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A Note on 'Neutrality Theorem' In Private Provision of Pure Public Good

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Abstract

In case of private provision of single pure public good, Warr (1983) claimed that if the set of contributors is not singleton then the amount of public good provided in the economy depends on the aggregate income of the contributors. Hence income redistribution among the contributors leaving the set of contributors and their aggregate income unchanged has no effect on the amount of public good. In this note we characterize an income transfer scheme which although affects the gross aggregate income of the contributors, but is still neutral in effect on the amount of public good. Thus we conclude that gross income invariance property of an income redistribution scheme is not necessary for the 'Neutrality' result. Further we also observe that such kind of transfer directed from contributors to the non-contributors is still neutral over the level of public good, provided it does not alter the set of contributors.

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1. Introduction

Warr (1983) presented a seminal result in the context of privately provided single pure public good, famously known as 'Neutrality' theorem. He showed that if the set of contributors remains unchanged, redistribution of income among them leaves the amount of public good unchanged. The driving force behind this is the result showing that the equilibrium amount of public good depends on the aggregate income of the contributors. Thus neutrality works under two apparent pre-conditions – (1) the set of contributors must remain the same in both pre and post-transfer situations; and (2) income transfer must keep the aggregate income of the contributors unchanged. The second pre-condition is satisfied only for unconditional transfers, where the recipient adds the transfer amount to her income and then decides on its optimal allocation among the goods.

A scrutiny of the literature suggests that while some papers have illustrated the validity of neutrality in some environments, some have shown its invalidity in other environments. Becker (1974), Barro (1974) for intergenerational transfers, Kemp (1984) for multiple public goods, Boadway, Pestieau and Wildasin (1989) for taxes and subsidies on private goods and Varian (1994) for Stackelberg equilibria – all of them show validity of neutrality in respective situations. In contrast, Bergstrom, Blume and Varian (1986) show that Neutrality does not hold if the transfer amount fails to satisfy the first pre-condition. Buchholz and Konrad (1995), Konrad and Lommerud (1995) and Ihori (1996) suggest that neutrality result is invalid if the marginal cost of providing the public good differs among the individuals. Finally Ruebbelke (2003), in a framework of 'impure' public good, enumerates different conditions under which foreign aid is potentially neutral/non-neutral over public good (GHG abatement) provision level.

It is worthy to mention that all of the above papers considered unconditional cash transfers only. The consequence of conditional transfer where the recipient cannot add the amount directly to her income and spends it entirely on the good with which it is tied, on the validity of neutrality has remained unexplored. The reason is perhaps obvious. Conditional transfer does not keep the aggregate income of the contributors unchanged and hence, is not supposed to be neutral. But, in this note, we show that a cash transfer tied to the provision of the public good i.e. the recipient can spend it only for the provision of public good, is also neutral over the level of public good if the set of contributors remains unaffected. This result holds irrespective of the asymmetry in preference pattern and income distribution of the contributors. Hence the result contributes to the literature demonstrating that only the first pre-condition is necessary for the neutrality to hold.

Moreover, we explore the possibility of obtaining neutrality in situations where tied cash transfer is directed from a contributor to a non-contributor and vice-versa. We observe that such transfer scheme is neutral over the level of public good only in the circumstance where it is directed from a contributor to a non-contributor in such a way that the composition of the two disjoint sets is unaltered. This result, in fact, reiterates the necessity of the first pre-condition for neutrality to hold. It also marks another contribution to the literature by showing that while unconditional transfer is neutral only for redistribution where both transfer donors and recipients are contributors; neutrality of conditional transfer requires only the donors as contributors. The recipients may or may not be contributors.

We plan the paper in the following way: we develop the theoretical model in the next section, the section following it presents an illustration using Cobb-Douglas utility function, then we discuss the consequences of tied transfer from a contributor to a non-contributor and vice-versa in the context of neutrality and finally we conclude.

