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THE TRANSFER PROBLEM WITH THREE AGENTS ONCE AGAIN

Characterization, Uniqueness and Stability

Graciela CHICHILNISKY*

Columbia University, New York, NY 10027, USA

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An earlier paper in this Journal [Chichilnisky (1980)] gave for the first time sufficient conditions for the transfer paradox to occur in 3-agent economies, with *stable* markets. This paper comments on several other papers written about these results, and extends the results further. Here we give necessary as well as sufficient conditions for the transfer problem to occur in an economy with three agents, at a unique and Walrasian stable equilibrium.

1. Introduction

In a recent paper in this Journal [Chichilnisky (1980)],[1] I re-examined the problem of the negative effects of a transfer on the welfare of the recipient, but setting it for the first time in the context of a stable 3-agent economy. Each agent is an income group; the high income group transfers some of its initial endowment to the lowest income group. The paper established sufficient conditions for the transfer to decrease the welfare of the receiver, in a stable market.

The welfare analysis of transfers has, of course, a long and distinguished tradition in trade theory. The negative effects of transfers on the receiver were studied first by Leontieff (1936). However, these effects have been attributed for many years to market *instability* following Samuelson (1947) and Mundell (1956). The *stable* results in Chichilnisky (1980) have received a clattering amount of notice, being the subject of several other papers in this issue, and of others elsewhere, e.g., Geanakoplos and Heal (1982), Gunning (1983), de Meza (1982), Saghafi and Nugent (1983), Polemarchakis (1982), Ravallion (1983), and Srinivasan and Bhagwati (1982 and 1983). This note comments on the contributions of these papers, and allows me to clarify and

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[1] Chichilnisky (1980) is a revised version of a 1978 Development Discussion Paper, Harvard Institute for International Development, see Chichilnisky (1978).

complete the discussion with a rather straightforward generalization of my earlier results. I give here necessary as well as sufficient conditions for the negative effects of transfers on the recipient's welfare, within a 3-agent economy with a *unique* and globally stable equilibrium, Theorem 2. I also characterize the cases in which the transfer has a positive welfare effect on the donor — and those when it has a negative effect instead. All conditions are on the initial data of the problem, i.e., on initial endowments, and on the preferences of the agents.

A discussion of some of this recent literature on the transfer problem in a three-agent setting, is in Jones (1982).

2. The transfer problem with 3 agents once again

The model is that of Chichilnisky (1980). The economy has 3 agents, or groups, and two goods A and B. The groups are identified as H, high income; L, lower income; and S, the South. The two goods are called basic goods, B, and industrial goods, A.[2] We can think of the groups H and L either as being two income groups within *one* country [the North in Chichilnisky (1980)], or else as one country each. As an illustration it will be useful later to think of H as the industrial countries, L as the newly industrializing countries, and S as the less industrialized countries of the South.

Each group is identified by its initial endowment of goods, and its preferences, which are of the fixed proportion type. The endowments of H are denoted H_A and H_B, those of L, L_A and L_B, and those of S, S_A and S_B. The preferences of H, L and S are denoted U, V and W respectively:

$$U=\min(aB,A),\quad V=\min(B,bA),\quad W=\min(B,cA).$$

The parameters a, b and c are larger than or equal to 1, since lower income groups consume proportionately more B than A. We normalize $b=1$.

In view of the comments in Geankoplos and Heal (1982), Gunning (1983), Ravallion (1983), and Srinivasan and Bhagwati (1982 and 1983) it will be useful to state again here, and discuss in more detail, the conditions required in Chichilnisky (1980). There were two types of conditions: regularity conditions, and another type of condition, on initial endowments or net trading positions. The regularity conditions were denoted (C.1) and (C.2). The first condition is

$$\text{(C.1)}\qquad H_B+L_B+S_B<(1/a)H_A+L_A+cS_A.$$

[2]In Chichilnisky (1980) A was called a luxury/investment good instead.

As discussed in Chichilnisky (1980) this condition (C.1) is required to ensure that the price of B, p_B, is always different from zero in equilibrium. Therefore we may normalize prices, considering the relative price $p = p_A/p_B$. Since this model is homogeneous, only relative prices are relevant.

