i)$ of total output, $y^H + y^L$, and the donor ends up with the remaining share, $1/(1 + \alpha_i)$.

Hence, the equilibrium transfer is *not* a fixed share of the donor's wealth (such as giving a tenth), nor is it proportional to the difference in wealth, except in the case of maximal altruism. Instead, the equilibrium transfer is such that total wealth is divided in certain fixed proportions. For instance, the recipient's share of total wealth is $1/3$ when $\alpha_i = 1/2$ (the genetic kinship factor between siblings) and it is $1/2$ when $\alpha_i = 1$ ("full" altruism).

3.2 Efforts

In the first period each individual chooses an effort-*cum*-probability for high output. In subgame perfect equilibrium, each individual correctly anticipates the ensuing transfers in the different states in the second period. Denote by $\Pi_i(\mathbf{p})$ the *expected welfare* of individual i as evaluated in period 1, that is, $\Pi_i(\mathbf{p}) \equiv \mathbb{E}_{\mathbf{y}}[\pi_i(\mathbf{s}, \mathbf{y})]$, where $\mathbf{s} = (\mathbf{p}, \boldsymbol{\tau}^*)$ and $\boldsymbol{\tau}^*$ is the pair of conditional equilibrium transfer functions defined in Lemma 1. We then have

$$\begin{aligned}\Pi_i(\mathbf{p}) = {} & p_i p_j [u(y^H, p_i) + \alpha_i u(y^H, p_j)] \\ & + (1 - p_i)(1 - p_j)[u(y^L, p_i) + \alpha_i u(y^L, p_j)] \\ & + p_i(1 - p_j)\left[u(y^H - \tau_i^*(\mathbf{y}), p_i) + \alpha_i u(y^L + \tau_i^*(\mathbf{y}), p_j)\right] \\ & + p_j(1 - p_i)\left[u(y^L + \tau_j^*(\mathbf{y}'), p_i) + \alpha_i u(y^H - \tau_j^*(\mathbf{y}'), p_j)\right],\end{aligned} \tag{5}$$

where $\mathbf{y}$ is the state in which $y_i > y_j$, while $\mathbf{y}'$ is the state in which $y_i < y_j$. The pair (Π_1, Π_2) of payoff functions defines a simultaneous-move game $\hat{G}$ in which a (pure) strategy for each player i is his or her probability $p_i \in [0, 1)$. Moreover, each Nash equilibrium in $\hat{G}$ corresponds to a subgame perfect equilibrium of the two-stage game G, and *vice versa*.

We solve for (pure-strategy) Nash equilibrium in $\hat{G}$ in the special case of Cobb-Douglas preferences. In this case, each player has a unique best reply to the other's strategy. This follows from the analysis in the preceding section. After some algebraic manipulation, one finds that individual i's best reply p_i to any probability p_j that the other individual may choose is

$$p_i^* = \max\left\{0, 1 - \frac{\gamma}{H_i(p_j)}\right\} \tag{6}$$

(for $i = 1, 2$ and $j \neq i$), where

$$\begin{aligned} H_i(p_j) = \ln\beta + (1 - p_j)\ln\left[\left(1 + \max\left\{0, \frac{\alpha_i\beta - 1}{1 + \alpha_i}\right\}\right)^{\alpha_i}\left(1 - \max\left\{0, \frac{\alpha_i - 1/\beta}{1 + \alpha_i}\right\}\right)\right] \\ - p_j\ln\left[\left(1 + \max\left\{0, \frac{\alpha_j\beta - 1}{1 + \alpha_j}\right\}\right)\left(1 - \max\left\{0, \frac{\alpha_j - 1/\beta}{1 + \alpha_j}\right\}\right)^{\alpha_i}\right]. \end{aligned} \tag{7}$$

As expected, the optimal effort-*cum*-probability p_i^*, given the other's effort-*cum*-probability p_j, is increasing in the individual's own altruism, α_i: A more altruistic individual makes a greater work effort, $x_i^* = -\ln(1 - p^*)$, in order to be able to have more to give to the other if in need.[14] Hence, a more altruistic individual not only gives a larger transfer, see (4), but also makes a bigger effort to obtain the high output level. However, this is true for both individuals. So if the other individual, j, would become more altruistic — α_j would increase — then his conditional transfer and effort-cum-probability, p_j, would both increase, *ceteris paribus*. So, by the same token, facing a more altruistic person reduces one's effort to obtain the high output (since the other individual is more likely to obtain the high output). We call the first, positive, effect the *empathy effect* (from own altruism) and the second, negative, effect the *free-riding effect* (from other's altruism).

We determine the equilibrium effort-*cum*-probability in the special case of equally altruistic individuals, $\alpha_1 = \alpha_2 = \alpha$. When this common degree of altruism is sufficiently small, but still positive, no transfer takes place: $\alpha\beta \leq 1$ implies $t_i = t_j = 0$, by (4). It is as if each individual then lived in autarky. Letting p^0 denote this *autarky* effort-*cum*-probability, we have (from (6)):

$$p^0 = \max\left\{0, 1 - \frac{\gamma}{\ln\beta}\right\} \tag{8}$$

Hence, $p^0 > 0$ if and only if $\ln\beta > \gamma$. In other words, no effort is exerted in autarky if β is small and/or γ is large. This fully describes the equilibrium outcome when $\alpha\beta \leq 1$.

When $\alpha\beta > 1$, a positive transfer may be given when the two individuals' outputs differ

[14] This follows from noting that $\frac{\partial H_i(p_j)}{\partial\alpha_i} > 0$ whenever $\alpha_i > 1/\beta$.

— from the "rich" individual to the "poor." However, even in this case both individuals may still choose to exert no effort, in which case their outputs are identical and thus no transfer is given. The following proposition characterizes the equilibrium outcome in the "non-autarkic" case when $\alpha\beta > 1$. Let

$$F(p) = \alpha \ln \alpha + (1+\alpha) \ln \frac{1+\beta}{1+\alpha} - (1+\alpha) \left(\ln \frac{1+\beta}{1+\alpha} + \ln \frac{\alpha + \alpha/\beta}{1+\alpha} \right) p - \frac{\gamma}{1-p}. \tag{9}$$

For $\alpha, \beta, \gamma > 0$ this defines F as a continuous and strictly concave function on $[0, 1)$, with $\lim_{p \to 1} F(p) = -\infty$. Hence, $F(p)$ is negative for all p sufficiently close to 1. The following proposition is proved in the Appendix.

Proposition 1 *Suppose that the two individuals have identical Cobb-Douglas preferences (2) and* $\alpha\beta > 1$. *Then* $\hat{G}$ *has a unique Nash equilibrium. This equilibrium is symmetric,* $p_1 = p_2 = p^*$, *and* $p^* = \max\{0, \bar{p}\}$, *where* $\bar{p} = \{p \in [0, 1) : F(p) = 0\}$.

In sum: In the special case of identical individuals with Cobb-Douglas material utility there exists a unique subgame perfect equilibrium, for all parameter combinations. In this equilibrium, both individuals choose the same effort-cum-probability in the first period, p^*, defined in (8) for $\alpha\beta \leq 1$ and in Proposition 1 for $\alpha\beta > 1$. If both individuals end up with the same (high or low) output level, no transfer is given, while if they end up with distinct output levels, then the conditional transfer

$$t^* = \max\left\{0, \frac{\alpha\beta - 1}{1+\alpha}\right\} \cdot y^L \tag{10}$$

(see equation (4)) is given from the rich to the poor. We next analyze how this equilibrium depends on the parameters of the model, in particular, on the climate and the common degree of altruism.[15]

[15] It seems natural to us to model the strategic interaction as a two-stage game. However, the results are essentially the same if instead the players would simultaneously choose both efforts and transfer functions (transfers conditional upon outputs). The subgame perfect equilibrium effort levels and transfer functions, given in Lemma 1 and Proposition 1, would also form a Nash equilibrium of the simultaneous-move game. Moreover, every Nash equilibrium in the latter game, in which efforts are positive, constitutes a subgame perfect equilibrium of the two-stage game.

4 Comparative statics

Consider two identical individuals with Cobb-Douglas preferences. We saw in proposition 1 that the equilibrium effort-cum-probability p^* then is a function of the three parameters α, β and γ. We also saw, in equation (10), that the conditional transfer in equilibrium, t^*, is a function of the three parameters α, β and y^L. With a slight abuse of notation we will write $s^* = (p^*, t^*)$, or, more explicitly:[16]

$$s^*(\alpha, \beta, \gamma, y^L) = (p^*(\alpha, \beta, \gamma), t^*(\alpha, \beta, y^L)). \tag{11}$$

The quantities we will focus on in the subsequent analysis are: the equilibrium effort-cum-probability $p^*(\alpha, \beta, \gamma)$, the equilibrium expected income $y^*\left(\alpha, \beta, \gamma, y^L\right)$, and the equilibrium expected material utility $u^*\left(\alpha, \beta, \gamma, y^L\right)$, where

$$y^*\left(\alpha, \beta, \gamma, y^L\right) = \left[(\beta - 1)\, p^*\left(\alpha, \beta, \gamma\right) + 1\right] y^L \tag{12}$$

$$\begin{aligned} u^*\left(\alpha, \beta, \gamma, y^L\right) &= \ln y^L + \gamma \ln\left[1 - p^*(\alpha, \beta, \gamma)\right] + p^*(\alpha, \beta, \gamma)^2 \ln \beta \\ &\quad + p^*(\alpha, \beta, \gamma)\left[1 - p^*(\alpha, \beta, \gamma)\right] \ln\left[\beta - \max\left\{0, \frac{\alpha\beta - 1}{1+\alpha}\right\}\right] \\ &\quad + p^*(\alpha, \beta, \gamma)\left[1 - p^*(\alpha, \beta, \gamma)\right] \ln\left[1 + \max\left\{0, \frac{\alpha\beta - 1}{1+\alpha}\right\}\right]. \end{aligned} \tag{13}$$

Certain comparative-statics results fall out immediately. In particular, an increase in the low output, y^L does not affect effort but increases both the expected income and the expected material utility. Moreover, an increase in the utility of leisure, γ, reduces effort (when positive) and hence the expected income.[17]

4.1 The effect of altruism

As for the common degree of altruism, α, we begin by pointing out that there is a simple and clear answer to the following question: For a given climate, y^L and y^H, and disutility of

[16] A pair $s^* = (p^*, t^*)$ is, strictly speaking, not a *strategy* in the game G, since it only specifies the conditional transfer, not the full transfer function. However, such a pair uniquely determines a strategy in G.

[17] It does not appear meaningful to analyze the comparative-static effect on material utility of such a parameter change.

effort, γ, what common degree of altruism, α, leads to the highest expected material utility in equilibrium? The answer is: full altruism.

Proposition 2 $\arg\max_{\alpha\in[0,1]} u^*(\alpha, \beta, \gamma, y^L) = \{1\}$.

This result, which is proved in the appendix, is not surprising. When both individuals are fully altruistic, each individual fully internalizes the external effect of his or her own behavior on the other's material utility. Hence, their incentives are then perfectly aligned, with each individual acting like a utilitarian welfare maximizer. For other degrees of altruism, however, their incentives are imperfectly aligned and there is room for both free-riding and empathy.

This result can be used to further conclude that equilibrium is Pareto-efficient (in terms of the individuals' altruistic preferences) if and only if both individuals are fully altruistic:

Corollary 1 *Suppose that the two individuals have identical Cobb-Douglas preferences (2) with altruism $\alpha \in [0, 1]$. The unique subgame perfect equilibrium is Pareto efficient if and only if $\alpha = 1$.*

Proof: Given the symmetry of the unique equilibrium outcome, this is Pareto efficient if and only if it maximizes the sum of both individuals' expected welfare levels, as defined in equation (1). If each individual chooses the effort-*cum*-probability p and gives the transfer t when rich and the other is poor, the mentioned sum is $S(p,t) = 2(1+\alpha)W(p,t)$, where $W(p,t)$ is defined in the proof of proposition 2. For any value of α, this is strictly increasing in $W(p,t)$. But, by proposition 2, in an equilibrium of game G the expected material utility u^* coincides with the maximum value of $W(p,t)$ if and only if $\alpha = 1$. **End of proof.**

It may come as a surprise that the outcome is inefficient even in the absence of altruism, $\alpha = 0$. In the absence of this externality, why does not the strife of selfish individuals lead to a Pareto-efficient outcome? The answer is that both individuals' utility can be increased by having them make the same effort as in equilibrium, but have the rich give a transfer to the poor when they end up with distinct outcomes. For a sufficiently small such "forced transfer", their expected material utility increases. This follows from the concavity of the material utility from consumption (here the logarithm function).[18]

We next analyze the effect of altruism on effort, income and material utility.

