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Limiting the Number of Charities∗

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Abstract

We consider a model where creating a charity implies a fixed cost and individual contributions depend on how close donors feel with respect to the charity. In that setting we show that there are an optimal number of charities and an optimal rate of subsidization that depend on the set-up cost and on the attachment of donors to charities that share the same values as theirs. We also consider the case of free-entry and compare it with the second-best solution controlling for the number of charities.

Keywords: charities, joy of giving
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1 Introduction

In the winter 2004-2005, the Tsunami tragedy triggered an unprecedented spurt of generosity all over the world. Individuals contributed to this cause through a number of charities. In Belgium, e.g., they did that through charities associated with political or religious movements (Catholics, liberals, socialists, ...), and it has been show that people were more willing to donate through charities close to their religious, political or other leanings.

In most countries, charitable funds benefit from tax breaks, but need to be licensed by public authorities. In other words, the government can control the number of charities, and at the same time grant tax exemptions to charitable contributions. Establishing a charitable fund involves fixed costs, and for that reason one does not imagine a world in which everyone would have his own charity. To put it differently, if there were no such costs involved to establishing a charity and if the government were in favor of the charitable cause in question, there would be no reason not to have a charity for each individual that would share the same values as his. However, because of fixed cost, their number needs to be limited. The question is how limited? And where are they to be located on the scale of individual values? There are the two questions addressed by this paper.

More concretely, we take a society consisting of a number of individuals all alike but for some specific religious, political, cultural values that are parametrized on a single dimension. Each individual has a utility function with three arguments: a composite consumption good, the amount of resources devoted to a charitable cause (e.g. the Tsunami relief) and his personal contribution. The utility for consumption and for the charitable cause is the same for all of them; the utility for the contribution itself depends on the distance between the individual’s characteristic and the "nearest" charity. Take the example of Belgium and of the Tsunami relief. If there had been just one charity, e.g. Caritas Catholica, it is clear that the Belgian Catholics would have contributed more than the non Catholics. Within such a setting, we want to see the optimal number of charities and the amount of tax relief that a utilitarian social planner would choose. Individuals choose freely how much to contribute given the existing charities and the tax subsidy. Charities that have a licence locate so to maximize funds.

In the rest of this paper, we sketch the basic model and show that the optimal number of charities is a function of the set-up cost and of the joy of giving itself a function of the location of charities on the value scale. Then we introduce subsidies. If subsidies can be collected without distortion and income can be redistributed in a lump-sum way, the optimal number of charity is one. Introducing distortions, this number is likely to be larger than
one and the subsidies larger than zero. We then move to a setting with free entry, the role of the government being restricted to subsidize contributions. We compare the free-entry number of charities with the second-best number.

2 Basic model

2.1 Individual choice

We consider a society consisting of $N$ individuals who differ in terms of religion, values, political views. These differences are modelled in section 3. Each individual $i$ has a quasi linear utility function:

$$U_i = c_i + v(Z) + g(s_i, \gamma_i)$$

where $c_i$ is consumption, $Z$ is the aggregate amount of contributions, $s_i$ the individual contribution and $\gamma_i$ a function to be defined below.\(^1\) It reflects the intensity of the joy of giving and depends on how close the contributor feels valuewise towards the nearest charity.\(^2\) The function $v(\cdot)$ is strictly concave. The function $g$ is increasing in $s$ and $\gamma$; $g_i$ reflects the joy of giving and will take a particular specification:

$$g_i = g(s_i, \gamma_i) = \gamma_i s_i - \frac{1}{2} s_i^2.$$  

As long as $Z$ comes from individual contributions, we have

$$Z = \sum_{i}^N s_i.$$ 

Each individual will choose $s_i$ given the following budget constraint.

$$c_i = (1 - \tau) y - f - (1 - \sigma) s_i$$

where $\tau$ is a flat tax rate, $y$, income, $f$, the cost of contribution that will be shown to decrease with the size of the charity, and $\sigma$ is the subsidy rate, if any.

\(^1\)In this paper, we consider a single charitable cause to which everyone contributes through charities. Introducing several causes would complicate things. See on this Carmichael (2006).