It has been shown in Geanakoplos and Heal (1982) that condition (C.1) is equivalent to requiring that, as the price of B approaches zero, the excess demand for B becomes strictly positive. This can therefore be interpreted as a boundary condition, requiring that the excess demand vector points inward at a boundary of the price space, see Dierker (1974).

The regularity condition (C.2) in Chichilnisky (1980) is that there exists an equilibrium, and at the equilibrium a four-by-four subdeterminant of the Jacobian of the system is non-singular.

This condition (C.2) assures that an equilibrium exists, each equilibrium is locally unique and it depends smoothly on the parameters as required for comparative statics exercises. Since a new boundary condition (C.3) is required here, which implies existence of an equilibrium, we shall consider here a weaker version of (C.2):

(C.2') At the equilibrium, a four by four subdeterminant of the Jacobian of the system is non-singular.

To the two regularity conditions (C.1) and (C.2') we add here a further regularity condition, which was not required in Chichilnisky (1980) as it was not needed there. This third condition is needed here in order to generalize the earlier results, and in particular to prove global uniqueness and stability of the equilibrium:

(C.3) $$L_A + S_A + H_A < L_B + S_B/c + aH_B.$$

This condition is symmetric to (C.1) in that it requires the excess demand for A to become strictly positive as its price p_A approaches 0. This condition appears also in Geanakoplos and Heal (1982).

In addition to (C.1) and (C.2), a further condition appeared in Theorem 1 of Chichilnisky (1980), *not* a regularity condition but rather a condition giving information on the initial endowments, of the 'middle income' group L. This is a condition on the parameter $\lambda = L_A - L_B$ [as defined on p. 513, (9) of Chichilnisky (1980)], i.e., on the difference between the endowment of industrial and basic goods of the middle income group L. Because this group consumes as many units of A as of B ($b=1$) the sign of λ determines the net trade position of the middle income group. *When λ is positive, the middle income group L is a net importer of basic goods; if λ is negative, this group is instead a net importer of industrial goods A.*[3]

[3]This was discussed on p. 513 of Chichilnisky (1980).

The condition that the middle group is a net importer of the industrial good, i.e., $\lambda < 0$, appeared in the third sentence of Theorem 1, p. 510, where the South is a net importer of basic goods, since $\lambda < 0$ implies that the South imports basic goods, as shown in footnote 9 to p. 513 of Chichilnisky (1980). The condition $\lambda < 0$ was also invoked explicitly on p. 515, line 8 from end. It can be considered a plausible condition if the middle income group is interpreted as the group of newly industrializing countries, because these countries are generally importers of industrial goods, so that $\lambda < 0$. Ravillion (1983) and Geanakoplos–Heal (1982), discuss its economic significance. Other commentators, e.g., Gunning (1983) and Srinivasan–Bhagwati (1982) do not acknowledge that this condition was explicitly invoked in Theorem 1 which leads them to inapplicable statements. Jones (1982) provides a clear discussion of the role of the condition $\lambda < 0$ in Chichilnisky (1980), and of the inapplicability of Srinavasan–Bhagwati's comments on the results of Chichilnisky (1980).

The condition $\lambda < 0$, together with the regularity conditions (C.1) and (C,2), is sufficient to prove that the transfer problem with 3 agents will occur in stable markets: The receiver is, in this case, necessarily worse off after the transfer. This precisely what was proved in Theorem 1 of Chichilnisky (1980) which is restated here for the sake of clarity. The proof of this theorem is, of course, identical to that in Theorem 1 of Chichilnisky (1980):

Theorem 1 [*Chichilnisky (1980)*]. *Consider a 3-agent world economy as defined above. Then a transfer of industrial goods from the high income group H to the lowest income group S will necessarily decrease the welfare of the receiver in a stable market, whenever the regularity conditions (C.1) (C.2) are satisfied, and the middle income group imports industrial goods, i.e.,* $\lambda < 0$.