2. The Model

Consider an economy consisting of two individuals. We label them as *individual 1* and *individual 2*. The income of *ith* individual is $M_i \in \mathbb{R}_{++}$, $\forall i = 1,2$. Both the individuals consume a pure public good and a private good. The public good is provided by the voluntary contribution of the individuals. If the *ith* individual contributes $g_i \in \mathbb{R}_+$, then the total amount of contribution becomes $(g_i + g_j), \forall i, j = 1,2$ and $i \neq j$.[1] Assume that $1 of contribution yields 1 unit of the public good. Thus the total amount of public good provided in the economy becomes $G = g_i + g_j$. The amount of private good consumed by the *ith* individual is $c_i \in \mathbb{R}_{++}, \forall i$. Lastly, we assume all goods are normal in consumption and the price of private good is unity.

Now we define the utility function of *ith* individual as $u^i = u^i(G, c_i)$ where u^i is continuous, monotonically increasing in its arguments, strictly quasi-concave and at least twice differentiable with $u^i_G, u^i_c > 0$; $u^i_{GG}, u^i_{cc} < 0$ and $u^i_{Gc} = u^i_{cG} > 0$. Replacing G by $(g_i + g_j)$ we rewrite the utility function as:

$$u^i = u^i(g_i + g_j, c_i) \tag{1}$$

The *ith* individual maximizes her utility given in equation (1) subject to her budget constraint:

$$g_i + c_i \leq M_i \tag{2}$$

Since this is a static model with no incentive of savings, the budget constraint holds with equality in equilibrium. Therefore, substituting $c_i = M_i - g_i$ we rewrite the utility function of equation (1) as:

$$u^i = u^i(g_i + g_j, M_i - g_i) \tag{3}$$

Definition 2.1: ***Unconditional Cash Transfer Scheme*****:** In case of unconditional transfer of $1 from individual i to individual j, the income distribution changes from (M_i, M_j) to $(M_i - 1, M_j + 1)$. So individual *j* now allocates her net income i.e. $(M_j + 1)$ optimally between contribution towards public good and private good. Note that this transfer scheme does not alter the gross income i.e. $(M_i + M_j)$ in the economy. Warr (1983) derived the Neutrality theorem considering such income redistributive scheme.

Definition 2.2: ***Conditional/Tied Cash Transfer Scheme*****:** The recipient of conditional cash transfer can spend the amount only in the good for which it is intended. No part of it can be spent in the other good. Thus $1 tied transfer from i to j alters the income distribution from (M_i, M_j) to $(M_i - 1, M_j)$. Clearly, $(M_i + M_j)$ also changes in the post-transfer situation to $\left(M_i + M_j - 1\right)$.

The two types of cash transfer defined above differ significantly in the mode in which it is dispensed. In case of unconditional transfer, a fraction of transfer amount is spent for providing the public good and the residue amount is spent on private consumption. But conditional transfer amount is spent entirely on the good with which it is tied. In the

[1] At first it seems unusual that all the individuals of an economy contribute positive amount for the public good, especially when Bergstrom, Blume and Varian (1986) pointed out that only individuals having income above a critical level contribute positive amount. But minor change in the framework makes it convenient. Let the set of individuals be $N = \{1, 2, \ldots\ldots, n\}$ where $|N| = n > 2$. Suppose the initial income distribution induces the set of contributors to be $C \subset N$ and $|C| = 2$. Since we focus on the set of contributors for verifying neutrality result, the set $N \setminus C$ is irrelevant for the purpose of the paper.

following section we consider a conditional cash transfer to public good and explore its implication in the context of the neutrality result.[2]

3. The Case of Conditional Cash Transfer

Assume that in the pre-transfer situation both the individuals contributed positive amount towards the public good in pure strategy Nash equilibrium.[3] Without loss of generality, consider a conditional cash transfer of amount $T \in \mathbb{R}_+$ to public good from individual 1 to individual 2. The transfer amount is chosen in such a way that both the individuals contribute in post-transfer equilibrium also. Continuing with the same notation, let individual 1 contribute $g_1 \in \mathbb{R}_{++}$ and the net contribution from individual 2 becomes $(g_2 + T) = g_2' \in \mathbb{R}_{++}$. From equation (3) we write the utility maximization problem of individual 1 as:

