On Formal and Informal Insurance Markets under Altruistic Preferences*

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Abstract

I explore the interaction between siblings with altruistic concerns towards one another and a formal insurance market. Each individual can exert effort to reduce the probability of suffering a loss, as well as buying an insurance policy from an insurer. Altruism in this model induces a form of informal insurance, where the siblings can transfer resources to one another. I show that equilibrium transfers always go from the richer sibling to the less fortunate one, but only if the degree of altruism is sufficiently high. I also show that altruism is never strong enough to preclude the existence of formal insurance, in the form of a firm (or several) proposing contracts to the agents, and that formal and informal insurance coexist when selfishness is not too strong.

Keywords: Moral hazard in teams, insurance, altruism.

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1 Introduction

It is not uncommon to observe interactions between market and nonmarket institutions in contemporaneous societies. For instance, individuals rely not only on insurance contracts to protect themselves against occasional losses, but also on family members to help in adverse situations. Students may depend on their parents to finance their studies instead of contracting a loan from a bank. In most cases, such reliance on nonmarket institutions is more pronounced in less developed societies, or those where kinship among its members is higher (Cox et al. (2006), Cox and Fafchamps (2008)). On the other side of the coin, the literature on institutions and economic development points out that more developed societies are associated with stronger formal institutions, such as the rule of law and well established banking and credit markets.

What, then, are the determinants of the long-run dynamics of formal markets formation? Alternatively, which factors contribute to the emergence of formal institutions? In this paper, I explore the possibility of economic agents engaging in nonmarket relationships among themselves instead of contracting with a formal market institution. In particular, I study the profitability of an insurance company who sells insurance contracts to a pair of agents who individually and independently face the possibility of a loss, and that can rely on one another to provide help in case the realized outcome is unfavorable. There are, of course, other reasons that may prevent the emergence of formal markets. Taking the insurance and credit markets as examples once again, fraud, the lack of big players and the lack of verifiability of claims can be cited as halting the emergence and development of such markets. In what follows, however, I abstract from such considerations and focus on the individuals and firms choosing whether to participate or not in a formal market. In other words, I want to verify under which conditions the substitutability between market and nonmarket institutions is the mechanism arresting the emergence of the former.

The setting here considered is an insurance one, where the agents can *self-protect* by exerting effort to reduce the probability of a loss taking place; *cross-insure* by transferring wealth to one another; and buy *market insurance* by individually engaging in a contractual relationship with the insurance provider. Such environment allows us to study the interaction between market and nonmarket trades, in contrast to the pioneering work of Arnott and Stiglitz (1991), which considers the setups with only market and only nonmarket trades separately. I also take the model in a static, non-cooperative framework: the first implies that the transfers between agents do not depend on threats of punishments over time[1] (as in Bénabou and Tirole (2006), Ligon et al. (2002) and Dubois et al. (2008)); meanwhile, the second implies that agents choose equilibrium transfers and efforts non-cooperatively, thus avoiding issues of bargaining, multiplicity of equilibria and commitment (as in Bloch et al. (2008)).

The agents are characterized by altruistic preferences in the classical sense proposed by Becker (1974) and Becker (1976), where each agent's utility equals his own material payoff plus a his pair's payoff weighted by the degree of altruism. This is the same specification of such preferences in Bergström (1995) and Alger and Weibull (2010), and most of my analysis hinges on the equilibrium behavior of all participating players for different degrees of altruism.

In equilibrium, I find that transfers are strictly positive for sufficiently high degrees of altruism, while efforts exhibit a non-monotonic behavior with respect to that parameter. Intuitively, when altruism is low and transfers are null, for any given contract offered by the insurer, the agents behave as in autarky and therefore choose a level of effort that equalizes the marginal benefit and marginal cost of avoiding the loss. As altruism increases and transfers become positive, equilibrium effort must balance two different effects. The first one is a free-riding effect on the transfer received from the other agent: as one individual becomes more protected against a loss due to cross-insurance, he has fewer incentives to exert costly effort to avoid such loss. On the other hand, the same individual would like to impose a smaller reduction in his pair's expected wealth, and thus would increase his effort to avoid

[1]The specification here can be interpreted as a reduced-form of a repeated game. More on this point will be made later, when the model is introduced.

receiving help[2]. My results show that the first effect prevails for intermediate degrees of altruism, while the second dominates as altruism becomes larger.

With regards to the interaction between market and nonmarket institutions, I find that for low degrees of altruism only market trades exist. As altruism increases, market and nonmarket institutions coexist, in the sense that the agents not only buy the insurance contract from the firm, but also make positive transfers to one another when one of them suffers a loss. Last, but not least, numerical example shows that the insurance company can be driven out of the market for sufficiently high degrees of altruism, since transfers and effort would drive the insurer's profits below zero.

The text is organized as follows. The next subsection provides a short review of the related literature, while Section 2 describes the model. Sections 3 analyze the equilibrium behavior of the agents facing a the option to buy a fixed insurance policy, while section 4 introduces an insurance firm making the choice of which contract to offer. Section 5 concludes. For ease of exposition, all proofs are relegated to the Appendix.

1.1 Related Literature

In a broad view, my model studies the interaction of a formal market institution, captured by a principal offering insurance contracts to a pair of agents, who can also share risk in an informal manner by providing transfers to one another. Instead of modelling a repeated game between these agents, the static framework to be explored relies on altruistic concerns the agents have towards one another to determine not only their behavior in the informal and formal sectors, but also their susceptibility to free-ride in each others' transfers and efforts.

The presence of informal transfers and kin networks is widely documented. Alger et al. (2016) study the effect of informal transfer on the incentives to work, while Azam and Gubert (2006) explore the link of remittances and labor migration when credit and insurance markets

[2] In other words, the agents internalize the externality caused by their choices of efforts as the degree of altruism becomes larger.

are missing. Looking at a cross-section of developing countries, Cox et al. (2006) report stylized facts about private transfers, such as them always flowing from the rich to the poor, while flowing from the young to the old members of the household (or the reverse) in only certain countries.

A recent literature has explored the role of altruism, transfers and risk-sharing in networks. Fafchamps and Lund (2003), Bramoull and Kranton (2007), Cox and Fafchamps (2008), Falco and Bulte (2013) empirically explore altruism in economic networks as a means to diversify risk, and their results shows that stronger kinship ties lead to more risk-sharing among agents in the same network. Bourl'es et al. (2017) and Bourls et al. (2018) provide formal models of social networks where agents care about each other and may transfer funds to one another to share risk. Their focus, however, lies in identifying conditions on the network structure that induces positive transfers among its members. I study a simpler network structure, namely one with only two individuals, but focus on the agents equilibrium choices of risk-sharing, self-protection and demand for insurance policies, where the last two are lacking in the papers cited above.

Arnott and Stiglitz (1991) provided the first modelling attempt at understanding the interaction between market and nonmarket institutions. Their approach relied on computing the agents' indirect utility in each situation, and then comparing under which conditions one would outperform the other. The model below doesn't have the same limitation: the agents can participate simultaneously in trades in the two classes of institutions, and therefore choose when to trade in both, one or none of them. Jain (1999) also proposes a model where the agents can choose in which kind of institution to participate, but the formal sector exhibits an advantage in deposit mobilization, while the informal sector has an informational advantage. Dubois et al. (2008) study both theoretically and empirically a similar problem to mine, but their analysis is based on a dynamic setting with limited commitment and incomplete contracts. They obtain participation in informal transfers as a self-enforcing agreement, relying on the threat of punishment and exclusion from trade, while I obtain the same kind of results in a static framework relying on the altruistic preferences of the agents. Finally, Mobarak and Rosenzweig (2012) experimentally study the demand for formal insurance in rural India, where farmers are incompletely insured through risk-sharing networks.

Prosocial preferences have been studied since the early contributions of Becker (1974) and Becker (1976) in altruism, as well as Andreoni (1990) study in warm-glow and Alger and Weibull (2013) and Alger and Weibull (2016) ground-breaking work in morality. Some recent papers explore the role of prosocial behavior in contracting situations, such as von Siemens (2011), Rotemberg (2006), Rey-Biel (2008), Itoh (2004), Sarkisian (2017) and Biener et al. (2018). Most of these authors explore the effects of prosocial preferences in alleviating contracting constraints, either in moral hazard (i.e. reducing the incentives to free-ride or to slack) or screening (individuals self-selecting to job propositions according to their perception of the firms' missions). Alger and Weibull (2010) study a setting very similar to mine, but absent a formal insurance market: their focus is on determining the evolutionarily stable degree of altruism, how it changes according to the environment and its effects on economic outcomes.

My model is also related to the literature in moral hazard in teams, firstly analyzed by Alchian and Demsetz (1972) and Holmström (1982). As in the original settings, our model has a principal facing two agents who can exert unobservable, and therefore non-contractible, effort to avoid loss. The principal is interested in offering contracts that maximize his profits, while inducing the agents to participate in the relationship and mitigate free-riding. The big departure here is that the siblings can also engage in trades between themselves, namely the transfers each one makes to the other, which creates an additional channel through which they can reduce or increase equilibrium efforts. More recently, Che and Yoo (2001) provide a general approach to design optimal incentives in teams.

Lastly, because the agents in the model to be introduced in the next section are allowed to complement the insurance policy bought in the market with risk-sharing transfers made to one another, the insurance company faces a problem of non-exclusive contracting. While Attar et al. (2011), Attar et al. (2014) and Attar et al. (2017) study adverse selection environments and provide conditions for existence of equilibria and market breakdown, Bisin and Guaitoli (2004) focus on environments with hidden actions and show that agents may engage in several contractual relationships at once at the same time as providing intermediaries with positive profits. Attar and Chassagnon (2009) extends Bisin and Guaitoli (2004) analysis by showing that some the equilibrium conditions imposed in the latter are not necessary and finds a set of equilibrium allocations that fails to satisfy Bisin and Guaitoli (2004)'s conditions.

2 The Model

This section presents the basic model. While the first subsection focus on underlying the environment, the second one characterizes altruism and the siblings strategies. Equilibrium behaviors of the agents for a given contract will be analyzed subsequently, while an insurer is introduced in a later section.

2.1 Environment

Consider an environment with two agents, A and B, and one risk-neutral insurer (the Principal). Each individual chooses an effort level $x \geq 0$ that determines the probability of suffering a loss $L > 0$. The wealth of each agent is either high, w^H, when he suffers no losses, or low, $w^L = w^H - L \geq 0$, when losses take place. The probability of a loss happening is $1-p$, and the losses are independent events between agents. The probability p for avoiding losses is increasing in the individual effort, i.e. $p = f(x)$ for $f : \mathbb{R}_+ \to [0, 1)$ twice continuously differentiable, with $f(0) = 0$, $f' > 0 > f''$ and $f(x) \to 1$ as $x \to +\infty$.

Assuming additive separability, let $u(w)$ denote the utility of consuming wealth $w \geq 0$, and $v(x)$ be the disutility of exerting effort $x \geq 0$. I assume that both u and v are twice continuously differentiable, with $u' > 0 > u''$, $v' > 0$ and $v'' \geq 0$. Therefore, an effort level

$x \geq 0$ leads to an expected material payoff of

$$f(x)u(w^H) + [1 - f(x)]u(w^L) - v(x) \tag{1}$$

for each sibling.