\(^2\)For a good survey, see Andreoni (2006).
Each individual $i$ makes a positive\(^3\) contribution $s_i$ to the charitable cause acting non cooperatively, namely taking all the other contributions $s_{\ell}$ as given \(\sum_{\ell \neq i} s_\ell = Z_{-i}\). In other words, he chooses:
\[
 s^*_i = \gamma_i - (1 - \sigma) + v'(s^*_i + Z_{-i}). \tag{1}
\]
Reintroducing this value of $s_i$ in the utility function, we obtain an indirect utility:
\[
 V_i(\tau, f, \sigma, \gamma_i, Z_{-i}) = (1 - \tau) y - f - (1 - \sigma) s^*_i + \left(\gamma_i s^*_i - (s^*_i)^2 / 2\right) + v(s^*_i + Z_{-i})
\]
with
\[
 \frac{\partial V_i}{\partial \gamma_i} = s^*_i > 0.
\]
Aggregating $s^*_i$ we obtain the Nash equilibrium value of $Z$,
\[
 Z^* = N (\bar{\gamma} - (1 - \sigma) + v'(Z^*))
\]
where $\bar{\gamma} = \sum \gamma_i / N$ and $Z^* = Z(\bar{\gamma}, \sigma)$. The sign under an argument is the sign of the function with respect to that argument.

### 2.2 First-best

In this paper, we assume that the social planner is interested by the sum of individual utilities from which the joy of giving is excluded.\(^4\) Denoting consumption by $c_i$, a social planner that can control quantities directly would solve the following problem:
\[
 Max \sum_{i=1}^{N} [c_i + v(Z)] - \lambda \sum_{i=1}^{N} (c_i - y) + Z
\]
which leads to the Samuelson condition.
\[
 Nv'(Z) = 1.
\]
The multiplier $\lambda$ is associated with the resource constraint.

---

\(^3\)Allowing for zero contribution would not change the main result, but it would make our problem less tractable.

\(^4\)This approach that implies laundering out individual utilities is justified by Hammond (1987). Using the alternative assumption would not change the qualitative nature of our results.
Note that another version of the first-best could impose that financing the public good has to go through charities. In that case, the social optimum is $M = 1$ and the social planner’s problem is to maximize:

$$
\sum_{i=1}^{N} [y - s_i + v(Z)] - \lambda \sum_{i=1}^{N} (y - s_i) + F
$$

where $F$ is the set up cost of creating a charity. We get the Samuelson condition with a loss of resources equal to $F$. This optimum can be decentralized in an economy with subsidies on contributions financed by a lump-sum tax. The reason is simple: with a quasi-linear utility function, redistribution does not matter.

Instead of $c_i$ we could introduce a strictly concave transformation $u(c_i)$. This would reflect some aversion to inequality. In that case, the objective function of the social planner becomes:

$$
\sum_{i=1}^{N} [u(c_i) + v(Z)].
$$

Then decentralization requires individualized lump-sum taxes along with Pigouvian subsidies. Individuals with higher $\gamma_i$'s have to be compensated for a higher contribution than those with lower $\gamma_i$'s.

3 Three stage game

We now turn to the problem of charities which have not been introduced explicitly. In this section and the next one, the number of charities is determined by the government through some kind of licensing. In other words free entry is not allowed. Later we consider the possibility of free entry and thus we adopt an approach close to that used in spatial models of firms and in model of breaking up of nations.

Charities are characterized by a set of values that are captured by their location on a circle following the spatial model of the circular city (See Tirole (1988)). We do not regard these values as given but assume that charities choose them, i.e., their location on the circle to cater to a certain group of individuals and maximize the amount of donations. We now consider a game in three stages:

(i) the government chooses the number of charities $M < N$,

(ii) each charity $j (= 1, ..., M)$ locates itself, namely chooses $\hat{x}_j$ on a circle along which individuals values $x_i$ are uniformly distributed,
(iii) each individual $i$ makes a contribution to the closest charity in terms of distance between his $x_i$ and that of the charity $\hat{x}_j$.

Figure 1 presents the case of 3 charities located in $\hat{x}_1$, $\hat{x}_2$ and $\hat{x}_3$ with the range of their influence $\bar{x}_j$ and $\bar{x}_j$ for $\hat{x}_j$. They are located equidistantly from each other as we show below that this is going to be the outcome under the assumptions made. The circumference of the circle is 1 and thus each charity covers a range of potential contributors equal to $1/3$. We also represent the location of an individual $x_i$ who is clearly in the field of attraction of charity $i$. The number of charities will be made endogenous in section 5.

As in a standard subgame perfect, we proceed backwards.

