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Flavio Toxvaerd
University of Cambridge

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Contacts, Altruism and Competing Externalities*

Flavio Toxvaerd†

February 24, 2021

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1. Introduction

In trying to contain the spread of COVID-19, authorities have implemented severe restrictions on social and economic life across a variety of spaces, sectors and activities, including work places, entertainment venues, schools and shops. Yet even at the height of severe lockdowns across the world in the Spring of 2020, some activities were still permitted. For example, in the UK some public transport remained available, as did schooling for children of key workers such as those working for the NHS. The reason for these exceptions is economically sound and has to be found in the role that those services play in supporting other sectors in the economy. Schooling for children of key workers is necessary to ensure the functioning of hospitals and intensive care units, as is public transport. In other words, these sectors have strong socioeconomic externalities on other sectors in the economy. On the other hand, it is also true that by maintaining open schools at the height of the epidemic, there were higher chances of disease transmission than would have been achieved by a blanket lockdown.

Both infection transmission and economic and social life relies on different degrees of physical proximity and it is the very activities that make up the fabric of everyday life that causes the infection to spread, and not some optional side activity that can be scaled back at minor cost or inconvenience. But this means that what people do or do not do to protect themselves does not only have an effect on whether infection spreads through the population. By altering their behavior, people also impact others' economic and social possibilities and well-being. In other words, there are multiple competing externalities, namely *infection externalities* and *socioeconomic externalities*. In evaluating the welfare effects of different courses of action, one must weigh these different externalities against each other.

In this paper, I distinguish between two types of contacts which may potentially cause transmission of infection between people. An *essential* contact is any interaction between individuals in which physical proximity is an essential component of the interaction. This

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†Faculty of Economics, University of Cambridge and CEPR. Email: fmot2@cam.ac.uk.

can include any economic or professional transaction such as that between a customer and a waiter in a restaurant, between doctors and nurses in a hospital or between students in the classroom. In addition, essential contacts include most voluntary sexual interactions where physical proximity is of the essence. In contrast, an *incidental* contact is any interaction that comes about by chance and which is not essential for the creation of surplus or exchange. For example, people sharing an elevator can be thought of as incidental, as each individual would be better off not sharing a confined space. Of course, some interactions do not fit neatly into these extremes and should be found on the continuum in between. For example, most people enjoy the presence of other people in a bar or in a restaurant. Their presence is not essential for the consumption of a meal or a drink, but it does contribute to improving the overall atmosphere. The thing to note is that while incidental contacts entail only a disease externality, essential contacts feature both infection externalities and socioeconomic externalities.

In a simple model of contact and disease transmission, I consider equilibrium exposure decisions under incidental and essential contacts, respectively. I also evaluate the social value of such contacts and find that equilibrium exposure may be too high or too low from a social perspective, depending on the nature of the contacts. With incidental contacts, I find that because individuals do not fully internalize the infection externality, they expose themselves too much. This echoes the traditional finding in the economic epidemiology literature on self-protection such as vaccination and social distancing. In contrast, I find that with essential contacts, individuals do not expose themselves enough from a social perspective. The reason is that they do not internalize the socioeconomic externalities of their exposure decisions.

While most of the economic-epidemiological literature on disease control relies on the assumption of self-interested behavior, there is widespread recognition that people have mixed motives when deciding how to act during an epidemic. Altruism in the context of sexual decision making has been discussed by Philipson and Posner (1993) and Gong (2015). O'Dell et al. (2008) argue that *"In the context of sexual risk behavior, both self-interest and concern for others may play a role in the decision to practice safer sex"*. How then, does altruism impact peoples' exposure decisions and how does it influence the spread of diseases in the population? Duffin (2004) reports that in HIV education, *"[Altruism] describes the responsibility of a person with HIV to avoid transmitting the virus"*.[1] While this approach may accurately reflect the effects of altruism in some contexts, it is somewhat odd because it conflates a statement about peoples' underlying preferences (namely regard for the welfare of others), with statements about specific actions which may or may not further the well-being of others, depending on context. As noted by Philipson and Posner (1993), *"An altruist is less likely to risk infecting his sexual partner [...] than an egoist. [...] On the other hand an altruist may be more willing to engage in risky sex if his or her partner derives utility from it"*. This is a key insight, because it makes explicit that altruism is a commitment to include others' well-being when deliberating and thus is two-way between people. This means that in contexts where individuals' participation is voluntary, like most professional and sexual interactions, it is the altruism of the most reluctant party which will determine whether contact takes place. As will be shown formally below, this may imply that more altruism may lead to more risky contacts and thus to *more* disease transmission than would be the case between egoists.