I reinterpret the problem above as each agent directly choosing his success probability p, at a cost $\psi(p) = v\left(f^{-1}(p)\right)$, where the previous assumptions on v and f imply that $\psi', \psi'' > 0$ and $\psi'(0) = 0$, that is, the cost of choosing probability p is increasing and strictly convex. The expected payoff of an agent is

$$\mathbb{E}[U(p, w^H, w^L)] = pu(w^H) + (1 - p)u(y^L) - \psi(p). \tag{2}$$

2.2 The Choices of a Single Agent

Consider first the case in which one agent is alone in the economy[3], and must therefore choose the effort (self-protection) that maximizes his expected utility, i.e. he solves

$$\max_p \quad \mathbb{E}[U(p, w^H, w^L)] = pu(w^H) + (1 - p)u(y^L) - \psi(p).$$

The optimal choice is given by the first order condition

$$\psi'(p^{Aut}) = u(w^H) - u(w^L). \tag{3}$$

As expected, the higher the loss $L = w^H - w^L$ the agent can potentially suffer, the higher will be his effort to prevent it from happening. Let

$$U^{Aut}(w^H, w^L) \equiv p^{Aut}u(w^H) + (1 - p^{Aut})u(w^L) - \psi(p^{Aut}) \tag{4}$$

denote the agent's expected utility in autarky.

Now, suppose the agent can buy an insurance policy $C = (q, t)$, where $q \in \mathbb{R}_+$ denotes the coverage of the policy, while $t \in \mathbb{R}_+$ is the insurance premium. If the agent hires the insurance policy C, his expected utility can be written as

$$\mathbb{E}[U(p, w^H, w^L, C)] = pu(w^H - t) + (1 - p)u(w^L - t + q) - \psi(p). \tag{5}$$

[3] Alternatively, suppose either that each agent ignores the existence of the other, or simply cannot engage in any trade with the other agent.

The agent's rejection of such contract is equivalent to trading the null contract $C_0 = (0, 0)$, which makes 5 identical to the expected utility of the agent under autarky, and thus leads to the same choice of effort as when no transaction between insurer and agent exists. The agent's choice of effort in this case is given by

$$\psi'(p^{MH}) = u(w^H - t) - u(w^L - t + q). \qquad (6)$$

For the remainder of the presentation, I assume that $0 \leq t \leq q \leq L$. Indeed, any policy with a premium larger than the coverage would be rejected by the agents, since it would reduce his wealth after any realized outcome. The second inequality can be justified by the fact that an insurance company would not offer a coverage larger than the loss, since such contract would induce the agents to exert zero effort, and therefore, such firm would always incur a loss[4].

Last but not least, the equilibrium effort made by the agent when contracting the insurance policy is smaller than the one he would exert in autarky. This is a consequence of the agent's risk-aversion together with the fact that the icontract reduces the overall risk he faces[5].

2.3 Altruism and Transfers

Suppose now that the agents have altruistic feelings towards each other, so that in case one of them suffers a loss, the one who didn't may feel inclined to transfer part of his wealth to the poorer agent. This transfers between individuals can be thought of as an informal insurance complementing the contract $C = (q, t)$.

To formalize this notion, imagine that the agents interact over three periods. In the

[4]Such restrictions may be relaxed if one considers an environment where the government subsidizes insurance policies. Since my model seeks to explain the emergence of formal insurance companies, this assumptions improves the likelihood of a firm making a positive profit, and therefore fit the model well.

[5]Formally, one can check that $\psi'(p^{Aut}) = u(w^H) - u(w^L) \geq u(w^H - t) - u(w^L - t + q) = \psi'(p^{MH})$ due to concavity of u and $t \leq q \leq L$. Then, since $\psi(\cdot)$ is a strictly increasing and strictly convex function, I conclude that $p^{Aut} \geq p^{MH}$.

first period, each of them observes the contract $C = (q, t)$ being offered, and simultaneously and individually choose whether to accept or reject the insurance policy. Given the chosen contract (that includes $(q, t) = (0, 0)$ in case of rejection), the agents then simultaneously choose their effort levels x_i, or alternatively, the probability p_i of not suffering a loss. The period ends with the realization of wealth $\omega = (w_A, w_B) \in \Omega = \{w^L, w^H\}^2$. At the beginning of the third period, the agents observe the outcome $\omega = (w_A, w_B)$ and simultaneously choose whether to transfer resources to one another, and if so, how much to transfer. The final wealth of each sibling, which will be fully consumed at the end of this stage, equals his net wealth plus or minus any transfer received or given, respectively, where the net wealth at the end of the first stage, conditional on the contract taken, is given by

$$y(\omega) = \begin{cases} w^H - t & \text{if no loss occurred,} \\ w^L - t + q & \text{if the loss occurred.} \end{cases}$$

Define a pure strategy in the three-stage game for agent $i \in \{A, B\}$ as a triple $s_i = (a_i, p_i, \tau_i)$, where $a_i \in \{0, 1\}$ is the decision[6] to reject or accept the contract C, $p_i \in [0, 1)$ is the success probability chosen by agent i given the contract bought[7], and $\tau_i \in [0, w^H]$ is the transfer made, if any, when the outcome is ω, satisfying $0 \le \tau_i(\omega) < y_i(\omega)$.

Each strategy profile $\mathbf{s} = (s_A, s_B)$ determines the utility to each agent i and outcome ω:

$$U_i(\mathbf{s}, \omega) = V_i(\mathbf{s}, \omega) + \alpha_i V_j(\mathbf{s}, \omega), \tag{7}$$

where $j \neq i$, V_i denotes sibling i's material payoff,

$$V_i(\mathbf{s}, \omega) = u(y_i(\omega) - \tau_i(\omega) + \tau_j(\omega)) - \psi(p_i), \tag{8}$$

and $\alpha_i \in [0, 1]$ represents i's degree of altruism towards his sibling[8,9].

[6] I will restrict attention to pure strategies equilibria.

[7] Either $(0, 0)$ or (q, t).

[8] If $\alpha_i = 0$, sibling i is said to be selfish, while for $\alpha_i = 1$ the agent is called fully altruistic.

[9] Alternatively, one can think of the agents having preferences that take into consideration the internalization of the collective benefits generated by their actions. Indeed, let x_i and x_j denote the strategies for two different agents, and suppose that agent i's utility is given by $U_i(x_i, x_j, \alpha_i) = (1-\alpha_i)\pi_i(x_i, x_j) + \alpha_i[\pi_i(x_i, x_j) + \pi_j(x_j, x_i)]$, where $\pi_i(x, y)$ denotes the material payoff of the game played between agents i and j. This specification is also aligned with Bergström (1995) when $\alpha_i\alpha_j < 1$, where $U_i = U(\pi, \alpha_i, U_j) = \pi(x_i, x_j) + \alpha_i U_j$

3 The Siblings' Equilibrium Decisions

Each contract $C = (q, t)$ induces a sequential game played between agents A and B. In particular, the offered contracts will not only determine the agent's decision to accept or reject them, but also how much self-protection A and B will engage in and the transfers to be made in equilibrium.

In this section, I will explore the equilibrium transfers and effort decisions of the agents for two cases. In the first one, both agents accept the contract $C = (q, t)$, which includes the autarky ($C_0 = (0, 0)$) as a special case. Then, I focus attention in the case where only one of the agents buys the insurance policy.

In both cases, I will assume that $0 \leq t \leq q \leq L$. The second inequality must hold, otherwise the agents are always better off by rejecting the insurance policy. Moreover, I assume that when agents must choose their efforts, they know whether each other has accepted the contract or not. In this sense, the only private information the agents have is the self-protection effort.

3.1 Optimal Efforts and Transfers When Both Agents Accept the Insurance Policy

Fix the insurance policy $C = (q, t)$ satisfying $0 \leq t < q$, and suppose that both agents accept such contract. Thus, a two-stage game between agents A and B is induced: in the first period, they must simultaneously and independently choose the level of self-protection. In the second period, after observing the outcome, they simultaneously and non-cooperatively choose transfers. The next two sections analyze this interaction by backwards induction.

3.1.1 Equilibrium Transfers

At the beginning of the second period, the agents are aware of each other's having suffered a loss or not, and must decide whether or not to make a transfer. Indeed, for each outcome $\omega \in \Omega$, the decisions of the agents in the second stage can be thought of as a two-player simultaneous-move game in which each agent's strategy is his transfer to the other. Denote this game by $G(\omega)$. Thus, each agent chooses τ_i to maximize

$$u(y_i(\omega) - \tau_i + \tau_j) + \alpha_i[u(y_j(\omega) - \tau_j + \tau_i)]. \tag{9}$$

Proposition 1: *For each $\omega \in \Omega$, there exists at least one Nash equilibrium of $G(\omega)$. If $\alpha_A \alpha_B < 1$, then this equilibrium is unique, and at most one agent makes a transfer, which is never made from the poorer to the richer agent, and doesn't depend on the poorer agent's degree of altruism. If $\alpha_A = \alpha_B = 1$, there is a continuum of Nash equilibria, all resulting in equal sharing of total net wealth.*

The result above is very similar in spirit to Proposition 2 in Alger and Weibull (2010). Let $\tau_i(\alpha_i, C)$ denote the transfer an agent with higher net wealth with degree of altruism α_i gives to the poorer agent in equilibrium, for given a contract $C = (q, t)$. The transfer is positive if and only agent i's marginal utility at net wealth y_i is higher that the other agent's marginal utility of consumption at net wealth y_j weighted by the degree of altruism. Alternatively, we can say that the transfer is positive if and only if the agent is sufficiently altruistic, in the sense that $\alpha_i > \widehat{\alpha}_i(\mathbb{C})$, where

$$\widehat{\alpha}_i(\mathbb{C}) = \frac{u'(y_i)}{u'(y_j)} > 0 \tag{10}$$

for $j \neq i$. Of course that, if $y_j > y_i$, then $\widehat{\alpha}_i(\mathbb{C}) > 1$, and agent i would never make any positive transfer.

On the other hand, if $y_i > y_j$, then $\widehat{\alpha}_i(\mathbb{C}) \in (0,1)$, and for any $\alpha_i > \widehat{\alpha}_i$, the transfer $\tau_i(\alpha_i) \in (0, y_i)$ is uniquely determined by the first-order condition

$$u'(y_i - \tau_i(\alpha_i)) = \alpha_i u'(y_j + \tau_i(\alpha_i)). \tag{11}$$

Thus, I can summarize the transfer made by sibling i with degree of altruism $\alpha_i \in [0,1]$ by

$$T_i(\alpha_i, \mathbb{C}) = \max\{0, \tau_i(\alpha_i, \mathbb{C})\}, \tag{12}$$

where $\tau_i(\alpha_i, \mathbb{C})$ is defined by 11.

Lemma 1: *The equilibrium transfer function* $T_i(\alpha_i, \mathbb{C}) : [0,1] \times \mathcal{C} \to [0, w^H]$ *is continuous, positive if* $\alpha_i > \widehat{\alpha}_i(\mathbb{C})$*, and zero otherwise. Moreover,* T_i *is differentiable for all* $\alpha_i \neq \widehat{\alpha}_i(\mathbb{C})$*, with*

$$\frac{dT_i}{d\alpha_i} = -\frac{u'(y_j - T_i)}{u''(y_i - T_i) + \alpha_i u''(y_j + T_i)} > 0. \tag{13}$$

The result is intuitive: the more altruistic a rich agent becomes, the more he gives, for all degrees of altruism above the lower bound $\widehat{\alpha}(\mathbb{C})$. Also, it must be the case that the agent making the transfer remains richer than the other sibling; otherwise, the marginal utility of consumption would be higher for the former, and thus he would not make a positive transfer in equilibrium.

3.1.2 Equilibrium Efforts

With the equilibrium transfers properly established, I can analyze the choice of efforts in the second stage of the game for any contract $C = (q, t)$[10]. In the remainder of the presentation, I will assume that the agents are characterized by the same degree of altruism[11].

Assumption: $\alpha_A = \alpha_B = \alpha \in [0, 1]$.

Under this symmetry assumption, both agents have identical preferences: not only they care about each other's material well-being with the same intensity, their utility of consuming wealth w and disutility of effort x are also identical. Although this symmetry assumption may not be without loss of generality, it implies that the net wealth of agent i is larger than the net wealth of agent j if and only if the latter suffered a loss and the former didn't, as

[10] This is without loss of generality because rejecting the principal's offer is equivalent to accepting the contract $(q, t) = (0, 0) \in \mathcal{C}$.