### 3.1 Choice of contribution

We consider the tax parameters $\tau, \sigma$, and the number and location of charities as given. As it will be shown in the next subsection 3.2, charities are going to be located equidistantly from one another on the circle.

Up to now the parameter $\gamma_i$ reflected the joy of giving of an individual $i$. As mentioned in the introduction, this joy of giving depends on how close the contributor feels to the contribution in terms of religion or values. Not surprisingly, we need to rely on a concept of distance and define the joy of giving of an individual located in $x_i$ on the circle of values, who contributes to a charity located in $\hat{x}_j$ as:

$$\gamma_{ij} = a - b |x_i - \hat{x}_j|$$
where $|x_i - \hat{x}_j|$ is a standard measure of distance. As a consequence, an individual $i$ will always contribute to $j$ and not to $j'$ if

$$|x_i - \hat{x}_j| < |x_i - \hat{x}_{j'}|.$$ 

Define $\bar{x}_j = \frac{\hat{x}_j + \hat{x}_{j+1}}{2}$ and $\overline{x}_j = \frac{\hat{x}_{j-1} + \hat{x}_j}{2}$ as the boundaries of charity $j$ and $P_j$ as the number of potential contributors to $j$, we have:

$$P_j = (\bar{x}_j - \overline{x}_j) N = (\hat{x}_{j+1} - \hat{x}_{j-1}) \frac{N}{2}.$$ 

Note that $P_j$ is independent of charity $j$’s location, which simplifies our analysis. It results from our assumption of uniform distribution of $x_i$. The optimal contributions to charity $j$ denoted $S_j$ are then:

$$S_j = P_j [\bar{\gamma}_j - (1 - \sigma) + \nu' (S_j + Z_{-j})]$$ 

where $\bar{\gamma}_j$ is the mean value of $\gamma_{ij}$ and is defined by $\bar{\gamma}_j = \frac{N}{P_j} \int_{\bar{x}_j}^{\hat{x}_j} [a - b |x_j|] dx_j$. The above equation implicitly define $S_j$ as an increasing function of $\bar{\gamma}_j$, $P_j$ and $\sigma$ and a decreasing function of $Z_{-j}$.

### 3.2 The location of $M$ charities

We now see how the $M$ charities, $M$ being determined by the central planner, are choosing where to locate along the circle of values.\(^5\) Take charity $j$. We assume that it acts in a Nash manner and aims at maximizing $S_j$. This implies that charity $j$ will choose $\hat{x}_j$ taking as given $\hat{x}_{j-1}$ and $\hat{x}_{j+1}$, the locations of neighboring charities, and $Z_{-j}$ donations collected by other charities. Since $P_j$ is independent of $\hat{x}_j$, the maximization problem reduces to maximizing $\bar{\gamma}_j$, the first order condition of which is established by:

$$|\hat{x}_j - \bar{x}_j| = |\hat{x}_j - \overline{x}_j|$$

so that

$$\hat{x}_j = \frac{1}{2} (\bar{x}_j + \overline{x}_j).$$

Substituting the above into $\bar{\gamma}_j$ yields:

$$\bar{\gamma}_j = a - b \frac{P_j}{4N}.$$ 

---

\(^5\)In this paper we assume that a charity’s objective is restricted to maximizing total contributions. One admittedly finds more complex objectives in the literature. In particular, our charities are purely opportunistic as they have not prior values.
The Nash equilibrium is symmetric so that all charities have the same size in terms of the number of contributors $P_j$ and donations $S_j$. The result relies on our assumptions that individuals with different $x_i$ locate uniformly on the circle and they choose charities nearest to their locations. Two neighboring charities with different sizes of $P_j$ are not sustainable. An individual locating the boundary between them strictly prefer a smaller charity to a larger one since the location of the former that lies in the middle of the range of its contributors is closer to him. Therefore, we have $P_j = N/M$ for all $j$ leading to:

$$\gamma_j = \bar{\gamma} = a - \frac{b}{4M}.$$  

Eq. (2) can be moved before 3.3. In the Nash equilibrium, the aggregate contribution is given by:

$$Z^* = N\left(a - \frac{b}{4M} - 1(1 - \sigma) + v'(Z^*)\right).$$

It is straightforward to see $Z^*$ is increasing in $M$ and $\sigma$. This implies that the two policy instruments are substitutable as addressed in the next section.