While the literature on the economics of infectious diseases is rich and growing fast, a few papers are particularly relevant to the present work. Toxvaerd (2017), Toxvaerd (2019), Rowthorn and Toxvaerd (2020), Bisin and Gottardi (2020) and Assenza et al. (2020) all consider models in which the nature of externalities features heavily, but in different formal environments. McAdams (2020) considers a model in which matched individuals produce

[1] Similarly, Kerwin (2014) states that *"[...] purely self-interested people should see little or no marginal cost from further risky sex if they are already infected, while altruistic people would want to take measures to protect their prospective partners. A parallel logic applies to those who learn they are HIV-negative"*.

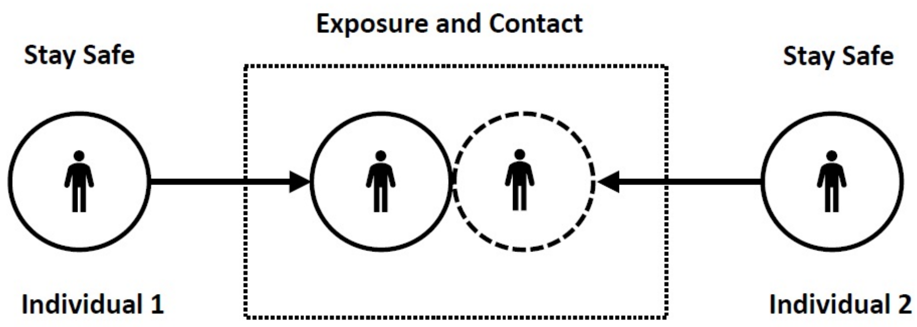

Figure 1: Exposure decisions and potential contact. Individual 1 has already chosen exposure, while individual 2 is deciding whether to do so.

output that is supermodular, like in Toxvaerd (2017) and in the extended model considered in the present work. Last, the paper is related to the literature on matching in disease contexts, such as Geoffard and Philipson (1995) and Dow and Philipson (1996).

In non-infection contexts, altruism has been studied by Bergstrom (1999) in an abstract setting and in the context of intergenerational models in papers by Kimball (1987) and Galperti and Strulovici (2017).

In Section 2, I set out the formal model and briefly consider the effects of sorting on disease transmission. In Section 3, I consider the case of incidental contacts, characterizing equilibria and evaluating their welfare properties. In Section 4, I do the same for the case of essential contacts. In Section 5, I conclude. Appendix A contains a brief analysis of a special case omitted in the main text.

2. A Model of Contacts and Externalities

The model is a variant of the framework of Philipson and Posner (1993), extended to allow for altruistic preferences and for different types of contacts as in Toxvaerd (2017). Consider two individuals i and j who simultaneously make exposure decisions $a_i \in \{0,1\}$. The setup is illustrated in Figure 1. Each individual i has a material utility function $U_i(a_i, a_j)$ but seeks to maximize the objective function

$$V_i(a_i, a_j) = U_i(a_i, a_j) + AU_j(a_j, a_i) \tag{1}$$

where $A \in [0,1]$ is the degree of altruism.[2] This is a common formalization of altruism that nests the cases of completely selfish behavior ($A = 0$) and perfectly altruistic behavior ($A = 1$).[3] In what follows, I will analyze Nash equilibria in which each individual i simultaneously and non-cooperatively chooses strategy a_i to maximise $V_i(a_i, a_j)$. As noted by Levine (2015), altruism itself means only that people include others' well-being in their deliberations; it does not ensure that individuals are able to coordinate their actions on mutually desirable outcomes. Thus for the purposes of this analysis, the *altruistic Nash equilibrium* seems an appropriate solution concept.

[2] An alternative formulation would be to assume that each individual maximizes $V_i(a_i, a_j) = U_i(a_i, a_j) + AV_j(a_i, a_j)$. Such preferences create what Kimball (1987) calls a "hall of mirrors" effect in which i values the utility that j attaches to the value that i attaches to the value of j,... See also an example of similar preferences in Bergstrom (1999). In this case, the objective can be rewritten as $V_i(a_i, a_j) = [U_i(a_i, a_j) + AU_j(a_i, a_j)]/(1-A^2)$ which implies that when individuals are perfectly altruistic and $A \to 1$, valuations are unbounded. With this formulation, aggregate welfare is $W(a_i, a_j) = V_i(a_i, a_j) + V_j(a_i, a_j) = [U_i(a_i, a_j) + U_j(a_i, a_j)]/(1-A)$.

[3] See Chen and Kempe (2008), who also consider the case $A = -1$, corresponding to spiteful preferences.

Turning to the material preferences, these are given by the function

$$U_i(a_i, a_j) = a_i \left[f(a_i, a_j) - a_j r_{ij} b \right] \tag{2}$$

where the transmission risk r_{ij} is the joint probability that i is susceptible and individual j is infectious. In the special case where the infection states of the two individuals are independent, the transmission risk from individual j to individual i is given by $r_{ij} = p_j(1-p_i)$. I will assume throughout that $r_{ij} \leq r_{ji}$ so that j is the (weakly) most at-risk individual.