$$\underset{\{g_1>0\}}{Max}\, u^1(g_1 + g_2 + T, M_1 - T - g_1)$$

The first order condition of the above problem yields:

$$u_G^1 - u_c^1 = 0 \tag{4}$$

The utility maximization problem of individual 2 is:

$$\underset{\{g_2>0\}}{Max}\, u^2(g_1 + g_2 + T, M_2 - g_2)$$

The first order condition that follows is:

$$u_G^2 - u_c^2 = 0 \tag{5}$$

Equations (4) and (5) derive the following proposition.

Proposition 1: *A conditional cash transfer tied to the provision of a pure public good from one contributor to another keeping the set of contributors unchanged but affecting their gross income is neutral in effect over the public good provision level. Thus, for cash transfer scheme to be neutral over the level of privately provided pure public good, the invariance of gross income of the contributors is not a necessary condition.*

Proof: Suppose $(\hat{g}_1, \hat{g}_2)$ is the pure strategy Nash equilibrium level of contributions that solve equations (4) and (5). Differentiating totally both sides of equations (4) and (5) and re-arranging the terms we obtain the following:

$$(u_{GG}^1 - 2u_{Gc}^1 + u_{cc}^1)d\hat{g}_1 + (u_{GG}^1 - u_{Gc}^1)d\hat{g}_2 = (2u_{Gc}^1 - u_{GG}^1 - u_{cc}^1)dT \tag{6}$$

$$(u_{GG}^2 - u_{Gc}^2)d\hat{g}_1 + (u_{GG}^2 - 2u_{Gc}^2 + u_{cc}^2)d\hat{g}_2 = (u_{Gc}^2 - u_{GG}^2)dT \tag{7}$$

Solving equations (6) and (7) yields $d\hat{g}_1 = -dT$ and $d\hat{g}_2 = 0$ .Therefore we have $d\hat{G} = d\hat{g}_1 + d\hat{g}_2 + dT = 0$ .This result holds for all values of transfer in the admissible domain $T \geq 0$. Thus it is also valid at $T = 0$ i.e. the pre-transfer equilibrium.
This completes the proof of the proposition. ■

The intuition of proposition 1 is clear. If \$1 is transferred from individual 1 to individual 2 as conditional transfer tied to the provision of public good, then individual 1 reduces her contribution by exactly \$1 compared to her contribution amount in pre-transfer equilibrium. As the transfer amount is tied with the public good, so individual 2 contributes

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[2]In reality there are several instances of conditional cash transfer for financing a public good. Think of a situation where the countries voluntarily invest to provide global public goods like cleaner and sustainable environment by reducing GHG emission level, combating against contagious diseases like AIDS, polio, and eradicating terrorism. In such cases a cash transfer from one country to another based on the condition that the entire amount is to be spent to finance a specific public good belongs to the category of conditional cash transfer that we consider here.

[3]The proof of existence and uniqueness of such kind of pure strategy Nash equilibrium in voluntary contribution game is provided by Bergstrom, Blume and Varian (1986).

entire \$1 to its provision and keeps her voluntarily contributed amount same as that in pre-transfer equilibrium. Thus the total contribution amount remains unchanged making such transfer scheme neutral over the level of public good provided in the economy.

The neutrality result stated in proposition 1 is distinct from that stated by Warr (1983). Warr derived that in a situation where all the individuals contribute positive amount for the public good, the amount of public good depends on the gross income of all the individuals. Thus, it followed as a corollary, income redistribution among the individuals keeping the set of contributors and gross income unchanged also leaves the amount of public good unchanged. It also appears apparently that restrictions on the set of contributors and gross income of the economy are necessary preconditions for neutrality to hold. Conversely, if a transfer scheme changes the gross income then the amount of public good is expected to change. But our proposition shows that although the restriction on set of contributors is a necessary condition but that on gross income of the individuals is not necessary at all for neutrality to hold. The reason is: if T is transferred from individual i to individual j as conditional/tied transfer, then the income of i becomes $(M_i - T)$. Since the transfer is tied to a particular good so j has to spend T on that good only and cannot incorporate it into her income. This implies the disposable income of j still remains M_j even after the income redistribution. The above argument clearly shows that such type of conditional transfer scheme affects the gross income of the individuals and an interesting and significant contribution is that it is also neutral in the public good provision level like the unconditional transfer scheme. Thus not only Warr (1983) but several other papers discussing Neutrality theorem from different perspectives, as already reviewed in section 1, have by far ignored the redundancy of the restriction on invariance of aggregate income of contributors in post-transfer equilibrium for neutrality.