[18] To see this, differentiate $W(p,t)$ in quation (31) with respect to t at $t = 0$.

4.1.1 On effort

We saw previously that increasing altruism has two counter-acting effects on an individual's effort; what we called the free-rider effect and the empathy effect. What is the net equilibrium effect on efforts and transfers when moving from a society with less altruistic individuals to a society with more altruistic individuals? Numerical examples suggest that, for a given climate, an increase in the common level of altruism may result in an increase or a decrease of the equilibrium effort-*cum*-probability. For instance, in the climate $y^L = 7$ and $\beta = 2$: while selfish individuals choose effort-*cum*-probability .28, fully altruistic individuals choose effort-*cum*-probability .32. By contrast, in the harsher climate $y^L = 1$ and $\beta = 10$ a similar change in the common degree of altruism leads to a decrease in the effort-*cum*-probability from .78 to .72. Clearly then, in general, the equilibrium effort is not monotonic in altruism. We show in the appendix that p^* is decreasing in α at $\alpha = \hat{\alpha}$ and increasing in α at $\alpha = 1$, and we illustrate the dependence on α by means of numerical examples.

Proposition 3 *Suppose that both individuals are equally altruistic. If their common degree of altruism, α, equals $\hat{\alpha} = 1/\beta$, then $p^*(\alpha + \Delta\alpha) < p(\alpha)$ for $\Delta\alpha > 0$ sufficiently small. If instead $\alpha = 1$, then $p^*(\alpha - \Delta\alpha) < p(\alpha)$ for $\Delta\alpha > 0$ sufficiently small.*

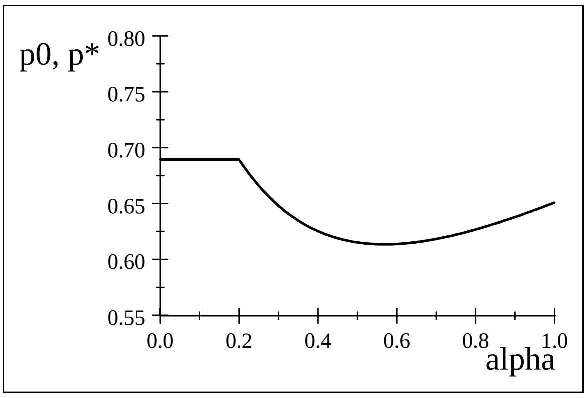

Figure 1: p^0 and p^* for $(\alpha, \beta, \gamma, y^L) = (\alpha, 5, \frac{1}{2}, y^L)$.

Figure 1 shows the equilibrium effort-*cum*-probability p^* as a function of the common degree of altruism α, for $\beta = 5$ and $\gamma = 1/2$. When altruism is weak ($\alpha \leq \hat{\alpha} = .2$), the individuals expect no transfers from each other, and therefore choose the autarky effort $p^0 \simeq .69$. As α increases beyond $\hat{\alpha}$, each individual expects to receive a transfer should he be unlucky and the other individual lucky. This gives rise to the free-rider effect; an increase in the other individual's altruism reduces the marginal expected material utility return from increasing one's own effort. However, there is also the empathy effect, namely, that an increase in own altruism, beyond $\hat{\alpha}$ increases the marginal expected psychic utility return from increasing one's own effort. We see in Figure 1 that when altruism is moderate, the free-rider effect dominates — an increase in α then decreases the equilibrium effort— while when altruism is strong the empathy effect becomes relatively more important at the margin—increasing α then increases the equilibrium effort. This result is in stark contrast with models with one-sided altruism, i.e., where only one individual cares about the other one: then the equilibrium effort of the selfish individual decreases in the altruism level of the other individual, since then only the free-rider effect is present.

In Figure 1 effort is highest for low levels of altruism: in this case the free-rider effect always outweighs the empathy effect.[19] This need not be the case, however. Figure 2 shows an example where the equilibrium effort level is highest for high levels of altruism ($\beta = 2$ and $\gamma = 1/2$).

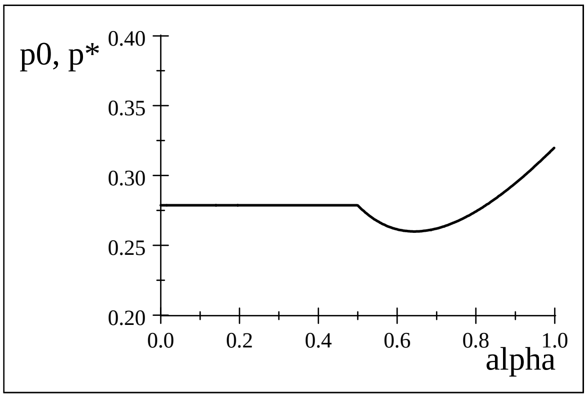

Figure 2: p^0 and p^* for $(\alpha, \beta, \gamma, y^L) = (\alpha, 2, \frac{1}{2}, y^L)$.

While the preceding discussion and examples focus on interior solutions, we conclude by examining an example when in autarky the individuals exert no effort; $p^0 = 0$. Then the free-rider effect evidently has no bite. As a result, the equilibrium effort may only increase when the common degree of altruism increases. See Figure 3, which shows how the equilibrium effort depends on altruism, for $\beta = 2$ and $\gamma = 0.75$.

[19] In the figure the lowest equilibrium level of effort is positive. In the Cobb-Douglas specification it can be shown generally that if the autarky equilibrium effort is positive (i.e., if $p^* > 0$ for $\alpha < \widehat{\alpha}$), then the equilibrium effort is also positive for $\alpha \geq \widehat{\alpha}$.

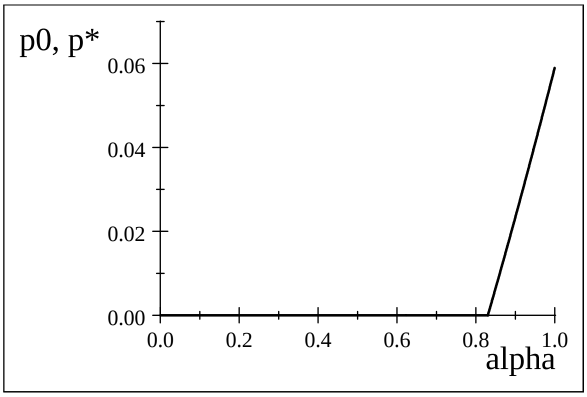

Figure 3: p^0 and p^* for $(\alpha, \beta, \gamma, y^L) = (\alpha, 2, \frac{3}{4}, y^L)$.

4.1.2 On expected income

In this two-person economy the expected income, as defined in (12), depends not only directly on the climatic conditions, by way of better output for given efforts, but also on the incentives to provide effort that they generate. Since the expected income is a positive affine function of the equilibrium effort $p^*(\alpha, \beta, \gamma)$ (see equation (12)), it follows that the expected per capita equilibrium income typically is a non-monotonic function of the degree of altruism α in society.

4.1.3 On expected material utility

Figures 4 and 5 show the expected material utility as a function of altruism, for two different climates. Figure 4 represents the harsher climate, and 5 the more favorable and more forgiving one. In both climates the expected material utility is monotonically increasing in the common degree of altruism as long as it is sufficiently strong for mutual insurance to occur. We do not have a general analytical result, beyond proposition 2, concerning how the expected material utility in equilibrium varies with the common degree of altruism.

4.2 The effect of climate

Here we study how the equilibrium depends on the climate, as represented by y^H and y^L, or, equivalently, by β and y^L. We will say that a climate gets *more favorable* if the baseline output y^L increases and the high output y^H does not decrease, and *more forgiving* if $\beta = y^H/y^L$ decreases. We saw in expression (9), that the equilibrium probability p^* is a function of α, β and γ. In particular, given these parameter values, it is independent of y^L, the base-

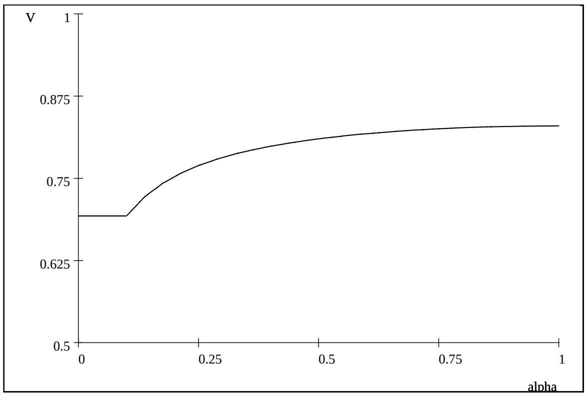

Figure 4: u^* for $(\alpha, \beta, \gamma, y^L) = (\alpha, 10, \frac{1}{2}, 1)$.

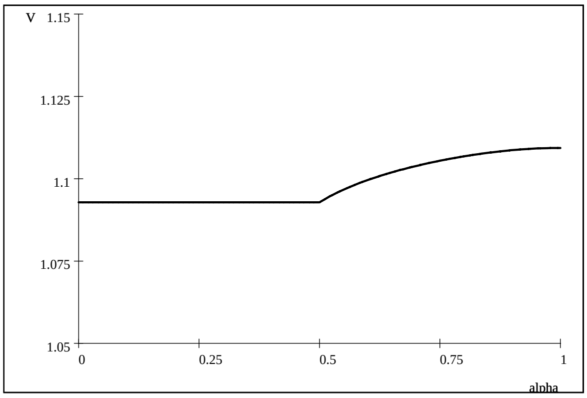

Figure 5: u^* for $(\alpha, \beta, \gamma, y^L) = (\alpha, 2, \frac{1}{2}, 5)$.

line output level. Hence, it does not depend on whether or not a climate is favorable *per se*, only on how forgiving it is. Moreover, it is easily verified that the equilibrium probability p^* is non-increasing in γ; as the disutility of effort increases, the equilibrium level of p^* decreases (when positive). Likewise, based on Proposition 1 one can verify that p^* is non-decreasing in β; as climate becomes "less forgiving," p^* increases (when positive). Formally:

Proposition 4 *Under the hypothesis of proposition 1: if $\alpha\beta \leq 1$ and $F(0) > 0$, then the unique equilibrium effort-cum-probability p^* is a function of α, β and γ, strictly increasing in β and strictly decreasing in γ.*

Proof: To show that p^* is strictly increasing in β, we note that, with some abuse of notation: $\frac{\partial}{\partial \beta} F(p) = \frac{1+\alpha}{1+\beta}(2-p) > 0$. **End of proof.**

We illustrate this result, and study the effect of climate on income and material utility, in the two extreme cases of purely selfish individuals and fully altruistic individuals, respectively.

4.2.1 On selfish individuals

In the case of two selfish individuals, $\alpha = 0$, each individual chooses effort-*cum*-probability p^0, defined in equation (8). Figure 6 shows the graph of p^0 as a function of β, for $\gamma = 1$ (lowest

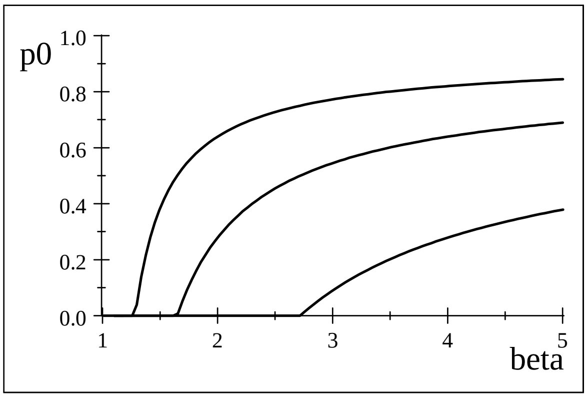

Figure 6: p^0 for $\gamma = 1$, $\gamma = 1/2$, and $\gamma = 1/4$.

curve), 1/2 (middle curve) and 1/4 (highest curve). Each individual's expected income is $y^*\left(0, \beta, \gamma, y^L\right)$, which equals y^L if $p^0 = 0$, i.e., if $\ln \beta \leq \gamma$, and

$$y^*\left(0, \beta, \gamma, y^L\right) = \left[1 + \left(1 - \frac{\gamma}{\ln \beta}\right)(\beta - 1)\right] \cdot y^L$$

otherwise. In sum: the equilibrium effort, p^0, is strictly increasing in β, for all β sufficiently large ($\beta > e^\gamma$). While the equilibrium effort is independent of the base-line output level y^L, the expected income is increasing in this parameter.

What happens if we move to a more *favorable and forgiving* climate: will the detrimental effect on effort be stronger or weaker than the positive effect on base-line output?