The activity benefit function $f(a_i, a_j) \leq 1$ captures the value of the activity and will depend on whether contacts are incidental or essential. In what follows, I will consider two specifications of the activity benefit function $f(a_i, a_j)$ and explore the effects that this function has on equilibrium outcomes and their welfare properties.

The parameter $b > 1$ captures the expected utility cost of becoming infected.[4] The bound on the benefit function f and the magnitude of b imply that a healthy individual facing certain infection $r_{ij} = 1$ would receive negative material utility $U_i(1, 1) < 0$ and so would abstain from contact with the other individual. Away from this special case, the individual faces a tradeoff between the intrinsic value of exposure and the potential of becoming infected. There are two qualitatively different cases to consider, namely the case where infection carries significant discomfort so b is large and the case in which the disease is minor and so b is small. In the main text, I consider the first of these cases and in Appendix A, I briefly consider the second.

Throughout, I will assume that the utilitarian social planner seeks to maximize the sum of the individuals' objectives, i.e. that its objective function is

$$\begin{aligned} W(a_i, a_j) &= V_i(a_i, a_j) + V_j(a_j, a_i) & (3) \\ &= (1 + A) \left[U_i(a_i, a_j) + U_j(a_j, a_i) \right] & (4) \end{aligned}$$

This formulation implies that the planner cares both about actual outcomes and about the indirect value that individuals derive from being altruistic.[5]

It is worthwhile dwelling on the sources of interaction. When two individuals have contact, they each derive the intrinsic benefit from the potentially transmissive activity, captured by the activity benefit function $f(a_i, a_j)$. How one individual's benefit from opting in depends on the choice of the other individual is exactly what distinguishes incidental contacts from essential contacts. In addition to the externality through the activity benefit, there is an infection externality because individuals can infect each other. Unless individuals are known to be either both healthy or both infected already, the possibility of disease transmission is a two-way externality. Individual i can infect individual j and vice versa. When evaluating the desirability of a contact, a social planner will care about both directions of this two-way infection externality. In contrast, partially altruistic individuals will assign some, but not necessarily equal, weight to the other individual's well-being and so not fully internalize this infection externality. It is clear that the infection externality and the socioeconomic externality pushes incentives in opposite directions and hence different types of interactions will entail different equilibrium contact choices and have potentially different welfare properties.

2.1. Controlling transmission through sorting. As is clear from the model, the infection externality works through the possibility of disease transmission between people. But note that since infection can only be transmitted from infected people to susceptible people,

[4]The parameter b subsumes both the probability of transmission between serodiscordant people and the severity of the disease.

[5]See Sen (1977) for a discussion of different formalizations of altruism. Note that if the planner only cares about material utilities, then pathological cases may arise in which individuals make equilibrium decisions that are socially suboptimal only *because* they are altruistic.

matches between individuals who share health status cannot help spread the disease. But this means that one set of tools that may be considered to reduce transmission is any initiative that effectively sorts individuals on health state. In the context of HIV/AIDS, this practice is known as *serosorting*. To see how this works in the present model, let the joint probabilities over health states be

$$p_{mn} \equiv \Pr(s_i = m, s_j = n) \tag{5}$$

where $s_i, s_j \in \{0, 1\}$ are the health states of the two individuals. Here the state $s_i = 1$ denotes that individual i is infected and thus infectious, while $s_i = 0$ denotes that individual i is healthy and thus susceptible. The marginal probabilities are then $p_i = p_{10} + p_{11}$ and $p_j = p_{01} + p_{11}$. Following Dow and Philipson (1996), I define

$$d \equiv \frac{p_{11}}{p_i} \left(\frac{p_{10}}{1 - p_i} \right)^{-1} \tag{6}$$

The measure d captures the degree of assortative matching on infection status, or serosorting in an HIV/AIDS context. To see this, note that the measure is the fraction of infected contacts of infected individuals, relative to the fraction of infected contacts of healthy individuals.

Disease transmission then takes place with probability

$$p_{10} + p_{01} = \frac{p_i \left[d(p_i - p_j) + (1 - p_i) \right] + p_j(1 - p_i)}{dp_i + (1 - p_i)} \tag{7}$$

i.e. with the probability that the match is between serodiscordant people. Note that $p_{10} = r_{ji}$ and $p_{01} = r_{ij}$. It is easily verified that

$$\frac{\partial (r_{ij} + r_{ji})}{\partial d} \leq 0 \tag{8}$$

In other words, the more individuals are sorted, i.e. the better we manage to match infected individuals with other infected individuals and likewise with healthy individuals, the less will infection be transmitted.

Note that in the special case with $d = 1$, i.e. the case in which there is no assortative matching, incidence is

$$p_{10} + p_{01} = p_i(1 - p_j) + p_j(1 - p_i) \tag{9}$$

Sorting could happen because of policy interventions that directly control the contact patterns in the population or endogenously. In Toxvaerd (2017), it is shown that when individuals interact repeatedly over time, their health states become more highly correlated and thus disease transmission becomes increasingly unlikely.

