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The Role of Altruism in Economic Interaction

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I. Introduction

Two hundred years ago Adam Smith examined the workings of an economy in which all individuals are "selfish," and discovered the important concept of the invisible hand. Since Edgeworth (see Sen (1977)), standard economic theory has followed Smith's lead and concentrated on a world where individual behavior is motivated by narrow self-interest. As Sen points out, however, this is not an assumption based on empirical observation, and, in fact, in a variety of circumstances its employment will yield quite misleading results.

In recent writings a number of authors have begun to move away from the strict assumption of narrow self-interest. In particular, attention has been paid to the idea that agents are sometimes motivated by a desire to behave altruistically.[1] Altruism here simply means that in choosing how to behave agents take into consideration how their behavior will affect the welfare of other agents in the population. In general, however, the literature has not considered the ramifications of agents being heterogeneous as regards this characteristic. That is, most authors have not concentrated on what happens in an environment when a proportion of agents are altruists, while others follow standard assumptions and might therefore best be described as egoists. In the present paper we consider the nature of equilibrium under this type of heterogeneity. This is an important issue if one is interested in the validity of the standard approach. The logic is that, since in many real world settings agents are heterogeneous as regards this property, the standard assumption that all agents are egoists will be relatively more defensible if egoists have a disproportionately large effect on equilibrium. However, if it is the altruists who are disproportionately important, then the standard practice would seem to be relatively less defensible.

Before proceeding to a description of our analysis and results, it is worthwhile pointing out that at least some of the previous work on altruism does address this question. That is, Becker (1974, 1976) considers a world where an altruist derives satisfaction from the utility level of a number of egoists, and because of these preferences the altruist transfers income to these egoists. A simple interpretation is that the altruist is a parent who cares about the welfare of his children, while the egoists are his children who happen to be rotten kids, and hence only care about their own well being. What Becker finds is that, as long as the income transfers take place after the egoists have chosen their behavior, the presence of this single altruist causes all the agents to behave as altruists.[2] The reason is that the income transfers link the agents in such a way that, even for those who are only motivated by narrow self-interest, private utility is maximized by adopting the behavior which maximizes the utility of the group. If we now consider this result in terms of our initial question, we see that Becker has identified an environment where the standard approach is poorly justified. That is, in this environment a small number of altruists will have a dramatic effect on how all agents behave, and hence, making the assumption that all agents are only motivated by narrow self-interest can yield quite misleading results.

Although we find Becker's results quite interesting, we feel that they are somewhat limited in their applicability. That is, in many environments where altruism is important there are either no pure income transfers which take place between agents, or even if there are, the transfers do not take place after the egoists have chosen their behavior. In this paper we consider a different environment than that considered by Becker – one which we feel has wider applicability. In particular, we consider a world in which agents choose between two behaviors, one of which has both a private and social return and might therefore best be described as being altruistic, while the other has only a private return and might best be described as being egoistic. It is further assumed that a proportion p of the agents are altruists, while a proportion (1-p) are egoists. As indicated earlier, this simply means that a proportion p of agents get positive satisfaction from the welfare of some or all of the other agents in the population, while a proportion (1-p) do not. We make one further simplifying assumption. That is, payoffs are such that either altruists always choose the altruistic behavior, or egoists always choose the egoistic behavior – but not both. Note that, this setup differs from Becker's in that first, altruists and egoists are assumed to choose their behaviors simultaneously, and second, there are no pure income transfers which take place between the two types.

As indicated above, the focus of the analysis is, given a world in which both altruists and egoists are present, under what situations will the altruists have a disproportionately large effect on equilibrium, and under what situations will it be the egoists. We find two things to be crucial in terms of answering this question: (1) what is the nature of the interaction among agents; and (2) which type of agent is the marginal decision maker. Consider first a world which displays what we will refer to as congestion. That is, for any agent i, the higher is the total number of agents who choose a particular behavior, the lower is the return to agent i choosing that behavior. Our analysis demonstrates that in this type of environment it is the marginal decision makers who are disproportionately important. For example, if the egoists are the marginal decision makers, then the equilibrium will more closely resemble what occurs when all agents are egoists than would be suggested by the relative number of altruists and egoists in the population.

The intuition behind this result can be explained as follows. Consider the case where altruists always choose the altruistic behavior. Because of congestion, the presence of agents who behave in this manner lowers the return to the altruistic behavior, and raises the return to the egoistic behavior. The result is that egoists respond to the presence of altruists by having a larger proportion of egoists choose the egoistic behavior. In other words, the marginal decision makers are disproportionately important given congestion, because the presence of the non-marginal decision makers is somewhat nullified by the response of the marginal decision makers to their presence.

Now consider a world which displays what we will refer to as synergism. That is, the higher is the total number of agents who choose a particular behavior, the <u>higher</u> is the return to agent i choosing that behavior. What we find for this type of environment is that the non-marginal decision makers are disproportionately important. That is, if egoists are again the marginal decision makers, then the equilibrium will more closely resemble what occurs when all agents are <u>altruists</u> than would be suggested by the relative number of altruists and egoists in the population.

The intuition behind this result is related to that given above. Consider again the case where altruists always choose the altruistic behavior. Because of synergism, the presence of agents who behave in this manner now raises the return to the altruistic behavior and lowers the return to the egoistic behavior. The result is that egoists respond to the presence of altruists by having a larger proportion of egoists choose the <u>altruistic</u> behavior. Or in other words, the non-marginal decision makers are disproportionately important given synergism, because the presence of non-marginal decision makers is now reinforced, rather than nullified, by the response of marginal decision makers to their presence.[3]

One might ask what conclusions can be drawn from the above results as regards the standard practice of assuming that all agents in the economy are egoists. The logic again is that, since in many real world settings agents are heterogeneous as regards whether they are altruists or egoists, the practice of assuming all agents are egoists is relatively more defensible when egoists have a disproportionately large effect on equilibrium. Thus, our results suggest that under congestion the standard approach would seem to be well justified when the marginal decision makers are egoists and poorly justified when the marginal decision makers are altruists, while under synergism the conclusions are reversed.

The outline for the paper is as follows. In Section II we construct a stylized model wherein agents choose between an altruistic and an egoistic behavior, and demonstrate the above mentioned results concerning congestion, synergism and disproportionality. The goal of the section is to demonstrate these results in a simple model where the intuition underlying the results can be easily followed. In Sections III-VI we then show how these results apply to four common economic environments: (1) a world where workers decide whether or not to shirk, and firms invest in monitoring in order to detect shirking; (2) the classic problem called the Prisoner's Dilemma; (3) a world where agents decide whether or not to pollute the environment; and (4) a world where agents decide whether or not to donate blood. Section VII presents some concluding remarks.

II. A Stylized Model

In this section we consider a stylized model wherein agents choose between an altruistic behavior and an egoistic behavior. Our goal is to demonstrate the earlier mentioned results concerning congestion, synergism and disproportionality in a manner such that the intuition underlying the results is easily understood. In later sections we consider applications of our general approach to less stylized environments.