3.1 An example with Cobb-Douglas utility function

In this section we corroborate our finding with an example of Cobb-Douglas type utility function. For convenience we use a log-linear transformation of it. Continuing with the same notations of section 2 we define the utility functions of individuals 1 and 2 as:

$$u_1 = \alpha_1 \ln G + \alpha_2 \ln c_1$$

$$u_2 = \beta_1 \ln G + \beta_2 \ln c_2$$

where $G = g_1 + g_2; \alpha_i, \beta_i \in \mathbb{R}_{++}$ for all $i = 1,2$. The budget constraint of the *ith* individual is $g_i + c_i = M_i; \forall i = 1,2$. Substituting $c_i = M_i - g_i$ for all $i = 1,2$ in the respective utility functions we obtain:

$$u_1 = \alpha_1 \ln(g_1 + g_2) + \alpha_2 \ln(M_1 - g_1) \tag{8}$$

$$u_2 = \beta_1 \ln(g_1 + g_2) + \beta_2 \ln(M_2 - g_2) \tag{9}$$

Maximizing u_1 and u_2 subject to $g_1 > 0$ and $g_2 > 0$ respectively, we have the following first order conditions:

$$\frac{\alpha_1}{g_1 + g_2} = \frac{\alpha_2}{M_1 - g_1} \tag{10}$$

$$\frac{\beta_1}{g_1 + g_2} = \frac{\beta_2}{M_2 - g_2} \tag{11}$$

Solving equations (10) and (11) yield: $g_1{*} = \dfrac{\alpha_1(\beta_1+\beta_2)M_1 - \beta_1\alpha_2 M_2}{(\alpha_1+\alpha_2)(\beta_1+\beta_2)-\alpha_2\beta_2}$ and $g_2{*} = \dfrac{\beta_1(\alpha_1+\alpha_2)M_2 - \alpha_1\beta_2 M_1}{(\alpha_1+\alpha_2)(\beta_1+\beta_2)-\alpha_2\beta_2}$, where $g_i{*}$ represents the pure strategy Nash equilibrium value of voluntary contribution of *ith* individual towards the public good.

Thus $G{*} = g_1{*} + g_2{*} = \dfrac{\alpha_1\beta_1(M_1+M_2)}{(\alpha_1+\alpha_2)(\beta_1+\beta_2)-\alpha_2\beta_2{}^2}$ (12)

Now we consider a conditional transfer of amount $T > 0$ to the public good from individual 1 to individual 2. So the utility function of the individuals in equations (8) and (9) transform to:

$u_1 = \alpha_1 \ln(g_1 + g_2 + T) + \alpha_2 \ln(M_1 - T - g_1)$

$u_2 = \beta_1 \ln(g_1 + g_2 + T) + \beta_2 \ln(M_2 - g_2)$

Consequently, the first order conditions of utility maximization in equations (10) and (11) get modified to:

$$\frac{\alpha_1}{g_1 + g_2 + T} = \frac{\alpha_2}{M_1 - T - g_1} \qquad (13)$$

$$\frac{\beta_1}{g_1 + g_2 + T} = \frac{\beta_2}{M_2 - g_2} \qquad (14)$$

Solving equations (13) and (14) yield: $\tilde{g}_1 = \dfrac{\alpha_1(\beta_1+\beta_2)M_1 - \beta_1\alpha_2 M_2}{(\alpha_1+\alpha_2)(\beta_1+\beta_2)-\alpha_2\beta_2} - T = g_1{*} - T$ and $\tilde{g}_2 = \dfrac{\beta_1(\alpha_1+\alpha_2)M_2 - \alpha_1\beta_2 M_1}{(\alpha_1+\alpha_2)(\beta_1+\beta_2)-\alpha_2\beta_2} = g_2{*}$, where $\tilde{g}_1$ and $\tilde{g}_2$ are the pure strategy Nash equilibrium contribution amounts of individuals 1 and 2 in post transfer situation. Observe that $\tilde{G} = \tilde{g}_1 + \tilde{g}_2 + T = G{*}$. Thus the above example confirms validity of Neutrality theorem in case of conditional cash transfer scheme.

4. Further Discussions

So far we have confined ourselves to income redistribution among the contributors which keeps the set of contributors unchanged. But an interesting question is: what happens to the neutrality result if income is transferred from a contributor to a non-contributor or vice-versa? It is clear from Bergstrom, Blume and Varian (1986) that for an unconditional transfer, the amount of public good changes in these situations, thus invalidating the neutrality result. Therefore, the question becomes more pertinent for the case of conditional transfer.

Continuing with the same notations as of section 2, without any loss of generality assume $M_1 > M_2$. It follows from Bergstrom et al (1986) that in equilibrium, all contributors have higher wealth than all non-contributors. Consequently, we define the pre-transfer equilibrium as the one where individual 1 contributes positive amount and individual 2 contributes nothing. We let the contribution amount of individual 1 be $g_1{*} \in \mathbb{R}_{++}$. Note that this is also the amount of public good provided.

Now we allow a conditional transfer of amount $T > 0$ from individual 1 to individual 2. For the time being, we assume that although the transfer reduces the income of individual 1, yet she remains as contributor even in the post-transfer equilibrium. Thus she reduces her contribution to $(g_1{*} - T)$. On the other hand, as the income of individual 2 remains the same after receiving the conditional transfer, she voluntarily chooses to contribute nothing. But due to the tied nature of the transfer, she spends T for the public good. Hence the gross spending towards the public good becomes $\{(g_1*-T)+T\}=g_1*$, which is the same as before. We note this interesting observation below.

Observation 1: *Unlike the unconditional transfer, a conditional cash transfer tied to the provision of public good, directed from a contributor to a non-contributor, is neutral in effect on the level of public good provided. This holds in a circumstance where the set of contributors remains unchanged even after the transfer.*

Proof: See the discussion above. ■

Now consider the possibility where the transfer amount reduces the income of individual 1 to such an extent that she becomes a non-contributor in post-transfer equilibrium. For this, we must have $T > g_1*$ (follows from Bergstrom et al (1986)). So, in post-transfer equilibrium, both the individuals are voluntarily contributing nothing. Only individual 2 spends T received as transfer. Hence compared to the initial equilibrium, the amount of public good reduces by g_1* but increases by T. Since we have $T > g_1*$, we conclude that the amount of public good increases. Nonetheless, the conditional cash transfer scheme is not neutral in this situation.

Finally we consider a conditional transfer from individual 2 to individual 1. Obviously it would not alter the sets of contributor and non-contributor. In this situation, since individual 1 would have to spend entire T for the public good, it prompts her to reduce her own contribution. But due to the altruistic nature, she reduces her contribution by an amount less than T. Clearly, the increase in spending is more than the reduction. This increases the level of provision of the public good. Thus the conditional cash transfer scheme is non-neutral in this situation as well.

Combining proposition 1 and observation 1, we present the neutrality obtained with respect to conditional cash transfer scheme in a single proposition as follows:

Proposition 2: *A conditional cash transfer tied to the provision of public good is neutral in effect over the level of its provision, provided the following two conditions are satisfied;*

(i) the transfer is directed from a contributor, and

(ii) the set of contributors remains unchanged after the transfer.

The neutrality holds irrespective of whether the recipient of transfer is a contributor or a non-contributor in pre-transfer equilibrium.