Dow and Philipson (1996) conjecture that the presence of altruism can intensify the incentives for individuals to engage in positive assortative matching, as people who are more likely to be infected would have added incentives to avoid matches with those more likely to be healthy. As will be shown here, altruism changes the incentives of both sides of a match and it is usually the most at-risk individual who is pivotal to a match being consummated. The total effect of increased altruism on the types of matches that take place is therefore not a priori clear.

3. Physical proximity is incidental

In this section, I consider the case in which contacts are incidental, i.e. where only infection externalities are present. In this case, I assume that $f(a_i, a_j) = 1$ and material preferences are thus given by

$$U_i(a_i, a_j) = a_i \left[1 - a_j r_{ij} b \right] \tag{10}$$

This utility function implies that the only possible interaction between individuals' material well-being is through the possibility of disease transmission and the presence or absence of others does not impinge on an individual's benefits from exposure.

Individual i will seek to maximize the altruistic criterion

$$V_i(a_i, a_j) = (a_i + Aa_j) - a_i a_j b(r_{ij} + Ar_{ji}) \tag{11}$$

Aggregate utilitarian social welfare is then

$$W(a_i, a_j) = (1 + A)\left[a_i + a_j - a_i a_j b(r_{ij} + r_{ji})\right] \tag{12}$$

3.1. Equilibrium outcomes. There are three cases to consider:
(i) Suppose that

$$V_i(1,1) \geq V_i(0,1) = A \tag{13}$$
$$V_j(1,1) \geq V_j(0,1) = A \tag{14}$$

In this case, the unique equilibrium is $(a_i^*, a_j^*) = (1, 1)$. This can happen when there is strong assortative matching, i.e. when r_{ij} and r_{ji} are sufficiently low.
(ii) Suppose that

$$V_i(1,1) \geq V_i(0,1) = A \tag{15}$$
$$V_j(1,1) < V_j(0,1) = A \tag{16}$$

In this case, the unique equilibrium is $(a_i^*, a_j^*) = (1, 0)$.
(iii) Suppose that

$$V_i(1,1) < V_i(0,1) = A \tag{17}$$
$$V_j(1,1) < V_j(0,1) = A \tag{18}$$

In this case, there are two equilibria, namely $(a_i^*, a_j^*) = (1, 0)$ and $(a_i^*, a_j^*) = (0, 1)$.

Summing up, in the first case, the infection externalities are sufficiently weak and so both individuals choose to expose themselves rather than opting out altogether. In the second case, one individual exerts such strong infection externalities on the other that only this individual chooses to be active, while the most vulnerable individual opts out. In the last case, mutual infection externalities are more balanced but still sufficiently high to preclude the presence of both individuals. Thus in equilibrium, one or the other necessarily stays out while the other remains active.

3.2. Socially optimal outcomes. Next, I consider the welfare properties of the equilibria. There are essentially two cases to consider. The first case is when there is only one active individual in equilibrium, whereas the second case is when there are two active individuals. Suppose that there is one active individual in equilibrium, e.g. $(a_i^*, a_j^*) = (1, 0)$. In this case, it turns out that

$$W(1, 0) = V_i(1, 0) + V_j(0, 1) > V_i(1, 1) + V_j(1, 1) = W(1, 1) \tag{19}$$

To understand this result, first note that the inequality holds if and only if

$$b(r_{ij} + r_{ji}) \geq 1 \tag{20}$$

This inequality simply means that the aggregate external effects of adding one active individual when one other individual is already active, are larger than the additional benefit from that additional individual joining.

Turning to the incentive constraints, note that $V_j(1,1) < V_j(0,1)$ if and only if

$$b(r_{ij} + Ar_{ji}) > 1 \tag{21}$$

In other words, individual j does not wish to have contact with individual i exactly when its altruism-adjusted external effect is higher than the activity benefit. But then it follows immediately that if the altruism-adjusted external effect is sufficiently high to outweigh the added benefit, then so must the aggregate external effect used in the planner's calculation. In conclusion, when there is a unique active individual in equilibrium, then this is also the socially optimal outcome.