Let there be a continuum of agents who choose between an altruistic behavior, denoted behavior A, and an egoistic one, denoted behavior E. It is assumed that this choice of behaviors is an irreversible choice, and that it is made simultaneously by all the agents. If agent i chooses behavior A, then he gets a private return $f_A(N_A)-c_i$. Similarly, if the agent chooses behavior E, then he gets a private return $f_E(N_E)-(C-c_i)$. The term $N_A(N_E)$ denotes the total number of agents who choose behavior A(E), while c_i and $(C-c_i)$ can be interpreted as the costs incurred by agent i in choosing each behavior. When an agent chooses the egoistic behavior there is no effect on the welfare of any agents other than those in the continuum. However, when agents choose the altruistic behavior there is a set of agents outside the continuum who benefit, and they benefit by an amount N_AB.

The agents who are choosing between the two behaviors vary in terms of their values for c_i. In particular, the distribution of c_i's is described by a density function g(.) which is positive over the interval [0,C], and equals zero elsewhere. There are two types of agents making this choice. A proportion p of the agents are altruists, and a proportion (1-p) are egoists, where p is public information and the distribution of altruists and egoists in the population is independent of the distribution of c_i's. Egoists are only concerned with their own private return when choosing a behavior, and hence, egoist i chooses behavior A(E) if $f_A(N_A)-c_i>(<)f_E(N_E)-(C-c_i)$. On the other hand, altruists get some satisfaction from the welfare of the additional set of agents who are benefitted when the altruistic behavior is chosen. Thus, altruist i chooses behavior A(E) if $f_A(N_A)-c_i+rB>(<)f_E(N_E)-(C-c_i)$, where r is the weight altruists place on the welfare of this other group of agents.

One might argue that rather than introducing altruism through the additional set of agents who are benefitted by the altruistic behavior, we could simply allow altruists to derive satisfaction from some or all of the other agents in the continuum. We chose not to do this because the goal of this section is to demonstrate our results in a simple model where the intuition is easy to follow, and we felt this was best accomplished by introducing an additional set of agents. Note, however, in some of the later applications we do allow altruism to enter in the above suggested manner, and the results indicate that the validity of our intuition is not at all dependent on this aspect of the specification.

Finally, we want to impose a number of simplifying assumptions. First, as long as $0<p<1$, we want it to be the case that at least some agents choose each behavior. This is accomplished by assuming $f_A(0)+rB>f_E(\bar{N})-C$ and $f_E(0)>f_A(\bar{N})-C$, where $\bar{N}$ is the total number of agents in the continuum. Second, we want to abstract away from multiple equilibria problems which might arise under synergism. We thus assume $[f_A'(\int_0^z g(c_i)dc_i)+f_E'(\int_z^C g(c_i)dc_i)]g(z)/2<1$ for all $0\leq z\leq C$. Third, as indicated in the Introduction, we only want one of the types of agents to be marginal decision makers. That is, payoffs are assumed to be such that either altruists always choose the altruistic behavior, or egoists always choose the egoistic behavior — but not both.[4]

Note, that, assuming the marginal decision makers are always of the same type may seem quite restrictive. There are two reasons for imposing this condition. First, it allows us to identify some important relationships concerning the identity of the marginal decision makers and the manner in which agents interact. Second, as will become clear when we later consider specific applications, many economic environments satisfy the condition.[5]

The rest of the section consists of an analysis of the above model. Let $N_A^A(N_E^A)$ denote the total number of agents who choose behavior A(E) when all agents are altruists, i.e., p=1, and $N_A^E(N_E^E)$ denote the total number of agents who choose behavior A(E) when all agents are egoists, i.e., p=0. Obviously, for any functions $f_A(.)$ and $f_E(.)$ which satisfy our restrictions it is the case that $N_A^A>N_A^E$ and $N_E^E>N_E^A$. We will first consider what happens when the environment exhibits congestion, i.e., $f_A'\leq 0$ and $f_E'\leq 0$ (where one of the two is everywhere strictly negative). Note, all proofs are relegated to an Appendix.

Proposition 1: Suppose $f_A'\leq 0$, $f_E'\leq 0$ (where one of the two is everywhere strictly negative), and $0<p<1$. If the altruists (egoists) are the marginal decision makers, then $N_A>(<)pN_A^A+(1-p)N_A^E$ and $N_E<(>)pN_E^A+(1-p)N_E^E$.

Proposition 1 tells us that, if the environment exhibits congestion, then it is the marginal decision makers who are disproportionately important. For example, suppose payoffs are such that altruists always choose the altruistic behavior. Then the equilibrium will more closely resemble what occurs when all agents are egoists than would be suggested by the relative number of altruists and egoists in the population. The intuition for the result is as follows. Non-marginal decision makers lower the return to the behavior which they choose, and raise the return to the other behavior. In turn, marginal decision makers respond to the presence of non-marginal decision makers by having a larger proportion choose this other behavior. The result is that marginal decision makers are disproportionately important given congestion, because the presence of non-marginal decision makers is somewhat nullified by the response of the marginal decision makers to their presence.

We will now consider what happens when the environment exhibits synergism, i.e., $f'_A \geq 0$ and $f'_E \geq 0$ (where one of the two is everywhere strictly positive).

Proposition 2: Suppose $f'_A \geq 0$, $f'_E \geq 0$ (where one of the two is everywhere strictly positive), and $0<p<1$. If the altruists (egoists) are the marginal decision makers, then $N_A<(>)pN^A_A+(1-p)N^E_A$ and $N_E>(<)pN^A_E+(1-p)N^E_E$.

Proposition 2 states that, if the environment exhibits synergism, then the conclusions are reversed. That is, under synergism it is the non-marginal decision makers who are disproportionately important. The intuition for this result is related to that given above. Non-marginal decision makers now raise the return to the behavior which they choose and lower the return to the other behavior. Hence, marginal decision makers respond to the presence of non-marginal decision makers by having a larger proportion choose the behavior favored by the non-marginal decision makers. The result is that non-marginal decision makers are disproportionately important given synergism, because the presence of non-marginal decision makers is now reinforced, rather than nullified, by the response of marginal decision makers to their presence.

This concludes the analysis of our stylized model. We have demonstrated our results concerning congestion, synergism and disproportionality in a model where congestion and synergism were easy to identify, and hence, the intuition underlying the results was easy to follow. In the following sections we consider a number of models with more economic content, and show some of the implications of our results for common economic environments.

III. Application 1: A World of Monitoring and Shirking

In this section we consider a labor market setting where workers have the opportunity to shirk, and firms invest in monitoring in order to detect shirking.[6] With a slight alteration the model can also be interpreted as one where agents decide whether or not to steal, and property owners invest in protection against theft. We will first present and analyze the model using the labor market interpretation, and then describe the alternative interpretation and the conclusions which follow from it.