Figure 7 shows three isoquants for the expected equilibrium income (for $\gamma = 1/2$), the relevant region being the triangle above the diagonal. We see that the expected equilibrium income may be higher or lower in a more favorable and forgiving climate. Hence, if climate A is a less favorable and less forgiving than climate B, then selfish individuals exert more effort in climate A, and they may earn a higher or a lower expected income in climate B.

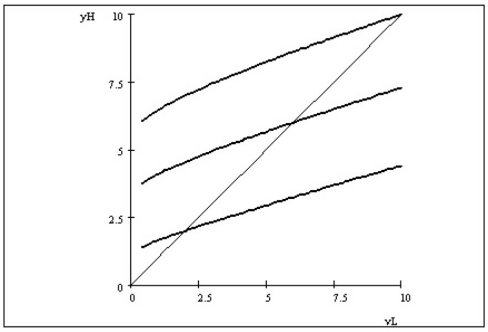

Figure 7: Isoquants $y^0 = 1$, $y^0 = 3$, and $y^0 = 5$ for $(\alpha, \beta, \gamma, y^L) = (0, \beta, \frac{1}{2}, y^L)$.

Although a more favorable climate has an ambiguous effect on the expected income, the expected material utility increases. In sum:

Proposition 5 *Suppose that $\alpha = 0$ and $\ln \beta > \gamma$. The equilibrium effort-cum-probability is then positive. The expected income may be higher or lower in more favorable and forgiving climates. The expected material utility, however, is higher in more favorable climates, even if these are less forgiving.*

Proof: It remains to prove the last claim. This is immediate when $\ln \beta \leq \gamma$, since then $p^0 = 0$ and hence $c = y^L$ with probability one. For $\ln \beta > \gamma$:

$$\begin{aligned} u^*(0, \beta, \gamma, y^L) &= \frac{\gamma}{\ln \beta} \ln y^L + \left(1 - \frac{\gamma}{\ln \beta}\right) \ln y^H + \gamma \ln\left(\frac{\gamma}{\ln \beta}\right) \\ &= \ln y^H + \gamma \ln\left(\frac{\gamma}{\ln y^H - \ln y^L}\right) - \gamma, \end{aligned}$$

an increasing function of y^L and y^H. (To see the latter claim, write $x = \ln y^H$ and note that the derivative of u^* with respect to x is $1 - \gamma / \ln \beta > 0$.). **End of proof.**

4.2.2 On fully altruistic individuals

Consider the opposite extreme case of fully altruistic individuals: $\alpha = 1$. With concave utility from consumption, this implies that they always share the total output equally. More exactly, the conditional transfer, from the rich individual to the poor, is $t = \left(y^H - y^L\right)/2$, resulting in consumption

$$\bar{y} = \frac{y^H + y^L}{2}$$

whenever one individual is rich and the other poor. From the above proposition, we obtain that the unique Nash equilibrium probability p^*, when positive — that is, when $2\ln\left[(1+\beta)/2\right] > \gamma$ — is defined by

$$p^* = \frac{2\ln\left(\frac{(1+\beta)^3}{8\beta}\right) - \sqrt{4\left(\ln\left(\frac{(1+\beta)^3}{8\beta}\right)\right)^2 - 8\ln\left(\frac{(1+\beta)^2}{4\beta}\right)\left(2\ln\left(\frac{1+\beta}{2}\right) - \gamma\right)}}{4\ln\left(\frac{(1+\beta)^2}{4\beta}\right)}. \tag{14}$$

Figure 8 shows p^* as a function of β, for $\gamma = 1$ (lowest curve), 1/2 (middle curve) and 1/4

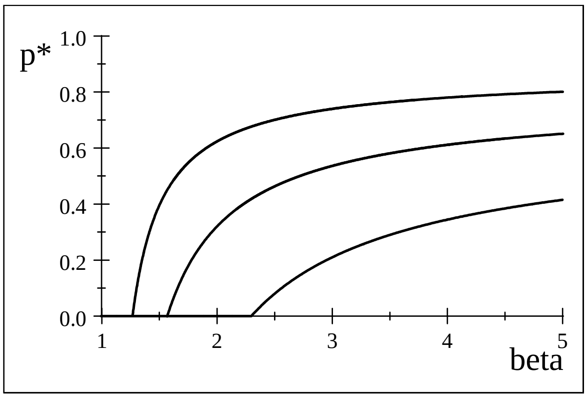

Figure 8: p^* for $(\alpha, \beta, \gamma, y^L) = (1, \beta, 1, y^l)$ (bottom curve), $(\alpha, \beta, \gamma, y^L) = (1, \beta, \frac{1}{2}, y^l)$, and $(\alpha, \beta, \gamma, y^L) = (1, \beta, \frac{1}{4}, y^l)$ (top curve).

(highest curve). Just as in the case of purely selfish individuals, the expected income also to full altruists may be higher or lower in a more favorable and forgiving climate, as the following numerical example shows. In the climate $y^L = 1$ and $\beta = 10$ the equilibrium effort with fully altruistic individuals is $p^1 \simeq .72$ and the expected income is close to 7.5. Now if the climate changes to the more favorable and forgiving climate $y^L = 5$ and $\beta = 2$ the equilibrium effort decreases to $p^1 \simeq .32$, and the expected income to around 6.6. By contrast, if the climate instead becomes $y^L = 7$ and $\beta = 2$, which is also more favorable and forgiving than the original one, then the equilibrium effort decreases to $p^1 \simeq .32$ as well (since $\beta = 2$ in both cases), but the expected income increases to about 9.24. As with selfish individuals we find:

Proposition 6 *Suppose that both individuals are fully altruistic,* $\alpha = 1$*. The equilibrium effort-cum-probability is positive when* $2\ln\left[(1+\beta)/2\right] > \gamma$*. The expected income may be higher or lower in more favorable and forgiving climates. The expected material utility, however, is higher in more favorable climates, even if these are less forgiving.*

Proof: It remains to prove the last claim. We saw in the proof of proposition 2 that the equilibrium coincides with the Benthamite social optimum when $\alpha = 1$. It is evident that the Benthamite optimum is non-decreasing in y^L and non-decreasing in y^H, since the social planner could have suggested the same (p, t) if these parameters were raised. Hence, the same holds for the (unique) equilibrium. Moreover, we have already noted, by inspection of equation (13), that the expected material utility is strictly increasing in y^L. Since $p^* > 0$ when $2\ln[(1+\beta)/2]$ exceeds γ, it is easily verified that then the expected material utility is strictly increasing also in y^H. **End of proof.**

4.2.3 On somewhat altruistic individuals

Figures 9 and 10 illustrate the ambiguous effect of climate on the expected income for all levels of altruism. Figure 9 displays the expected per capita equilibrium income as a function

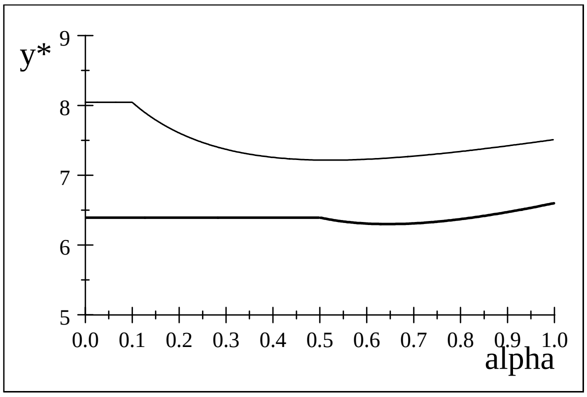

Figure 9: y^* for $(\alpha, \beta, \gamma, y^L) = (\alpha, 10, \frac{1}{2}, 1)$ (thin line), and for $(\alpha, \beta, \gamma, y^L) = (\alpha, 5, \frac{1}{2}, 2)$ (thick line).

of altruism, for two different climates. The thin line corresponds to a harsh climate: the base-line output is small ($y^L = 1$), and the potential relative return to effort is high ($\beta = 10$). The thick line represents a more favorable and more forgiving climate ($y^L = 5$ and $\beta = 2$). The low output is higher in the more favorable than in the harsh climate, and the high outputs are the same. But because the return to effort is smaller in the more favorable climate, also the equilibrium effort is then smaller. Here the effect is so strong that the expected *per capita* income is larger in the harsh climate, despite the larger maximal output in the more favorable climate. This need not be the case, however. For instance, if in the more favorable climate the low output is $y^L = 7$ instead, then the expected *per capita* income is higher in the more favorable climate, as shown in Figure 10.

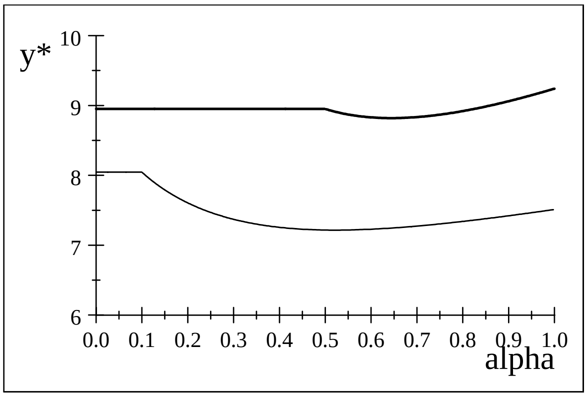

Figure 10: y^* for $(\alpha, \beta, \gamma, y^L) = (\alpha, 10, \frac{1}{2}, 1)$ (thin line), and for $(\alpha, \beta, \gamma, y^L) = (\alpha, 2, \frac{1}{2}, 7)$ (thick line).

4.3 Income taxation

Suppose that all income were taxed at a fixed rate $\tau \in [0, 1]$, but transfers were not taxable, and suppose that the accrued tax revenue were spent on some public good that does not interact with private consumption and effort. What would the effect of such taxation be on the equilibrium outcome, in a given climate and for a given degree of altruism? The answer can be obtained directly from the above analysis, by way of replacing the two output levels, y^L and y^H, by $(1 - \tau) y^H$ and $(1 - \tau) y^L$, respectively, while keeping all other parameters fixed. In particular, β would be unaffected—a flat income tax rate is equivalent with a less favorable but equally harsh climate. From the preceding analysis we conclude that, with Cobb-Douglas preferences, effort would not be affected by a proportional income tax. Hence, the expected disposable income would simply shrink by the factor $1 - \tau$.

By contrast, effort would decrease if a progressive income tax were introduced—a higher tax rate for the high output than for the low—since this would be equivalent with a decrease in β. In this case, it is as if climate would become less favorable but more forgiving.

4.4 Institutional quality

Countries not only differ in climate (and tax systems) but also with respect to the quality of their institutions. Of particular relevance for the present context is the protection of private property. Our model is easily extended to incorporate a crude representation of this aspect as follows. Suppose that "rich" individuals are exposed to the risk of being "robbed" (by a third party). More exactly, let $(1 - \delta) \in [0, 1]$ be the probability that an individual who has obtained the high output level, y^H, is robbed before any potential transfer has been given, and suppose that the amount robbed is $y^H - y^L$. Hence, robbery brings down a rich individual's wealth to that of a poor individual, from y^H to y^L. Poor individuals are not robbed and no robbing occurs after interpersonal transfers have been made. We interpret the parameter δ as a measure of institutional quality, with $\delta = 0$ representing the lowest possible institutional quality (minimal protection of private property) and $\delta = 1$ the highest possible (maximal protection of private property).

This extension is formally straight-forward in the special case of Cobb-Douglas material utility. For any effort $x_i \geq 0$ that an individual i makes, the probability for the high output level y^H is now $p_i = \delta\left(1 - e^{-x_i}\right)$, where $\delta = 1$ is the special case analyzed in the two preceding sections. Hence, for an individual with disutility γ of effort, the material utility function becomes

$$u(c_i, p_i) = \ln c_i + \gamma \ln(1 - p_i/\delta),$$

where $p_i \in [0, \delta)$ is the resulting probability of possessing the high output, with due account for the probability of robbery.[20]

Hence, the formal analysis of conditional transfers is unaffected, while the determination of equilibrium probabilities do change. More precisely, equations (6) and (8) generalize to

$$p_i^* = \max\left\{0, \delta - \frac{\gamma}{H_i\left(p_j\right)}\right\} \quad \text{and} \quad p^0 = \max\left\{0, \delta - \frac{\gamma}{\ln \beta}\right\},$$

and the function F in proposition 1 becomes

$$F\left(p\right) = \alpha \ln \alpha + (1+\alpha) \ln \frac{1+\beta}{1+\alpha} - (1+\alpha)\left(\ln \frac{1+\beta}{1+\alpha} + \ln \frac{\alpha + \alpha/\beta}{1+\alpha}\right) p - \frac{\gamma}{\delta - p}.$$

It follows that, *ceteris paribus*, the equilibrium effort is lower in a society with lower institutional quality. If we compare a society with strong family ties (high α) but low institutional quality (low δ) — the case in many developing countries — with one with weak family ties (low α) but high institutional quality (high δ) — the case in some of the most advanced economies — the preceding analysis implies that, for moderately strong family ties (α not too close to 1), the equilibrium effort would be higher in the second society, even if the two countries had identical climates. However, if the family ties in the first society are very strong (α close to 1) and the institutional quality not too low (δ not too far below 1), then the equilibrium effort may be higher in the first society than in the second.