Next, consider the case with two active individuals, i.e. where $(a_i^*, a_j^*) = (1,1)$. For this to be the case, it must be that

$$V_i(1,1) \geq V_i(0,1) = A \tag{22}$$
$$V_j(1,1) \geq V_j(0,1) = A \tag{23}$$

Adding these inequalities implies that

$$V_i(1,1) + V_j(1,1) = (1+A)[U_i(1,1) + U_j(1,1)] \geq V_i(0,1) + V_j(0,1) = 2A \tag{24}$$

This can also be written as

$$U_i(1,1) + U_j(1,1) \geq \frac{2A}{1+A} \tag{25}$$

For the social planner, the presence of two active individuals is only socially optimal if it yields higher aggregate welfare than the alternative. Since contact is incidental, this means that for the planner to prefer two active individuals, it must yield higher welfare than having just one active individual. The condition for optimality of an outcome with two active individuals then becomes

$$V_i(1,1) + V_j(1,1) = (1+A)[U_i(1,1) + U_j(1,1)] \geq V_i(1,0) + V_j(0,1) = 1 + A \tag{26}$$

This implies that

$$[U_i(1,1) + U_j(1,1)] \geq 1 \tag{27}$$

Since $2A/(1+A) < 1$, it follows that with two active individuals, the condition for social optimality is harder to satisfy than the condition for an equilibrium.

To understand why there may be socially excessive contact in equilibrium, note that an individual who contemplates becoming active will compare his or her direct benefit of contact with the altruism-adjusted infection externality. Whenever the net value is positive, the individual will opt for contact. From the planner's perspective, the value of an additional active individual is the sum of the individual's utility and the external effect that the contact has on the other individual. But this means that the planner would value the activity of i only if the activity benefit 1 is larger than the sum of mutual external effects. Unless the potential entrant is perfectly altruistic and weighs his or her external effect on the other individual as highly as the external benefit that the incumbent has on the well-being of the entrant, then excessive contact may take place.

A typical scenario is illustrated in Figure 2, which plots the different conditions for equilibrium and social optimality in (p_i, p_j)-space for the special case where the individuals' health states are independent and where the individuals are selfish. The upward-sloping red switching

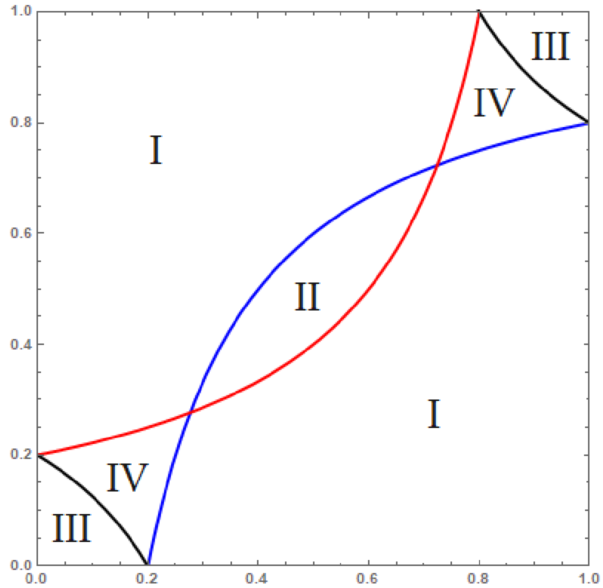

Figure 2: Equilibria and optimal outcomes under incidental contacts in (p_i, p_j)-space.

curve shows combinations of infection probabilities (p_i, p_j) such that individual i is indifferent between contact and no contact, *given* that the other individual j chooses to expose him or her self.[6] At points above the switching curve, individual i prefers to abstain, while for points below it, individual i prefers contact. Similar interpretation holds for points above and below individual j's switching curve, rendered in blue. Last, the switching curves for the social planner are shown in black. The curves trace out different areas as follows. In areas I, equilibrium is unique and one individual will choose to enter while the other will stay out. In such cases, it is always the most at-risk individual who chooses to abstain. But as contact is incidental, the at-risk individual j's reluctance to have contact does not preclude individual i from benefiting from being active. Thus the individual who would potentially have the strongest negative externality on the other is the sole individual to actually be active. One can think of this equilibrium as a situation in which only the infected access the public space, because everyone else is (justifiably) afraid of becoming infected. In area II, there are multiple equilibria. In either equilibrium, only one individual enters, while the other stays out. In contrast to the cases in areas I, in area II it is not necessarily the most at-risk individual who abstains. In areas III and IV, equilibrium is again unique and both individuals always choose contact.

Turning to socially optimal choices, the planner would prefer both individuals to have contact only in areas III and for only a single individual to be active otherwise. This means in particular that equilibrium decisions are socially optimal *except* in areas IV. The intuition for these results can be understood in terms of external effects that the decisions of the individuals have on each other's valuations. Recall that the planner only prefers contact when the external effects are not too high. In the case of incidental contacts, this externality is one of potential transmission of infection. From the figure, it is clear that this externality is smallest when there is positive assortative matching so the individuals are likely to have the same health state. In these cases, neither individual can infect the other and thus it is socially optimal to have contact. In other cases, transmission risks are more substantial and so the infection externalities will be greater. In Appendix A, I consider the case in which the switching curves are non-overlapping.

[6] In case individual j decides not to be active, then the relevant part of the figure is the set of all points along the x-axis, at which individual i has a dominant strategy to become active.

