Trade Reform with a Government Budget Constraint

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Abstract: The standard theory of trade reform uses a passive government budget constraint, in which changes in tariff revenue are offset by changes in lump sum transfers. This paper offers a general framework for the analysis of trade reform when the government budget constraint is active, meaning that tariff revenue cuts must be offset by distortionary fiscal policy changes --- public good supply cuts or alternative tax increases. Useful and simple new expressions characterizing welfare improving trade reform compare the Marginal Cost of Funds (MCF) of trade taxes with the MCF of consumption taxes. The MCF expressions provide an intuitive index number which is operational with Computable General Equilibrium models. The theoretical analysis and an application to Korean data in 1963 both cast doubt on the desirability of tariff cuts in convex competitive economies with active government budget constraints.

1. Introduction

Practical trade policy advice must usually recognize that trade taxes help raise government revenue required for other fiscal purposes. In contrast, the theory of trade policy analysis typically uses the simplifying assumption that tariff revenue is 'passively' redistributed, so a fall in revenue is offset by a fall in the lump sum transfer from the government to the private sector. The passive transfer assumption was perhaps an appropriate simplification in OECD economies in the era of rapid growth, but it is clearly inappropriate to the present concern over public debt along with resistance to tax increases or public good cuts.[1] The passive transfer assumption was never appropriate for developing nations which are typically dependent on tariff revenue.

The standard case against taxing trade is based on the passive budget constraint. This paper shows that cuts in trade taxes may well be inefficient in the standard convex competitive model with an active government budget constraint, along which changes in distortionary fiscal instruments must be made. Thus trade reform is probably better argued from the benefits of the international division of labor, the stimulation of competition, and the reduction of rent seeking behavior.

The analysis offers simple and useful sufficient conditions under which trade reform matched by revenue neutral spending cuts or tax increases will raise welfare. The elements of the analysis differ fundamentally from those of a passive budget constraint, in ways not previously appreciated in the trade literature or in the related public finance literature. The key concept is the (compensated) Marginal Cost of Funds or MCF of a given class of taxes. The MCF is compared to the marginal benefit of the funds in terms of goods and services so financed, or in terms of the marginal benefit of reductions in other taxes, equal to *their* MCF.

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[1] For example, the current US government budget process requires that revenue cuts be matched by spending cuts or other revenue increases. This requirement temporarily threatened the NAFTA obligations.

The analysis also points to operationality, as the MCF is a very useful summary index number of the properties of tariff and tax systems. As a demonstration, the paper concludes with calculations of the MCF for tariffs and for consumption taxes from a CGE model of Korea in 1963. With more experience on reasonable values of MCF for tariffs and for domestic taxation from simulations of other Computable General Equilibrium (CGE) models, it may be possible to make trade reform recommendations with confidence, and perhaps even extrapolate to countries where no CGE model is available.

The theoretical analysis and its application in this paper both cast doubt on the general desirability of tariff cuts matched with consumption tax rises within the class of convex competitive models. The theoretical conditions which guarantee welfare improvement are implausibly stringent, and the simulation results show that even with higher initial tariffs than indirect taxes, welfare falls with a cut in tariffs combined with a revenue neutral rise in consumption taxes.

The analysis ties the theory of protection together with the theory of public finance. The two literatures have developed somewhat separate terminologies, and integration based on a dual approach proves useful. The standard theory of protection assumes that a benevolent welfare maximizing government seeks a welfare improving tariff reform subject to unspecified constraints which make impossible the move all the way to free trade (Bertrand and Vanek, 1972, Bruno, 1972, Lloyd, 1974, Hatta, 1977). The government budget constraint is passive, as the fall in distortionary tax revenue is offset in the budget by a fall in the lump sum transfer from the government to the private sector. The theory of public finance in contrast uses the active budget constraint in which the provision of goods and services by the government sector (hereafter termed 'public goods' for convenience)[2] is paid for by distortionary taxation. In the marginal analysis of this problem, the MCF plays a key role. The MCF is usually developed in an uncompensated (real income variable) form, often in the context of a rather

[2] There is no difference between public goods and government provided goods in a representative consumer economy.

opaque primal analysis. In contrast, the compensated version developed here with dual methods is necessary for a clean analysis of the MCF of trade taxes vs. the MCF of consumption or other taxes.[3]