[20] To see this, note that $e^{-x_i} = 1 - p_i/\delta$ and hence the utility from effort, $-\gamma x_i$, equals $\gamma \ln\left(1 - p_i/\delta\right)$.

5 Coerced altruism

The model developed and analyzed above presumes voluntary transfers, given because of altruism. It seems empirically relevant to study a closely related, but distinct case, namely, when transfers are given more because of family and cultural expectations than by an "inner motive." As suggested in some of the quotes in the introduction (notably from Max Weber), such a tension between, on the one hand, the individual's desires and, on the other hand, the surrounding society's expectations and social norms, may be an important explanatory factor behind economic growth and development in parts of the world. An individual who lives in a society where he or she is expected to share his or her income with other family members, sometimes even with such relatively distant family members as first or second cousins, may rationally expect to have to transfer so much that the motive for making effort in the first place is diluted. The same phenomenon occurs in partnerships between selfish individuals who share output according to some prescribed but not formally sanctioned rule.

In order to shed some light on this phenomenon, we analyze the following variant of the model in section 2: In the second stage, individuals give transfers according to a (socially) prescribed rule, which is for the rich to give a transfer to the poor just as an altruistic rich person would do. In other words, both individuals are forced to behave in the second period of the game as if they had more altruistic preferences than they actually have. This modification amounts to replacing the game G by the following game: In the first period each individual simultaneously chooses an effort-*cum*-probability for high output. Each individual then correctly anticipates the ensuing transfers in the different states in the second period. These transfers are defined by the pair of conditional equilibrium transfer functions in lemma 1, when applied to a common high degree of altruism, which we denote $\tilde{\alpha} > 0$. Both individuals' true degree of altruism, however, is $\alpha \leq \tilde{\alpha}$.[21]

Denote by $\tilde{\Pi}_i(\mathbf{p})$ the *expected welfare* of individual i as evaluated in period 1. Then

$$\begin{aligned}\tilde{\Pi}_i(\mathbf{p}) = {} & p_i p_j[u(y^H, p_i) + \alpha u(y^H, p_j)] \\ & + (1-p_i)(1-p_j)[u(y^L, p_i) + \alpha u(y^L, p_j)] \\ & + p_i(1-p_j)\left[u(y^H - \tilde{\tau}_i(\mathbf{y}), p_i) + \alpha u(y^L + \tilde{\tau}_i(\mathbf{y}), p_j)\right] \\ & + p_j(1-p_i)\left[u(y^L + \tilde{\tau}_i(\mathbf{y}'), p_i) + \alpha u(y^H - \tilde{\tau}_i(\mathbf{y}'), p_j)\right],\end{aligned} \tag{15}$$

where $\tilde{\boldsymbol{\tau}}$ is the pair of conditional equilibrium transfer functions in lemma 1 that would apply

[21] For identical individuals, the game $\tilde{G}$ is a generalization of the game $\hat{G}$, with the latter being the special case $\alpha = \tilde{\alpha}$.

if both individuals' degree of altruism had been $\tilde{\alpha}$, and the states $\mathbf{y}$ and $\mathbf{y}'$ are the same as in equation (5). This defines a two-player simultaneous-move game $\tilde{G}$.

We analyze this game in the special case of (a) Cobb-Douglas utility, (b) selfish individuals, $\alpha = 0$, and (c) $\tilde{\alpha} y^H > y^L$, where condition (c) asserts that a "rich" individual is coerced to give a positive transfer to a "poor" individual. Under these conditions, the transfer function $\tilde{\boldsymbol{\tau}}$ satisfies

$$\tilde{\tau}_i(\mathbf{y}) = \frac{\tilde{\alpha} y^H - y^L}{1 + \tilde{\alpha}}$$

whenever $\mathbf{y}$ is such that $y_i > y_j$, while $\tilde{\tau}_i(\mathbf{y}) = 0$ in all other states $\mathbf{y}$.[22] We thus have

$$\begin{aligned} \tilde{\Pi}_i(\mathbf{p}) &= \gamma \ln(1 - p_i) + p_i p_j \ln y^H + (1 - p_i)(1 - p_j) \ln y^L \\ &\quad + p_i(1 - p_j) \ln\left(\frac{y^H + y^L}{1 + \tilde{\alpha}}\right) + p_j(1 - p_i) \ln\left(\frac{\tilde{\alpha}\left(y^H + y^L\right)}{1 + \tilde{\alpha}}\right). \end{aligned} \tag{16}$$

This expression shows that only the free-rider effect is present here: as $\tilde{\alpha}$ increases, the marginal benefit of making effort decreases, since the donor's consumption decreases whereas the recipient's consumption increases. Moreover, the external effect on the other individual is not internalized at all, since $\alpha = 0$. Individual i's best reply $\tilde{p}_i$ to any probability p_j that the other individual may choose is

$$\tilde{p}_i = \max\left\{0, 1 - \frac{\gamma}{\tilde{H}_i(p_j)}\right\} \tag{17}$$

(for $i = 1, 2$ and $j \neq i$), where

$$\tilde{H}_i(p_j) = \ln\beta + (1 - p_j) \ln\left(\frac{1 + 1/\beta}{1 + \tilde{\alpha}}\right) - p_j \ln\left(\frac{\tilde{\alpha}(1 + \beta)}{1 + \tilde{\alpha}}\right).$$

Hence, when positive, $\tilde{p}_i$ is strictly decreasing and concave in p_j. A necessary first-order condition for an interior and symmetric Nash equilibrium is $\tilde{F}(p) = 0$, where

$$\tilde{F}(p) = \ln\frac{1 + \beta}{1 + \tilde{\alpha}} - p \ln\left[\frac{\tilde{\alpha}}{\beta}\left(\frac{1 + \beta}{1 + \tilde{\alpha}}\right)^2\right] - \frac{\gamma}{1 - p}.$$

Proposition 7 *Suppose that the two individuals have identical Cobb-Douglas preferences (2), that they are selfish ($\alpha = 0$), but are coerced to give transfers as if their altruism level*

[22] A more subtle social norm, also possible to analyze, is when transfers are expected only if the recipient has made a (sufficient) effort to sustain him- or herself.

were $\tilde{\alpha}$, where $\tilde{\alpha}\beta > 1$. Then the associated game, $\tilde{G}$, has a unique Nash equilibrium. This equilibrium is symmetric, $p_1 = p_2 = \tilde{p}^*$, and $\tilde{p}^* = \max\{0, \tilde{p}\}$, where $\tilde{p} = \{p \in [0,1) : \tilde{F}(p) = 0\}$.

This proposition is proved in the appendix. Since here only the free-rider effect is present, the following result comes as no surprise:

Proposition 8 *Suppose that $\tilde{\alpha}\beta > 1$. If the level of coerced altruism $\tilde{\alpha}$ is increased, while individuals remain selfish, then the equilibrium effort-cum-probability decreases.*

Proof: Differentiation of the equilibrium equation $\tilde{F}(p) = 0$ with respect to $\tilde{\alpha}$ gives

$$\frac{d\tilde{p}}{d\tilde{\alpha}} = -\frac{\tilde{\alpha} + \tilde{p}(1-\tilde{\alpha})}{\tilde{\alpha}(1+\tilde{\alpha})\left[\ln\left(\frac{\tilde{\alpha}}{\beta}\left(\frac{1+\beta}{1+\tilde{\alpha}}\right)^2\right) + \frac{\gamma}{(1-\tilde{p})^2}\right]} \tag{18}$$

From the proof to proposition 7 we recall that $\ln\left(\frac{\tilde{\alpha}}{\beta}\left(\frac{1+\beta}{1+\tilde{\alpha}}\right)^2\right) \geq 0$ iff $(\beta - \tilde{\alpha})(\tilde{\alpha}\beta - 1) \geq 0$, and hence $d\tilde{p}/d\tilde{\alpha} < 0$ when $\tilde{\alpha}\beta > 1$. **End of proof.**

This proposition implies that there is a trade-off between risk-sharing—by way of coerced altruism—and the incentive to provide effort. Is the expected benefit of risk-sharing sufficiently large to outweigh the cost of having the incentives to provide effort? Relatedly, can the optimal level of coerced altruism be sufficiently high for mutual insurance to occur?

In order to find this out, we note that equation (16) implies that the expected material utility in equilibrium is, with a slight abuse of notation,

$$\tilde{\Pi} = \gamma \ln(1-\tilde{p}) + \tilde{p}^2 \ln y^H + (1-\tilde{p})^2 \ln y^L + \tilde{p}(1-\tilde{p})\left[\ln\tilde{\alpha} - 2\ln\frac{1+\tilde{\alpha}}{y^H + y^L}\right]. \tag{19}$$

Figure 11 shows this equilibrium expected material utility as a function of the level of coerced altruism $\tilde{\alpha}$, when preferences are Cobb-Douglas, $y^L = 1$, $\gamma = 1/2$, and $\beta = 5$. This figure suggests that in this example the level of coerced altruism that maximizes the expected material utility is approximately 1/2: in a society without formal insurance markets, a social norm of coerced altruism may be a substitute (see next section).

6 Insurance

Consider an economy consisting of a large number of identical individuals engaged in pairwise interactions of the form analyzed in sections 2 and 3. We saw in sections 4 and 5

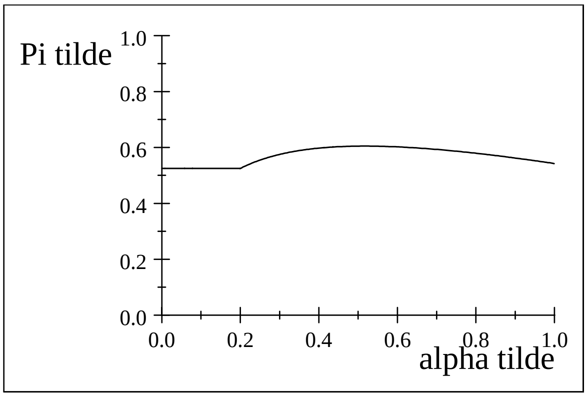

Figure 11: Expected material utility under coerced altruism for $(\alpha, \tilde{\alpha}, \beta, \gamma, y^L) = (0, \tilde{\alpha}, 5, \frac{1}{2}, 1)$.

that strong altruism, voluntary or socially coerced, can act as a form of insurance within interacting pairs. Suppose, instead, that individuals are selfish but can buy insurance. If insurance companies cannot observe effort, only output, can private insurance companies operate in this moral-hazard environment, and can the presence of an insurance market lead to a Pareto improvement? How does such formal insurance compare with informal insurance by way of coerced altruism? How do individuals fare, in terms of their material utility, in comparison with a situation in which they would be fully altruistic? We here analyze these questions.[23]

6.1 Formal insurance of selfish individuals

Consider a large population of selfish individuals engaged in pair-wise interactions of the form described in section 3.1. By the law of large numbers, the fraction of individuals who end up with the low output is approximately $1 - p^*$, where p^* is the unique equilibrium probability for low output in each pair. Can private insurance companies operate in this environment, and can this lead to a Pareto improvement? How does formal insurance compare with coerced altruism?

Consider insurance policies (π, σ), where the insurance premium is πy^L and the coverage of the loss to an individual who obtains the low output instead of the high is $\sigma \left(y^H - y^L\right)$.

[23] We do not analyze, however, formal insurance when individuals are altruistic. In such situations, there is an additional moral-hazard problem that could be significant, namely, that individuals may strategically choose to under-insure in the hope of being helped out by others, if the latter cannot commit not to help uninsured individuals in dire straits (c.f. Lindbeck and Weibull, 1988).

We require an insurance policy (π, σ) to satisfy $\pi, \sigma \geq 0$, $\pi < \beta$ and $\pi < 1 + \sigma(\beta - 1)$, so that an insured individual's consumption always is positive.

In the extreme case of $\sigma = 1$ there is full coverage, i.e., an insured individual's consumption would then be the same whether his or her output is high or low. Clearly this would eliminate all incentive to exert effort. For lower coverage, however, individuals may still have some incentive to exert effort. We suppose that individuals' efforts are non-verifiable to the insurer, while the obtained output levels are verifiable. The only interesting case is when individuals in autarky exert positive effort. We therefore focus on the case when $\ln \beta > \gamma$.