### 3.3 The choice of $M$ and $\sigma$

We now turn to the first stage of the game; the choice by the social planner of the social welfare maximizing value of the number of charities and the level of subsidy to voluntary contribution. We consider that the taxation is distortionary that is captured by a quadratic deadweight loss parameterized by $\theta$. This yields the revenue function:

$$N\tau \left(1 - \frac{\theta}{\tau}\right) y = \sigma \sum s_i^* = \sigma Z^*. \tag{2}$$

We can now write the objective of social planner keeping in mind that he is not interested by the joy of giving but by individuals' disposal income and aggregate contributions.

$$SW = \sum \{u[(1 - \tau) y - f - (1 - \sigma) s_i^*] + v(Z^*)\}. \tag{3}$$

where $f = F/P$ (one can also write $f = FM/N$) is the cost share borne by each individual and $u'' < 0$ implies that the social planner is concerned with inequality. In the case of $u(c_i) = c_i$, we have the utilitarian objective. The planner’s problem is to maximize (4) subject to (3) and to the values of $s_i^*$ and $Z^*$ defined by (1) and (2).
We totally differentiate (4):

\[ dSW = v'(Z^*)dZ^* - (1 - \sigma)\sum \alpha_i ds_i^* - \alpha Ny d\tau - \alpha F dM + [N \text{ cov}(\alpha_i, s_i^*) + \alpha Z^*] d\sigma \]  

(4)

where \( \alpha_i = u'(c_i) \) and \( \alpha = \sum u'(c_i) / N \). Given the strict concavity of \( u(c_i) \), one gets \( \text{cov}(\alpha_i, s_i^*) > 0 \), as high contributors have a relatively low disposable income.

From (1), one writes:

\[ ds_i^* = d\gamma_i + d\sigma + v''(Z^*)dZ^* \]  

(5)

and from (3),

\[ d\tau = \frac{Z^*d\sigma + \sigma dZ^*}{Ny(1 - \theta\tau)}. \]  

(6)

Substituting (6) and (7) in (5), we obtain:

\[ dSW = (v' - \alpha) dZ^* - \alpha F dM + N \text{ cov}(\alpha_i, s_i^*) d\sigma - (1 - \sigma)N \text{ cov}(\alpha_i, d\gamma_i^*) - \frac{\alpha\sigma\theta}{1 - \tau\theta}(Z^*d\sigma + \sigma dZ^*) \]  

(7)

where \( \text{cov}(\alpha_i, d\gamma_i^*) \) cannot be easily signed. However one can easily show that \( \text{cov}(\alpha_i, s_i) > 0 \).

4 Optimal policy

We now use equation (8) to see the optimal policy under different assumptions.

4.1 No distortion \((\theta = 0)\), no aversion to inequality. \((u(c) = c)\)

This is the case considered in 2.2 where we were considering the decentralization of the first-best solution under the same conditions: lump-sum tax along with a subsidy on contributions and quasi-linear utility function.

We have the same solution. Using a tilde for the first-best, we have:

\[ v'(\tilde{Z}) = 1 \]

which defines \( \tilde{Z} \). The value of \( \tilde{\sigma} \) is given by:

\[ \tilde{Z} = N \left[ a + \frac{b}{4M} - 1 + \tilde{\sigma} + v'(\tilde{Z}) \right]. \]
From this and from (5), we have that
\[ dSW = -\alpha F dM < 0, \]
which implies that \( M = 1. \)

4.2 No aversion to inequality \( (u(c) = c) \) and tax distortion \( (\theta > 0) \)

Assuming that \( u''(c) = 0 \) means that the covariance terms vanish from equation (8). To dispose of \( Z^* \), we differentiate (2) so that:
\[ (1 - Nv'')dZ^* = N d\sigma + \frac{bN}{4M^2}dM. \] (8)

Substituting (9) in (8) and assuming interior solution (in particular \( \frac{dSW}{dM} = 0 \)) we obtain:
\[ \left[ (v' - 1) - \frac{\tau\theta\sigma}{1 - \tau\theta} \right] \frac{N}{1 - Nv''} = \frac{\tau\theta}{1 - \tau\theta}Z^* \] (9)
\[ \left[ (v' - 1) - \frac{\tau\theta\sigma}{1 - \tau\theta} \right] \frac{N}{1 - Nv''} \frac{b}{4M^2} = F. \] (10)

To obtain the (second best) optimal values \( \hat{M}, \hat{\sigma}, \) and \( \hat{t} \), one uses (10), (11), (2) and (3). We are here interested by the number of charities.