[11] Alger and Weibull (2010) discusses in more depth this assumption. The argument there, based on finding the evolutionarily stable degree of altruism, implies that both agents would display the same degree of altruism if this interaction was to be repeated infinitely many times.

long as $q \leq L$ and both of them accepted the contract C. Therefore, the ambiguity between net wealth and occurrence of a loss is solved, and equilibrium transfers can only be given from the agent that has suffered no loss in period 1 to the other who wasn't so lucky[12].

Now, proceeding by backward induction, each agent simultaneously chooses his individual success probability to maximize his *ex-ante* expected utility

$$\begin{aligned} U_i(p_i,p_j) = &\ p_i p_j(1+\alpha)u(w^H - t) \\ & + (1-p_i)(1-p_j)(1+\alpha)u(w^L - t + q) \\ & + p_i(1-p_j)[u(w^H - t - T(\alpha,C)) + \alpha u(w^L - t + q + T(\alpha,C))] \\ & + (1-p_i)p_j[u(w^L - t + q + T(\alpha,C)) + \alpha u(w^H - t - T(\alpha,C))] \\ & - \psi(p_i) - \alpha\psi(p_j) \end{aligned} \tag{14}$$

for $i, j = A, B$ and $j \neq i$.

As was the case with equilibrium transfers, I can think about the choices of effort as a two-player simultaneous-move game G^* in which a pure strategy for each agent i is his success probability $p_i \in [0,1)$, for any given insurance contract $C = (q,t)$, and thus, a necessary and sufficient condition[13] for the pair $(p_A, p_B) \in (0,1)^2$ to be a Nash equilibrium of $G^*(C)$ is that each of them satisfy the first-order condition

$$\begin{aligned} \psi'(p_i) = &\ u(w^H - t - T(\alpha,C)) - u(w^L - t + q) \\ & + \alpha[u(w^L - t + q + T(\alpha,C)) - u(w^L - t + q)] \\ & - p_j(1+\alpha)\big[(u(w^L - t + q + T(\alpha,C)) - u(w^L - t + q)) \\ & -(u(w^H - t) - u(w^H - t - T(\alpha,C)))\big] \end{aligned} \tag{15}$$

for $j \neq i$.

[12]The next subsection analyzes the case where only one agent buys the insurance policy $C = (q,t)$, and thus the outcomes of the agents prior to the their choices of transfers are asymmetric. As I will present later, equilibrium transfers will be made for all outcomes as long as the common degree of altruism is high enough, and thus equilibrium efforts will be asymmetric as well, reflecting the differences in wealth due to the different decisions to purchase the policy.

[13]The second-order condition is given by $-\psi''(p) < 0$ by assumption for all values of p.

Notice that the right-hand side of equation 15 is an affine function of p_j. For $\alpha \leq \widehat{\alpha}(C)$, $T(\alpha, C) = 0$ and the slope is equal to zero, while the intercept is $u(w^H - t) - u(w^L - t + q) \geq 0$ since $q \leq L$ and $u' > 0$ by assumption. This leads to exactly the same first-order condition that determined the self-protection of a single agent faced with an insurance policy C in 6. In other words, if altruism is not high enough to induce transfers between the agents, each will ignore the presence of the other and choose the level of effort that maximizes expected utility under the insurance contract $C = (q, t)$.

For $\alpha > \widehat{\alpha}(C)$ on the other hand, $T(\alpha, C) > 0$ is given by the equilibrium condition

$$u'(w^H - t - T(\alpha, C)) = \alpha u'(w^L - t + q + T(\alpha, C)). \tag{16}$$

Because $u'' < 0$ and $\alpha \in (\widehat{\alpha}(C), 1]$ by assumption, I find that $w^H - t - T(\alpha, C) \geq w^L - t + q + T(\alpha, C) > w^L - t + q$, and thus the slope is strictly negative. Meanwhile, given the assumptions about the disutility of effort, the right-hand side of equation 15 is strictly increasing in p_i. This observations lead to the following result.

Proposition 2: *If $\alpha_A = \alpha_B = \alpha$, then $G^*(C)$ has a unique symmetric equilibrium (p^*, p^*). If $p^*(\alpha, C) > 0$, then it solves the equation*

$$\begin{aligned}\psi'(p) = \; & u(w^H - t - T(\alpha, C)) - u(w^L - t + q) \\ & + \alpha[u(w^L - t + q + T(\alpha, C)) - u(w^L - t + q)] \\ & - p(1 + \alpha) \big[(u(w^L - t + q + T(\alpha, C)) - u(w^L - t + q)) \\ & -(u(w^H - t) - u(w^H - t - T(\alpha, C)))\big] .\end{aligned} \tag{17}$$

Contrary to equilibrium transfers, the behavior of equilibrium efforts is not monotonic on the degree of altruism. Indeed, for low degrees of altruism ($\alpha \leq \widehat{\alpha}(C)$), agents cannot affect each other's material payoff because no transfers are made in equilibrium and the occurrence of a loss for one of them is independent from the other's choice of effort. Thus, agents A and B behave as if they were in an autarky relation with the insurer. For degrees of altruism larger than, but close to, $\widehat{\alpha}(C)$, the positive transfers between agents reduce the expected loss they face, and thus a free-riding effect appears: agents reduce their equilibrium effort on the vicinity of $\widehat{\alpha}(C)$ due to the decrease in the risk each of them faces because of the equilibrium transfers. However, as α goes to 1, the problem faced by each agent in $G^*(C)$ becomes ever more similar to one that would be solved by a social planner seeking to maximize total utility, and thus the free-riding problem would be mitigated and a higher equilibrium effort will be exerted[14]. These observations are summarized in the next proposition.

Proposition 3: *Consider the unique symmetric Nash equilibrium (p^*, p^*) of $G^*(C)$. If $p^*(\widehat{\alpha}(C), C) > 0$ and $p^*(1, C) > 0$, then there is an $\overline{\varepsilon} > 0$ such that $p^*(\widehat{\alpha}(C) + \varepsilon, C) < p^*(\widehat{\alpha}(C), C)$ and $p^*(1 - \varepsilon, C) < p^*(1, C)$ for all $\varepsilon \in (0, \overline{\varepsilon})$ and $C \in \mathbb{R}^2_+$.*

Example 1: Figure 3.1.2 illustrates the results in Lemma 1 and Proposition 3 for $u(w) = \sqrt(w)$ and $\psi(p) = \frac{p^2}{2}$. I also assume that $w^H = 3$ while $w^L = 1$. I consider two offers by the principal: $C = (0, 0)$ captured by the blue lines, and $C = (0.2, 0.1)$ in the red line.

The threshold levels are $\widehat{\alpha}(0, 0) = \frac{\sqrt{1}}{\sqrt{3}} \approx 0.577$ and $\widehat{\alpha}(0.2, 0.1) = \frac{\sqrt{1-0.1+0.2}}{\sqrt{3-0.1}} \approx 0.616$. For degrees of altruism below those levels, the siblings do not make transfers to one another and the effort on self-protection is kept constant, as in autarky. For higher degrees of altruism, while transfers increase as each agent becomes more concerned with the other's material payoff, equilibrium effort exhibits the non-monotone behavior described before. Last, but not least, the introduction of the insurance policy reduces both equilibrium transfers and effort for each degree of altruism, since each agent faces a smaller loss. The second effect is exactly the moral hazard problem in the single agent insurance problem in the previous section.

[14]For $\alpha = 1$, the agents fully internalize the effects of their choices on each other's payoffs, and therefore the free-riding problem disappears.

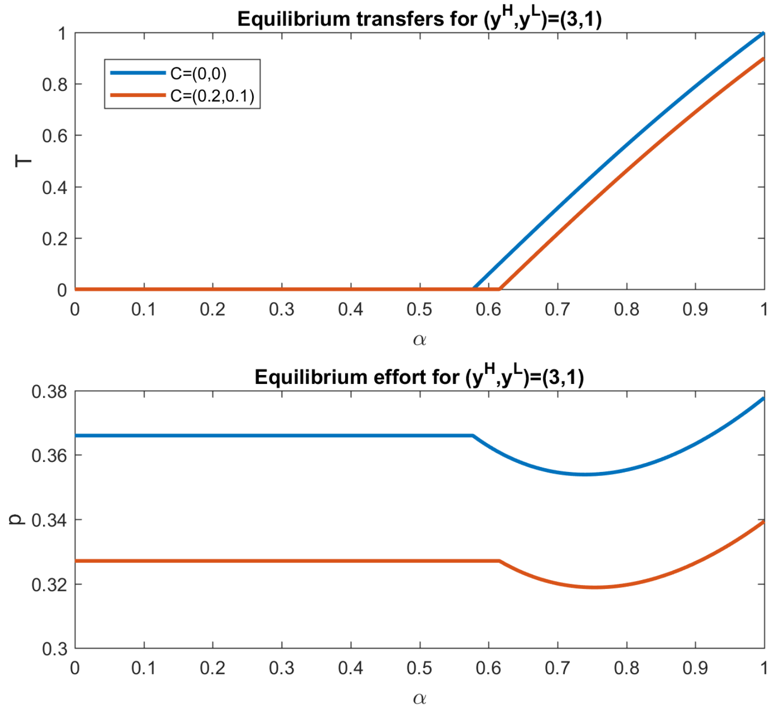

Figure 1: Equilibrium transfer and effort for $u(w) = \sqrt{w}$ and $\psi(p) = \frac{p^2}{2}$

3.1.3 Ex Ante Expected Material Payoff and Utility

After computing transfers and efforts in the unique symmetric equilibrium of $G^*(C)$, the equilibrium expected material payoff of each agent is given by

$$\begin{aligned} V^*(\alpha, C) = {} & [p^*(\alpha, C)]^2 u(w^H - t) + [1 - p^*(\alpha, C)]^2 u(w^L - t + q) \\ & + p^*(\alpha, C)[1 - p^*(\alpha, C)][u(w^H - t - T(\alpha, C)) + u(w^L - t + q + T(\alpha, C))] \\ & - \psi(p^*(\alpha, C)), \end{aligned} \tag{18}$$

while symmetry implies that the utility function can be written as

$$U^*(\alpha, C) = (1 + \alpha)V^*(\alpha, C). \tag{19}$$

Two important comparative statics results about the equilibrium expected material payoff (and consequently expected utility) can be taken from Alger and Weibull (2010) by setting

$y^H = w^H - t$ and $y^L = w^L - t + q$ in their model. The first result (Proposition 11 in Alger and Weibull (2010)) states that the highest expected material payoff is reached at full altruism, that is, when $\alpha = 1$. In that case, each agent weights their material payoffs equally in each utility function, and therefore any free-riding effect is nullified. The second result (Proposition 12 in Alger and Weibull (2010)) shows that the expected material payoff will be increasing in the degree of altruism even in the region where equilibrium effort decreases with α. These statements are collected below.

Proposition 4: *Fix any insurance contract $C = (q, t) \in \mathbb{R}^2_+$ accepted by the siblings. Then,*

1. $V^*(1, C) \geq V^*(\alpha, C)$ *for all* $\alpha \in [0, 1]$*;*
2. *If* $p^*(\widehat{\alpha}(C), C) > 0$*, there is an* $\overline{\varepsilon} > 0$ *such that* $V^*(\widehat{\alpha}(C) + \varepsilon, C) > V^*(\widehat{\alpha}(C), C)$ *for all* $\varepsilon \in (0, \overline{\varepsilon})$.

One important consequence of this result is that higher degrees of altruism may represent bad news for an insurance company trying to trade with these agents, since their outside option, given by $U^*(\alpha, (0, 0))$, becomes larger. In order to verify if that is the case, I turn attention to all contracts $C = (q, t)$ that yield the same utility to the agents as the null contract $C_0 = (0, 0)$, for varying degrees of altruism.