Following the original algebraic proof given in Chichilnisky (1980), Geanakoplos and Heal (1982) recently produced a geometric proof of Theorem 1. Their geometric version of the proof is helpful to highlight the role of the conditions of the theorem, and also for the construction of examples. A further numerical example of Theorem 1 is offered in Polemarchakis (1982). It may be useful to point out that for small transfers the above result does *not* depend on which good is transferred:

Corollary 1 [*Geanakoplos and Heal (1982)*]. *Under the conditions of Theorem 1, a transfer from H to S will necessarily lower the welfare of S in a stable market, even if the transfer is of basic goods or of any combination of basic and industrial goods, provided transfers are small.*

In view of the comments appearing in this issue of the Journal, it seems useful to discuss further the condition that the middle income group imports industrial goods, i.e., $\lambda<0$. A footnote in Chichilnisky (1980)[6] explained that when λ is negative, then the South must be a net importer of basic goods, i.e., $\sigma>0$.[4] The condition that the South imports basic goods, i.e., $\sigma>0$ is plausible when we interpret basic goods as food, because many LDC's are at present net importers of food.

Lemma 1. In a 3-agent world economy as above, whenever the middle income group L imports industrial goods ($\lambda<0$), and (C.1) is satisfied, the lowest income group S always imports basic goods ($\sigma>0$). In particular, under the conditions of Theorem 1, the South imports basic goods.[5]

Proof. Assume $\lambda<0$ *and* $\sigma<0$, and let

$$\rho=H_A-aH_B,\quad \lambda=L_A-L_B,\quad \sigma=S_A-S_{B/c},$$

as defined in (9) of Chichilnisky (1980).

Since in equilibrium the market for B clears, i.e., $D_B=0$, we have from (10) in Chichilnisky (1980):

$$D_B=\frac{\rho}{a+1/p}+\frac{\lambda}{1+1/p}+\frac{\sigma}{1/c+1/p}=0, \tag{1}$$

Now, condition (C.1) can be rewritten as

$$\rho/a+\lambda+\frac{\sigma}{1/c}>0. \tag{2}$$

Subtracting (1) from (2), we obtain

$$\frac{\rho}{(a+1/p)a}+\frac{\lambda}{1+1/p}+\frac{\sigma}{(1/c+1/p)1/c}>0. \tag{3}$$

Since $a>1$, $c>1$, and $\sigma<0$ by assumption, (3) implies

$$\frac{\rho}{a+1/p}+\frac{\lambda}{1+1/p}+\frac{\sigma}{1/c+1/p}>0, \tag{4}$$

which contradicts the market clearing condition (1). Therefore, when $\lambda<0$, σ cannot be negative. This completes the proof of Lemma 1.

[4]Footnote 9 to p. 513.

[5]The example of Srinivasan and Bhagwati (1982) was constructed assuming, to the contrary, that the South *exports* basic goods B. Therefore it is not a counterexample to Theorem 1 of Chichilnisky (1980). The example of Gunning (1983) is also in violation of one condition of Theorem 1, namely $\lambda<0$; it is therefore not a counterexample either

3. Disadvantageous reallocations, and the strict transfer paradox

So far we have only considered the welfare impact of the transfer on the receiver. However, in view of the results of section 4 in Chichilnisky (1980), we can also characterize precisely the impact of a transfer on the welfare of the donor. This will ascertain whether our transfer result in Theorem 1 is a so-called 'disadvantageous reallocation', where the donor is *worse* off and the receiver *worse* off as well, or whether it is the 'strict transfer paradox', instead, where the donor is *better* off, and the receiver *worse* off.[6] The following lemmas provide such characterization: they are a restatement of the results in section 4 of Chichilnisky (1980) on transfers, welfare and coalitions.

The first lemma establishes conditions under which Theorem 1 gives the so-called 'disadvantageous reallocation' problem, in stable markets:

Lemma 2. In a 3-agent economy as above, the welfare of the donor group H and of the receiver group S move in the same direction following the transfer when $c>1$. Therefore, under the conditions of Theorem 1, both the welfare of the donor and of the receiver decrease following the transfer, in stable markets.

The proof of this lemma is on p. 517, section 4 of Chichilnisky (1980).

The following lemma establishes conditions under which Theorem 1 yields the *strict transfer paradox* in stable markets:

Lemma 3. In a 3-agent economy as above, the welfare of the donor group H and that of the receiver S move in opposite directions following the transfer if $c<1$. Therefore, under the conditions of Theorem 1, when $c<1$, the donor is better off and the receiver worse off following the transfer, in a stable market.