In the presence of such an insurance policy (π, σ), each individual in effect faces a binary choice: either to not buy the insurance and make the optimal autarky effort $p^0 = 1 - \gamma / \ln \beta > 0$, or else to buy the insurance and make the optimal autarky effort when y^H is replaced by $y^H - \pi y^L$ and y^L is replaced by $y^L - \pi y^L + \sigma\left(y^H - y^L\right)$,

$$p^* = \max\left\{0, 1 - \frac{\gamma}{\ln \beta^*}\right\}, \tag{20}$$

where

$$\beta^* = \frac{\beta - \pi}{(\beta - 1)\sigma + 1 - \pi} \geq 1.$$

The expected profit to the insurer, per insured individual, is

$$\Pi = \pi y^L - \sigma\left(y^H - y^L\right)(1 - p^*),$$

where $\Pi = 0$ if and only if the insurance policy is actuarially fair. Using (20), we re-write the *profitability condition* $\Pi \geq 0$ as

$$\frac{\pi}{(\beta - 1)\sigma} + \max\left\{0, 1 - \frac{\gamma}{\ln\left[\frac{\beta - \pi}{(\beta - 1)\sigma + 1 - \pi}\right]}\right\} \geq 1 \tag{21}$$

For given parameters γ and β, this condition defines an upper bound, $\bar{\sigma}(\pi) \leq 1$, on the coverage σ for each premium $\pi \in [0, 1]$. More exactly, (21) holds for all $\sigma \leq \bar{\sigma}(\pi)$.[24]

Suppose, first, that $\ln \beta^* < \gamma$. Then each insured individual finds it optimal to exert no effort, $p^* = 0$. In this case, the insurance plays no role: no-one buys it if it gives a profit, and all individuals are indifferent between buying and not buying an actuarially fair policy

[24] The left-hand side is continuous and decreasing in σ, from $+\infty$ when $\sigma = 0$. Hence, the inequality is met on a closed interval of the form $[0, b]$.

since they anyhow receive the income y^L for sure.

Secondly, suppose that $\ln \beta^* > \gamma$. Then each insured individual finds it optimal to exert the effort $p^* = 1 - \gamma / \ln \beta^*$. In this case, the profitability condition (21) boils down to

$$\frac{\pi}{(\beta - 1)\,\sigma} \ln \left[\frac{\beta - \pi}{(\beta - 1)\,\sigma + 1 - \pi} \right] \geq \gamma \tag{22}$$

Will anyone buy the insurance in this second case? By definition, each individual then finds it optimal to buy the insurance if and only if the expected utility from doing so and taking the effort resulting in p^* is no less than the expected utility from not buying the insurance and taking the effort resulting in p^0. After some algebraic manipulation, we find that insurance is optimal to buy, assuming $\ln \beta^* > \gamma$, if and only if

$$\left(\frac{\beta - \pi}{\beta} \right)^{1/\gamma} \ln \beta \geq \ln \left[\frac{\beta - \pi}{(\beta - 1)\,\sigma + 1 - \pi} \right]. \tag{23}$$

We have established:

Proposition 9 *Suppose that* $\ln \beta > \gamma$. *There exists a profitable insurance policy* (π, σ) *that individuals buy, and under which all individuals make positive effort if and only if (22), (23) and*

$$\ln \left[\frac{\beta - \pi}{(\beta - 1)\,\sigma + 1 - \pi} \right] > \gamma. \tag{24}$$

We illustrate the three constraints in Figure 12, with the premium rate π on the horizontal axis and the coverage rate σ on the vertical, for $\gamma = 1/2$, and $\beta = 5$. For these parameter values, constraint (24) is not binding. Insurance polices $(\pi, \sigma) \geq 0$ below the initially steeper curve satisfy the profitability condition (22) and policies above the initially flatter curve satisfy the buying condition (23).[25]

6.2 Comparing with informal insurance by way of altruism

We now turn to an investigation of whether informal insurance, achieved by means of voluntary or socially coerced transfers between pairs of individuals (say, siblings), is a better or worse alternative to formal insurance as analyzed above. A limitation of informal insurance, involving only two individuals, is that no transfers occur from the state of nature in which

[25] We note that all individuals' consumption is positive in all states of nature if $\pi < \max\{5, 1 + 4\sigma\}$.

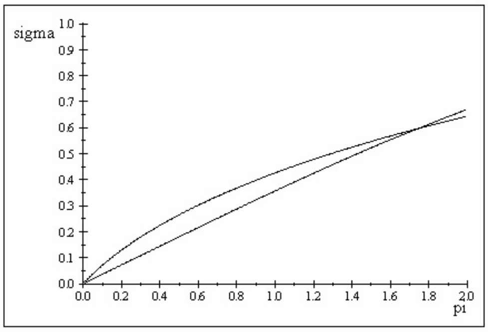

Figure 12: Profitability and buying constraints for formal insurance.

both individuals are rich to the state of nature in which both are poor. By contrast, with a formal insurance market covering a large population (which we assume here), such transfers are possible. However, a comparison between formal and informal insurance also needs to take into account the effect on effort, which differ across such schemes.

6.2.1 Selfish individuals with access to formal insurance

Assume that all individuals are selfish ($\alpha = 0$) and have access to an actuarially fair insurance policy, *i.e.*, $\pi = \sigma(1 - p^*)(\beta - 1)$. The *optimal* actuarially fair policy, that is, the one that yields the highest expected material utility, has a coverage rate σ^* that solves

$$\max_{\sigma \in [0,1]} (1 - p^*) \ln(1 + \sigma p^*(\beta - 1)) + p^* \ln(\beta - \sigma(1 - p^*)(\beta - 1)) + \gamma \ln(1 - p^*), \tag{25}$$

subject to the defining equation for the equilibrium probability of high output, given the insurance policy in question,

$$(1 - p^*) \ln\left(\frac{\beta - \sigma(1 - p^*)(\beta - 1)}{1 + \sigma p^*(\beta - 1)}\right) = \gamma. \tag{26}$$

Using Mathematica to solve this optimization problem, we obtain, for $\beta = 5$ and $\gamma = 1/2$, the coverage $\sigma^* \simeq .323317$. This implies $p^* \simeq 0.48865$ and an expected material utility of about 0.63223.[26]

[26] Note that all three conditions stated in Proposition 9 are satisfied since the equilibrium effort is positive ($p^* > 0$), the solution is interior ($\sigma^* > 0$), and the insurance policy yields zero expected profit.

6.2.2 Fully altruistic individuals without access to formal insurance

We saw that, conditional on there being no formal insurance market, the expected material utility is maximized when individuals are fully altruistic towards each other ($\alpha = 1$): such individuals fully internalize the effect of their own effort choice on the other individual, and total output is always divided equally within a pair. We here provide a numerical example where informal insurance by way of full altruism yields a higher expected material utility than any formal insurance can achieve.

Suppose that $y^L = 1, \gamma = 1/2$, and $\beta = 5$. In the absence of formal insurance, the equilibrium probability of high output is $p^* \simeq 0.65$,and the expected material utility is approximately 0.655, which exceeds the expected material utility under the optimal actuarially fair insurance policy for selfish individuals. With formal insurance but fully altruistic individuals, a poor individual always receives a transfer from the insurance company. However, due to moral hazard, the optimal insurance coverage for selfish individuals is quite low; a poor individual consumes significantly less than a rich one (1.632 compared to 4.339). With full altruism but no formal insurance, conditional on being poor there is a probability .35 of not receiving any transfer, but with probability .65 the other's output is high and the poor individual ends up with the same consumption as the rich one.

6.2.3 Selfish individuals under coerced altruism but without access to formal insurance

We saw before that coerced altruism may be advantageous *ex ante*, in spite of its adverse effect on effort. Here we develop a numerical example where formal insurance is better than coerced altruism (for selfish individuals), despite the even lower effort under formal insurance. Thus, assume again that $y^L = 1$, $\beta = 5$, and $\gamma = 1/2$. The lower line in Figure 13 reproduces the expected material utility as a function of the degree of coerced altruism $\tilde{\alpha}$, as shown previously in Figure **11.** For $\tilde{\alpha} \leq 1/\beta = 0.2$ there is no transfer between the individuals, who therefore choose the autarky effort $p^* = 1 - 0.5/\ln 5 \simeq .689$, so that the expected material utility is

$$(1 - \frac{.5}{\ln 5}) \ln 5 + .5 \ln(\frac{.5}{\ln 5}) \simeq 0.525. \tag{27}$$

As $\tilde{\alpha}$ increases beyond $1/\beta$ the expected material utility increases: here the marginal benefit of coerced altruism (mutual insurance) outweighs its marginal cost (decreased effort). However, at some point the marginal benefit becomes smaller than the marginal cost, and

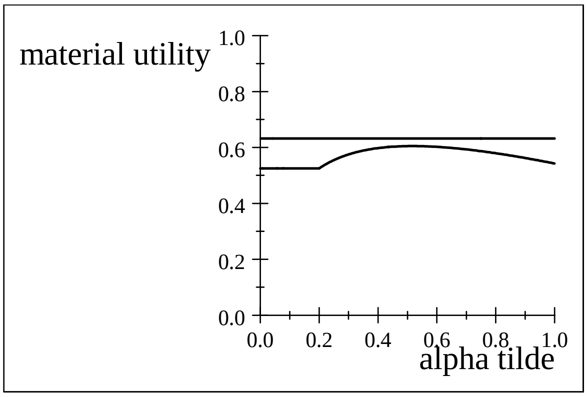

Figure 13: Expected material utility under coerced altruism $(\alpha, \tilde{\alpha}, \beta, \gamma, y^L) = (0, \tilde{\alpha}, 5, \frac{1}{2}, 1)$ (bottom line) and with optimal formal insurance for $(\alpha, \beta, \gamma, y^L) = (0, 5, \frac{1}{2}, 1)$ (top line).

the expected material utility decreases as the degree of coerced altruism is further increased. The figure also shows that the expected material utility under coerced altruism is below 0.63223 (represented by the horizontal line in the figure), the expected material utility under optimal formal insurance (as found above).

6.2.4 In sum

In the above numerical example, the ranking—from best to worst in terms of expected material utility—is as follows: first, informal insurance by way of full altruism, second, actuarially fair insurance, third, informal insurance by way of coerced altruism, and finally, no access to formal or informal insurance. Effort is lowest in a society with selfish individuals and formal insurance, highest in a society with selfish individuals with no insurance possibility. Moreover, effort is lower among selfish individuals under coerced altruism than among fully altruistic individuals without formal insurance possibilities.

7 Evolutionary robustness of altruism

We saw (in proposition 2) that, in the absence of formal insurance and informal insurance by way of coerced altruism, the maximal degree of altruism, $\alpha = 1$, results in higher expected material utility than any lower degree of altruism (including $\alpha = 0$), irrespective of climate. In this sense, full altruism is good. We have also seen (in section 5) that socially coerced altruism may result in low expected material utility. What altruistic behaviors, if any, are robust to evolutionary selection forces, biological and social? How do these forces interact, if at all, with climate? Can migration from one society and climate to another destabilize altruistic or selfish behaviors in the recipient society? These are huge and difficult questions, and we here only show how our model can shed some new light on a few aspects of these questions.

Evidently altruists are vulnerable to "exploitation" by selfish individuals; not only do rich altruists help poor selfish individuals, altruists may even exert extra work effort in order to be able to later help others, while selfish individuals exert just enough effort to sustain themselves, even counting on being helped out by altruists if need be. If selfish "mutants" would enter a homogeneous population of altruistic individuals, the "mutants" would thus seem to thrive in terms of material utility, granted the "incumbent" altruists would behave just as altruistically towards the mutants as they do against other altruists. This would be the case, for instance, if altruists do not know when they meet a mutant, but act as if the other individual were just as altruistic as themselves. It would not necessarily be the case, however, if the altruists would recognize selfish mutants and behave selfishly against them. In such encounters, our numerical examples above suggest that the mutants may not fare so well in comparison with the incumbents if the latter are sufficiently altruistic to each other. What about a large population of selfish individuals? Can it be "invaded" by a small number of altruistic mutants?