We assume a single period economy in which only one good is produced, and the price of this good is normalized to one. There are a continuum of workers each of whom has the same ability. Following Calvo and Wellisz (1979) we assume that at the beginning of the employment period each worker makes an irreversible decision concerning whether or not to shirk for the entire period. In particular, if worker i is employed at a firm and he shirks he then produces an amount Y, while if he expends effort he produces an amount X, where X>Y. Each worker i also has the following utility function which describes the utility he receives if he is employed at a firm.

$$U_i = U(W_i - \delta_i k + \gamma_i r\Pi_i), \quad (1)$$

where $U'>0$ and $U''\leq 0$. In (1) W_i is the wage received by worker i and Π_i is the profits of the firm employing worker i. $\delta_i = 0(1)$ if the worker does (does not) shirk, and thus, k can be loosely interpreted as the disutility for effort. $\gamma_i = 1(0)$ if worker i is an altruist (egoist). That is, if the worker is an altruist then he derives utility from the profit level of his employer, where r is the weight he places on this profit level, while if the worker is an egoist the employer's profit level does not enter into utility.[7] As previously, it is assumed that a proportion p of the agents are altruists, and a proportion (1-p) are egoists, where p is public information. It is also assumed that whether or not any particular agent is an altruist or an egoist is private information to that worker.

There is free entry into production, and firms are risk neutral. Additionally, it is assumed that the only input used in the production process is labor, and that a worker's wage cannot be made directly contingent on his output. This last restriction can be justified by assuming that only aggregate output can be observed, and that there are economies of scale, although not modeled, such that firms hire many workers. What firms do instead is monitor workers. In particular, again following Calvo and Wellisz (1979), an inspection is carried out at the beginning of the employment period. It is assumed that if the worker is caught shirking he is then fired and becomes self-employed, in which case he receives utility U(H), where $H<Y$. If he is not caught shirking, he is then employed for the entire period and he receives wage W.

The monitoring technology is described as follows. Suppose a firm expends z in the monitoring of worker i. The firm will then receive an indicator of whether or not the worker is shirking, where the indicator can take on two values, S (shirk) and NS (not shirk). If worker i in actuality is not shirking, then independent of the expenditure z the indicator will take on the value NS. If worker i is shirking, then the indicator will take on the value S with probability $q(z)m_i$, and it will take on the value NS with probability $1-q(z)m_i$.[8] The function q(.) is assumed to satisfy the following properties: $q'(0)=\infty$, $q'>0$ and $q''<0$. The above simply states that the monitoring technology never detects shirking if shirking is not occurring. However, when shirking is taking place there is only a probability that it will be detected, where this probability depends on both the expenditure on monitoring and a worker specific parameter m_i. m_i simply captures the idea that workers vary in terms of their ability to avoid being detected, where it is further assumed that each worker's value for m_i is private information to that worker. The distribution of m_i's in the population is independent of the distribution of altruists and egoists, and, in particular, is described by a density function g(.) which is positive over the interval $[0,\infty)$, and equals zero elsewhere. Finally, it is assumed that firms cannot make binding promises concerning expenditures on monitoring. The logic is that these expenditures are not publicly observable, and hence, they must satisfy an incentive compatibility condition.[9]

We will now proceed to analyze the above model.[10] If a worker is an egoist then his decision concerning whether or not to shirk depends on both the expenditures firms make on monitoring, and the worker's value for m_i. For example, if we assume risk neutrality, i.e., $U''=0$, then the worker will (will not) shirk as long as $(W-H)q(z)m_i<(>)k$, where W denotes the wage and z now denotes the expenditure on monitoring which satisfies incentive compatibility. On the other hand, if a worker is an altruist then his decision concerning whether or not to shirk also depends on the potential lost profits of the firm due to shirking. For example, if we again assume risk neutrality, then the worker will (will not) shirk as long as $(W-H)q(z)m_i+r(X-Y)<(>)k$. It is easily demonstrated that equilibrium will be characterized by some egoists shirking and others expending effort. Hence, to stay consistent with the model of the previous section we will restrict our analysis to parameterizations for which altruists are non-marginal decision makers, i.e., all altruists choose not to shirk. From above it is clear that the restriction which guarantees this is $r(X-Y)\geq k$. We will now consider how changes in p affect the amount of both shirking and monitoring in the economy. Note, in the following $N_S(N_{NS})$ will denote the total number of workers in the population who decide to (not to) shirk, while z again denotes the expenditure on monitoring which satisfies incentive compatibility.

Proposition 3: A decrease in p causes $N_S(N_{NS})$ to increase (decrease) and z to increase.

Proposition 3 states that an increase in the proportion of egoists in the population causes an increase in shirking, and a corresponding increase in the amount of monitoring which firms undertake. The result is not particularly surprising. That is, if there is an increase in the proportion of workers willing to shirk, it is not surprising that more shirking will take place and firms will want to undertake more monitoring. The result is important, however, in that it tells us how this model relates back to the model considered in Section II. Specifically, it tells us that this is an environment which exhibits congestion. The more workers willing to shirk, or more precisely the more shirking which actually takes place, the lower is the return to shirking. The logic is that more shirking leads to more monitoring, and more monitoring obviously lowers the return to shirking. In turn, now that we know this environment exhibits congestion, the following proposition becomes much easier to understand. Note, in the following $N_S^E(N_{NS}^E)$ denotes the total number of agents who shirk (do not shirk) when all agents are egoists, and z^E denotes the incentive compatible expenditure on monitoring when all agents are egoists.

Proposition 4: If $0<p<1$, then $N_S>(1-p)N_S^E$, $N_{NS}<(1-p)N_{NS}^E$, and $z>(1-p)z^E$.

Proposition 4 tells us that in this world it is the egoists who are disproportionately important. That is, the amount of shirking and monitoring which takes place more closely resembles what occurs when all agents are egoists than would be suggested by the relative number of altruists and egoists in the population. This result, however, should not be surprising given what we already knew. In particular, we knew that in this environment it is the egoists who are the marginal decision makers, and that this environment exhibits congestion. Hence, Proposition 1 of Section II had already indicated that the egoists should be disproportionately important.[11]

What this tells us, overall, is that the standard approach in this literature is relatively well justified. That is, assuming all agents are egoists, and are therefore willing to shirk, is relatively well justified because even if in reality there is a mix of agents, it is those agents willing to shirk who have a disproportionately large effect on equilibrium.

The above result can also be looked at in a slightly different manner. That is, rather than assuming some agents are altruists and some are egoists, it could be assumed that all agents are egoists, but only some derive disutility from exerting effort. What the above tells us is that in such a world those agents who derive disutility will be disproportionately important. That is, if the mix of agents is along this dimension, then the amount of shirking and monitoring which takes place will more closely resemble what occurs when all agents derive disutility than would be suggested by the relative numbers of the two types in the population. Note that, there is a large body of work in the labor economics literature which does abstract away from the possibility of shirking. What the above result suggests is that one should be cautious in doing so, since only a small number of workers willing to shirk can have a large effect on the nature of equilibrium.