Proof. The proof of this lemma is immediate. First note that the proof of Theorem 1 in Chichilnisky (1980, p. 515), holds when $c<1$, see, e.g., eq. (19) on p. 515. Therefore, the welfare of S decreases after the transfer in a stable market when $c<1$. Finally, the results of section 4 in Chichilnisky (1980, 517), show that when $b>c$, the welfare of S and of H move in opposite directions. Since $b=1$ and here c is smaller than 1, this completes the proof of Lemma 3.

We can now establish immediately a generalization of Theorem 1 of Chichilnisky (1980):

Theorem 2. Consider a 3-agent world economy as above, satisfying the regularity conditions (C.1), (C.2') and (C.3). Let the high income group H transfer basic goods, industrial goods, or any combination of these to the lowest

[6] Gale's (1974) example is a disadvantageous reallocation rather than a strict transfer paradox: in addition, Gale does not study stability of the market.

income group S.[7] *Then the welfare of the receiver will decrease after the transfer in a unique and globally stable equilibrium, if and only if the third (non-participant) group L imports industrial goods, i.e., $\lambda<0$. Furthermore, under these conditions, the welfare of the donor increases following the transfer if and only if $c<1$; it decreases if and only if $c>1$.*

Proof. The proof of this theorem is straightforward.

Note that under the regularity conditions (C.1) (C.2′) and (C.3), the economy has a unique equilibrium. This is proven as follows. First, this economy can have at most two (non-zero) price equilibria because its excess demand function, whose zeroes determine the equilibria, is of the second order in $p=p_A/p_B$, being equal to

$$D_B=\frac{\rho}{a+1/p}+\frac{\lambda}{1+1/p}+\frac{\sigma}{1/c+1/p}, \tag{5}$$

see (10), p. 513 of Chichilnisky (1980).

Secondly, in view of the boundary conditions (C.1) and (C.3) this economy must have an odd number of equilibria. This is proved, e.g., in Dierker (1974, p. 140). Therefore, our economy has exactly one equilibrium. In particular, local stability implies here *global stability*.

The proof of Theorem 1 in Chichilnisky (1980) establishes that

$$\left(\frac{\partial z}{\partial T_A}\right)_{\overline{D_B}}=\left(\frac{\partial D_B}{\partial p}\frac{\partial z}{\partial T_A}-\frac{\partial z}{\partial p}\frac{\partial D_B}{\partial T_A}\right)\Big/\frac{\partial D_B}{\partial p}, \tag{6}$$

where z is consumption of B in the South, and T_A is the transfer: see eq. (19) of Chichilnisky (1980).

It follows therefore that the sign of (6) is always equal to that of its numerator when the market is stable, since stability is equivalent to

$$\partial D_B/\partial p>0$$

(recall $p=p_A/p_B$).

Note that the numerator of (6) equals

$$\frac{-p\lambda}{(1+p/c)(1+p)}\left[\frac{1}{1+pa}-\frac{1}{1+p}\right] \tag{7}$$

[7]Transfers are small.

by (19) of Chichilnisky (1980),[8] and that $1/(1+pa)$ is always smaller than $1/(1+p)$ because $a>1$. It follows therefore that the sign of $(\partial z/\partial T_A)$ across equilibria $(D_B=\bar{D}_B)$ *is always equal* to the sign of λ in stable markets. Thus the welfare of the South decreases in stable markets if and only if λ is negative. The rest of the statement of Theorem 2 follows from Lemmas 1 and 3.

Finally, to complete the discussion, I shall refer to another condition that appeared in the statement of Theorem 1 in Chichilnisky (1980) and which was discussed in some of the comments: this is that the endowments of the South be small and consist mostly of basic goods B. This condition turns out not to be required in the proof of Theorem 1 of Chichilnisky (1980). As a matter of fact, nowhere in the proof of Theorem 1 was this condition used;

[8]Eq. (19) of Chichilnisky (1980) was only sketched there, and we give here a detailed computation: From eq. (16) and (17), and the equality $z=S_B+(p/1+p/c)(\sigma+T_A)$ we obtain:

$$\frac{\partial D_B}{\partial p}\cdot\frac{\partial z}{\partial T_A}-\frac{\partial z}{\partial p}\frac{\partial D_B}{\partial T_A}=\left(\frac{\rho-T_A}{(1+pa)^2}+\frac{\lambda}{(1+p)^2}+\frac{\sigma+T_A}{(1+p/c)^2}\right)\left(\frac{p}{1+p/c}\right)$$