To obtain some insights into these and related questions, we first specify a few distinct population scenarios, then apply our model to pair-wise interactions within these. In each scenario, imagine a homogeneous "incumbent" or "native" population of individuals, all with the same degree of altruism α, in a given climate. This population is exposed to a small-scale "invasion" of "mutants", that is, individuals who differ only in their degree of altruism, which we denote $\alpha' \neq \alpha$. Each individual, incumbent or mutant, may encounter an incumbent or a mutant, where the incumbents constitute an overwhelming majority. We consider the following alternative scenarios in such pair-wise encounters:

> *Scenario 1 (naïve individuals):* Here each individual believes that the other individual is of his or her own kind, and behaves accordingly; that is, an incumbent expects the other to behave like an incumbent and a mutant expects the other to behave like a mutant, irrespective of whether the other individual actually is an incumbent or a mutant.
>
> *Scenario 2 (observant individuals):* Here each individual correctly assesses whether the other individual is an incumbent or a mutant, and acts accordingly.
>
> *Scenario 3 (observant and discriminatory individuals):* Here each individual cor-

rectly assesses whether the other individual is an incumbent or a mutant, and acts accordingly when meeting his or her own kind. However, when an incumbent meets a mutant, then both individuals behave selfishly. We will refer to this behavior as *discriminatory altruism*.

In each of these scenarios, we will say that the incumbents' behavior is *evolutionarily robust* against the mutants' behavior, if (i) an incumbent does at least as well against an incumbent as a mutant does against an incumbent, and (ii) a mutant who does equally well against incumbents as these do against themselves does strictly worse against another mutant than incumbents do.[27] It remains to provide a criterion for "doing well." We take the *expected material utility* as the criterion.

If the incumbents' behavior is robust against a certain mutant behavior in this sense, then the mutants will fare less well, on average, than incumbents under uniform random matching in a population, granted the mutants make up a sufficiently small population fraction, since then the probability of meeting a mutant, for incumbents and mutants alike, is very small and hence the mutants do strictly worse than incumbents by continuity. This conclusion does not hold, of course, under selective matching, that is, when mutants interact mostly with each other. However, if mutants interact exclusively with other mutants, and incumbents exclusively with incumbents, then the analysis in section 4.1.3 applies: then mutants fare less well than incumbents if and only if, in equilibrium, the expected material utility to a pair of incumbents is lower than that to a pair of mutants. Under intermediate selective matching, the expected utilities will be convex combinations of those under uniform random matching and exclusively selective matching. Most of the subsequent analysis will be focused on situations in which α and α' are restricted to be either zero, one half or one.

Denote by $s(\alpha, \alpha')$ the unique equilibrium strategy in game G for a player with altruism α facing a player with altruism α' (see section 3). When material utility is additively separable, as we here assume, a strategy consists of an effort-*cum*-probability p, and a transfer function τ that maps output pairs to transfers. In equilibrium, positive transfers occur only if the outputs differ: this conditional transfer was denoted by t in section 3.1. By a slight abuse of notation, write $p(\alpha, \alpha')$ for the equilibrium effort-*cum*-probability of a player with altruism α when playing against a player with altruism α', and let $t(\alpha)$ denote the equilibrium transfer from a player with altruism α in states where this player is rich and the other poor (this transfer is independent of the other player's degree of altruism).

[27] This definition of robustness is nothing but an adaptation of the game-theoretic concept of evolutionary stability (see Maynard Smith (1982) or Weibull (1995)).

Consider now scenarios 1 and 2. If an individual i has altruism α_i, for $i = 1, 2$, and believes that the other has altruism α_j', where $j \neq i$, then the expected material utility to individual i is

$$\begin{aligned} V(\alpha_i, \alpha_j', \alpha_j, \alpha_i') &= p\left(\alpha_i, \alpha_j'\right) p\left(\alpha_j, \alpha_i'\right) u\left[y^H, p\left(\alpha_i, \alpha_j'\right)\right] \\ &+ \left[1 - p(\alpha_i, \alpha_j')\right]\left[1 - p\left(\alpha_j, \alpha_i'\right)\right] u\left[y^L, p\left(\alpha_i, \alpha_j'\right)\right] \\ &+ p\left(\alpha_i, \alpha_j'\right)\left[1 - p\left(\alpha_j, \alpha_i'\right)\right] u\left[y^H - t(\alpha_i), p\left(\alpha_i, \alpha_j'\right)\right] \\ &+ p\left(\alpha_j, \alpha_i'\right)\left[1 - p\left(\alpha_i, \alpha_j'\right)\right] u\left[y^L + t(\alpha_j), p\left(\alpha_i, \alpha_j'\right)\right]. \end{aligned} \tag{28}$$

In scenario 3, the expected material utility to an incumbent is $V(\alpha, \alpha, \alpha, \alpha)$ when matched with another incumbent, while it is $V(0, 0, 0, 0)$ when matched with a mutant, and likewise for mutants.

7.1 Robustness against behavioral mutations

Can a population of fully altruistic individuals resist an invasion by a small number of selfish individuals? Is the reverse true?

7.1.1 Scenario 1

In the first scenario that was laid out above, each individual believes that the other individual has the same degree of altruism as himself, i.e., $\alpha_i = \alpha_j'$, $i, j = 1, 2$. Applying the definition introduced above, selfishness is evolutionarily robust if

$$V(0, 0, 0, 0) > V(1, 1, 0, 0). \tag{29}$$

It is straight-forward to show that (29) holds whenever material utility is additively separable in effort and consumption (see the proof of the proposition below). This is intuitive: the altruist would give a transfer if his output were larger, but would not receive one if his output happened to be smaller. Moreover, here a selfish individual is almost certainly right in believing that his opponent is also selfish—and conditional on this he chooses the effort that maximizes his expected material utility.

Conversely, intuition might suggest that a population consisting of full altruists would not resist a small invasion by selfish individuals, since a selfish individual playing against an altruist may receive a transfer but would not give one. However, this argument fails to recognize the role played by the choice of effort. If the selfish individual chooses a higher effort level than the altruist, $p(0,0) > p(1,1)$, then he is less likely to enjoy the benefit of receiving a transfer than if he were an altruist. Calculations show that this drawback of being selfish may outweigh the benefits, *i.e.*, that $V(1,1,1,1) > V(0,0,1,1)$ sometimes holds, in which case full altruism is evolutionarily robust.

The following proposition is proved in the appendix.

Proposition 10 *In Scenario 1, selfishness is robust against full altruism, for any additively separable material utility function u. Full altruism is not robust against selfishness if $p(1,1) \geq p(0,0)$. There exist parameter values for which full altruism is robust against selfishness.*

Numerical examples using Cobb-Douglas preferences suggest that β has to be above a certain threshold for altruism to be evolutionarily robust, and that this threshold value increases as γ increases. Figure 14 shows the threshold value for β (on the vertical axis) as a function of γ (on the horizontal axis). The intuition is that the benefit from playing against

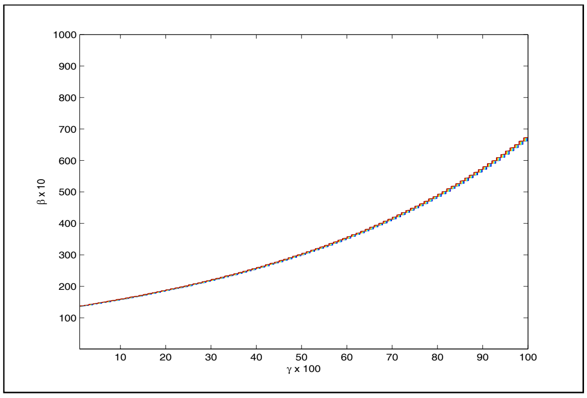

Figure 14: Evolutionary robustness of full altruism when players are randomly matched.

an altruist increases as β increases (since the transfer increases), and, moreover, the effort of a selfish individual increases. Hence, the larger β is, the less likely is a selfish individual to reap the (larger) benefits from meeting an altruist. By contrast, an altruist always reaps those benefits and, when being an incumbent, chooses the approximately optimal effort level. For β sufficiently large, the mutant selfish individual fares less well than an incumbent altruist when meeting an incumbent altruist.

7.1.2 Scenario 2

Suppose instead that each individual observes the other's degree of altruism. Then selfishness is evolutionarily robust if $V(0,0,0,0) > V(1,0,0,1)$, and full altruism is evolutionarily robust if $V(1,1,1,1) > V(0,1,1,0)$. In this scenario, an altruistic mutant does better against a selfish incumbent, as compared with scenario 1. However, selfishness is still robust, since a selfish individual maximizes his expected material utility whereas an altruist in general does not maximize his or her own expected material utility, because of his or her concern for the other. A selfish individual makes less effort in anticipation of the altruist's help if need be. Hence, full altruism is no longer evolutionarily robust. The following proposition is proved in the appendix.

Proposition 11 *In Scenario 2, selfishness is evolutionarily robust whereas full altruism is not.*

7.1.3 Scenario 3

Finally, consider observant and discriminatory individuals. By assumption, such individuals behave selfishly whenever the other individual has a different degree of altruism. Thus, if the incumbents are selfish, then any mutant would obtain the same expected material utility as an incumbent when matched with an incumbent. Moreover, fully altruistic individuals do very well against each other, so selfishness is not robust against full altruism. By contrast, a population consisting of discriminatory and fully altruistic individuals would be robust to a small invasion of selfish mutants, since the incumbents would then behave selfishly against the mutants, and, by proposition 2, $V(1,1,1,1) > V(0,0,0,0)$. This proves

Proposition 12 *In Scenario 3, selfishness is not evolutionarily robust whereas full altruism is.*

7.1.4 Selective matching

In the preceding analysis we assumed that players were randomly matched with equal probability for all potential matches. If instead matching were completely selective, so that mutants were always paired with each other and incumbents with each other, then only full altruism would be robust, since $V(1,1,1,1) > V(0,0,0,0)$. Fully altruistic individuals then have an advantage over selfish individuals in that they provide mutual insurance to each other.

7.2 Kinship altruism

Here we follow Bergstrom's (1995, 2003) analysis of interactions between siblings, where altruism is inherited from parents to children. More specifically, the degree of altruism of an offspring depends on both parents' degrees of altruism in the following way: an offspring is equally likely to inherit the degree of altruism from the father or the mother.[28] Thus, if both parents have degree of altruism α, then both siblings also have altruism α. But if the parents' degrees of altruism differ, say the father's is α whereas the mother's is α', then with probability 1/4 both siblings have degree of altruism α, with probability 1/4 both siblings have degree of altruism α', and with probability 1/2 they have different degrees of altruism. In pair-wise interactions between such siblings we ask whether a population where all siblings have the same degree of altruism α towards each other would resist an "invasion" of a small number of mutant siblings who have a different degree of altruism.

Consider, thus, a homogeneous population where the initial degree of altruism is α. We can think of a sequence of generations in this population as follows. At the beginning of each time period, the individuals who survived to the age of reproduction mate randomly. Each matched pair then has exactly two offspring. Finally, each pair of siblings play the game G exactly once. An individual's payoff in this game can be thought of as a proxy for that individual's probability of surviving until the age of reproduction (the next time period). Now assume that a mutation occurs, and that a proportion $\varepsilon > 0$ of the individuals who are about to reproduce carry the mutant degree of altruism α'. Random mating takes place, and reproduction occurs. Whether or not the mutant degree of altruism is able to invade this population depends on how well a child carrying the mutant degree of altruism does compared to a child carrying the incumbent degree of altruism (since among the offspring approximately the proportion ε carry the mutation). If the latter obtains a greater expected material utility than the former, we will say that the incumbent degree of altruism is *evolutionarily robust* against the mutant (under random mating but sibling interaction).

For any given pair of parents the degrees of altruism of their children are not statistically independent as we saw above. This needs to be taken into account when computing the

[28] If transmission were genetic, this would correspond to the *sexual haploid reproduction* case, where each parent carries one copy of the gene, and the child inherits either the father's or the mother's gene. The human species uses *sexual diploid reproduction*: then each individual has two sets of genetic information, or chromosomes; one set is inherited from the father, and the other from the mother. Whether a gene is expressed or not depends on whether it is recessive (two copies are needed for the gene to be expressed), or dominant (one copy is sufficient for the gene to be expressed). Bergstrom's (2003) analysis of games between relatives shows that the condition for a population carrying the same gene to resist the invasion by a mutant gene in the haploid case, is the same as the condition for a population carrying the same recessive gene to resist the invasion by a dominant mutant gene in the diploid case.

expected material utility of a child. We limit our attention to Scenario 1 above, namely, an individual with degree of altruism α believes that his or her sibling has the same degree of altruism.[29] Then the condition for the incumbent degree of altruism α to resist the invasion by a mutant degree of altruism α' is $D(\alpha, \alpha') > 0$, where

$$D(\alpha, \alpha') = V(\alpha, \alpha, \alpha, \alpha) - \left[\frac{1}{2} V(\alpha', \alpha', \alpha', \alpha') + \frac{1}{2} V(\alpha', \alpha', \alpha, \alpha) \right]$$

and V is the expected material utility defined in (28). The intuition behind this condition is as follows. The first term, $V(\alpha, \alpha, \alpha, \alpha)$, approximates the expected material utility to a child with the incumbent degree of altruism α. For if the proportion of mutant carriers in the parent generation, $\varepsilon > 0$, is close to zero, then with near certainty both parents of this child carry α, implying that the child's sibling also does. The term in the square brackets approximates the expected material utility to a child carrying the mutant degree of altruism α'. For if ε is close to zero, then with near certainty any such child has one parent carrying the mutant degree of altruism, and one parent carrying the incumbent degree of altruism α. Therefore, with probability $1/2$ this child's sibling would carry the mutant degree of altruism α', and with the complementary probability the sibling would carry the incumbent degree of altruism α.