Generally speaking, for any given utility level $\overline{u}$, I can derive the isoutility curve parameterized by the degree of altruism $\alpha \in [0, 1]$ in the (q, t)-plane by the marginal rate of substitution between coverage and premium, i.e.

$$MRS_{q,t}(q, t; \alpha) = \frac{dt}{dq} = -\frac{\partial U^*/\partial q}{\partial U^*/\partial t}. \tag{20}$$

Such an exercise is important because it can determine whether there are gains of trade to be obtained by signing a formal insurance coverage with the firm, once the zero profit line for the insurer is defined (which will be done in the next section).

Claim: *The isolutility curve $U^*(\alpha, C) = \overline{u}$, for $\overline{u} \in \mathbb{R}$, is strictly increasing and concave in the (q, t)-plane for any $\alpha \in [0, 1]$ for sufficiently large ψ''.*

The proof for the claim is partitioned in two spaces: one has $\alpha \in [0, \widehat{\alpha}(0,0)] \bigcup 1$, where either there are no transfers and all insurance is provided through a marketable policy or transfers equalize the marginal utilities of consumption with and without the occurrence of a loss. In either case, the computations are made easy because equilibrium transfers and efforts are constant. The same doesn't happen in the second case, where $\alpha \in [\widehat{\alpha}(0,0), 1)$: the possibility of free-riding on the sibling's transfers make the interaction between self-protection, insurance acquisition and cross-insurance non-trivial.

Example 2: In the same parametrization of the previous example, I compute the isoutility curves passing by the point $(q, t) = (0, 0)$ *for the degrees of altruism* $\alpha = \{0, 0.6, 0.9, 1\}$ *in Figure 3.1.3 . Any choice of* $\alpha \leq \widehat{\alpha}$ *leads to the same curve as for* $\alpha = 0$ *since no transfers are made and effort is constant. Also, one must notice that the isoutility curves do not change monotonically with changes in* α*: this is a reflection of the non-monotonicity of effort and the combinations of contracts that yield the same level of expected utility.*

3.2 Optimal Efforts and Transfers When Only One Agent Accepts the Insurance Policy

As in the preceding section, suppose that the insurance policy $C = (q, t)$ is available to both agents, but now only agent A accepts the offer, while agent B remains uninsured. Again, I will proceed by backward induction, first analyzing the equilibrium transfers and then equilibrium efforts[15].

[15]This situation is akin to a household contracting a single insurance policy to protect a car driven by two of its members, for instance. I do, however, keep the assumption that the agents will select transfers and effort non-cooperatively rather than jointly. For $\alpha = 1$, the problems are equivalent, since each agent would be choosing transfers and efforts to maximize total welfare.

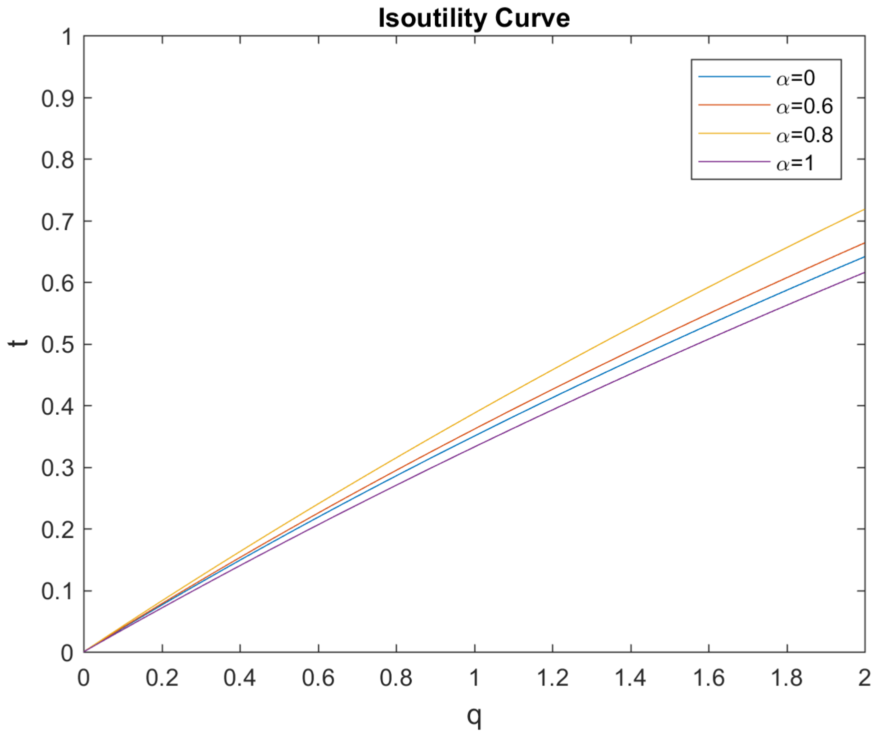

Figure 2: Isoutility curve for $u(w) = \sqrt{w}$ and $\psi(p) = \frac{p^2}{2}$

3.2.1 Equilibrium Transfers

I will start with the decision of sibling A, who is insured. He must choose transfers τ_A to maximize

$$\begin{cases} u(w^H - t - \tau_A) + \alpha u(w^H + \tau_A) & \text{if } (w_A, w_B) = (w^H, w^H), \\ u(w^H - t - \tau_A) + \alpha u(w^L + \tau_A) & \text{if } (w_A, w_B) = (w^H, w^L), \\ u(w^L - t + q - \tau_A) + \alpha u(w^H + \tau_A) & \text{if } (w_A, w_B) = (w^L, w^H), \\ u(w^L - t + q - \tau_A) + \alpha u(w^L + \tau_A) & \text{if } (w_A, w_B) = (w^L, w^L). \end{cases}$$

The first observation is that if $w_B = w^H$, $\tau_A = 0$. Indeed, if the uninsured agent B doesn't suffer a loss, he will enjoy the highest wealth at the end of the first period, and therefore agent A has no incentive to make him any transfer. On the other hand, if $w_B = w^L$, agent

A makes transfer $\tau_A > 0$ satisfying

$$\begin{array}{ll} u'(w^H - t - \tau_A) = \alpha u'(w^L + \tau_A) & \text{if } w_A = w^H \text{ and } \alpha \geq \frac{u'(w^H - t)}{u'(w^L)} \equiv \widehat{\alpha}_A^1 \\ u'(w^L - t + q - \tau_A) = \alpha u'(w^L + \tau_A) & \text{if } w_A = w^L \text{ and } \alpha \geq \frac{u'(w^L - t + q)}{u'(w^L)} \equiv \widehat{\alpha}_A^2. \end{array}$$

Notice that $0 \leq \widehat{\alpha}_A^1 \leq \widehat{\alpha}_A^2 \leq 1$: agent A will have to display a higher degree of altruism to make a positive transfer when he suffers a loss as well in comparison with when he's lucky, as one would expect. Let $T_A(\omega) = \max\{0, \tau_A(\omega)\}$ denote the optimal transfers made by A. Then one can check that $T_A(w^H, w^L) \geq T_A(w^L, w^L)$: the insured agent will make larger transfers when he hasn't suffered a loss.

For the uninsured agent B, transfer τ_B must maximize

$$\begin{cases} u(w^H - \tau_B) + \alpha u(w^H - t + \tau_B) & \text{if } (w_A, w_B) = (w^H, w^H), \\ u(w^H - \tau_B) + \alpha u(w^L - t + q + \tau_B) & \text{if } (w_A, w_B) = (w^L, w^H), \\ u(w^L - \tau_B) + \alpha u(w^H - t + \tau_B) & \text{if } (w_A, w_B) = (w^H, w^L), \\ u(w^L - \tau_B) + \alpha u(w^L - t + q + \tau_B) & \text{if } (w_A, w_B) = (w^L, w^L). \end{cases}$$

Now, I argue that $\tau_B = 0$ whenever $w_B = w^L$. Indeed, in this case the uninsured agent experiences the worst possible outcome, and therefore never makes a positive transfer to the other agent, irrespective of his own degree of altruism. On the other hand, if $w_B = w^H$, the transfers made by B must satisfy

$$\begin{array}{ll} u'(w^H - \tau_B) = \alpha u'(w^H - t + \tau_B) & \text{if } w_A = w^H \text{ and } \alpha \geq \frac{u'(w^H)}{u'(w^H - t)} \equiv \widehat{\alpha}_B^1 \\ u'(w^H - \tau_B) = \alpha u'(w^L - t + q + \tau_B) & \text{if } w_A = w^L \text{ and } \alpha \geq \frac{u'(w^H)}{u'(w^L - t + q)} \equiv \widehat{\alpha}_B^2. \end{array}$$

As before, an intuitive result obtains: $1 \geq \widehat{\alpha}_B^1 \geq \widehat{\alpha}_B^2 \geq 0$, i.e. positive transfers from the uninsured agent to the insured one happen at lower degrees of altruism when the later suffered a loss. Similarly defining $T_B(\omega) = \max\{0, \tau_B\}$, I find that $T_B(w^H, w^H) \leq T_B(w^L, w^H)$, i.e. the uninsured agent will make larger transfers when his counterpart has suffered a loss.

Table 1 below summarizes when agents A and B will make transfers T_A and T_B to one another. In particular, it is important to notice that each possible state of the world will induce some transfer from one agent to the other, but no two two transfers are made concomitantly.

Table 1: Transfers for each state of the world $\omega \in \Omega$ when only one agents accept the insurance policy.

ω	$w_B = w^H$	$w_B = w^L$
$w_A = w^H$	$0, T_B^{HH}$	$T_A^{HL}, 0$
$w_A = w^L$	$0, T_B^{LH}$	$T_A^{LL}, 0$

Proposition 5: *For each $\omega \in \Omega$, there exists at least one Nash equilibrium of $G'(\omega)$ in which only one agent accepts the insurance contract. If $\alpha_A \alpha_B < 1$, then this equilibrium is unique, and at most one agent makes a transfer, which doesn't depend on the receiving agent's degree of altruism. If $\alpha_A = \alpha_B = 1$, there is a continuum of Nash equilibria, all resulting in equal sharing of total net wealth.*

One final remark must be made about the equilibrium transfers when only one agent accepts the insurance policy $C = (q, t)$, which is how do they compare with the transfers made when both agents are insured. As intuition would predict, transfers are larger in the former case than in the latter. This is true for three reasons. First, agents will also make positive transfers when either both of them experienced a loss, or when none of them has been adversely hit, something that doesn't happen when both agents are insured. Second, for the cases when only one agent faced a loss, transfers are made for lower degrees of altruism. Finally, the because the difference in wealth experienced by the agents in these cases are larger when uninsured, transfers must necessarily increase in order to equalize the altruism-weighted marginal utilities of wealth.