Combining these conditions (10) and (11) yields:
\[ \hat{M} = \left[ \frac{b}{4F} \frac{\hat{\tau}\theta}{\hat{\tau} \hat{\theta} \hat{Z}} \right]^{1/2}. \] (11)

Equation (12) along with (2) and (3) indicates that the optimal number of charities is negatively related to \( F \) (which is intuitive) and is positively related to \( \theta, \tau \) and \( Z \). If \( \theta \) is relatively high, the distortionary tax is also high which makes the subsidy, \( \sigma \), socially costly. As we have seen \( M \) is a substitute for \( \sigma \); the government is induced to increase the number of charities, which is an alternative way of encouraging charitable contribution.

4.3 General case

We now turn to the general case by imposing a redistributive concern through the strict concavity of \( u(c) \). So doing the optimal policy takes into account the fact that big contributors are also those with low disposable income.
Combining (8) and (9) and assuming again interior solutions, we have:

\[
\frac{dSW}{d\sigma} = \left( v' - \alpha - \frac{\tau \theta \sigma}{1 - \tau \theta} \right) \frac{N}{1 - N v^*} - \frac{\alpha \tau \theta}{1 - \tau \theta} Z^* + N \text{ cov}(\alpha_i, s_i^*) = 0 \quad (12)
\]

and

\[
\frac{dSW}{dM} = \left( v' - \alpha - \frac{\tau \theta \sigma}{1 - \theta} \right) \frac{N}{1 - N v^*} \frac{b}{4M^2} - \alpha F - (1 - \sigma) N \text{ cov}(\alpha_i, \frac{d\gamma_i}{dM}) = 0 \quad (13)
\]

Formula (13) gives the optimal subsidy and (14) the optimal number of charities. Note that \(\sigma\) does not affect \(\gamma_i\), which explain why one does not find \(\text{cov}(\alpha_i, d\gamma_i)\) in (13).

From (13) and (14) we get:

\[
M = \frac{b^{1/2} \left[ \frac{\alpha \hat{\tau} \theta}{1 - \tau \theta} \hat{Z} - N \text{ cov}(\alpha_i, s_i^* \gamma) \right]^{1/2}}{[\alpha F + (1 - \hat{\sigma}) N \text{ cov}(\alpha_i, \frac{d\gamma_i}{dM})]^{1/2}}. \quad (14)
\]

Clearly, when the covariance terms are nil we get formula (12). To interpret the role of the two covariance terms in this expression, it is important to see where they intervene in the social welfare maximization. The \(\text{cov}(\alpha_i, s_i^*)\) is linked to the choice of \(\sigma\); clearly, when \(\sigma\) increases, the distribution of disposable income becomes more equal. As there is a trade-off between \(\sigma\) and \(M\), it is not surprising to see that this covariance term pushes for less charities.

The \(\text{cov}(\alpha_i, \frac{d\gamma_i}{dM})\) is related to the formula of \(M\). Without further assumptions it cannot be signed. Assume it is negative. What does it mean? It means that there is a positive relation between individual consumption and the effect of an additional charity on the joy of giving. In other words adding one charity has an impact and it thus not surprising that if negative this covariance implies more charities. Increasing \(M\) reduces the range \((\bar{x}_j, x_j)\) and thus the dispersion in the joy of giving across contributors of a given charity. We normally expect that increasing \(M\) has a positive effect on average joy of giving and thus on average contributions.

5 Free entry

Up to now the number of charities was determined by the government along with the level of subsidy on contributions. We now consider an alternative
setting wherein the role of the central planner is restricted to subsidizing contributions. Charities can settle down as they want. Given our symmetric setting, they will all collect $Z^*/M$ where $Z^*$ is given by (2). Following Aldasheev and Verdier (2006) the payoff for the charity manager is a function $\delta$ of this amount, namely $\delta Z^*/M$. Now entry will continue as long as

$$\delta Z^* (M, \sigma) > MF.$$  

(15)

We hence assume that the charity’s manager is not concerned by the joy of giving. The payoff $\delta Z^*/M$ can be interpreted as a financial return or a proxy for power and prestige. We want to compare the outcome of free entry with that of the second-best optimal number of charities.