In particular, a population of individuals who are fully altruistic towards their siblings (and they are only matched with siblings here), would resist a small-scale invasion by individuals who are fully selfish if $D(1, 0) > 0$, and the condition for the reverse to be true is $D(0, 1) > 0$. Figure 15 displays the threshold value for β above which a population of altruistic individuals would resist an invasion of selfish mutants, when preferences are Cobb-Douglas. The numerical examples using Cobb-Douglas preferences suggest that altruism between siblings resist the invasion by selfish mutants whenever a selfish mutant's effort is strictly positive. When this effort is zero, however, either an altruist's effort is also zero, in which case $D(1, 0) = 0$, or it is positive, in which case $D(1, 0) < 0$.

Figure 16 shows when selfishness between siblings would resist the invasion by altruistic mutants with Cobb-Douglas preferences. Two distinct sets of parameter pairs (β, γ) satisfy this requirement: either γ is small and β is large (the upper left corner), or β is very small (at the bottom in the graph). Selfishness among siblings resists the invasion by altruists only if β is small enough, or when it is large enough. For small values of β, it seems that a strong driving force behind the resistance of selfishness is that a selfish individual provides little or no effort. The intuition for why selfishness would resist the invasion by altruists

[29] We are aware that scenario 2 might be more realistic, but scenario 1 is the easiest case to analyze.

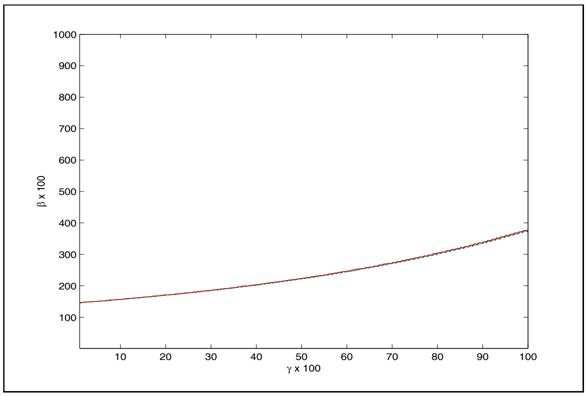

Figure 15: Resistance of full altruism among siblings.

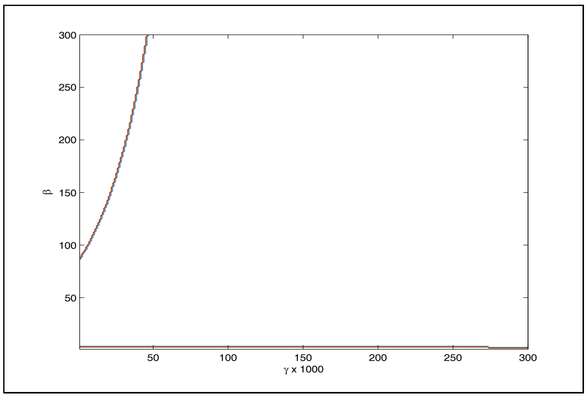

Figure 16: Resistance of selfishness among siblings.

for (β, γ)-pairs above the top curve in Figure 16 is as follows. For these parameter values output variability is high. An altruist would stand to lose much by sharing some of his output, when high, with the other, and by not receiving anything from a selfish sibling, when his own output is low: $V(1,1,0,0)$ is small relative to $V(0,0,0,0)$. For sufficiently large β, this loss is sufficiently large to outweigh the benefit that mutual altruism confers on altruistic siblings.

7.3 Comparing altruism among randomly matched individuals with altruism between siblings

Our analysis suggests that when the interaction takes place between individuals with statistically independent degrees of altruism, as in subsections 7.1.1-7.1.3, evolutionary forces tend to select for selfishness, unless altruistic individuals are quite altruistic, and sophisticated enough to avoid being exploited by selfish individuals (scenario 3). By the same token, if selfish individuals are not sophisticated enough to exploit altruists when meeting them (scenario 1), full altruism is evolutionarily robust in sufficiently unforgiving climates (large β). By contrast, when the interaction takes place between siblings, as in subsection 7.2, evolutionary forces tend to select for altruism and against selfishness (here only scenario 1 is considered). Since siblings' degrees of altruism are positively correlated, an altruist is more likely to meet another altruist than a selfish child is, implying that altruism among siblings resists mutations to selfishness in a wider parametric range of environments than under random matching (compare Figures 14 and 15). Likewise, selfishness among siblings is more vulnerable to altruistic mutations than selfishness among randomly matched individuals. Nonetheless, selfishness between siblings resists altruistic mutations when β is large, *i.e.*, when an altruist would suffer a large loss from interacting with a selfish individual. By contrast, selfishness among randomly matched individuals is always evolutionarily robust—at least when all individuals naïvely believe that their opponent has the same degree of altruism as themselves, as we assume in the present comparison.

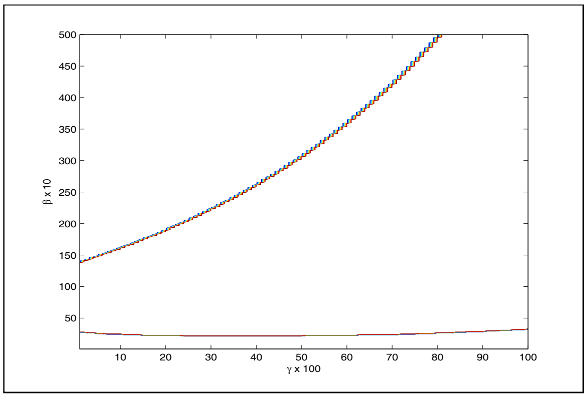

Figure 17: Resistance of full altruism among siblings, and of selfishness among randomly matched players.

Consider, finally, a society in which each individual either is involved only in random pairwise interactions with non-relatives, or interact only with his sibling. The area between the two curves in Figure 17 is the set of values for (β, γ) for which (naïve) altruism among randomly matched individuals is not evolutionarily robust, while (naïve) altruism among siblings is robust and (naïve) selfishness among siblings is not. We can also identify environments in which both (naïve) altruism among randomly matched indiividuals and selfishness among siblings are evolutionarily robust. This is the case for (β, γ)-pairs above the curve in Figure 18.

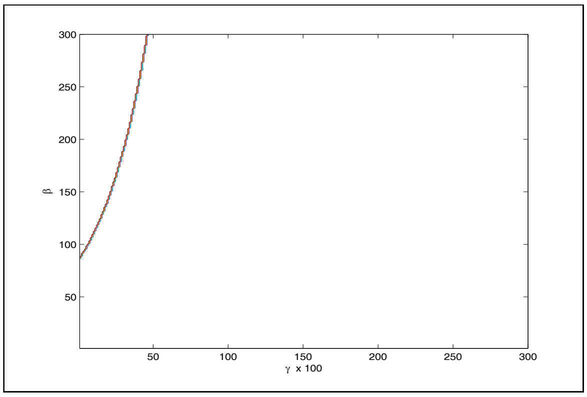

Figure 18: Evolutionary robustness of full altruism among randomly matched players, and resistance of selfishness among siblings.

8 Conclusion

This study was motivated by the observation that intrafamily transfers are more significant in some parts of the world than in others, and that this may have been so for several centuries. Our objective was twofold. First, we wanted to study how, in a pre-industrial society without formal insurance, the informal insurance that may be provided through the family affects various economic outcomes, such as effort, income, and material welfare. In particular, we sought to better understand how the exogenously given environment, such as the climate, interacts with these effects. Second, we relied on this analysis to explore the possibility that evolutionary forces may lead to different levels of intrafamily altruism in different climates. This thought-experiment may shed some light on why family ties may have been weaker in some parts of the world than in others, and thus why there may have been differences in formal institutions.

We analyzed a two-player game in which the players choose effort, affecting the probability of receiving a high output level, and, conditional on the outputs of both players, a transfer from one to the other. We found that the informal insurance provided by the family is not necessarily detrimental to effort: in our basic model an altruistic individual has an additional incentive (as compared with a selfish individual) to make effort because he or she wants to have enough output to share with the other, in case the other receives a low output level, and this additional incentive may outweigh the incentive to free-ride on the other individual's altruism, that is, of being helped out by the other in case own output is low. Thus, in a given climate, effort may be higher in families with very strong family ties than in families with weak family ties. We also saw that altruism has a positive effect on effort in forgiving climates (environments with a low marginal return to effort): an increase in altruism may induce individuals to provide more effort if initially effort is low (because the return to effort is low) and hence the marginal disutility of effort is low. However, individuals may not always fully enjoy helping others: under (socially) *coerced altruism,* only the free-rider effect is present and therefore efforts fall as the extent of informal (but coerced) insurance increases.

These insights also shed light on the effects of altruism on material welfare. With coerced altruism, the usual trade-off between insurance and incentive appears: coerced altruism is beneficial because it provides some insurance against adverse shocks, but it comes at a cost because it reduces effort. Hence, if a family could choose the level of coerced altruism, in order to maximize the expected material utility of its members, then it should choose a positive level but not completely eliminate their exposure to risk. By contrast, if the family members would help each other voluntarily, *i.e.*, if they would be driven by true altruism towards each other, then full altruism, whereby total output is always shared equally, would be optimal. This conclusion is valid even in environments where full altruism leads to lower effort than full selfishness, as is the case in unforgiving climates.

In the evolutionary analysis we asked whether full altruism would stand a chance against selfishness from an evolutionary perspective, and whether this depends on climate. We distinguished between two settings: one where the players' degrees of altruism are statistically independent, as under random matching in a large population, and another, where the players' degrees of altruism are correlated, as between siblings. In the first setting, we found that a population of fully altruistic individuals would resist the invasion by selfish individuals if altruists were discriminatory in the sense of behaving selfishly when matched with a selfish individual. Full altruism would also be evolutionarily robust in the same setting, if all individuals were naïve in the sense of assuming that the other individual had the same degree of altruism as themselves, granted the climate was sufficiently unforgiving. Naïve selfish individuals would then make large efforts since they would not expect to be helped.

In the second setting, where the individuals are siblings, full altruism resists the invasion by selfishness for a wider range of climates than under random matching, even if individuals are not discriminatory. The reason is that in this setting an altruist is more likely to interact with another altruist. Due to this effect, reminiscent of group selection, selfishness among siblings tends to be selected against: with probability one-half a mutant altruist confers benefits on another altruist. However, numerical simulations showed that selfishness among siblings would be evolutionarily robust in very unforgiving climates: a naïve altruist would then suffer such a large loss from interaction with a selfish sibling, which happens with probability one-half, that this would outweigh the benefit from interacting with an altruistic sibling, which also happens with probability one-half. This is consistent with observations made by historians such as Macfarlane (1978, 1992), and by Max Weber (1951), that in pre-industrial times individualism in the form of weak family ties seemed to be more prevalent in northwestern Europe, where the climate is arguably less forgiving, than elsewhere.

Our main analysis was conducted for individuals in a pre-industrial society without access to formal insurance markets. However, we extended the framework to include a perfectly competitive insurance market. We found that such formal insurance, in a society of selfish individuals, while having a negative effect on effort, just as coerced altruism has, but would, according to our numerical simulations, still be better than coerced altruism. The reason is that formal insurance pools the risks of a larger number of people while informal insurance only operates within small groups, here pairs, and hence gives no coverage if both individuals in the group obtain the low output. Interestingly, despite its limited risk-pooling, our numerical simulations show that full altruism may be even better than a competitive formal insurance market, thanks to the individuals' internalization of the external effects of their effort choice. Whether these results would hold more generally is an open question.

Our analysis could be extended to study whether a strong degree of altruism between individuals may lead to insurance market failure. Will altruistic individuals choose not to buy insurance, in the hope of being helped out by other altruistic individuals? We note that this potential cause for market failure adds to the more well-known source, moral hazard, studied here (among selfish individuals). Public insurance, or social security, could then be welfare-enhancing (*c.f.* Lindbeck and Weibull (1988)). If this is so, will the benefit of social security be more pronounced in more or less favorable and/or forgiving climates, in less or more altruistic populations?