Lemma 2: *Suppose that $u''' \geq 0$ and $0 \leq t < q \leq L$. Then, $\widehat{\alpha}_A^1 \leq \widehat{\alpha} \leq \widehat{\alpha}_A^2$ and $\widehat{\alpha}_B^1 \geq \widehat{\alpha} \geq \widehat{\alpha}_B^2$, as well as $T_i(\omega) \geq T(\omega)$ for $i = A, B$.*

Example 3: Fixing the offer of the insurance company to the contract $C = (0.2, 0.1)$, Figure 3.2.1 plots each equilibrium transfer made by agents A and B as a function of the *degree of altruism α. Figure 3.2.1 does the same, but for a different policy $C' = (1, 0.2)$, where one can see that the transfer made by the insured agent when both suffer a loss can be larger than the transfer made from the uninsured agent when he is the only one that didn't suffer a loss.*

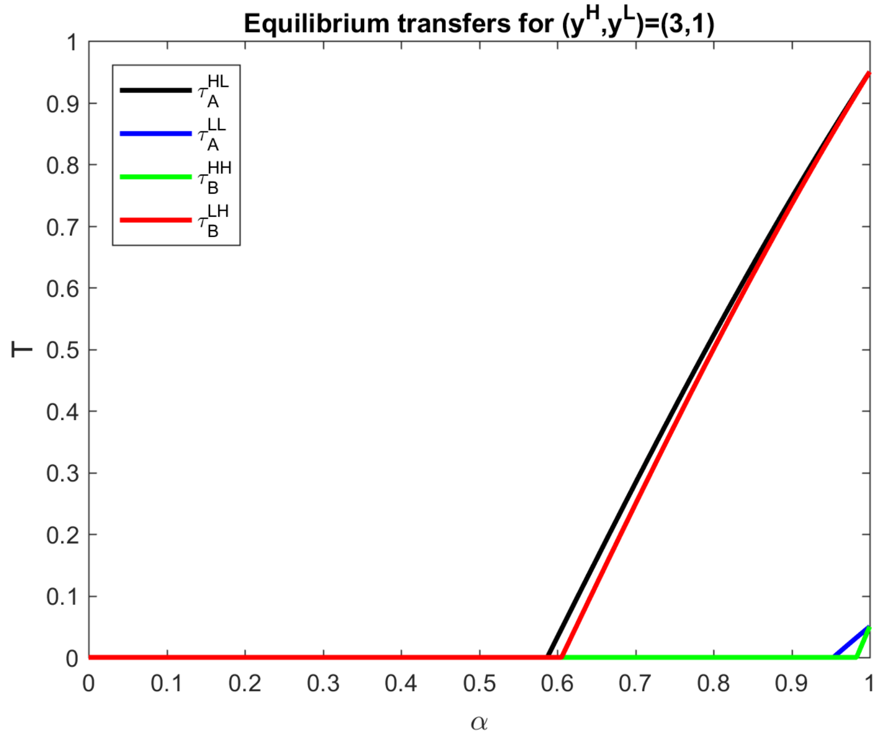

Figure 3: Equilibrium transfers for a single agent accepting the insurance policy $C = (0.2, 0.1)$, for $u(w) = \sqrt{w}$ and $\psi(p) = \frac{p^2}{2}$

3.2.2 Equilibrium Efforts

Once equilibrium transfers are calculated, I can turn attention to the preceding step in the agents' decision process, i.e. the choice of self-protection. As was the case when both agents were insured (or not), each must choose the level of effort that maximizes expected utility.

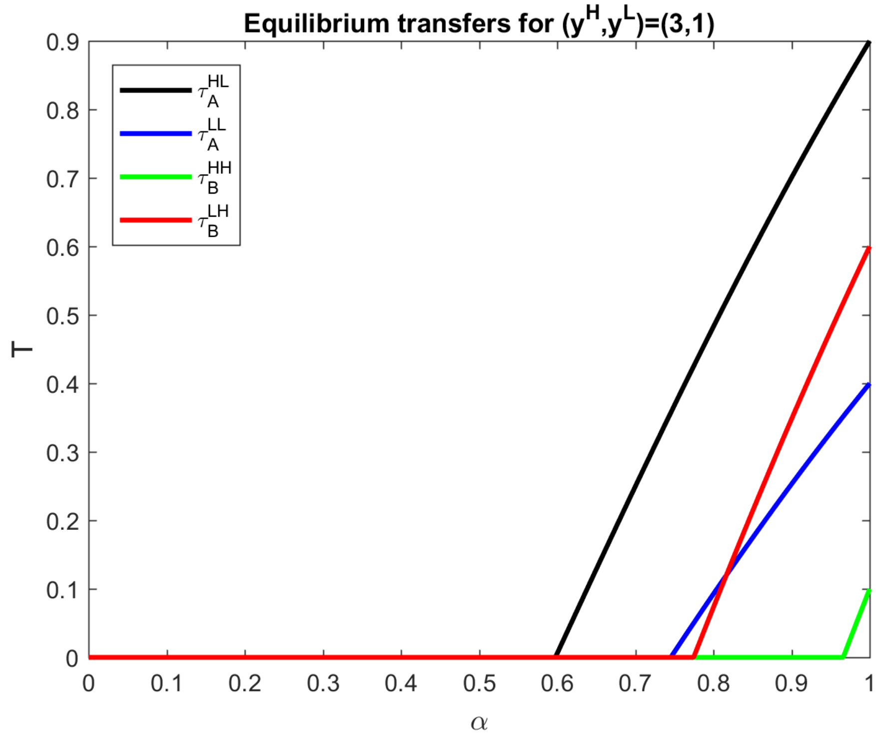

Figure 4: Equilibrium transfers for a single agent accepting the insurance policy $C' = (1, 0.2)$, for $u(w) = \sqrt{w}$ and $\psi(p) = \frac{p^2}{2}$

For agent A, this is equivalent to solving

$$
\begin{aligned}
\max_{\widetilde{p}_A} \widetilde{p}_A p_B & \left[u(w^H - t + T_B^{HH}) + \alpha u(w^H - T_B^{HH})\right] \\
& \widetilde{p}_A(1-p_B)\left[u(w^H - t - T_A^{HL}) + \alpha u(w^L + T_A^{HL})\right] \\
& (1-\widetilde{p}_A)p_B\left[u(w^L - t + q + T_B^{LH}) + \alpha u(w^H - T_B^{LH})\right] \\
& (1-\widetilde{p}_A)(1-p_B)\left[u(w^L - t + q - T_A^{LL}) + \alpha u(w^L + T_A^{LL})\right] \\
& \psi(\widetilde{p}_A) - \alpha\psi(p_B),
\end{aligned}
\tag{21}
$$

while agent B must solve

$$
\begin{aligned}
\max_{\widetilde{p}_B} p_A \widetilde{p}_B & \left[u(w^H - T_B^{HH}) + \alpha u(w^H - t + T_B^{HH})\right] \\
& p_A(1-\widetilde{p}_B)\left[u(w^L + T_A^{HL}) + \alpha u(w^H - t - T_A^{HL})\right] \\
& (1-p_A)\widetilde{p}_B\left[u(w^H - T_B^{LH}) + \alpha u(w^L - t + q + T_B^{LH})\right] \\
& (1-p_A)(1-\widetilde{p}_B)\left[u(w^L + T_A^{LL}) + \alpha u(w^L - t + q - T_A^{LL})\right] \\
& \psi(\widetilde{p}_B) - \alpha\psi(p_A). \qquad (22)
\end{aligned}
$$

The optimal level of self-protection exerted by the agents is a solution the system of first order equations

$$
\begin{cases}
a_A(q,t,\alpha) + b_A(q,t,\alpha)p_B - \psi'(p_A) = 0 \\
a_B(q,t,\alpha) + b_B(q,t,\alpha)p_A - \psi'(p_B) = 0
\end{cases}
$$

where

$$
a_A(q,t,\alpha) = \left[u(w^H - t - T_A^{HL}) - u(w^L - t + q - T_A^{LL})\right] + \alpha\left[u(w^L + T_A^{HL}) - u(w^L + T_A^{LL})\right], \qquad (23)
$$

$$
a_B(q,t,\alpha) = \left[u(w^H - T_B^{LH}) - u(w^L + T_A^{LL})\right] + \alpha\left[u(w^L - t + q + T_B^{LH}) - u(w^L - t + q - T_A^{LL})\right], \qquad (24)
$$

and

$$
\begin{aligned}
b_A(q,t,\alpha) = {} & u(w^H - t + T_B^{HH}) - u(w^H - t - T_A^{HL}) + u(w^L - t + q - T_A^{LL}) - u(w^L - t + q + T_B^{LH}) \\
& + \alpha\left[u(w^H - T_B^{HH}) - u(w^H - T_B^{LH}) + u(w^L + T_A^{LL}) - u(w^L + T_A^{HL})\right], \qquad (25) \\
b_B(q,t,\alpha) = {} & u(w^H - T_B^{HH}) - u(w^H - T_B LH) + u(w^L + T_A^{LL}) - u(w^L + T_A^{HL}) \\
& + \alpha\left[u(w^H - t + T_B^{HH}) - u(w^H - t - T_A^{HL}) + u(w^L - t + q - T_A^{LL}) - u(w^L - t + q + T_B^{LH})\right]. \qquad (26)
\end{aligned}
$$

One must notice that for sufficiently small degrees of altruism[16], all transfers between agents are zero, thus implying that equations 25 and 26 are equal to zero while equations 23 and 24 reduce, respectively, to

$$
a_A(q,t,\alpha) = u(w^H - t) - u(w^L - t + q) \qquad (27)
$$

[16]More precisely, for $\alpha \leq \min\left\{\widehat{\alpha}_A^1, \widehat{\alpha}_A^2, \widehat{\alpha}_B^1, \widehat{\alpha}_B^2\right\}$.

and

$$a_B(q,t,\alpha) = u(w^H) - u(w^L) \tag{28}$$

thus yielding precisely the first-order conditions determining optimal self-protection efforts under autarky in equations 3 and 6.

Example 4: Once more, take $C = (0.2, 0.1)$. Figure 3.2.2 plots equilibrium efforts made by agents A and B as a function of the degree of altruism α. For sufficiently low degrees of altruism, efforts are constant, reflecting the agents choice when they do not trade with one another. As the degree of altruism increases, self-protection for both agents behave non-monotonically, reflecting the countervailing effects of free-riding on each others transfers and the desire to help one another.

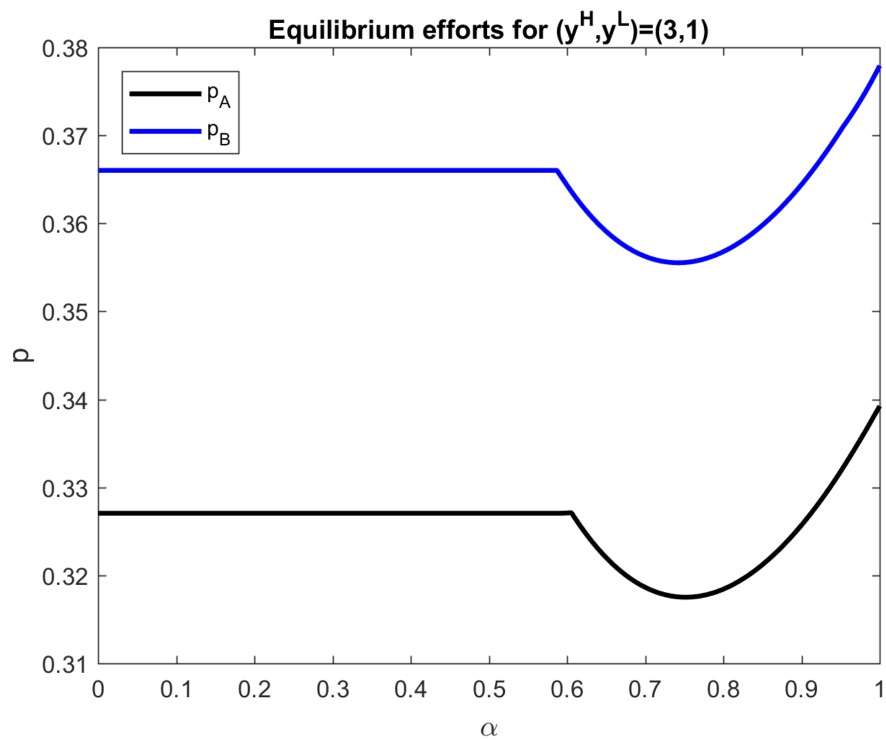

Figure 5: Equilibrium efforts when a single agent accepting the insurance policy $C' = (0.2, 0.1)$, for $u(w) = \sqrt{w}$ and $\psi(p) = \frac{p^2}{2}$

3.2.3 Ex Ante Expected Material Payoff and Utility

Focus now on the expected utility for each agent. The objective of this section is to provide answers to three questions, namely whether the expected utilities are increasing in the degree of altruism for any fixed contract, whether the expected utility for the insured agent is greater than for the uninsured agent for any degree of altruism, and finally how do these functions compare to the expected utility of the agents when both accept the insurance contract. The last two questions are essential in the following analysis, because they determine whether the agents can profitably deviate by rejecting the contract offered by the insurance company.