4. PHYSICAL PROXIMITY IS ESSENTIAL

In this section, consider the case in which contacts are essential, i.e. where both infection and socioeconomic externalities are present. In this case, I assume that $f(a_i, a_j) = \min\{a_i, a_j\}$ and thus material preferences are given by[7]

$$U_i(a_i, a_j) = a_i \left[\min\{a_i, a_j\} - a_j r_{ij} b\right] \tag{28}$$

This utility function implies that for either individual to benefit from being active, there *must* be contact. In addition, it implies that either individual can unilaterally block the other from deriving any benefit from being active. Similar preferences were used in Philipson and Posner (1993) to capture voluntary sexual interactions.

Individual i will seek to maximize the altruistic criterion

$$V_i(a_i, a_j) = \min\{a_i, a_j\}(a_i + Aa_j) - a_i a_j b(r_{ij} + Ar_{ji}) \tag{29}$$

Aggregate utilitarian social welfare is then

$$W(a_i, a_j) = (1 + A)\left[\min\{a_i, a_j\}(a_i + a_j) - a_i a_j b(r_{ij} + r_{ji})\right] \tag{30}$$

4.1. Equilibrium outcomes. There are two cases to consider:
(i) Suppose that

$$V_i(1,1) \geq V_i(0,1) = 0 \tag{31}$$
$$V_j(1,1) \geq V_j(0,1) = 0 \tag{32}$$

In this case, the unique equilibrium is $(a_i^*, a_j^*) = (1,1)$.
(ii) Suppose that

$$V_i(1,1) \geq V_i(0,1) = 0 \tag{33}$$
$$V_j(1,1) < V_j(0,1) = 0 \tag{34}$$

In this case, some individual objects to the contact and thus $(a_i^*, a_j^*) = (0,0)$.[8]

Summing up, in equilibrium either both agree to have contact or one of the two individuals find the risks from exposure too high and so blocks the contact. In the latter case, it is always the individual with most to lose from the contact who will be pivotal and will effectively decide whether contact takes place. This will turn out to be important, once the effects of increased altruism are considered.

4.2. Socially optimal outcomes. First consider case (i) with $(a_i^*, a_j^*) = (1,1)$. Adding up the two incentive constraints yields

$$V_i(1,1) + V_j(1,1) \geq V_i(0,1) + V_j(0,1) = 0 \tag{35}$$

But this is exactly the condition that ensures that the planner prefers there to be two active individuals rather than none (recall that since contact is now essential, the alternative to two active individuals is that no individual is active).

Next, consider case (ii) with $(a_i^*, a_j^*) = (0,0)$. It is easily seen that in this case, it is not necessarily true that $V_i(1,1) + V_j(1,1) \geq 0$, which is the condition for social optimality of

[7] Since $a_i, a_j \in \{0,1\}$, this formulation is equivalent to the contact benefit function $f(a_i, a_j) = a_i a_j$.
[8] Under essential contacts, the equivalent of case (iii) under incidental contacts is superfluous as it takes only one individual abstaining for the contact to be blocked.

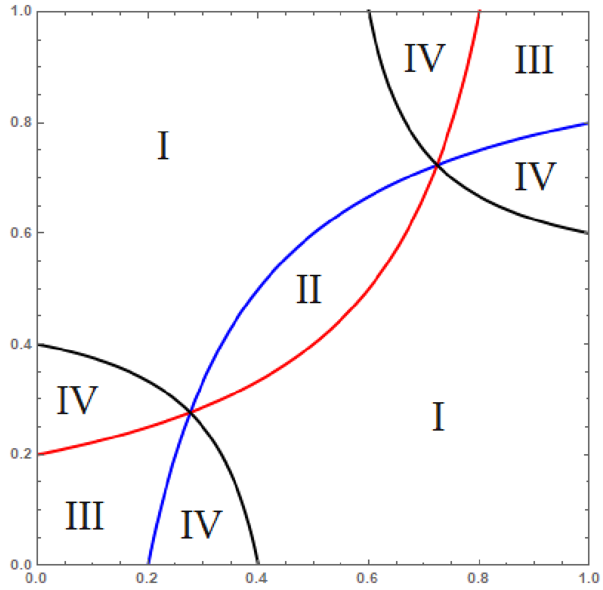

Figure 3: Equilibria and optimal outcomes under essential contacts in (p_i, p_j)-space.

outcomes with contact between individuals. In this case, social optimality depends on the magnitudes of the individuals' respective valuations.

A typical example is illustrated in Figure 3. The basic switching curves of the individuals are exactly as in Figure 2, but the switching curves for the planner are now modified due to the presence of the socioeconomic externality. Also note that even though the individual's switching curves are unaltered, the equilibrium outcomes differ radically from those under incidental contacts.