Proof: See the discussion above. ■

In the beginning, Warr (1983) showed that when a single public good is provided at positive level by private individuals, its provision is unaffected by a redistribution of income. This neutrality holds regardless of differences in individual preferences. But the problem with this observation was the difficulty to accept an equilibrium where every individual in an unequal society is a contributor. It was only when Bergstrom et al (1986) proposed that all contributors have higher wealth than all non-contributors, it became clear that neutrality holds only when income redistribution is done among the contributors and its set remains unchanged even after the cash transfer program. They also confirmed that the result still holds for other forms of public good production function and for more general solution concepts other than Nash equilibrium.

The basic reason behind the neutrality result is that level of public good provided depends on gross income of the contributors. Hence and quite obviously, a general kind of cash transfer among the contributors leaves their gross income unchanged and so also the level of public good provided. In proposition 1 we show that a conditional cash transfer tied to the public good alters the gross income of the contributors but is still neutral over the amount of public good produced. Thus we assert that for the neutrality of cash transfer, invariance of gross income of the contributors is not necessary.

In fact, the Neutrality theorem obtained by Warr (1983) and Bergstrom et al (1986) in case of unconditional transfer can be reconciled with the same proposed here with respect to conditional transfer. According to them, the transfer donor reduces her voluntary contribution exactly by the transfer amount and the recipient increases her contribution by the same amount. Alternatively, we can view this as the recipient keeping her voluntary contribution amount unchanged and spending the entire transfer amount for the provision of the public good. But this is exactly the case of conditional transfer tied to the public good. Thus it is the behavior of the individuals that make the two transfer schemes equivalent when income redistribution is done among the contributors only.

Bergstrom et al (1986) also show that unconditional cash transfer from contributors to non-contributors decreases the amount of public good, if both the sets remain unchanged. This is not true for conditional transfer. Proposition 2 shows that in such situation, neutrality of conditional transfer is preserved. The rationale for this difference is although a non-contributor voluntarily contributes nothing, but due to the tied nature of the transfer, she spends the entire amount that she has received for the provision of public good. So the fall in contribution of the contributor resulting from loss of income is neutralized by the spending of the non-contributor. Whereas, since there is no condition imposed on the mode of spending of the untied transfer amount, the non-contributor spends it entirely on the private consumption good. Thus there is no scope to offset the fall in contribution of the contributor.

An interesting implication follows from propositions 1 and 2. The neutrality of unconditional cash transfer requires the redistribution of income to remain confined to the set of contributors only. But neutrality of conditional cash transfer requires a milder condition: the transfer donor must be a contributor. The recipient can be a contributor or a non-contributor. Thus the redistribution can be both within the contributing set as well as across the sets.

5. Conclusion

This note considers an economy where two individuals voluntarily contribute positive amount to provide a single pure public good. Alongside, each consumes a private good as well. It shows that a conditional cash transfer tied to the provision of a public good from one individual to another is neutral over the level of public good provided in the economy, provided the set of contributors remains unchanged after the transfer. The result is significant as it nullifies the necessity of invariance of gross income of the contributors as a pre-requisite for the neutrality result which was apparently evident from the Neutrality theorem proposed by Warr (1983). Also, such kind of transfer from a contributor to a non-contributor is neutral if the two sets remain unchanged.

The result presented here has interesting policy implication. Consider a world consisting of a developed country and a developing country. Both the countries contribute voluntarily for the provision of global public good like clean environment by abatement of GHG emission. In such situation, if the developed country transfers an amount to the developing country on the condition that it would be spent entirely on GHG abatement, then according to our proposition, the global pollution level would remain unchanged. Often in many situations, non-transferable tied transfers are preferred over unconditional transfers in achieving the desired objectives. For example, a poor individual may spend a part of the amount received as unconditional transfer on goods other than food. Thus malnutrition may still prevail and the government policy of eradication of malnutrition through general subsidy program would fail to meet the target. In this situation, a non-transferable conditional transfer tied to food can serve as a better instrument. But in the case of privately provided public good, tied transfers have identical neutral effect on the amount of public good as that of unconditional transfers. This makes the policymaker indifferent between the two.

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