Example 5: Figures 3.2.3 and 3.2.3 plot the expected utilities for agents A and B for the insurance policies $C = (0.2, 0.1)$ *and* $C' = (1, 0.2)$*, respectively. While in the first there is very little difference between the two curves, mainly due to the very close values of the equilibrium transfers in Figure 3.2.1, the same is not true for the second graph. As intuition would suggest, the insured agent has a higher expected utility than his uninsured counterpart, due in large part to the smaller self-protection effort exerted by him in equilibrium. It is noteworthy that such difference decreases when altruism becomes larger.*

3.3 The Agents Decision to Buy Insurance

I can now analyze the agents' demand for insurance policy. Intuitively, when altruism is low, the agents must rely solely on the insurance policy being offered to protect themselves against the risk they face, in addition to the self-protection effort they exert. As altruism increases just enough so that transfers become positive, the agents can enjoy an increase in utility by also purchasing the insurance policy to complement the risk-sharing due to transfers in uneven outcomes. However, even higher degrees of altruism may lead contracts to be rejected by the agents because risk-sharing through transfers in addition to self-protection effort are more than enough to compensate risk for a given premium.

One remark is in order here. Any contract offering full coverage will not be rejected by the agents as long as the premium is not larger than the loss. This is true for two

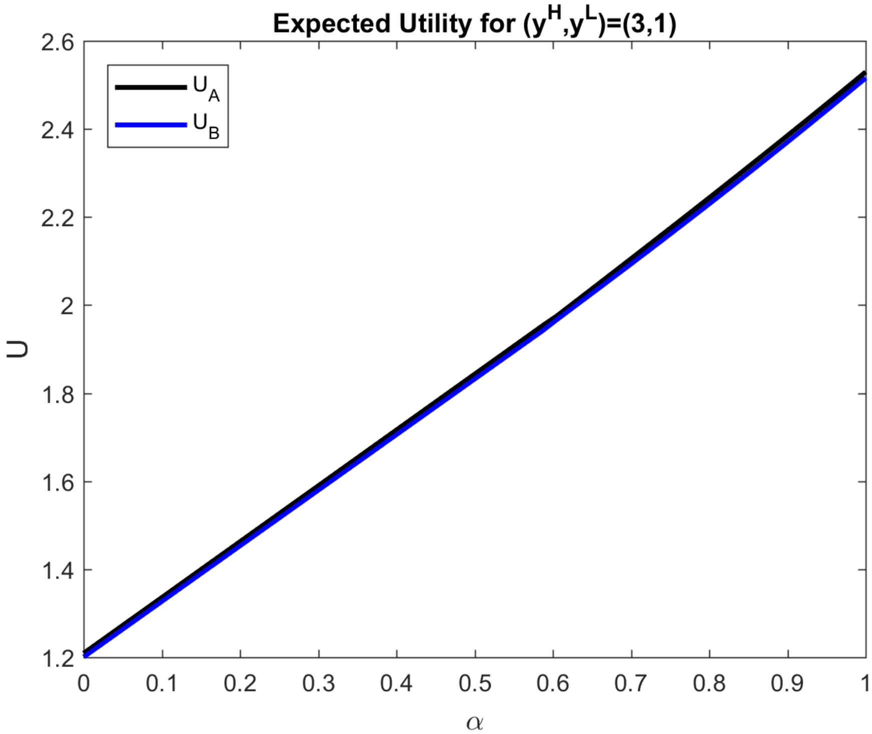

Figure 6: Expected utilities when a single agent accepts the insurance policy $C' = (0.2, 0.1)$, for $u(w) = \sqrt{w}$ and $\psi(p) = \frac{p^2}{2}$

reasons. First, full coverage implies zero self-protection, and thus the agents do not suffer the disutility of effort associated with self-protection. Second, full coverage leads to zero transfers in equilibrium (since $\widehat{(1, t)} = 1$), so that risk-sharing between pairs of agents no longer affect the individual demands for insurance.

Example 6: Figure 3.3 depicts the difference in expected utility for a single agent when both of them buy the contract $C = (0.2, 0.1)$ *against when only the other agent buys such contract. While transfers are not made, the insurance policy* C *makes the agent indifferent between buying or not the contract. As altruism increases and transfers become positive, the agent is first better off acquiring the insurance policy to complement the transfers that will be made for each realized outcome. However, as altruism becomes even larger, the increase in*

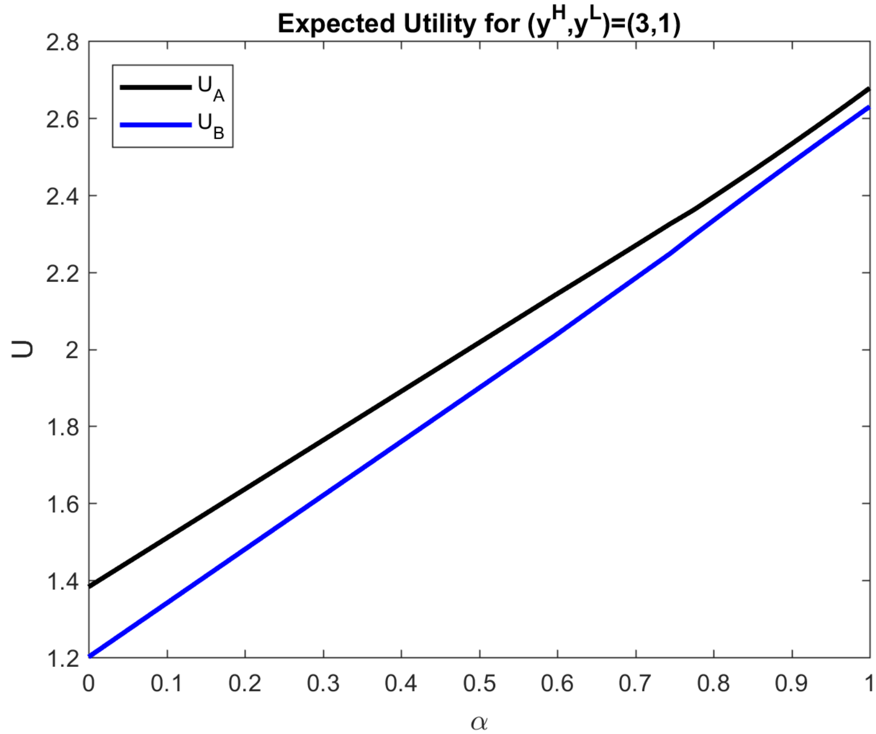

Figure 7: Expected utilities when a single agent accepts the insurance policy $C' = (0.2, 0.1)$, for $u(w) = \sqrt{w}$ and $\psi(p) = \frac{p^2}{2}$

the size of equilibrium transfers together with higher self-protection effort reduces the overall utility for an agent when both buy the insurance contract.

4 The Insurer's Problem

I can now focus on the insurer, who seeks to maximize expected profits given the equilibrium behavior of the siblings for any offer of contract C. As a first step, consider again the first-order condition determining equilibrium efforts, equation 17, and notice that its right-hand side can be rewritten as

$$h(p, \alpha, C) = u(w^H - t) - u(w^L - t + q) + g(p, \alpha, C), \tag{29}$$

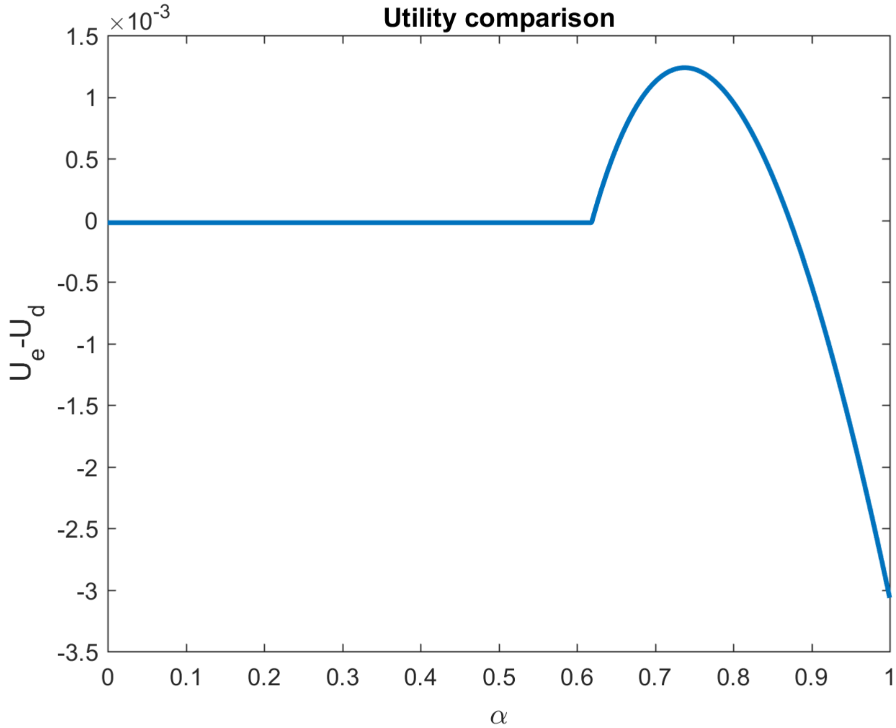

Figure 8: Difference in expected utilities when either both or a single agent accepts the insurance policy $C' = (0.2, 0.1)$, for $u(w) = \sqrt{w}$ and $\psi(p) = \frac{p^2}{2}$

where

$$\begin{aligned} g(p,\alpha,C) = (1-p)\,&\big[u(w^H - t - T(\alpha,C)) + \alpha u(w^L - t + q + T(\alpha,C)) \\ &-(u(w^H - t) + \alpha u(wL - t + q))\big] \\ &- p\,\big[u(y^L - t + q + T(\alpha,C)) + \alpha u(y^H - t - T(\alpha,C)) \\ &-(u(w^L - t + q) + \alpha u(w^H - t))\big]\,. \end{aligned} \tag{30}$$

Notice that $g(p,\alpha,C) = 0$ for any $\alpha \leq \widehat{\alpha}(C)$.

Thus, I can finally write

$$
\begin{aligned}
\max_{q,t} \quad & 2[t-(1-p^*(\cdot))q] & & \\
s.t. \quad & T(\cdot)=0 & \text{if } \alpha \leq \widehat{\alpha}(C) \quad & (IC_{T1}) \\
& u'(w^H-t-T(\cdot))=\alpha u'(w^L-t+q+T(\cdot)) & \text{if } \alpha > \widehat{\alpha}(C) \quad & (IC_{T2}) \\
& \psi'(p^*(\cdot))=u(w^H-t)-u(w^L-t+q)+g(p^*(\cdot),\alpha,q,t) & & (IC_p) \\
& U^*(\alpha,q,t) \geq U^R(\alpha,q,t) & & (IR)
\end{aligned}
$$

where the first three constraints summarize the equilibrium behavior of the siblings with respect to transfers and effort, respectively, for any proposed contract $C=(q,t)$, while the last inequality is the participation constraint.

The agents' participation constraint also implies that any contract in which the premium is equal to or larger than the coverage will never be accepted, as will also any contract with zero coverage and positive premium: indeed, any contract satisfying these conditions reduces the siblings' wealth whether or not a loss has occurred, and thus they are better off rejecting the insurer's offer. On the other hand, contracts with a coverage larger than the loss, or with zero premium, are not profitable for the insurer: in the latter case, for any effort exerted by the siblings, the principal's expected profit is negative, while in the former case, since the siblings are fully insured against losses, they do not exert any effort, and thus a profitable contract for the principal would involve a premium larger than the coverage, which I have already argued would be rejected by the agents. Therefore, in equilibrium, either $C^*=(0,0)$, or $C^* \in \mathbb{R}^2_{++}$ such that $(1-p^*)q \leq t < q < L$. As a consequence, equilibrium effort is always strictly positive ($p^*(\alpha,C^*)>0$ for every $\alpha \in [0,1]$) and there is a range of degrees of altruism for which positive transfers are made (i.e. $\widehat{\alpha}(C^*) \in (0,1)$).