The only systematic treatment of the gradual reform of tariffs in the presence of an active government budget constraint is in two papers by Abe (1992, 1995).[4] This paper generalizes and simplifies Abe's results, considers some additional structures and cleans up his (1992) treatment of marginal changes in public goods supply. Related work by Diewert, Turunen-Red and Woodland (1989, 1991) analyzes sufficient conditions for tariff reform to improve productivity and Pareto efficiency. Commodity tax changes replace transfers as a means of compensating households , but since all goods can be taxed, lump sum transfers in effect are back in their model. This paper uses a limited set of commodity tax changes, working in the second-best tradition of the gradual reform and public finance literatures. Significantly, the two most famous results in second-best public finance are extended here to the gradual reform context. The Ramsey (1927) inverse elasticity optimal tax principle is to tax every taxable good in inverse proportion to its elasticity of demand. This suggests trade should be taxed. The Diamond and Mirrlees (1971) optimal commodity tax principle is to preserve productive efficiency. This implies that a small (price-taking) country should not discriminate between foreign and domestic supply of identical products.[5] The gradual reform extension of the Ramsey principle is the 'wider base' intuition that it is efficient to at least begin taxing differentiated trade a bit. The gradual reform extension of the Diamond and Mirrlees principle (that it pays to cut trade taxes and raise consumption taxes) applies only under quite stringent conditions which restrict substitution.

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[3] Anderson and Martin (1995) argue that the compensated version of the MCF is a much cleaner concept and avoids the potential errors which have often cropped up with use of the uncompensated MCF.

[4] Panagariya (1992) treats a revenue neutral switch among tariffs in a 3 final good, one imported input model. Falvey (1994) considers conditions under which tariff cuts may both raise welfare and raise revenue.

[5] A large country achieves productive efficiency with a tariff structure which equates the domestic marginal rates of transformation with the marginal rates of transformation in trade.

The political reasons for gradualism as opposed to a move all the way to constrained optimal taxes are left outside the analysis, in common with all the gradual reform literature. Endogenous choice of gradualism is easy to derive by embedding the present analysis in a *political support function* analysis (Hillman, 1989). In planning its trade reform and fiscal policy the government trades off general welfare (representing the interests of informed but unorganized interests) against the interests of informed and organized factions (the source of funds usable for winning the support of uninformed and unorganized interests which lose from increases in taxes or cuts in government spending)). Whether the welfare increase from a reform package analyzed in this paper is large enough to offset the loss of the special interests depends on the weights of the political support function. A more complete analysis requires a development along the lines of Grossman and Helpman (1994) which endogenizes that portion of the political support function which relates policies offered to contributions given.

The paper focuses on efficiency while ignoring distributive issues by using the representative agent model. (Grossman and Helpman submerge distributive issues by using the special case in which utilities are directly transferable.) For analysis of trade reform in a model where the benevolent government engages in redistribution, including via the provision of public goods, see Diewert, Turunen-Red and Woodland (1989,1991).

Section 2 develops the intuition of the analysis. Section 3 sets out the basic structure of the model and relates it to the classic analysis of trade reform with redistribution. Section 4 considers tariff reform matched by public goods supply cuts. Trade reform is welfare improving if public goods are over-supplied in an intuitive and useful sense. Section 5 shows that with substitutability, marginal replacement of trade taxes with consumption taxes on traded goods is welfare improving --- the marginal reform version of the Diamond and Mirrlees theorem. Section 6 considers the relative efficiency of the taxation of nontraded goods, showing that some taxation of both traded and nontraded goods is efficient. From given interior positions of taxes and tariffs, it is not generally possible to rank the MCFs. Section 7 illustrates the estimation of MCF for trade taxes and for nontraded good consumption taxes.

2. Intuitive Sketch of the Analysis

The general method of analysis of trade or tax reform is founded on the concept of the Marginal Cost of Funds (MCF). The MCF of a tax (say tariffs) is compared to the marginal benefit of the funds raised by the tax. The marginal benefit is equal either to the marginal value of the goods and services financed by the tax (tariff) or to the MCF of the taxes which are reduced as a response to the rise in tariff revenue. MCF is often not cleanly developed and may be unfamiliar to trade theorists, so this section discusses its intuition in detail.

In contrast, all readers will be familiar with the concept of marginal dead weight loss and may have the impression that this is the key concept for understanding the desirability of trade reform. This indeed is the focus of all textbook analysis of trade reform and all the classic gradual reform papers are based on it. If trade reform takes place along an active government budget constraint, however, the concept of marginal dead weight loss is generally irrelevant. It characterizes only the special case in which the only role of government is to levy trade taxes and redistribute them in a lump sum. The graphical analysis here will drive this point home.