Again, the curves give rise to a number of different areas, but the equilibrium outcomes are now different because of the change in the activity benefit function. In areas I, II and IV, equilibrium is unique and involves either or both individuals abstaining. As contacts are essential, it is enough for either individual to abstain for the contact to be blocked. Only in areas III do both individuals agree to contact and so in such cases, the unique equilibrium involves activity by both. Turning to the outcomes preferred by the planner, equilibria are socially optimal except in areas IV. But note that in contrast to the case with incidental contacts, under essential contacts the planner would prefer there to be contacts for such combinations (p_i, p_j) in which one or the other individual would choose to object.

To better understand these results, recall that under essential contacts, the most at risk individual can always block the contact. This implies that there are cases in which the potential benefits from contact of the willing individual far outweigh the expected loss of the unwilling individual. Thus on aggregate, social welfare would be increased by the contact taking place, but as participation must be voluntary, in equilibrium the contact is blocked.

In Appendix A, I consider the case in which the switching curves are non-overlapping.

5. INCREASING ALTRUISM

In this section, I will briefly outline what happens when people become increasingly altruistic. By construction, the case $A = 0$ yields the perfectly selfish equilibrium outcomes, while for $A = 1$, people's incentives coincide exactly with those of the social planner. But note that while increasing altruism thus helps align private and public incentives, social welfare itself also increases. In fact, for $A = 1$, welfare becomes

$$W(a_i, a_j) = 2\left(U_i(a_i, a_j) + U_j(a_j, a_i)\right) \tag{36}$$

The reason is simply that each person values the material utility of the other person as much as his or her own material utility. Thus on aggregate, welfare becomes twice the sum of the material utilities.

So altruism clearly makes everyone better off. More interestingly, I will now consider how increased altruism influences the incentive constraints and thus the equilibrium outcomes. As is to be expected, this turns out to depend on whether contacts are incidental or essential.

Incidental contacts. For incidental contacts, recall that the for exposure to be a best response for individual i to the exposure by individual j, it must be that $V_i(1,1) \geq V_i(0,1) = A$, which can be rewritten as

$$U_i(1,1) \geq Abr_{ji} \tag{37}$$

In other words, individual i's material utility must be larger than the altruism-adjusted infection externality that exposure has on individual j. But as the level of altruism A increases, this inequality becomes harder to satisfy as the material utility does not depend on A. This means that starting in a situation in which both individuals are active and thus there is contact, increasing altruism may result in equilibrium switching so that only one individual remains active. Thus increasing altruism unambiguously decreases contact, disease transmission and infection externalities.

Essential contacts. For essential contacts, there are several cases to consider. To set the stage, recall that for exposure to be a best response for an individual i to the exposure by the other individual j, it needs to be the case that $V_i(1,1) \geq V_i(0,1) = 0$, which can be rewritten as

$$U_i(1,1) + AU_j(1,1) \geq 0 \tag{38}$$

For $(a_i^*, a_j^*) = (1,1)$ to be an equilibrium, necessarily $U_i(1,1) \geq 0$. But the magnitude of $U_j(1,1)$ can in principle be of either sign, giving rise to different cases. This means that the left-hand side of the constraint, which increases at the rate $U_j(1,1)$ when altruism A is increased, can be either increasing or decreasing.

Case 1: $U_i(1,1) \geq U_j(1,1) \geq 0$. In this case, increasing altruism unambiguously makes the inequality easier to satisfy and so starting from an equilibrium $(a_i^*, a_j^*) = (1,1)$, this outcome remains an equilibrium with more altruistic individuals.

Case 2: $U_i(1,1) \geq 0 \geq U_j(1,1)$, with

$$U_i(1,1) + AU_j(1,1) \geq 0 \tag{39}$$
$$U_j(1,1) + AU_i(1,1) \geq 0 \tag{40}$$

In this case, since $U_i(1,1) \geq U_j(1,1)$, an increase in A does not alter the inequalities and $(a_i^*, a_j^*) = (1,1)$ remains the equilibrium.

Case 3: $U_i(1,1) \geq 0 \geq U_j(1,1)$, with

$$U_i(1,1) + AU_j(1,1) \geq 0 \tag{41}$$
$$U_j(1,1) + AU_i(1,1) < 0 \tag{42}$$

In this case, $(a_i^*, a_j^*) = (0,0)$ is the unique equilibrium because individual j blocks the contact. When altruism increases, the left-hand side of individual i's incentive constraint decreases, while that of individual j increases. Thus the incentive for i to have contact weakens while that of j strengthens, meaning that one of two things can happen. If $U_j(1,1)$ is only marginally below zero and so individual j is almost indifferent, an increase in altruism can increase individual j's incentives to become active and may switch the equilibrium to $(a_i^*, a_j^*) =$

$(1, 1)$. Conversely, if individual i is almost indifferent but j is not, then an increase in altruism can instead switch the incentive constraint of i so that neither will wish to have contact. In this case, increased altruism does not change the outcome as j already blocked the contact before A was increased.[9]

In summary, higher altruism may switch equilibrium in the direction of higher exposure and contact and would therefore lead to higher disease transmission.