Let us define $M^e = M(\sigma, F, \delta)$ as the solution of $\delta Z^* (M, \sigma) = MF$. In this section, we assume that $u'(c) = \alpha = 1$ and that $u'' < 0$ is also constant. This latter assumption is just made to simplify matters. Given that the social planner is concerned with inequality, distribution of the burden of the set up cost $F$ does not matter, so that we can carry our previous analysis to the present context. The second-best optimal number of charities, $\hat{M}$, is given by (12). At that level and given the subsidy rate $\hat{\sigma}$, additional entry occurs if:

$$\frac{\delta Z^*}{\hat{M}} > F$$

or

$$\delta > \left(\frac{bF}{4Z^*} \frac{\hat{\tau} \theta}{1 - \hat{\tau} \theta}\right)^{1/2} = \tilde{\delta}.$$  

(16)

If this is the case: $M^e (\hat{\sigma}) > \hat{M}$. In other words, for a subsidy equal to $\hat{\sigma}$, the free entry equilibrium number of charities exceeds its second-best optimal number if $\delta > \tilde{\delta}$. Naturally if $\delta < \tilde{\delta}$, we have the reverse result.

In a setting of free-entry, one does not expect the subsidy rate to be the same as that of the second-best optimum. With a single instrument, the social planner has to be concerned by what it may consider as an inefficient level of contributions and an inefficient number of charities.

We now study what would be the optimal subsidy rate with free entry. Assume that $M^e > \hat{M}$. In other words, inequality (17) holds. We differentiate $SW$ with respect to $\sigma$ with $M = M^e(\sigma)$. This yields:

$$\frac{dSW}{d\sigma} = \frac{\partial}{\partial \sigma} SW(\sigma, M) + \frac{\partial}{\partial M} SW(\sigma, M) \frac{dM^e}{d\sigma}.$$  

12
Assuming concavity of $SW$ and making use of $\frac{\partial^2 SW}{\partial M \partial \sigma} < 0$, we have

$$\frac{dSW}{d\sigma} \bigg|_{\sigma = \hat{\sigma}, M = M^e} = \frac{\partial}{\partial \sigma} SW(\hat{\sigma}, M^e) + \frac{\partial}{\partial M} SW(\hat{\sigma}, M^e) \frac{dM^e}{d\sigma} < 0.$$ 

Thus, the optimal subsidy with free entry, denoted $\tilde{\sigma}$, should be lower than $\hat{\sigma}$ if the free-entry number of charities exceeds the second-best optimal number. Naturally, if there was an undersupply of charities, $\tilde{\sigma} > \hat{\sigma}$. Formally

$$\tilde{\sigma} \leq \hat{\sigma} \quad \text{iff} \quad \delta \geq \left( \frac{bF}{4Z^* (1 - \tau \theta)} \right)^{1/2}.$$ 

These results are quite intuitive.

6 Conclusion

In this paper we dealt with the question of the optimal number of charities. The objective is to reach a certain level of aggregate contributions to some common causes. Contributions are made through charities. If there were not set-up cost in establishing a new charity, there would be as many charities as individuals. With set-up costs, the number of charities has to be reduced. Without aversion towards inequality and without tax distortion, one charity suffices.

There are two reasons why there will be more than one charity. First with tax distortion subsidies are becoming costly and increasing the number of charities has the effect of fostering contributions. Second, with concern for inequality, the range of disposable income decreases with the number of charities. As a consequence the optimal number of charities increases with the distortion and the concern for inequality and decreases with the size of the fixed cost.

Comparing this second-best optimal number of charities with the number resulting from free entry we see that the likelihood of an oversupply decreases with the mark up $\delta$, the distortion $\theta$ and the fixed cost $F$. In case of oversupply, the optimal subsidy rate is lower than it would be when the number of charities is directly controlled.

Finally, in case of free entry, we have a problem that is related to that of the size of nations studied by Alesina and Spolaore (1997).

\[\text{From (10) and (11) we obtain:}\]

$$\frac{\partial}{\partial M} \left( \frac{\partial SW}{\partial \sigma} \right) = \frac{dZ^*}{dM} \left[ \frac{N}{1 - N v''} - \frac{\tau \theta}{1 - \tau \theta} - (Z^* + \frac{N}{1 - N v''}) \frac{d}{d\tau} \left( \frac{\tau \theta \sigma}{1 - \tau \theta}, dZ^* \right) \right] < 0.$$
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