MCF for any tax is defined here as the ratio of the marginal compensation required to maintain real income as the tax rises to the compensated marginal tax revenue raised by the tax increase. In other words, it gives, at the margin, the compensation required per dollar of revenue raised. The public finance literature also (more often) presents an uncompensated, or money metric utility version of MCF, and this version is the usual one reported in computations. See Anderson and Martin for an argument as to why this is not an appropriate definition.

The general method of this paper is to compare MCF for a given tax with the marginal benefit of the revenue raised --- either of the government spending or of the reduction in other taxes (valued at their MCF) which it permits. If the marginal benefit exceeds the MCF of the tax which must be raised, the prospective change is welfare improving. The marginal benefit is also defined at constant real income. The MCF has a clear and intuitive structure and readily extends to aggregation in the many tax case and to incorporate other fixed distortions.

2.1. MCF Illustrated

To illustrate the concepts in the scalar case, consider an imported good with quantity denoted m selling at price p wedged above its international price p^* by a tariff. A small change in the tariff results in the following key elements:

mdp, the external compensating transfer at the margin,

and

$[m+(p-p^*)m_p]dp$, the revenue change at the margin.

The ratio of these defines the Marginal Cost of Funds:

$$MCF^p = \frac{mdp}{[m+(p-p^*)m_p]dp} = \frac{m}{MR},$$

the compensation cost per dollar of revenue raised at the margin via dp.

The earlier tradition of trade reform analysis (and public finance tax incidence analysis) relied on the concept of marginal dead weight loss, equal to $(p-p^*)m_p dp$. Marginal dead weight loss applies only in the case of a lump sum redistribution of the revenue (in which case the MCF of the lump sum tax is equal to one and the marginal gain of a switch from distortionary tax to lump sum tax is equal to the marginal dead weight loss). The analysis below shows that the marginal dead weight loss and the MCF have no tight relationship to each other, and an example is provided in which the marginal dead weight loss and the MCF are negatively correlated both as the tax rises and as the strength of the substitution effect (the responsiveness of demand to price) increases.

Figure 1 illustrates the concepts of MCF and dead weight loss. MR is the marginal revenue schedule based on the import demand schedule. The tax is set at level t. The areas of rectangles a and b, and of triangle d are the basic building blocks for the standard welfare analysis. $a+b$ is the revenue raised, while $a+b+d$ is the consumer surplus lost. The net welfare effect of a tariff t with revenue redistributed in a lump sum is the dead weight loss of triangle d. The 'average' version of the MCF idea, the compensation cost per dollar raised, is equal to $(a+b+d)/(a+b)$. In this form, dead weight loss d appears to be the central concept. In contrast,

$$MCF = tB/tA = (a+b)/a$$
$$\neq (a+b+d)/(a+b).$$

The marginal version of MCF is the central concept of tax analysis, as the formal analysis below shows. Only in the special case of a lump sum redistribution does a further cancellation of terms permit reducing the problem so that marginal dead weight loss, $(p - p^*)m_p dp$ (the area of the shaded thin vertical trapezoidal section of the triangle d) is relevant.

2.2. MCF vs. Marginal Dead Weight Loss

It is clear both from the diagram and the algebra that while MCF has some relationship to marginal dead weight loss, the relationship is highly nonlinear and the two concepts are fundamentally different. They share a property in that MCF differs from 1 and marginal dead weight loss differs from zero due to the existence of the substitution effect.[6] However, varying the strength of the substitution effect or the size of the tax can affect the two concepts in opposite directions. To see this, note that MCF in the scalar case can be reduced to:

$$MCF = \frac{1}{1 + (p - p^*)m_p / m} = \frac{1}{1 - \frac{\tau}{1+\tau}\varepsilon}$$

where ε is the elasticity of demand and τ is the ad valorem tax rate. In contrast the negative of the marginal dead weight loss formula is:

$$-MDWL = \frac{\tau}{1+\tau}\varepsilon m.$$

For the constant elasticity case, $m = \mu(1+\tau)^{-\varepsilon}$, MCF is everywhere increasing in τ, while the negative of MDWL is first increasing and then decreasing in τ. Moreover, MCF is everywhere increasing in ε while the negative of MDWL is first increasing and then decreasing in ε. Alternatively, for the linear case the negative of MDWL varies linearly with the specific tax, while MCF is first increasing and then decreasing in the tax.

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[6] For an inelastic demand curve, MR and the demand curve coincide, MCF is equal to one and the dead weight loss is equal to zero.