We will end this section by describing an alternative interpretation of the above model. In this alternative interpretation agents decide whether or not to steal, and property owners invest in protection against theft.[12]

Instead of firms, let there be a continuum of identical risk neutral property owners, each of whom owns a number of objects valued an amount V by everyone in the economy. Let there also be a skill involved in stealing, and let this skill be possessed by a set of agents referred to as potential thieves. Potential thieves can either be risk neutral or risk averse, but they are all identical as regards this characteristic. Further, each potential thief attempts either zero robberies or one robbery, where a successful robbery consists of taking one of the objects valued an amount V. If a potential thief attempts a robbery and is successful, his final wealth level is then $V+V^o$, where V^o is his initial wealth level (in our previous notation $V+V^o-W$). There is also a possibility, however, he will be caught, in which case his final wealth level is V^o-T, where T is the amount he is penalized (in our previous notation V^o-T-H). Of course, he may decide not to steal in which case his final wealth level equals V^o (in our previous notation V^o-W-k).

Analogous to the expenditures on monitoring described previously, property owners can expend resources on protection against theft, where it is assumed these expenditures are not publicly observable. If potential thief i attempts a robbery from a property owner who has invested z in protection, then he is caught (successful) with probability $q(z)m_i$ $(1-q(z)m_i)$, where q(.) has the properties described previously. Also similar to the earlier specification, m_i captures the idea that potential thieves vary in terms of their ability to avoid being detected, where the distribution of m_i's in the population is described by a density function g(.) which is positive over the interval $[0,\infty)$, and equals zero elsewhere.

Of the potential thieves, not all are actual threats to steal. That is, a proportion p of the potential thieves are altruists, and thus, although they possess the skill needed to commit a robbery, they steal under no circumstance. On the other hand, a proportion (1-p) of the potential thieves are egoists, and thus will steal if it is in their narrow self-interest to do so. Further, it is again assumed that p is public information, and that the distribution of altruists and egoists in the population is independent of the distribution of m_i's.

Mathematically this model is almost identical to our earlier model of shirking and monitoring. Consequently, results analogous to Propositions 3 and 4 are easily demonstrated. First, an increase in the proportion of egoists in the population causes an increase in attempted robberies and an increase in protection. Second, in this world it is the egoists who are disproportionately important. That is, the number of robberies and the expenditures on protection which take place more closely resemble what occurs when all agents are egoists than would be suggested by the relative number of altruists and egoists in the population.

The overall conclusion one might draw from the above is that in a world where theft is an issue, it does not take too many agents willing to steal for the number of robberies and investments in protection to become significant. That is, since the egoists are disproportionately important, the presence of just a small number of them will have a significant effect on equilibrium.

IV. Application 2: The Prisoner's Dilemma

In this section we apply our approach to the classic problem called the Prisoner's Dilemma.[13] Suppose there are two individuals, called Smith and Jones, who are suspected of committing a crime. The district attorney interrogates our two agents separately and tells each of them the following. If you confess and your partner does not, then you will receive T years in jail and your partner will receive V years, $T<V$. On the other hand, if you both confess, then you will both receive X years, $T<X<V$. Further, both Smith and Jones realize that if neither confesses then they will be convicted of a lesser crime, and they will both receive Z years, $T<Z<X$.

The above is the standard setup for the Prisoner's Dilemma. We now provide some additional assumptions which place the problem in our framework. Both Smith and Jones are assumed to have the following utility function.

$$U_i=-Y_i-E(\gamma_i Y_k), \quad i=S,J, \tag{2}$$

where Y_i is the number of years served by agent i and Y_k is the number of years served by his partner. $\gamma_i=0$ if agent i is an egoist and/or if the agent's partner confesses. If agent i is an altruist and the agent's partner does not confess, then γ_i is a draw from a random variable which has a probability density function g(.), where g(.) is positive over the interval [0,1], and equals zero elsewhere. That is, if the agent is an altruist and the partner does not confess, then the agent cares about the number of years served by his partner. Otherwise, the agent does not care. It is assumed that each agent is an altruist with probability p and an egoist with probability (1-p), where p is public information. Further, whether an agent is an altruist or an egoist (and his value for γ_i if he is an altruist) is private information to that agent.

This completes the setup of the model, and we can now proceed to the analysis. As is well known, if an agent is an egoist, then the agent's dominant strategy is to confess. On the other hand, if he is an altruist, then whether or not he confesses depends on his value for γ_i and on the probability his partner will confess. In particular, he will (will not) confess if $P_{NC}(Z-T)+(1-P_{NC})(V-X)+\gamma_i P_{NC}(Z-V)>(<)0$, where P_{NC} denotes the probability that his partner does not confess. It is easily demonstrated that any Nash equilibrium must be symmetric. Hence, an equilibrium is characterized by a single value for P_{NC} which is common to both agents.

Before proceeding to the proposition, one further point needs to be addressed. This is an environment which exhibits synergism. That is, the return to an altruist not confessing is positively related to the probability that his partner will not confess. As opposed to the synergistic case in Section II, however, for this model there is no simple restriction on the parameters which rules out the possibility of multiple equilibria. This can be seen by noting that, independent of the value for p, $P_{NC}=0$ is always an equilbrium. Hence, in the following proposition we present a multiple equilbria analogue to the disproportionality results of previous sections.

Proposition 5: Suppose payoffs and the density function g(.) are such that, if p=1, then there exists an equilibrium for which $P_{NC}>0$. Let $\bar{P}^{A}_{NC}$ be the maximum of the equilibrium values for P_{NC} when p=1. Then if $0<p<1$, $P_{NC}<p\bar{P}^{A}_{NC}$ for all equilibrium values for P_{NC}.

Proposition 5 tells us that in this world it is again the egoists who are disproportionately important. That is, suppose there exists a pure altruistic equilibrium for which the probability of not confessing is greater than zero. Then there necessarily exists a pure altruistic equilibrium such that, for any equilibrium corresponding to a value for p between 0 and 1, the probability that an agent does not confess is less than that suggested by the relative number of altruists and egoists in the population. Although the above result is qualitatively similar to the result found in the previous section, the intuition is somewhat different. In the previous section the intuition was that the environment exhibited congestion and egoists were the marginal decision makers. Hence, Proposition 1 told us that it was the egoists who should be disproportionately important. As should be clear from the above discussion, the Prisoner's Dilemma environment exhibits synergism and altruists tend to be the marginal decision makers. Hence, it is now Proposition 2, rather than Proposition 1, which tells us that egoists should be the dominant decision makers.

Overall, therefore, we have again identified an environment where the standard approach is relatively well justified. That is, assuming all agents are only interested in their narrow self-interest is relatively well justified, because even if in fact there is a mix of agents, it is again the egoists who are disproportionately important.