6. DISCUSSION

In this paper, I have considered a simple model of disease transmission in which infection externalities and socioeconomic externalities can be studied in conjunction. In this setup, I distinguished between different types of contacts and externalities and showed that they lead to different equilibrium inefficiencies in exposure behavior. In particular, the analysis showed that social welfare considerations call for limiting incidental contacts that have no intrinsic benefits but lead to disease transmission. In contrast, essential contacts, which society deems to be intrinsically beneficial because of their socioeconomic externalities, may need to be weighed against their harm in terms of propagating the disease.

In terms of implementing socially desirable contact and activity patterns, a straightforward way is to influence behavior not only though direct restrictions on contacts but also by means of penalties and subsidies. By aligning individual incentives with the interests of society at large, they may go some way towards correcting uninternalized external effects, be they disease externalities or broader socioeconomic externalities.

A. THE NON-OVERLAPPING CASE

In the main text, I considered the cases where the two individuals' switching curves intersected. This is the scenario that occurs for sufficiently high value of the parameter b. For sufficiently low levels of b, the switching curves no longer intersect. In this appendix, I briefly outline the results for this case.

Figure 4 shows the case of incidental contacts. For simplicity, I have labeled the relevant areas with Arabic numerals. In all cases, the equilibrium is unique. In areas 1, in equilibrium only one individual is active and this is socially optimal. In area 2, both individuals are active but it would be socially optimal to have only one active individual. Last, in areas 3, in equilibrium both individuals are active, which is also the socially optimal outcome. Figure 5 shows the case of essential contacts. In all cases, there is a unique equilibrium. In areas 1, in equilibrium only one individual is active and this is socially suboptimal. In area 2, in equilibrium both individuals are active and this is socially optimal. Last, in areas 3, in equilibrium only one individual is active and this is socially optimal.

[9]Note that the left-hand side of individual i's incentive constraint always decreases at a lower rate than the rate at which the left-hand side of individual j's incentive constraint increases. Whether the incentive constraint of one or the other individual switches sign first, depends on their relative distance to zero. A sufficient condition for an increase in A to lead to an unambiguous shift to the equilibrium $(a_i^*, a_j^*) = (1, 1)$ is that $2 > b(r_{ij} + r_{ji})$.

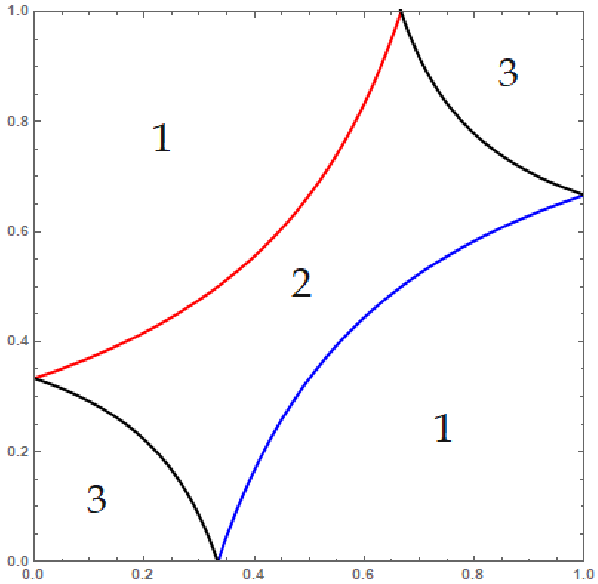

Figure 4: Equilibria and optimal outcomes under incidental contacts in the non-overlapping case in (p_i, p_j)-space.

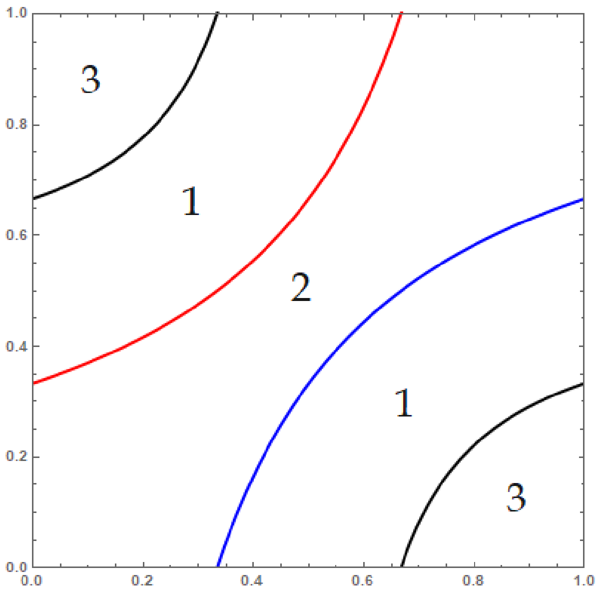

Figure 5: Equilibria and optimal outcomes under essential contacts in the non-overlapping case in (p_i, p_j)-space.

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