The difference in the two concepts means that the general analysis of distortionary tax tradeoffs based on MCF is fundamentally different from the classic special case analysis of distortionary vs. nondistortionary tradeoffs based on the marginal dead weight loss concept. MCF is the basic concept, while the marginal dead weight loss only applies to a special case.

3. Formal Elements of the Analysis

The key relationships of the model are the private sector budget constraint and the public sector budget constraint. For any exogenous fiscal policy change there must be an endogenous fiscal policy change to balance the government budget. The two fiscal changes then imply a change in welfare along the private sector budget constraint. To demonstrate the method of this paper and its relation to the earlier literature, this section reviews the standard analysis of a tariff cut offset by a rise in lump sum taxes.

The model throughout is of a competitive economy with no distortions other than fiscal distortions. All tradable goods face fixed international prices. Nontradable goods play an important role. Where necessary for clarity and sharp results, further restrictions on tastes and technology will be employed, especially as regards nontraded goods. Substitutability assumptions will be introduced as needed. Finally, for simplicity, the model is static. This assumption is appropriate for a credit constrained government and economy, and is also rationalized by political agreements which constrain the government budget deficit. For a treatment of the complexities of intertemporal tax structure issues, see Anderson and Young (1992).

The basic building blocks of the model are the representative consumer's expenditure function and the gross domestic product function. The consumer's expenditure function $e(p,\pi,u)$ gives the minimum value of expenditure on private goods at price vector p and public goods at marginal valuation π required to support utility level u. The gross domestic product function $g(p,\pi^*,v)$ gives the maximum value of production of private goods at price p and public goods at price π^* using the vector of primary inputs v in a convex technology. The value g also measures the total payments to factors. (If necessary, a diminishing returns technology can be augmented by dummy factors to receive the residual returns.) There are also some untaxed tradable goods with unit price which are suppressed as active arguments, so that p is a relative price vector.[7] Untaxed nontraded introduce no essential element and so are suppressed for simplicity.

The level of public good production G is set by the government, so it is convenient to work with quantity restricted private behavioral functions. Thus, define the private goods expenditure and private goods GDP functions as:

(3.1) $\bar{e}(p,G,u) = \max_{\pi} \ \{e(p,\pi,u) - \pi G\}$

(3.2) $\bar{g}(p,G,v) = \min_{\pi^*} \ \{g(p,\pi^*,v) - \pi^* G\}$.

See Anderson and Neary (1992) for a similar development and further details. The net expenditure on private goods at domestic prices is defined as

(3.3) $E(p,G,u,v) = \bar{e}(p,G,u) - \bar{g}(p,G,v)$.

Conventionally, subscripted variable labels denote partial differentiation. Then from the properties of (3.1)-(3.3), $-E_G = -\bar{e}_G + \bar{g}_G = \pi - \pi^*$, the gap between the virtual price of the public goods π and the marginal resource cost of public goods π*. E_p is the vector of excess demands.

The next step is to build the private and government budget constraints. The private budget constraint is:

(3.4) $E(p,G,u,v) + G\bar{g}_G(p,G,v) - \rho = 0$.

The second (negative) term is needed because private consumption is covered by factor payments received from public as well as private production. The third term ρ, the lump sum transfer from the government to the private agent, is to connect with the earlier literature. The government budget constraint is:

(3.5) $(p - p^*)' E_p(p,G,u,v) + G\bar{g}_G(p,G,v) - \rho = 0$.

The first term is the government (distortionary tax) revenue, the second term is minus the government expenditure on the public good and the third term

[7]This convention is necessary in order to study a model in which distortionary taxation is necessary.

is the transfer to the private sector. (If lump sum taxation is allowed, ρ can be negative.)

A tariff reform is equivalent to a change in the domestic price vector *p.* It is convenient to incorporate various classes of tariff reforms in the convention

$$dp^i = W^i p dt,$$

where dt is a scalar and W^i is a diagonal matrix and the superscript i denotes a further restriction on *W, i* being a member of an index set. For example, the *uniform radial cut* rule implies that the elements of the principal diagonal of *W* are equal to the initial tariff rates on the domestic base, so that $dp = (p - p^*)dt$.