V. Application 3: Pollution

In this section we consider a world where agents choose whether or not to pollute the environment. As opposed to the two previous sections, in this section slight variations of the model allow us to illustrate two of the four possibilities discussed in Section II.[14]

Let there be a continuum of agents who choose whether or not to pollute the environment. If agent i chooses to pollute then he gets a private return s_i, where the distribution of s_i's in the population is described by a density function g(.) which is positive over the interval $[\underline{S},\bar{S}]$, and equals zero elsewhere. Further, the societal cost of pollution equals $\bar{N}h(N_P)$, $h'>0$, where $\bar{N}$ is the total number of agents in the population and N_P is the number of agents who choose to pollute. We also assume $1+pg(z)\bar{N}h''(p\int_z^{\bar{R}}g(s_i)ds_i+(1-p)\bar{N})>0$ for all $\underline{S}\leq z\leq\bar{S}$. This assumption rules out the possibility of multiple equilibria.

There are two types of agents in the population. A proportion p of the agents are altruists and a proportion (1-p) are egoists, where p is public information and the distribution of altruists and egoists in the population is independent of the distribution of s_i's. Altruists are concerned with the welfare of the society as a whole, while egoists are not. That is, if agent i is an altruist, then he will choose to (not to) pollute if $s_i>(<)r\bar{N}h'(N_P)$, where r is the weight altruists place on societal welfare. On the other hand, if agent i is an egoist then his decision rule is to always pollute.[15]

We will now proceed to the analysis. Note, in the following N_P^A denotes the total number of agents who choose to pollute when all agents are altruists.

Proposition 6: Suppose h(.) and g(.) are such that $0<N_P^A<\bar{N}$, and that $0<p<1$. If $h''>(<)0$, then $N_P<(>)pN_P^A+(1-p)\bar{N}$ and $\bar{N}h(N_P)<(>)p\bar{N}h(N_P^A)+(1-p)\bar{N}h(\bar{N})$.

Proposition 6 tells us that if there are increasing marginal costs of pollution ($h''>0$), then both in terms of the quantity of pollution and the social costs of pollution it is the altruists who are disproportionately important. However, if there are decreasing marginal costs of pollution ($h''<0$), then it is the egoists who are dominant.[16] The intuition for these results can again be traced back to Propositions 1 and 2. Consider the case where the marginal costs of pollution are increasing. This means that the more agents who pollute, the higher is the social cost any altruist who is a polluter attributes to his own decision to pollute. That is, increasing marginal costs of pollution translate into congestion. Hence, because we are now dealing with an environment where altruists are the marginal decision makers, Proposition 1 tells us that it is the altruists who should be disproportionately important. Similar logic yields that decreasing marginal costs of pollution translate into synergism, and thus, Proposition 2 tells us that for this case it is the egoists who should dominate.[17]

Overall, then, we have discovered the following concerning the validity of the standard approach for an environment where agents are choosing whether or not to pollute. First, the justification for the standard approach is strong when there are decreasing marginal costs of pollution, because then egoists tend to be disproportionately important. Second, the justification for the standard approach is weak when there are increasing marginal costs, because then it is the altruists who tend to be the dominant decision makers.

VI. Application 4: Donating Blood

In this section we consider a world where agents choose whether or not to donate blood. We will analyze this issue by slightly altering the model constructed in the previous section.[18,19]

There will now be a continuum of agents who choose whether or not to donate blood. If agent i donates then he incurs a cost s_i, where the distribution of s_i's in the population satisfies the properties described in the previous section. Further, the societal benefit derived from blood donations equals $\bar{N}h(N_D)$, $h'>0$, where N_D is the total number of agents who choose to donate. What we have in mind with this specification is that agents donate blood at some initial date, and then some subset of agents have accidents or become ill in the succeeding period and use the blood which was previously donated.

There are two types of agents in the population — a proportion p are altruists and a proportion (1-p) are egoists — where the assumptions of the previous section again hold. This means that if agent i is an altruist, then he will choose to (not to) donate if $r\bar{N}h'(N_D)>(<)s_i$, where r is again the weight altruists place on societal welfare. On the other hand, if he is an egoist then he will always choose not to donate.

As with the model of pollution, for the above model two of the possibilities contained in Section II are possible. As opposed to the pollution world, however, we feel that now only one of these possibilities is realistic. In our analysis we will concentrate on this case.

In the following proposition we assume there are decreasing marginal returns to donating blood ($h''<0$). There are a number of different reasons why we would expect the real world to display this property. First, we would expect this to be the case if when shortages arise blood is allocated to its highest valued use. Second, in the real world the probability that an incremental unit relieves a shortage is likely to be decreasing in the total number of units donated. This would also help ensure that there are decreasing marginal returns to donating blood. Note, in the following N_D^A denotes the total number of agents who choose to donate when all agents are altruists.

Proposition 7: Suppose h(.) and g(.) are such that $0<N_D^A<\bar{N}$. If $0<p<1$, then $N_D>pN_D^A$ and $\bar{N}h(N_D)>p\bar{N}h(N_D^A)+(1-p)\bar{N}h(0)$.

Proposition 7 states that under plausible assumptions concerning the model, it is the altruists who are disproportionately important. The intuition for this result again follows from Section II. Decreasing marginal returns to donating means that the more agents who donate, the less social benefit does any altruist who donates attribute to his own action, i.e., decreasing marginal returns translates into congestion. Combining this with the fact that altruists are the marginal decision makers, we have from Proposition 1 that it is the altruists who should be disproportionately important.

The above result may help explain why in the literature concerning this issue economists have not typically employed the standard approach of assuming all agents are egoists, but have rather allowed for agents to be altruists. Our analysis states that in this environment the presence of even a relatively small number of altruists will result in significant donations. Hence, it is not surprising that the level of donations which actually take place in the real world are so clearly inconsistent with an environment in which everyone is an egoist, that economists do not in general even attempt the standard approach.

VII. Conclusion

The present paper is concerned with the nature of equilibrium when a proportion of the population cares about the welfare of some or all of the other agents in the population, i.e., are altruists, while others follow standard assumptions and are therefore best described as egoists. We argued that this is an important issue if one is interested in the validity of the standard approach. That is, since many economic environments are characterized by a mix of altruists and egoists, the standard assumption that all agents are egoists is relatively more defensible if egoists have a disproportionately large effect on equilibrium. However, if it is the altruists who dominate, then justifications for the standard approach would seem to be relatively weak.

We found two things to be crucial in terms of answering this question: first, what is the nature of the interaction among agents; and second, which type of agent is the marginal decision maker. Consider a world which exhibits congestion, i.e., for any agent i, the higher is the total number of agents who choose a particular behavior, the smaller is the return to agent i choosing that behavior. For this case we found that the marginal decision makers are disproportionately important. For example, if the altruists are the marginal decision makers, then the equilibrium will more closely resemble what occurs when all agents are altruists than would be suggested by the relative number of altruists and egoists in the population. On the other hand, consider an environment which exhibits synergism, i.e., for any agent i, the higher is the total number of agents who choose a particular behavior, the <u>higher</u> is the return to agent i choosing that behavior. For this case we found that the non-marginal decision makers are disproportionately important.