Today, the income of an individual in an developed economy no longer depends to a significant degree upon the climate, as it did and still does in pre-industrial societies. Perhaps it would be fair to assume that an individual's baseline output (baseline disposable income) is higher in a more developed economy, while the marginal return to effort may be higher or lower, for a given climate. In a developed economy with low income taxes and little welfare, the baseline output level may not be much higher than in a less developed economy but the marginal return to effort would arguably be much higher. By contrast, in a developed economy with high income taxes and a significant welfare system, the base-line output level may be much higher than in a less developed economy, while the marginal return to effort may not be so much higher, or even lower, than in the less developed economy. We hope that our analysis can be helpful for comparisons of this sort, also with regard to migration, and to a deeper understanding of links between altruism, climate and economic development.

9 Appendix

9.1 Proof of Proposition 1

Note that

$$F\left(p\right) \equiv \left.\frac{\partial \Pi_i \left(p_1, p_2\right)}{\partial p_i}\right|_{p_1=p_2=p}$$

If $\alpha \in [1/\beta, 1]$ a common strictly positive equilibrium effort p necessarily satisfies $F\left(p\right) = 0$, which after some algebraic manipulation yields the following polynomial equation in p:

$$\left[\ln\left(\frac{\alpha}{\beta}\right) + 2\ln\left(\frac{1+\beta}{1+\alpha}\right)\right] \cdot p^2 - \left[\ln\left(\frac{\alpha}{\beta}\right) + 3\ln\left(\frac{1+\beta}{1+\alpha}\right) + \frac{\alpha}{1+\alpha}\ln\alpha\right] \cdot p \qquad (30)$$
$$+ \ln\left(\frac{1+\beta}{1+\alpha}\right) + \frac{\alpha}{1+\alpha}\ln\alpha - \frac{\gamma}{1+\alpha} = 0.$$

For $\alpha \in [1/\beta, 1]$, the largest of the two roots to this equation exceeds 1. To see this, let A, B, and C be the coefficients in equation (30), when written in the form $Ap^2 - Bp + C = 0$. The two roots are

$$p = \frac{B - \sqrt{B^2 - 4AC}}{2A} \quad \text{and} \quad q = \frac{B + \sqrt{B^2 - 4AC}}{2A},$$

where $B^2 - 4AC \geq 0$ for all $\alpha \in [0, 1]$, $\beta \geq 1$ and $\gamma \geq 0$ such that $\alpha\beta \geq 1$. Note that $A \geq 0$ iff $(\beta - \alpha)(\alpha\beta - 1) \geq 0$ and $B^2 - 4AC > (2A - B)^2$ iff $A\left(A - B + C\right) < 0$ iff $A - B + C < 0$ iff $\gamma/\left(1+\alpha\right) \geq 0$. It follows that $q \geq p$. It remains to prove that $q > 1$ when $\alpha\beta > 1$ and $\gamma > 0$. For this purpose, note that $q > 1$ iff $\sqrt{B^2 - 4AC} > 2A - B$ iff $B^2 - 4AC > (2A - B)^2$ iff $A\left(A - B + C\right) < 0$, an inequality that holds if $\alpha \in [0, 1]$, $\beta \geq 1$, $\alpha\beta > 1$ and $\gamma > 0$. Finally, we note that $p > 0$ iff $F(0) > 0$ iff

$$\gamma < \ln\beta + \ln\left(\frac{\alpha(1+\beta)}{1+\alpha}\right)^{\alpha} + \ln\left(\frac{1+\beta}{\beta(1+\alpha)}\right).$$

End of proof.

9.2 Proof of Proposition 2

We proceed in two steps. First, we characterize the socially optimal probability p and transfer t, to be given by the rich to the poor, under a Benthamite social welfare function. Secondly, we characterize the equilibrium probability p and transfer t, and verify that these two characterizations coincide if and only if $\alpha = 1$.

Consider a hypothetical social planner who chooses a probability p and transfer t so as to maximize the sum of the expected material utilities to each individual,

$$W(p,t) = p^2 \ln y^H + (1-p)^2 \ln y^L + p(1-p)[\ln(y^H - t) + \ln(y^L + t)] + \gamma \ln(1-p). \quad (31)$$

The necessary first-order condition for an interior solution for p is

$$\frac{\gamma}{1-p} = 2p \ln y^H - 2(1-p)\ln y^L + (1-2p)[\ln(y^H - t) + \ln(y^L + t)],$$

which may be rewritten as

$$\frac{\gamma}{1-p} = \ln \beta + \ln\left(\frac{(y^L + t)\left(y^H - t\right)}{y^L y^H}\right) - 2p \ln\left(\frac{(y^L + t)\left(y^H - t\right)}{y^L y^H}\right). \quad (32)$$

A symmetric interior Nash equilibrium p^* of the game $\hat{G}$ necessarily satisfies:

$$\frac{\gamma}{1-p} = \ln \beta + \alpha \ln\left(\frac{(y^L + t)\left(y^H - t\right)}{y^L y^H}\right) - (1+\alpha)p \ln\left(\frac{(y^L + t)\left(y^H - t\right)}{y^L y^H}\right). \quad (33)$$

We see that (33) is identical with (32) iff $\alpha = 1$. Moreover, for any value of p, the value of t that maximizes $W(p,t)$ is such that both individuals end up with the same consumption in all states. In particular, $y^H - t = y^L + t$, or, equivalently, $t = \left(y^H - y^L\right)/2$. But the same relationship holds in equilibrium of a transfer subgame $G(y)$ where $y_1 \neq y_2$ (with identical individuals) iff $\alpha = 1$. **End of proof.**

9.3 Proof of Proposition 3

First assume that $\alpha \in (\hat{\alpha}, 1)$. Then the unique equilibrium effort-*cum*-probability p^* is differentiable with respect to α, and straightforward calculations show that

$$\frac{\partial p^*(\alpha,\beta,\gamma)}{\partial \alpha} = \frac{1}{K}\left[(1-p^*)\ln\left(\frac{y^L + t^*}{y^L}\right) + p^* \ln\left(\frac{y^H}{y^H - t^*}\right) - \frac{1-\alpha^2}{y^L + t^*} \cdot \frac{\partial t^*(\alpha,\beta,y^L)}{\partial \alpha}\right],$$

where, by (10), $\frac{\partial}{\partial\alpha}t^*(\alpha,\beta,y^L)>0$ when positive, and

$$K=\frac{\gamma}{(1-p^*)^2}+(1+\alpha)\ln\left(\frac{(y^L+t^*)(y^H-t^*)}{y^Ly^H}\right)>0. \tag{34}$$

As $\alpha\downarrow\hat{\alpha}$ (at which point p^* is not differentiable), the first two terms within the square brackets tend to zero, so that the last term determines the sign, whereas the opposite is true when $\alpha\uparrow 1$. Indeed, this property holds whenever utility is separable in consumption and effort. **End of proof.**

9.4 Proof of Proposition 7

This proof is similar to the proof of proposition 1. Note that $\tilde{F}(p)=0$ iff

$$\ln\left(\frac{\tilde{\alpha}}{\beta}\left(\frac{1+\beta}{1+\tilde{\alpha}}\right)^2\right)\cdot p^2-\ln\left(\frac{\tilde{\alpha}}{\beta}\left(\frac{1+\beta}{1+\tilde{\alpha}}\right)^3\right)\cdot p+\ln\left(\frac{1+\beta}{1+\tilde{\alpha}}\right)-\gamma=0. \tag{35}$$

For $\tilde{\alpha}\in[1/\beta,1]$, the largest of the two roots to equation (35) exceeds 1. To see this, let A, B, and C be the coefficients in equation (35), when written in the form $Ap^2-Bp+C=0$. The two roots are

$$p=\frac{B-\sqrt{B^2-4AC}}{2A}\quad\text{and}\quad q=\frac{B+\sqrt{B^2-4AC}}{2A},$$

where $B^2-4AC\geq 0$ for all $\tilde{\alpha}\in[0,1]$, $\beta\geq 1$ and $\gamma\geq 0$ such that $\tilde{\alpha}\beta\geq 1$. Note that $A\geq 0$ iff $(\beta-\tilde{\alpha})(\tilde{\alpha}\beta-1)\geq 0$ and $B^2-4AC\geq(2A-B)^2$ iff $A\,(A-B+C)\leq 0$ iff $A-B+C\leq 0$ iff $\gamma\geq 0$. It follows that $q\geq p$. It remains to prove that $q>1$ when $\tilde{\alpha}\beta>1$ and $\gamma>0$. For this purpose, note that $q>1$ iff $\sqrt{B^2-4AC}>2A-B$ iff $B^2-4AC>(2A-B)^2$ iff $A\,(A-B+C)<0$, an inequality that holds if $\tilde{\alpha}\in[0,1]$, $\beta\geq 1$, $\tilde{\alpha}\beta>1$ and $\gamma>0$. Finally, we note that $p>0$ iff $\gamma<\ln(1+\beta)-\ln(1+\tilde{\alpha})$. **End of proof.**

9.5 Proof of Proposition 10

Selfishness is robust against altruism if

$$V(0,0,0,0)\geq V(1,1,0,0). \tag{36}$$

Writing $u(c,p) = h(c) - k(p)$ we note that $V(0,0,0,0) - V(1,1,0,0)$ may be written

$$\begin{aligned}
&\left[p(0,0)h\left(y^H\right) + (1-p(0,0))\,h\left(y^L\right) - k(p(0,0))\right] \\
&- \left[p(1,1)h\left(y^H\right) + (1-p(1,1))\,h\left(y^L\right) - k(p(1,1))\right] \\
&+ p(1,1)\,(1-p(0,0))\left[h\left(y^H\right) - h\left(y^H - t(1)\right)\right].
\end{aligned}$$

The difference between the first two terms within square brackets is non-negative since the autarky effort $p(0,0)$ maximizes $ph\left(y^H\right) + (1-p)\,h\left(y^L\right) - k(p)$. The last term is non-negative. The expression equals zero if and only if $p(1,1) = p(0,0) = 0$.

Altruism is robust against selfishness if $V(1,1,1,1) \geq V(0,0,1,1)$. Write the difference $V(0,0,1,1) - V(1,1,1,1)$ as

$$\begin{aligned}
&\left[p(0,0)h\left(y^H\right) + (1-p(0,0))\,h\left(y^L\right) - k(p(0,0))\right] \\
&- \left[p(1,1)h\left(y^H\right) + (1-p(1,1))\,h\left(y^L\right) - k(p(1,1))\right] \\
&+ p(1,1)\,(1-p(1,1))\left[h\left(y^H\right) - h\left(y^H - t(1)\right)\right] \\
&+ p(1,1)\,(p(1,1) - p(0,0))\left[h\left(y^L + t(1\right) - h\left(y^L\right)\right].
\end{aligned}$$

We recognize the difference between the first two terms within square brackets from the previous expression: this difference is non-negative. The next term is also non-negative. The last term is non-negative if $p(1,1) \geq p(0,0)$. The last statement of the proposition is supported by numerical examples. **End of proof.**

9.6 Proof of Proposition 11

We begin by proving that selfishness is evolutionarily robust. First, conditional on facing a selfish player who chooses effort $p(0,0)$, a selfish player maximizes his expected material utility, whereas an altruist also takes into account the material utility of the opponent and therefore fails to maximize his own expected material utility: hence $V(0,0,0,0) > V(1,0,0,0)$. Second, *ceteris paribus* the expected material utility of an altruistic player, conditional on his or her effort-*cum*-probability being positive, is increasing in his or her opponent's effort-*cum*-probability. Now, we know from Section 3.2 that a player's effort level decreases as the opponent's degree of altruism increases (as long as that entails a larger transfer). In particular, equations (6) and (7) imply $p(0,0) > p(0,1)$. As a result, $V(1,0,0,0) > V(1,0,0,1)$. Taken together, these two inequalities imply $V(0,0,0,0) > V(1,0,0,1)$.

We can use similar arguments to show that full altruism is not evolutionarily robust.

First, conditional on facing a player choosing $p(1,0)$, a selfish player maximizes his expected material utility, whereas an altruist, by taking into account the material utility of the opponent, fails to maximize his or her own expected material utility: therefore $V(0,1,1,0) > V(1,1,1,0)$. Second, *ceteris paribus* the expected material utility of an altruistic player, conditional on his or her effort-*cum*-probability being positive, is increasing in his or her opponent's effort-*cum*-probability. Again, we can use (6) and (7) to note that $p(1,0) > p(1,1)$. As a result, $V(1,1,1,0) > V(1,1,1,1)$. Taken together these two inequalities imply $V(1,1,1,1) < V(0,1,1,0)$. **End of proof.**

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