The classic treatment of tariff reform (Hatta, 1977 and others) considers the effect on the differential of system (3.4)-(3.5) of an *exogenous* change in *dp* solved for the *endogenous* change in the redistribution $d\rho$ and the welfare change *du.* Illustrating the method, analyze a uniform radial change *dt.* Differentiate the government budget constraint and solve for $d\rho/dt$:

$$\frac{d\rho}{dt} = E_p'(p-p^*) + (p-p^*)'E_{pp}(p-p^*) + G\bar{g}_{Gp}(p-p^*) + (p-p^*)'E_{pu}\frac{du}{dt}.$$

Substitute into the differential of the private budget constraint, isolating terms in *du* on the left hand side:

$$\begin{aligned}(3.6)\qquad \left(1-(p-p^*)'E_{pu}/E_u\right)E_u\frac{du}{dt} &= -\left(E_p'(p-p^*) + G\bar{g}_{Gp}(p-p^*)\right) + \frac{d\rho}{dt}\Big|_u \\ &= \left(E_p'(p-p^*) + G\bar{g}_{Gp}(p-p^*)\right)\left[-1 + \frac{1}{MCF^t}\right].\end{aligned}$$

On the left hand side, the change in money metric utility is multiplied by a term which is positive in the normal goods case (Hatta, 1977). On the right hand side, the first bracketed term is a scale effect, the lump sum compensation required to offset a 1% rise in taxes on the representative agent. The second, square bracketed term on the right hand side of (3.6) contains the essential welfare analysis. *MCF* is defined by:

$$(3.7)\qquad MCF^t = \frac{E_p'(p-p^*) + G\bar{g}_{Gp}(p-p^*)}{E_p'(p-p^*) + (p-p^*)'E_{pp}(p-p^*) + G\bar{g}_{Gp}(p-p^*)}.$$

Note that (3.7) properly generalizes the ratio *(a+b)/a* in Figure 1. The -1 term under the square bracket represents the direct effect of the rise in tax on welfare; a one dollar increase in tax payments requires a one dollar increase in compensation. The second, ratio term represents the offsetting effect of endogenous fiscal policy coming through the government budget constraint. For each dollar raised and redistributed, the benefit is one dollar, the numerator, but each dollar raised through distortionary tax comes at a marginal cost of MCF, the denominator. According to this analysis, the problem with raising tariffs in order to redistribute the resulting funds is that the MCF for tariffs is greater than one, which is the marginal benefit of the cut in lump sum taxes.

The structure of the right hand side expression allows a further simplification:

$$\left(E_p'(p-p^*)+G\bar{g}_{Gp}(p-p^*)\right)\left[-1+\frac{1}{MCF^t}\right]=(p-p^*)'E_{pp}(p-p^*),$$

where the right hand side is the familiar marginal dead weight loss term. Here, it appears that the problem with distortionary taxation vs. nondistortionary taxation is the existence of the substitution effect, as agents avoid distortionary tax. The existence of the substitution effect is the essential reason that MCF lies above 1 as well. However, the argument above in the linear case shows that there is no necessary relation between MCF and marginal dead weight loss; the magnitude of the substitution effect directly affects marginal dead weight loss while it has no unambiguous effect on MCF.

The usual treatment of this case first solves (3.5) for the government expenditure, then substitutes into (3.4) to obtain the social budget constraint

(3.8) $E(p,G,u,v)-(p-p^*)'E_p(p,G,u,v)=0,$

and then analyzes the link between dp and du at constant G. Redistributive fiscal policy thus makes the government budget constraint passive.

4. TARIFF REFORM WITH SPENDING CUTS

A simple story with practical importance is the analysis of trade reform where government budgetary balance implies that spending cuts must offset tariff revenue cuts. Formally, G must change endogenously as a result of the change in p. What rules can deliver welfare improvements along the path to the optimal tariffs?

The analysis proceeds in three steps. First, totally differentiate the government budget constraint (3.5) with respect to *p*,*G* and *u*, and solve for *dG/dt* under the restriction W^i.[8] This yields

$$\frac{dG}{dt} = \frac{1}{\gamma}\left([E_p^{'} + (p-p^*)' E_{pp} + G\bar{g}_{Gp}]W^i p + (p-p^*)' E_{pu}\frac{du}{dt}\right), \tag{4.1}$$

where γ is the marginal fiscal cost of the public good:

$$\gamma = -\left(\bar{g}_G + G\bar{g}_{GG} + (p-p^*)' E_{pG}\right) = \left(\pi^* + G\pi_G^* - (p-p^*)' E_{pG}\right). \tag{4.2}$$

The first two terms give the marginal cost of G to a monopsonistic buyer. The third term $(p - p^*)'E_{pG}$ is the tax revenue change induced by the change in G.[9]

Second, totally differentiate the private budget constraint (3.4) with respect to exogenous dp, and endogenous dG and du using previously established properties of E and $\bar{g}$:

$$\begin{aligned} E_u du &= -(E_p^{'} + G\bar{g}_{Gp})dp + (\pi - G\pi_G^*)dG \\ &= -(E_p^{'} + G\bar{g}_{Gp})dp + \tilde{\pi} dG. \end{aligned} \tag{4.3}$$

The second term on the right hand side, $\tilde{\pi}$, the marginal net benefit of the public good, is equal to the virtual price minus the net factoral income effect of the change in public goods production[10]. Note that $\tilde{\pi} \le \pi$ when public and private production are substitutes[11].