That is, if altruists are again the marginal decision makers, then the equilibrium will more closely resemble what occurs when all agents are egoists than would be suggested by the relative number of altruists and egoists in the population. Or to summarize, under congestion the standard approach would seem to be well justified when the marginal decision makers are egoists and poorly justified when the marginal decision makers are altruists, while under synergism the conclusions are reversed.

In the second half of the paper we then applied these results to four common economic environments: (1) a world where workers decide whether or not to shirk, and firms invest in monitoring in order to detect shirking; (2) the classic problem called the Prisoner's Dilemma; (3) a world where agents decide whether or not to pollute the environment; and (4) a world where agents decide whether or not to donate blood. For the first two applications we found that egoists are disproportionately important, and thus, that the standard approach is well justified. For the third application we found that the conclusion can go either way. That is, the standard approach is well justified if there are decreasing marginal costs of pollution, while it is poorly justified if marginal costs are increasing. Finally, for the fourth application we found that altruists are disproportionately important. This helps explain why the literature on the issue of blood donations has not typically employed the standard approach of assuming all agents are egoists, but has rather had to come to grips with the fact that altruism is an important factor in that environment. What this suggests, then, is that our framework may be useful for integrating the standard approach of assuming all agents are egoists, with the analysis of environments where altruism is recognized as an important factor.

Appendix

Proof of Proposition 1: Consider first the case where the altruists are the marginal decision makers. Let $D=(C+f_A(N_A)-f_E(\bar{N}-N_A)+rB)/2$, where $\bar{N}=\int_0^C g(c_i)dc_i$, and let $D=D^A$ when $N_A=N_A^A$. We now have that $N_A=\int_0^D g(c_i)dc_i$, $N_A^A=\int_0^{D^A} g(c_i)dc_i$, and $N_A^E=0$. Suppose $N_A<pN_A^A+(1-p)N_A^E$. From above this implies $D<D^A$. Since $f_A'\leq 0$ and $f_E'\leq 0$ (with one strict inequality), this in turn implies $N_A>N_A^A$, which is a contradiction. Hence, when the altruists are the marginal decision makers we have that $N_A>pN_A^A+(1-p)N_A^E$ and $N_E<pN_E^A+(1-p)N_E^E$. The case in which the egoists are the marginal decision makers follows similarly.

Proof of Proposition 2: Consider first the case where the altruists are the marginal decision makers, and let D and D^A be defined as in the proof of Proposition 1. Further, let $F(Z)=Z-p\int_0^{D(Z)} g(c_i)dc_i$, where $D(Z)=(C+f_A(Z)-f_E(\bar{N}-Z)+rB)/2$. By definition we have $F(N_A)=0$, while the assumption which rules out the possibility of multiple equilibria implies $F'(Z)>0$. Also, let $F_A(Z)=Z-\int_0^{D(Z)} g(c_i)dc_i$. The same arguments as previously now yield $F_A(N_A^A)=0$, and $F_A'(Z)>0$. Suppose $N_A>pN_A^A+(1-p)N_A^E$. This implies $D>D^A$. Since $f_A'\geq 0$ and $f_E'\geq 0$ (with one strict inequality), this in turn implies $N_A>N_A^A$. Since $F'>0$ and $F(N_A)=0$, this implies $F(N_A^A)<0$. But we also know $F_A(N_A^A)=0$, which given $F(N_A^A)<0$ implies $(1-p)\int_0^{D(N_A^A)} g(c_i)dc_i<0$, i.e., a contradiction. Hence, when the altruists are the marginal decision makers we have that $N_A<pN_A^A+(1-p)N_A^E$ and $N_E>pN_E^A+(1-p)N_E^E$. The case in which the egoists are the marginal decision makers follows similarly.

Proof of Proposition 3: We solve this model by looking for a single market clearing wage, W, and a value z which satisfy the following. First, because expenditures on monitoring are not publicly observable, z must satisfy an incentive compatibility constraint. Second, because of free entry, the value for W must be the highest value which does not violate a non-negative profit constraint.[20]

We begin by considering the behavior of egoists. Egoist i will shirk if

$$\text{(A1)} \qquad m_i<m^*=U(W)-U(W-k)/[q(z)(U(W)-U(H))],$$

which implies $N_S=(1-p)\int_0^{m^*} g(m_i)dm_i$. Expected profits per worker are therefore given by

$$\text{(A2)} \qquad \Pi=X-W-z+\left\{(1-p)\frac{1}{\bar{N}}\int_0^{m^*} g(m_i)dm_i\right\}\left\{(1-q(z)\int_0^{m^*} m_i g(m_i)dm_i)(Y-X)\right.$$
$$\left.+(q(z)\int_0^{m^*} m_i g(m_i)dm_i)(W-X)\right\}.$$

Further, the optimal contract must be such that $\partial\Pi/\partial z\Big|_{m^* \text{ constant}}=0$ since the firm takes m^* as constant in choosing z. This implies

$$\text{(A3)} \qquad q'(z)(W-Y)\left\{(1-p)\frac{1}{\bar{N}}\int_0^{m^*} g(m_i)dm_i\right\}\left\{\int_0^{m^*} m_i g(m_i)dm_i\right\}-1=0.$$

Our next step is to show that an increase in p causes W to either increase or remain the same. We will demonstrate this by showing that if there is an increase in p and the same wage is offered, then profits for the firm will not have fallen. There are four sub-cases. (i) Suppose the increase in p causes z to increase. Given W unchanged, this implies m^* decrease and N_S decreases. Given (A3) and q''<0, this implies z must decrease which is a contradiction. (ii) Suppose z stays the same. This also implies N_S decreases. Hence, (A3) and q''<0 again imply z must decrease — a contradiction. (iii) Suppose z decreases, but N_S increases or stays the same. (A3) and $q''<0$ now imply that z increase which is again a contradiction. Hence, the correct sub-case is that both z and N_S decrease. The question now is what has happened to expected profits. Given W has remained the same, the decrease in N_S implies that profits would have increased even if z had remained unchanged. Since the firm chose to change z, profits must be even higher. Overall then, if there is an increase in p and the same wage is offered, then profits will not have fallen. Hence, an increase in p must result in W either increasing or remaining the same.

Consider now the impact of an increase in p on z. Suppose z increases or stays the same. Since W is non-decreasing in p, this implies m^* decreases or stays the same and N_S decreases. Yet, given (A3) and $q''<0$, this implies z must decrease which implies a contradiction. Hence, an increase in p causes a decrease in z.

Finally, since W is non-decreasing in p and z is strictly decreasing in p, we have that m^* must decrease as p increases. Hence, N_S decreases and N_{NS} increases as p increases.