$$-\left(\frac{\sigma+T_A}{(1+p/c)}-\frac{p(\sigma+T_A)}{(1+p/c)^2}\frac{1}{c}\right)p\left(\frac{1}{1+p/c}-\frac{1}{1+pa}\right)$$

$$=\frac{p}{1+p/c}\left[\left(\frac{\sigma+T_A}{(1+p/c)^2}\right)\left(1+\frac{p}{c}\right)+\left(\frac{\rho-T_A}{(1+pa)^2}\right)+\left(\frac{\lambda}{(1+p)^2}\right)-\left(\frac{\sigma-T_A}{1+p/c}\right)\right]$$

$$+\frac{p}{1+pa}\left[\frac{\sigma+T_A}{(1+p/c)^2}\right]$$

$$=\frac{(\sigma+T_A)p}{(1+pa)(1+p/c)^2}+\frac{p}{1+p/c}\left(\frac{\rho-T_A}{(1+pa)^2}+\frac{\lambda}{(1+p)^2}\right)$$

$$=\frac{p}{(1+p/c)(1+pa)}\left(\frac{\sigma+T_A}{(1+p/c)}+\frac{\rho-T_A}{(1+pa)}+\frac{\lambda(1+pa)}{(1+p)^2}\right). \tag{8}$$

Since

$$D_B=p\left[\left(\frac{\rho-T_A}{1+ap}\right)+\left(\frac{\lambda}{1+p}\right)+\left(\frac{\sigma+T_A}{1+p/c}\right)\right]=0$$

in equilibrium, we obtain

$$\frac{-\lambda}{1+p}=\frac{\sigma+T_A}{1+p/c}+\frac{\rho-T_A}{1+pa},\quad \text{so that (8) equals}$$

$$\frac{p}{(1+p/c)(1+pa)}\left(-\frac{\lambda}{1+p}+\frac{\lambda(1+pa)}{(1+p)^2}\right),\quad \text{i.e.,}$$

$$\frac{\partial D_B}{\partial p}\frac{\partial z}{\partial T_A}-\frac{\partial z}{\partial p}\frac{\partial D_B}{\partial T_A}=\frac{p\lambda}{(1+p/c)(1+p)}\left(\frac{1}{(1+p)}-\frac{1}{(1+pa)}\right)$$

which is eq. (19).

this was pointed out both by Gunning (1983) and by Bhagwati and Srinivasan (1983), and we acknowledge their contribution. Their comments imply that Theorem 1 was actually stronger, or more general, than originally stated, since one of its assumptions could be dropped without any loss. It should also be pointed out that this condition merely implies that the point in R^2 denoting the initial endowments of the South, (S_B, S_A), lies *below* the 45 degree line, and is relatively close to the origin. This is clearly consistent with the other two conditions in Theorem 1 of Chichilnisky (1980), i.e., with the condition that the middle income group imports A, $\lambda < 0$, and with condition (C.1). It is obviously also consistent with the condition implied by $\lambda < 0$, namely that the South imports B, $\sigma > 0$, see, e.g., fig. 1 below.[9]

Finally, Saghafi and Nugent (1982) have expressed concerns with eq. (14) of Chichilnisky (1980);[10] their paper is focused singly on the sign of this eq. (14). The relationship between the transfer and the terms of trade was explained clearly in the text of Chichilnisky (1980, p. 514), but Saghafi and Nugent failed to notice a typo in eq. (14) when writing their paper; therefore, their comments are not applicable.[11]

4. Conclusions

My earlier (1980) results on the transfer problem in stable markets has served to show that this is potentially an issue of policy significance. The results showed that in a 3 agent economy, the transfer problem will occur in

[9]Bhagwati and Srinivasan have expressed concerns about the consistency of the assumptions in Theorem 1 of Chichilnisky (1980). As fig. 1 shows, these conditions are indeed consistent.