Third, substitute the expression for dG/dt from the differential of the government budget constraint into (4.3), then isolate terms in du on the left hand side of the equation:

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[8]If G is a vector, the analysis proceeds under some auxiliary rule $dG = H^j G d\alpha$, where H^j is a spending change rule and $d\alpha$ is a marginal change in the expenditure.

[9] A common theoretical convenience is to assume this term is equal to zero, a practice which is likely to be seriously wrong empirically and may be misleading in understating the marginal fiscal cost of the public good. $E_{pG} = 0$ requires 'additive separability' in both preferences and technology.

[10] One unit of public goods production reduces private production by $-\pi^*$, and raises the factoral income received from public goods production by $\pi^* + G\pi_G^*$.

[11] Public and private production are substitutes if the marginal cost of public goods π^* is raised by an increase in any element of p: $-\bar{g}_{Gp} = g_{\pi^*\pi^*}^{-1} g_{\pi^* p}$ is a positive vector (matrix in the case of multiple public goods).

(4.4) $$\mu^{-1}E_u \frac{du}{dt} = -(E_p' + G\bar{g}_{Gp})W^i p + \frac{\tilde{\pi}}{\gamma}\left(E_p' + (p-p^*)' E_{pp} + G\bar{g}_{Gp}\right)W^i p$$

$$= \left(-1 + \frac{\tilde{\pi}}{\gamma MCF^p}\right)E_p' W^i p,$$

where

(4.5) $$\mu^{-1} = \left(1 - \frac{1}{\gamma}(p-p^*)' E_{pu} / E_u\right)$$

and

(4.6) $$MCF^p = \frac{(E_p' + G\bar{g}_{Gp})W^i p}{\left(E_p' + (p-p^*)' E_{pp} + G\bar{g}_{Gp}\right)W^i p}.$$

Here, (4.6) generalizes (3.7) to the case where tax changes are not constrained to uniform radial changes.

On the left hand side of equation (4.4), the rate of change of money metric utility $E_u du/dt$ is multiplied by a coefficient, given by (4.5), usually assumed to be positive, the *normal economy assumption*. The inverse of this coefficient, μ, is often called the shadow price of foreign exchange in the international trade literature, while for fiscal policy Anderson and Martin (1995) suggest calling it the fiscal multiplier. Comparing (4.5) with the left hand side of (3.6), the coefficient will differ in form for each fiscal experiment while remaining positive with the normal economy assumption.

On the right hand side of (4.4) are the compensated terms which sign the rate of change of utility. The term outside the brackets is a positive scalar, by construction. The term in brackets signs the welfare change and is positive if the ratio of the marginal benefit $\tilde{\pi}$ to marginal social cost γMCF^p is greater than one. The term γMCF^p is the marginal social cost of a unit of the public good financed through distorting p.

The intuition of (4.4) is simple. Assuming a normal economy, (4.4) implies that welfare rises with tariffs if the marginal benefit of public goods $\tilde{\pi}$ exceeds the marginal social cost of obtaining the public good. Thus:

> Proposition 1: The Public Goods Supply Proposition. *Tariff reductions financed by cuts in government service are welfare*

decreasing (increasing) in a normal economy with underprovision (overprovision) of public goods relative to their cost, or as $\left(-1+\frac{\tilde{\pi}}{\gamma MCF^{p}}\right)$ *> (<) 0.*

More intuition about Proposition 1 follows by relating it to the optimal provision of public goods. With lump sum taxation available and distortionary taxes equal to zero, the differential of the government budget constraint implies: $dG/d\rho = -1/(\pi^* + G\pi_G^*)$.