Another important point about the participation constraint is that its right-hand side is not exogenously fixed. Any policy C proposed by the principal will affect the insured agent's equilibrium decisions, which in turn determines the choices of the uninsured agent as long as the degree of altruism is sufficiently large, as was discussed in the previous section. On the other hand, for very selfish agents, the participation constraint is identical to the one obtained in the benchmark moral hazard problem with a single agent due to the assumption of independence between losses.

If insurance is mandatory, in the sense that both agents must buy the policy proposed by the principal, I show that there are gains of trade to be had for any degree of altruism. This is true because both agents are unable to share risk when both suffer a loss unless they are covered by an insurance policy. Formally speaking, I show that the marginal rate of substitution between q and t for the agents is larger than the slope of the zero profit line of the principal in the neighborhood of the null contract for any degree of altruism.

For any strictly positive equilibrium efforts, I am able to draw the isoprofit lines for the insurer on the (q,t)-plane by

$$\Pi(k) = \{(q,t) \in \mathbb{R}^2_+ : t - [1 - p^*(\alpha, q, t)]q = k\}, \tag{31}$$

where $k \geq 0$ is the profit level for the principal, and p^* is determined by equation 17 for any fixed degree of altruism α and transfer satisfying equation 12. The following lemma summarizes the equilibrium behavior of the agents for any point along the zero profit line (henceforth ZPL) $\Pi(0)$.

Lemma 3: *For an increase in $C = (q,t)$ along the ZPL:*

i $\widehat{\alpha}$ *increases;*

ii *equilibrium transfers T decrease;*

iii *equilibrium efforts p^* decrease.*

The lemma implies that the isoprofit curve of the insurer is an increasing and convex function on the (q,t)-plane, for any given degree of altruism $\alpha \in [0,1]$.

A full characterization of an optimal contract can be found on the same plane, by considering the marginal rate of substitution (MRS) between insurance coverage and premium for fixed p and T, that is

$$\frac{dt}{dq} = \frac{(1-p)^2 u'(w^L - t + q) + p(1-p)u'(w^L - t + q + T)}{p^2 u'(w^H - t) + (1-p)^2 u'(w^L - t + q) + p(1-p)[u'(w^H - t - T) + u'(w^L - t + q + T)]}. \tag{32}$$

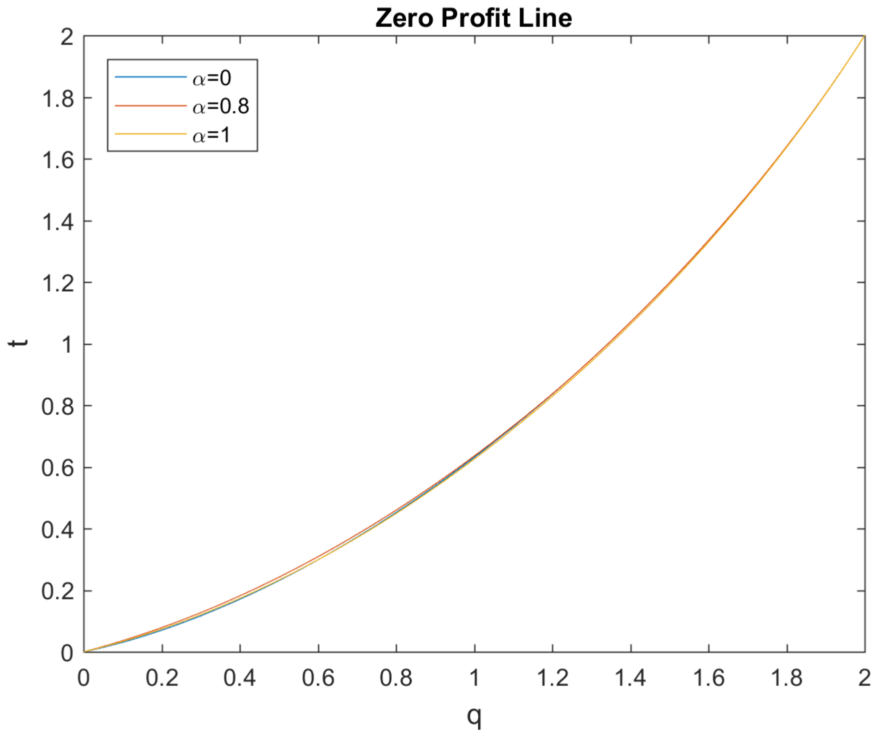

Figure 9: Zero Profit Line (ZPL)

Straightforward computations show that the second order derivative is negative, and thus, as intuition would suggest, the isoutility curves for the siblings are strictly increasing and strictly concave functions on the (q, t)-plane. Therefore, the following graphical argument can be employed to characterize a solution to the insurer's problem.

At $(q, t) = (0, 0)$, if the ZPL is steeper than the MRS, the same will be true for all other contracts along the two curves. Therefore, no gains of trade will exist, and the optimal contract offered by the insurer (and accepted by the siblings) is the null contract $(q, t) = (0, 0)$. In this circumstance, I say that altruism crowds out formal insurance, since the principal can do no better than to exit the market. On the other hand, if the MRS is the steeper curve, then gains of trade can be obtained by both parties by selecting any contract in the region below the MRS and above the ZPL, a non-empty region due to the convexity of both curves. For any contract $(q, t) \neq (0, 0)$ in this region, I say that formal insurance exists, and may or may not coexist with transfers between siblings depending on whether $\alpha \geq \widehat{\alpha}$ or not.

Proposition 6: *Altruism is never strong enough to crowd out formal insurance. Moreover, the equilibrium contract* $C^* = (q^*, t^*) \neq (0,0)$ *is determined by the system of (nonlinear) equations*

$$\begin{array}{ll} T(\alpha, C^*) = 0 & \text{if } \alpha < \widehat{\alpha}(C^*) \\ u'(w^H - t^* - T(\alpha, C^*)) = \alpha u'(w^L - t^* + q^* + T(\alpha, C^*)) & \text{if } \alpha \geq \widehat{\alpha}(C^*) \\ \psi'(p^*) = a(\alpha, C^*) - p^*(1+\alpha) b(\alpha, C^*) & \\ \left.\frac{dt}{dq}\right|_{C^*} = 1 - p^*(\alpha, C^*) & \\ V^*(\alpha, C^*) = V^*(\alpha, (0,0)) & \end{array}$$

where the functions $a(\alpha, C)$ *and* $b(\alpha, C)$ *are given by equations 40 and 41, respectively.*

Proposition 5 is central in the analysis. First, it states that trade between the insurer and the siblings is never precluded in the model, i.e. $C^* \neq (0,0)$. Moreover, given the optimal contract C^*, the interval $[0,1]$ can be divided in two disjoint regions, one in which only formal insurance takes place, and another in which formal and informal insurance coexist. These regions are defined by positive transfers being made in equilibrium: for $\alpha \leq \widehat{\alpha}(C^*)$, equilibrium transfers are null and the only possibility for the siblings to smooth consumption is to accept the insurer's offer; for $\alpha > \widehat{\alpha}(C^*)$, the siblings can complement the insurance policy with transfers between themselves.

Corollary 1**:** *For sufficiently low degrees of altruism, only formal insurance exist. On the other hand, for sufficiently high degrees of altruism, formal and informal insurance coexist.*

5 Concluding Remarks and Future Research

I have studied the interaction between altruistic agents and their choice to engage in trades over formal and informal markets. As so, I have found positive equilibrium transfers, when altruism is sufficiently high, always flowing from the richest sibling to the poor, as empirical evidence finds in a cross-section of developing countries. I have also found that effort provision is non-monotonic: agents may free-ride on each other if altruism is intermediate. Finally, formal insurance companies may have reduced profits due to informal risk-sharing and self-protection by the agents, thus suggesting that societies with high kinship may not yield the most favorable conditions for the emergence of formal insurance markets.

The last result is also captured in the numerical example, which highlights that only formal market exists when agents aren't very altruistic, but that there is coexistence of formal and informal institutions for intermediate degrees of altruism while informal transfers crowd-out formal insurance contracts when altruism is very high.

One important issue hasn't been fully addressed yet, namely a complete analytical characterization of the optimal insurance contract. In particular, under which conditions are the isoutility curves well-behaved, for intermediate degrees of altruism? Without such characterization, important comparative statics results still have to be made, such as how profits vary according to the degree of altruism. Moreover, the coevolution of societies and institutions remains an open question: determining the evolutionarily stable degree of altruism in this setting as a function of the harshness of the environment, namely the size of the loss, is fundamental in comprehending the societies that would have the most favorable conditions for the emergence of formal market institutions.

A Proofs

A.1 Proof of Proposition 1

Suppose, by contradiction, that $\alpha_A\alpha_B < 1$ and that $(b_A, b_B) \in \mathbb{R}^2_{++}$ is a Nash equilibrium of $G(\omega)$. The first-order conditions for the maximization problem of the siblings in 9 are

$$u'(y_A - b_A + b_B) = \alpha_A u'(y_B - b_B + b_A) \tag{33}$$

$$u'(y_B - b_B + b_A) = \alpha_B u'(y_A - b_A + b_B). \tag{34}$$

Substituting 33 into 34 yields $u'(y_B - b_B + b_A) = \alpha_A\alpha_B u'(y_B - b_B + b_A)$, which can only hold if $\alpha_A\alpha_B = 1$ since $u' > 0$ by assumption, a contradiction. Thus, if $\alpha_A\alpha_B < 1$, at most one transfer is positive.

Let $\widehat{\tau}_i : \omega \to [0, w^H]$ be the transfer sibling i would give to his sibling if the latter makes no transfer to i. Then, if $u'(y_i) \geq \alpha_i u'(y_j)$, sibling j is already richer than i, and thus i makes no transfers, i.e. $\widehat{\tau}_i(\omega) = 0$. Otherwise, $\widehat{\tau}_i(\omega)$ is positive and determined by the first-order condition $u'(y_i - \widehat{\tau}_i) = \alpha_i u'(y_j + \widehat{\tau}_i)$, which is uniquely defined.

Thus, if $\alpha_A\alpha_B < 1$, the unique Nash equilibrium of $G(\omega)$ is

- $(b_A, b_B) = (0, 0))$ when $y_A = y_B$;
- $(b_A, b_B) = (\widehat{\tau}_A(\omega), 0)$ when $y_A > y_B$;
- $(b_A, b_B) = (0, \widehat{\tau}_B(\omega))$ when $y_A < y_B$.

Finally, if $\alpha_A = \alpha_B = 1$, then

- if $y_A > y_B$, any $(b_A, b_B) = (\widehat{\tau}_A(\omega) + \varepsilon, \varepsilon)$ is a Nash equilibrium of $G(\omega)$ for all $\varepsilon \in (0, y_A - \widehat{\tau}_A(\omega))$;
- if $y_A < y_B$, any $(b_A, b_B) = (\varepsilon, \widehat{\tau}_B(\omega) + \varepsilon)$ is a Nash equilibrium of $G(\omega)$ for all $\varepsilon \in (0, y_B - \widehat{\tau}_B(\omega))$;
- if $y_A = y_B$, any $(b_A, b_B) = (\varepsilon, \varepsilon)$ is a Nash equilibrium of $G(\omega)$ for any $\varepsilon \in [0, y_A]$.

A.2 Proof of Lemma 1

Fix $\omega \in \Omega$ and consider sibling $i \in \{A, B\}$. For any $\alpha_i \leq \alpha_i(C)$, $T_i(\alpha_i) = 0$ and the statement holds trivially by construction of T_i. For $\alpha_i > \alpha_i(C)$, direct application of the Implicit Function Theorem of the first-order condition 11 yields the result, since $u' > 0 > u''$ by assumption.