Proof of Proposition 4: Consider a value $\hat{p}$ such that $0<\hat{p}<1$. Let $\hat{N}_S=(1-\hat{p})\int_0^{\hat{m}^*} g(m_i)dm_i$ and $N_S^E=\int_0^{m_E^*} g(m_i)dm_i$, where $\hat{m}^*=m^*$ when $p=\hat{p}$ and $m_E^*=m^*$ when $p=0$ (note: m^* is defined in the proof of Proposition 3). In the proof of Proposition 3 we demonstrated that m^* is decreasing in p. This implies $m^*<\hat{m}^*$. Hence, from the above definitions we have $\hat{N}_S>(1-\hat{p})N_S^E$ and $\hat{N}_{NS}<(1-\hat{p})N_{NS}^E$.

Let $\hat{z}$ be the z which results when $p=\hat{p}$. (A3) yields

$$q'(\hat{z})(W-Y)\frac{\hat{N}_S}{\bar{N}}\int_0^{\hat{m}^*} m_i g(m_i)dm_i-1=0, \tag{A4}$$

and

(A5) $$q'(z^E)(W-Y)\frac{N_S^E}{\bar{N}}\int_0^{m_E^*} m_i g(m_i)dm_i - 1 = 0.$$

Suppose $\hat{z}\leq(1-\hat{p})z^E$. Given $m_E^*<\hat{m}^*$ and $\hat{N}_S>(1-\hat{p})N_S^E$, (A5) can now be rewritten as

(A6) $$q'(\hat{z})(W-Y)\frac{\hat{N}_S}{\bar{N}}\int_0^{\hat{m}^*} m_i g(m_i)dm_i - 1 > 0,$$

which contradicts (A4). Hence, $\hat{z}>(1-\hat{p})z^E$.

Proof of Proposition 5: Let P_{NC}^A denote the probability of an agent not confessing when p=1. Consider the behavior of an altruist. An altruist will (will not) confess if $\gamma<(>)\gamma^*$, where $\gamma^*=((Z-T)/(V-Z))+(((1/P_{NC})-1)(V-X)/(V-Z))$. Hence, equilibrium values for P_{NC} and P_{NC}^A satisfy $P_{NC}=p\int_{\gamma^*}^1 g(\gamma_i)d\gamma_i$ and $P_{NC}^A=\int_{\gamma_A^*}^1 g(\gamma_i)d\gamma_i$, where $\gamma_A^*=\gamma^*$ when p=1. Let $K(\alpha)=\alpha-p\int_{\gamma(\alpha)}^1 g(\gamma_i)d\gamma_i$ and $K_A(\alpha)=\alpha-\int_{\gamma(\alpha)}^1 g(\gamma_i)d\gamma_i$, where $\gamma(\alpha)=((Z-T)/(V-Z))+(((1/\alpha)-1)(V-X)/(V-Z))$. By definition, if $K(\hat{P})=0$ then $\hat{P}$ is an equilibrium value for P_{NC}, while if $K_A(\hat{P})=0$ then $\hat{P}$ is an equilibrium value for P_{NC}^A. Note further that $K(\alpha)-K_A(\alpha)=(1-p)\int_{\gamma(\alpha)}^1 g(\gamma_i)d\gamma_i>0$.

We know that $K_A(1)=1-\int_{\gamma(1)}^1 g(\gamma_i)d\gamma_i$, where $\gamma(1)=(Z-T)/(V-Z)>0$. Hence, $K_A(1)>0$. Suppose $\hat{P}$ is an equilibrium value for P_{NC}. From above this implies $K_A(\hat{P})<0$. Given that K_A is a continuous function and that $K_A(1)>0$, we have that there must exist a P', $\hat{P}<P'<1$, such that $K_A(P')=0$. By definition P' is an equilibrium value for P_{NC}^A, and thus, $P_{NC}<\bar{P}_{NC}^A$ for all equilibrium values for P_{NC}.

Now suppose there exists an equilibrium P_{NC}, again denoted $\hat{P}$, such that $\hat{P}\geq p\bar{P}_{NC}^A$. Denote the value for γ^* associated with $\hat{P}$ as $\hat{\gamma}^*$, and the γ^* associated with $\bar{P}_{NC}^A$ as $\bar{\gamma}^*$. From the definition of γ^* we now have $\hat{\gamma}^*\leq\bar{\gamma}^*$. In turn, the definitions of P_{NC} and P_{NC}^A now tell us that $\hat{P}\geq\bar{P}_{NC}^A$, i.e., a contradiction. Hence, $P_{NC}<p\bar{P}^{A}_{NC}$ for all equilibrium values for P_{NC}.

Proof of Proposition 6: Consider first the case where $h''>0$, and suppose that $N_P>pN_P^A+(1-p)\bar{N}$. Since $N_P=\int_{r\bar{N}h'(N_P)}^{\bar{S}} g(s_i)ds_i+(1-p)\bar{N}$ and $N_P^A=\int_{r\bar{N}h'(N_P^A)}^{\bar{S}} g(s_i)ds_i$, this implies $N_P<N_P^A$, i.e., a contradiction. Hence, $N_P<pN_P^A+(1-p)\bar{N}$. Further, this in combination with $h''>0$ yields $\bar{N}h(N_P)<p\bar{N}h(N_P^A)+(1-p)\bar{N}h(\bar{N})$. The results for $h''<0$ follow in a similar manner.

Proof of Proposition 7: This follows along the same lines as the proof of Proposition 6.

Footnotes

[1]Recent literature on this topic includes Becker (1971, 1976), Collard (1978), Hirshleifer (1977, 1985), Hochman and Rodgers (1969), Margolis (1982), Phelps (1975), and Sen (1977).

[2]See Hirshleifer (1977) for the importance of the sequence in which players move in this environment.

[3]We have previously dealt with the concepts of congestion, synergism and disproportionality in earlier papers which were concerned with the robustness of the rational expectations assumption (see Haltiwanger and Waldman (1985a, 1985b)). In those papers we found that agents with rational expectations are disproportionately important under congestion, while agents with limited rationality, i.e., incorrect or adaptive expectations, are disproportionately important under synergism.

[4]The restriction which guarantees this under congestion is that either $f_A(\bar{N})+rB-C\geq f_E(0)$ or $f_E(\bar{N})\geq f_A(0)-C$. The restriction under synergism is that either $f_A(0)+rB-C\geq f_E(\bar{N})$ or $f_E(0)-C\geq f_A(\bar{N})$.

[5]If both types are marginal decision makers, one might interpret our results in terms of isolating the effect of each type.

[6]Previous papers concerned with the shirking/monitoring issue include Alchian and Demsetz (1972), Calvo (1979), Calvo and Wellisz (1979), Shapiro and Stiglitz (1984), and Yellen (1984).