Public goods provision will fall with a rise in lump sum transfers ρ. The differential of the private budget constraint implies:

$$\begin{aligned} E_u du/d\rho &= 1+(\pi - G\pi_G^*)dG/d\rho = 1-(\pi - G\pi_G^*)/(\pi^* + G\pi_G^*) \\ &= 1-\tilde{\pi}/\gamma \\ &= -(\pi-\pi^*)/(\pi^* + G\pi_G^*). \end{aligned}$$

Utility is increasing in lump sum tax reductions with no distortions when the ratio of the net benefit $\tilde{\pi} = \pi - G\pi_G^*$ to the marginal fiscal cost $\gamma = \pi^* + G\pi_G^*$ is less than one. This condition implies $\pi < \pi^*$ due to the canceling of terms, as is intuitive. But the fiscal policy logic of the marginal net benefit to marginal fiscal cost ratio is general. In the lump sum tax experiment, the MCF for lump sum taxation is implicitly present multiplying γ, but is identically equal to one. Recognizing this, Proposition 1 properly generalizes the logic of the first best case by using the appropriate MCF times the appropriate marginal fiscal cost formula in cost portion of the social benefit-cost ratio.

Proposition 1 relates to Proposition 2 of Abe (1992), but is a good deal more intuitive. In contrast to Abe, Proposition 1 does not require any added conditions on cross effects. Because Abe defines marginal cost and marginal benefit of public production in a highly eccentric way[12], his condition of underprovision of public goods is not the same, and he therefore needs auxiliary conditions to sign the welfare change. Moreover, his oversupply

[12] In my notation, Abe defines the 'marginal cost' as $p^{*\prime}\bar{g}_{pG}$ and the 'marginal benefit' as $p^{*\prime}\bar{e}_{pG}$. These expressions bear no particular relation to the marginal cost and virtual price which are the natural ones used here.

condition produces the anomaly that tariff increases may raise welfare even with public goods oversupplied under his definition.

Proposition 1 also relates to the extensive literature on project evaluation based on the concept of the shadow price of public goods (see for example Squire, 1989). The shadow price of G is the net marginal social benefit to the economy of a gift of the foreign exchange needed to buy one unit of G: $\sigma = [\tilde{\pi} + MCF^p (p - p^*)' E_{pG}]$. Welfare falls with a tariff reduction if, manipulating (4.4):

$$\sigma - MCF^p\left(\pi^* + G\pi_G^*\right) > 0.$$

That is, tariff cuts hurt welfare if public goods are undersupplied, where the undersupply condition, alternatively to Proposition 1, is that the shadow price of public production exceeds the product of the direct marginal outlay needed times the marginal cost of funds raised through distortionary trade taxation.

The bracketed 'underprovision of public goods' term in Proposition 1 is neat and intuitive, but in practice assessing its sign is complicated. Possibly the marginal fiscal cost γ and more probably MCF^p will be high in developing nations where the marginal benefit of public goods is also high. Empirical work must provide the assessment, and indeed there exist a number of estimates of MCF for various fiscal policies in a number of countries. While data is lacking for many developing nations, there is now available a set of Computable General Equilibrium (CGE) models which can be tweaked to provide some simulated values of γ and MCF. The most problematic variable is the marginal benefit of public goods. In some plausible models, such as the *dependent economy* model in which external prices entirely determine internal (nontraded good and factor) prices, the factoral income effect of public goods is equal to zero so the marginal benefit reduces to the unobservable virtual price of public goods π. Even here, for some important kinds of public goods such as education there are at least useful lower bounds available from observable data.

5. TARIFF REFORM WITH CONSUMPTION TAXES

A basic principle of public finance is that *optimal* revenue taxation should preserve production efficiency (Diamond-Mirrlees, 1971), which among other things means it should not discriminate between foreign and domestic sources of production for the same good. In this sense, trade should not be taxed (Anderson, 1994). In departing from a *suboptimal* tax structure, under what conditions is it possible to state a gradual reform result that it pays to reduce tariffs and increase consumption taxes?

This section shows that the policy of uniform radial reductions in tariffs matched by uniform radial increases in consumption taxation, or uniform radial replacement, cannot be guaranteed to be welfare improving without further substitutability restrictions between private and public goods, along with non-subsidization conditions. One sufficient condition is the *nonsubsidized dependent economy case* where there are at least as many traded goods and factors as there are nontraded goods and factors in a constant returns technology. This case implies a powerful general equilibrium zero substitutability restriction in the excess demand system.

Let q denote consumer prices and p denote producer prices of tradable goods, both taxed or subsidized away from international prices p*. No traded inputs are taxed in this section, for simplicity. Nontradable private goods are untaxed, with market clearing prices h. It is convenient now to drop the notation for lump sum transfers ρ.