A.3 Proofs of Propositions 3 and 4

Set $y^H = w^H - t$ and $y^L = w^L - t + q$, for any $t \geq 0$ and $q \in [0, L]$. The proofs are then identical to Propositions 9, 11 and 13 in Alger and Weibull (2010).

A.4 Proof of Lemma 2

By definition of the ZPL, I consider contracts $C = (q, t)$ such that $t = (1 - p^*)q$. In this proof, fix p^*, and consider infinitesimal increases in q.

I start first by the threshold $\widehat{\alpha}$. By construction,

$$\widehat{\alpha}(q, t) = \frac{u'(w^H - t)}{u'(w^L - t + q)}, \tag{35}$$

which can be rewritten using the ZPL as

$$\widehat{\alpha}(q) = \frac{u'(w^H - (1 - p^*)q)}{u'(w^L + p^*q)}. \tag{36}$$

Therefore, one can easily check that

$$\frac{\partial \widehat{\alpha}(q)}{\partial q} = \frac{-(1 - p^*)u''(w^H - (1 - p^*)q)u'(w^L + p^*q) - p^*u'(w^H - (1 - p^*)q)u''(w^L + p^*q)}{[u'(w^L + p^*q)]^2} > 0, \tag{37}$$

since $u' > 0 > u''$ by assumption and $p^* \in (0, 1)$ by the argument preceding the statement of Lemma 2.

Now, let me focus on transfers T. Let $C' = (q', t') > C = (q, t)$, such that $C', C \in \Pi(0)$. If $\alpha \leq \widehat{\alpha}(C)$, then $T(\alpha, C) = T(\alpha, C') = 0$ since $\widehat{\alpha}(C) < \widehat{\alpha}(C')$ by the first result of the

Lemma and construction of T. If $\widehat{\alpha}(C') \geq \alpha > \widehat{\alpha}(C)$, then $T(\alpha, C) > 0 = T(\alpha, C')$, and the statement holds. Finally, if $\alpha > \widehat{\alpha}(C')$, applying the ZPL condition on equation (IC_{T2}) yield $u'(w^H - (1-p^*)q - T) = \alpha u'(w^L + p^*q + T)$, and by the Implicit Function Theorem,

$$\frac{dT}{dq} = -\frac{\alpha p^* u''(w^L + p^*q + T) + (1-p^*)u''(w^H - (1-p^*)q - T)}{u''(w^H - (1-p^*)q - T) + \alpha u''(w^L + p^*q + T)} < 0 \tag{38}$$

by strict concavity of u.

Finally, I will analyze equilibrium efforts, determined by equation 17. Again, its left-hand side is an increasing function of p, which depends neither on the degree of altruism, nor on the contract or transfers. The right-hand side, on the other hand, is an affine function of p, whose intercept and slope are fully determined by transfers, altruism and the terms of the contract. In what follows, I rewrite equation 29 as

$$h(p, \alpha, C, T) = a(\alpha, C, T) - p(1+\alpha)b(\alpha, C, T) \tag{39}$$

where

$$a(\alpha, C, T) = \left[u(w^H - t - T(\alpha)) - u(w^L - t + q)\right] + \alpha\left[u(w^L - t + q + T(\alpha)) - u(w^L - t + q)\right] \tag{40}$$

and

$$b(\alpha, C, T) = \left[u(w^L - t + q + T(\alpha)) - u(w^L - t + q)\right] - \left[u(w^H - t) - u(w^H - t - T(\alpha))\right]. \tag{41}$$

First, suppose that $\alpha \leq \widehat{\alpha}(C)$. Then $T(\alpha) = 0$ and, thus, $b(\alpha, C, 0) = 0$ and $a(\alpha, C, 0) = u(w^H - t) - u(w^L - t + q)$. Therefore, I must only consider the effect of a change on C along the ZPL on the intercept of h, which I can rewrite as

$$a(\alpha, q, 0) = u(w^H - (1-p^*)q) - u(w^L + p^*q) \tag{42}$$

and compute

$$\frac{\partial a(\alpha, q, 0)}{\partial q} = -(1-p^*)u'(w^H - (1-p^*)q) - p^*u'(w^L + p^*q) < 0. \tag{43}$$

Thus, an increase in C along the ZPL shifts the function $h(p)$ down, and therefore equilibrium effort decreases.

Now, suppose that $\alpha > \widehat{\alpha}(C)$, so that $T(\alpha, C) > 0$. Again using the ZPL to write both $a(\cdot)$ and $b(\cdot)$ as functions of q rather than C, taking the derivative with respect to the coverage implies that

$$\begin{aligned}
\frac{\partial a(\alpha, q, T(\alpha, q))}{\partial q} &= -(1-p^*)u'(w^H - (1-p^*)q - T) - p^*u'(w^L + p^*q) \\
&\quad + \alpha p^* u'(w^L + p^*q + T) - \alpha p^* u'(w^L + p^*q) \\
&\quad + \frac{dT}{dq} \underbrace{\left[-u'(w^H - (1-p^*)q - T) + \alpha u'(w^L + p^*q + T)\right]}_{= 0 \text{ due to } (IC_{T_2})} \\
&= -(1-p^*)u'(w^H - (1-p^*)q - T) - p^*u'(w^L + p^*q) \\
&\quad + \alpha p^* \left[u'(w^L + p^*q + T) - u'(w^L + p^*q)\right] < 0 \qquad (44)
\end{aligned}$$

and

$$\begin{aligned}
\frac{\partial b(\alpha, q, T(\alpha, q))}{\partial q} &= p^* \left[u'(w^L + p^*q + T) - u'(w^L + p^*q)\right] \\
&\quad + (1-p^*) \left[u'(w^H - (1-p^*)q) - u'(w^H - (1-p^*)q - T)\right] \\
&\quad + \frac{dT}{dq} \underbrace{\left[u'(w^L + p^*q + T) - u'(w^H - (1-p^*)q - T)\right]}_{\geq 0 \text{ by } (IC_{T2})} \\
&\leq 0. \qquad (45)
\end{aligned}$$

Thus, an increase in q along the ZPL reduces the intercept of $h(\cdot)$ and also makes it flatter.

The overall effect is

$$
\begin{aligned}
\frac{\partial h(\alpha,q,T(\alpha,q))}{\partial q} &= \frac{\partial a(\alpha,q,T(\alpha,q))}{\partial q} - p^*(1+\alpha)\frac{\partial b(\alpha,q,T(\alpha,q))}{\partial q} \\
&= u'(w^H-(1-p^*)q)[-p^*(1-p^*)(1+\alpha)] \\
&\quad + u'(w^H-(1-p^*)q-T)[-(1-p^*)+p^*(1-p^*)(1+\alpha)] \\
&\quad + u'(w^L+p^*q+T)[\alpha p^*-(p^*)^2(1+\alpha)] \\
&\quad + u'(w^L+p^*q)[-p^*-\alpha p^*+(p^*)^2(1+\alpha)] \\
&\quad - \frac{dT}{dq}(1-\alpha)u'(w^L+p^*q+T)p^*(1+\alpha) \\
&= -p^*(1-p^*)(1+\alpha)[u'(w^H-(1-p^*)q)+u'(w^L+p^*q)] \\
&\quad + u'(w^L p^*q+T)\left[p^*\alpha(3+\alpha)-\alpha-(1+\alpha)^2(p^*)^2-p^*(1-\alpha^2)\frac{dT}{dq}\right] \\
&< -p^*(1-p^*)(1+\alpha)[u'(w^H-(1-p^*)q)+u'(w^L+p^*q)] \\
&\quad + u'(w^L p^*q+T)\left[p^*\alpha(3+\alpha)-\alpha-(1+\alpha)^2(p^*)^2+p^*(1-\alpha^2)\right] \\
&= -p^*(1-p^*)(1+\alpha)[u'(w^H-(1-p^*)q)+u'(w^L+p^*q)] \\
&\quad + u'(w^L p^*q+T)\left[p^*(1+3\alpha)-\alpha-(1+\alpha)^2(p^*)^2\right] \\
&\leq -p^*(1-p^*)(1+\alpha)[u'(w^H-(1-p^*)q)+u'(w^L+p^*q)] \\
&\quad + u'(w^L p^*q)\left[p^*(1+3\alpha)-\alpha-(1+\alpha)^2(p^*)^2\right] \\
&= -p^*(1-p^*)(1+\alpha)u'(w^H-(1-p^*)q) \\
&\quad + u'(w^L+p^*q)[2\alpha p^*-\alpha-(p^*)^2\alpha(1+\alpha)] \\
&< 0, \qquad (46)
\end{aligned}
$$

where the first strict inequality follows from the fact that $\frac{dT}{dq} \in (-1,0)$, the second comes from the strict concavity of u together with $T>0$, and the third one from the fact that the strictly concave function of p, $2\alpha p-\alpha-p^2\alpha(1+\alpha)$, reaches its maximum at $p=\frac{1}{1+\alpha}$, with a value of $-\frac{\alpha^2}{1+\alpha}<0$. Therefore, an increase in $C=(q,t)$ along the ZPL shifts $h(p,\alpha,C)$ down everywhere, and thus equilibrium effort decreases.

A.5 Proof of Proposition 6

Let $p_0 = p(\widehat{\alpha}(0,0),(0,0))$ be the equilibrium effort evaluated at $(q,t) = (0,0)$, and similarly define T_0. If $\frac{dt}{dq}\Big|_{(0,0)} \leq 1 - p_0$, the indifference curve of the agents is always below the ZPL, and thus the only equilibrium contact that leads to non-negative profits for the insurer is $\mathcal{C} = (0,0)$. I show this is not the case.

Suppose, by contradiction, that $\frac{dt}{dq}\Big|_{(0,0)} \leq 1 - p_0$. This is true iff

$$\frac{(1-p_0)^2 u'(w^L - t + q) + p_0(1-p_0)u'(w^L - t + q + T_0)}{p_0^2 u'(w^H - t) + (1-p_0)^2 u'(w^L - t + q) + p_0(1-p_0)[u'(w^H - t - T_0) + u'(w^L - t + q + T_0)]} \leq 1 - p_0$$

$$\Leftrightarrow (1-p_0)u'(w^L) + p_0 u'(w^L + T_0) \leq p_0 u'(w^H) + (1-p_0)u'(w^H - T_0),$$

which can never hold true if $\alpha \leq \widehat{\alpha}(0,0)$: in that case, $T_0 = 0$, and the expression becomes $u'(w^L) \leq u'(w^H)$, a contradiction since $w^H > w^L$ and $u' > 0 > u''$ by assumption.

On the other hand, if $\alpha > \widehat{\alpha}(0,0)$, then $T_0 > 0$ and by 11,

$$\begin{aligned}
(1-p_0)u'(w^L) + p_0 u'(w^L + T_0) &\leq p_0 u'(w^H) + (1-p_0)u'(w^H - T_0) \\
&= p_0 u'(w^H) + (1-p_0)\alpha u'(w^L + T_0) \Leftrightarrow \\
\alpha &\geq \frac{(1-p_0)u'(w^L) + p_0 u'(w^L + T_0) - p_0 u'(w^H)}{(1-p_0)u'(w^L + T_0)} \Leftrightarrow \\
\alpha &\geq \frac{p_0}{1-p_0}\left[1 - \frac{u'(w^H)}{u'(w^L + T_0)}\right] + \frac{u'(w^L)}{u'(w^L + T_0)} > 1,
\end{aligned}$$

a contradiction, since $w^L + T_0 > w^L$ implies that $u'(w^L + T_0) < u'(w^L)$ and $u'(w^H) < u'(w^H - T_0) = \alpha u'(w^L + T_0) \leq u'(w^L + T_0)$ by strict concavity of u, 11 and $\alpha \in [0,1]$.

Therefore, for all values of α, $\frac{dt}{dq}\Big|_{(0,0)} > 1 - p_0$, and an equilibrium contract must be different than $(0,0)$.

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