[10]Eq. (14) of Chichilnisky (1980) was only sketched there, and we give here a detailed computation:

$$D_B = p\left(\frac{\rho}{1+ap} + \frac{\lambda}{1+p} + \frac{\sigma}{1+p/c}\right) = 0 \quad \text{in equilibrium, i.e.,}$$

$$D_B = p\left(\frac{H_A - aH_B}{1+ap} + \frac{L_A - L_B}{1+p} + \frac{S_A - S_{B/c}}{1+p/c}\right) = 0.$$

Denote this $F(H_A, S_A, p) = 0$. By the implicit function theorem we obtain:

$$\frac{\partial p}{\partial H_A} = -\frac{\partial F/\partial H_A}{\partial F/\partial p} = -\frac{p/(1+ap)}{\partial D_B/\partial p} \quad \text{and} \quad \frac{\partial p}{\partial S_A} = -\frac{\partial F/\partial S_A}{\partial D_B/\partial p} = -\frac{p/(1+p/c)}{\partial D_B/\partial p}.$$

Therefore, (14) is:

$$\partial p/\partial H_A - \partial p/\partial S_A = (p/(1+p/c) - p/(1+ap))/\partial D_B/\partial p.$$

[11]Eq. (8): γ should read σ. Eq. (9): $S_A - S_{Bc}$ should read $S_A - S_{B/c}$. Eq. (10): $(\rho/(a+1/p))(\lambda/(1+1/p))(\sigma/(1/c+1/p))$ should read $\rho/(a+1/p) + \lambda/(1+1/p) + \sigma(1/c+1/p)$. Eq. (14): there should be a minus sign in front of the right-hand side. Eq. (15): $\rho + T_A$ should read $\rho - T_A$. Eq. (16): $-\rho T_A/(1+pa)^2 + \lambda/(1+p)^2 + (\sigma + T_A)/(1+p/c)$ should read $(\rho - T_A)/(1+pa)^2 + \lambda/(1+p)^2 + (\sigma + T_A)/(1+p/c)^2$.

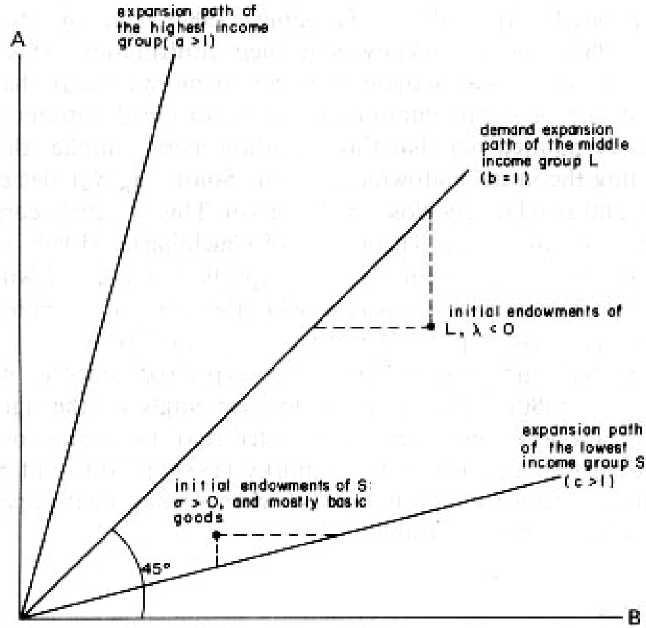

Fig. 1. Represents simultaneously three assumptions: The middle income group imports A, i.e., $\lambda < 0$; the low income group imports B, i.e., $\sigma > 0$, and the South's endowments consist mostly of basic goods, and are small, i.e., they lie below the 45 degree line, and near the origin.

stable markets whenever the non-participant group is an importer of the good which the giver consumes most intensively. When the non-participant group are the newly industrializing countries, this assumption seems plausible, as these countries generally import industrial goods.

With added regularity conditions, we proved here that the same assumption is indeed necessary and sufficient for the transfer problem to occur at a *unique* and *stable* equilibrium. We therefore have a complete, and rather simple characterization of cases when the transfer problem occurs, in our 3-agent economies.

Several extensions of these results seem possible. It would be useful to study economies with more than three agents, and with smooth preferences,[12] as well as general equilibrium models with production.

[12]An extension of my results to economies with smooth preferences could possibly be obtained along the lines of Aumann and Peleg's (1974) article. They extended Gale's example to economies with smooth preferences. It may be useful to point out that Gale's example has been extended to economies with smooth preferences in 1975, since Srinivasan and Bhagwati (1982) state in their footnote 5 that such extensions seem very difficult to obtain. Aumann and Peleg do not study stability of the market, nor the strict transfer paradox.

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