[7]One need not strictly interpret the workers who have less incentive to shirk as altruists who derive satisfaction from the profit levels of their employers. An alternative interpretation would be that they derive little or no disutility from effort, or that they derive disutility from violating the

implicit or explicit terms of an employment contract (see the discussion following Proposition 4).

[8]To be precise, the indicator takes on the value S with probability $\min\{q(z)m_i,1\}$, and it takes on the value NS with probability $\max\{1-q(z)m_i,0\}$.

[9]One implicit assumption being made is that the optimal contract calls for workers to expend effort, rather than to shirk. In a mathematical supplement available from the authors upon request we present a formal restriction which guarantees this result.

[10]Some papers in the shirking literature find that the possibility of shirking leads to a non-market clearing wage, and hence, important implications for the unemployment rate (see Calvo (1979), Shapiro and Stiglitz (1984), and Yellen (1984)). We do not find this in our analysis because, as opposed to what is true in those papers, in our model the penalty to being fired is independent of the unemployment rate. Note, our conjecture is that disproportionality results would hold in the type of world analyzed by these authors. However, we felt that for the present paper incorporating a non-market clearing wage would take away from the central theme of the analysis.

[11]To be precise Proposition 1 only suggests that disproportionality will hold in terms of the amount of shirking. The result for expenditures on monitoring follows from the shirking result and the assumption that there are decreasing marginal returns to expenditures on monitoring ($q''<0$).

[12]Previous papers concerned with crime and expenditures on protection include Bartel (1975), Becker and Ehrlich (1972), Fabrikant (1977), Ozenne (1974), and Tullock (1967).

[13]See Collard (1978) for a discussion of previous work concerning the

relationship between altruism and the Prisoner's Dilemma.

[14]The pollution model considered in this section is similar to that found in the literature (e.g., Baumol and Oates (1975), Hartley and Tisdell (1981), and Lee (1984)). The role of altruism, however, is not considered in this literature.

[15]From the discussion in the text it might be a little difficult to see why egoists behave in this way. That is because in the text we are somewhat sloppy concerning the fact that the model has a continuum of agents. To see why egoists do behave in the above manner consider the following. Suppose that egoist i had a weight δ in the population. By polluting this agent would receive a return δs_i, and the societal cost of his decision to pollute would be $\bar{N}\delta h'(N_p)$. Multiplying by $\frac{\delta}{\bar{N}}$ we get his own private cost of his pollution decision, i.e., $\delta^2 h'(N_p)$. He will thus pollute (not pollute) if $\delta s_i > (<) \delta^2 h'(N_p)$. Since we are dealing with a continuum of agents, we now want to let δ approach zero. In doing this we see that the decision rule is that the agent always pollutes. Note, further, this rationale for why egoists are non-marginal decision makers suggests that the results in this section are at least somewhat dependent on our use of a continuum of agents.

[16]Models in the pollution literature typically assume positive and increasing marginal costs of pollution (the case $h''>0$ in our analysis). This seems to be based on analytic convenience to avoid potential multiple equilibria problems, rather than on empirical evidence.

[17]To be precise Propositions 1 and 2 only suggest that disproportionality will hold in terms of the quantity of pollution. The result for the social cost of pollution follows from the result concerning the quantity of pollution, and the relationship between $h(N^*)$ and $ph(N_p^A)+(1-p)h(\bar{N})$, where $N^*=pN_p^A+(1-p)\bar{N}$.

[18] Previous literature on voluntary blood donations includes Arrow (1972), Collard (1978), and Titmuss (1971).

[19] Many blood donation systems consist of a mix of both voluntary and commercial contributions. The following could be thought of either as a model of the voluntary component of a mixed system (e.g., the United States), or as a more complete model of a purely voluntary system (e.g., the United Kingdom).

[20] In a mathematical supplement available from the authors upon request we demonstrate that, given the restriction mentioned in footnote 9, this contract corresponds to the unique Nash equilibrium for our model.

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<u>Mathematical Supplement for The Role of Altruism in Economic Interaction</u>

In this supplement we demonstrate that, given the restriction mentioned in footnote 9, the contract considered in the proofs of Propositions 3 and 4 corresponds to the unique Nash equilibrium for our model.

We will first present the restriction. What we want is a restriction which guarantees that the optimal contract calls for workers to expend effort, rather than to shirk. To guarantee it for all cases all we need do is derive a restriction for the case $p=0$. Let $m'=U(Y+k)-U(Y)/q(0)[U(Y+k)-U(H)]$. The restriction is that m' is such that $\frac{(X-Y)}{\bar{N}}\int_0^{m'} g(m_i)dm_i>k$. What this says is that if firms set $W=Y+k$ and expended zero on monitoring, then profits for the firm would be positive.

We will now show how this restriction causes the unique Nash equilibrium to correspond to the contract considered in the proofs of Propositions 3 and 4. We begin by showing that no other equilibrium exists. One other possibility is that two or more wages are offered in equilibrium. Let W_1 denote the highest wage being offered and W_2 the second highest. All altruists and any egoist who is not planning on shirking will clearly prefer the wage W_1. Hence, anyone accepting the wage W_2 will definitely shirk, which implies $W_2 \leq Y$. Since any $W_2<Y$ would be dominated by a contract where $W=Y$, $z=0$, and where the contract called for workers not to expend effort, it must be the case that $W_2=Y$. We also know that because of free entry W_1 must be associated with zero expected profits. Combining this with the restriction above yields $W_1>Y+k$. This means that egoists would prefer W_1 and expending effort to W_2 and shirking. Hence, W_2 is chosen by no workers.

The only other possibility is that there is a single market clearing wage, but the contract calls for workers not to expend effort. The proof here follows in a similar fashion to the above case. For this case it must be that $W=Y$ and $z=0$ ($W=Y$ follows from the zero expected profit condition). Suppose now another firm offered $W=Y+k+\epsilon$, but the contract called for workers to expend effort. Independent of z all workers would prefer this contract to the original one, and given the above restriction this would result in positive profits. Hence, this possibility is also not an equilibrium.

We now only need demonstrate that the contract we have considered is an equilibrium. Given the above restriction and that the wage must satisfy a zero expected profit condition, we have $W>Y+k$. If a lower wage was offered, then given logic presented above we have that only individuals planning to shirk would take this lower wage, and given a non-negative profit constraint we in turn have that this alternative wage must be less than or equal to Y. However, given that $W>Y+k$, we have that no workers would want to take this lower wage (this argument is consistent with the concept of a sequential equilibrium). Suppose now a higher wage was offered. Given that we are speaking of an action off the equilibrium path, we are somewhat free to state what the workers would do in this case. Suppose all workers would choose this higher wage. By construction this would guarantee the firm negative profits, and hence, such a contract would not be offered. This proves that the contract considered is a Nash equilibrium. Note, the last step of the proof is not consistent with the concept of a sequential equilibrium. Our conjecture, however, is that the proof could be extended to demonstrate that the equilibrium is sequential.