The net expenditure function is now derived as:

(5.1) $$E(p,q,G,u) = \max_{h}\{\bar{e}(q,h,G,u) - \bar{g}(p,h,G)\}$$

where the restricted expenditure and gross domestic product functions are obtained by extending (3.1) and (3.2) in the obvious way to incorporate private nontraded goods. Then E_q = x, the vector of final goods subject to tax or subsidy, and E_p = -y, minus the vector of supply subject to tax or subsidy.

The public sector budget constraint is

(5.2) $$(p - p^*)' E_p + (q - q^*)' E_q + \bar{g}_G G = 0.$$

The private sector budget constraint is:

(5.3) $E(p,q,G,u)+\bar{g}_G G=0$.

The exogenous fiscal policy is a change in trade taxes, offset for revenue neutrality by an endogenous change in consumption taxes, now with constant public good supply.

To specialize the fiscal policy to the uniform radial replacement case, it is assumed that:

(5.4) $dp=(p-p^*)d\tau$

$dq=dp+(q-p^*)d\theta$.

The meaning of (5.4) is simplest in the case of initial pure trade taxation, p=q. With $d\theta = 0$, $d\tau$ is a standard uniform radial change in trade taxes. The change in θ modifies this with an additional uniform radial change in the consumer tax vector.

As a preliminary step in what follows, denote the (utility and public good constant) private marginal cost of the tax changes as

$$R^q = E_q^{'}(q-p^*)+G\bar{g}_{Gq}(q-p^*)$$

for the consumption tax and

$$R = R^q + E_p^{'}(p-p^*)+G\bar{g}_{Gp}(p-p^*)$$

for the trade tax. These expressions are obtained from differentiating (5.3) and using (5.4). R^q and R give the lump sum transfer needed to maintain u at constant G under the consumption and trade tax changes respectively. They combine the direct marginal cost with the indirect marginal cost through changing factoral income from public goods production.

The fiscal policy change must meet the government budget constraint, implying by totally differentiating (5.2) and using (5.4) that:

(5.5) $d\theta / d\tau = -MCF^{\theta} / R^q\{R/MCF^{\tau}+[(p-p^*)'E_{pu}+(q-p^*)'E_{qu}]du\}$, where

$$MCF^{\theta}=\frac{R^q}{R^q+l^q} \qquad MCF^{\tau}=\frac{R}{R+l^q+l^p}$$

$$l^q=(q-p^*)'E_{qq}(q-p^*)+(p-p^*)'E_{pq}(q-p^*)$$

$$l^p=(q-p^*)'E_{qp}(p-p^*)+(p-p^*)'E_{pp}(p-p^*).$$

Here, l^q and l^p are familiar dead weight loss terms, while MCF^j stands for the Marginal Cost of Funds raised by a small change in the superscript variable j.

Substituting (5.5) into the differential of the private budget constraint (5.3) and isolating terms in du on the left hand side of the equation:

(5.6) $$\mu^{-1}E_u\frac{du}{d\tau} = \left(\frac{MCF^\theta}{MCF^\tau}-1\right)R,$$

where $\mu^{-1} = 1-MCF^\theta[(p-p^*)'E_{pu}+(q-p^*)'E_{qu}]/E_u$.

As always, μ is assumed to be positive. If trade is not subsidized, and if trade is a substitute for public goods production, R is positive. Then the sign of the welfare change from a uniform radial replacement of tariffs with consumption taxes ($d\tau<0$) is positive if the bracket term is positive, or $MCF^\theta < MCF^\tau$, the marginal cost of funds raised through consumption taxation is less than the marginal cost of funds raised through trade taxation. Condition (5.6) is entirely intuitive, and easy to apply based on simulations of MCF from CGE models.

What theoretical restrictions are able to guarantee the condition? Note that if $R^q \geq R > 0$, and l^q and l^p are both negative, MCF^θ is indeed smaller than MCF^τ. As for $R^q \geq R > 0$, this holds if:

- public and private goods are substitutes in production, meaning that $\bar{g}_{Gp} = -\pi^*_p > 0$ and $\bar{g}_{Gh} = -\pi^*_h > 0$;
- traded goods and home goods are substitutes, meaning that $h_q > 0$;
- trade is not subsidized, $E_p'(p-p^*)+E_q'(q-p^*)>0$;
- and consumption is not subsidized, $E_q'(q-p^*)>0$.

The restriction on l^q and l^p is far more problematic. The sum of l^q and l^p is necessarily negative. However, as for l^q and l^p separately, a cross effect arising through the nontraded good prevents signing them from theory, even under strong assumptions such as substitutability.

Sharp results come with the *dependent economy* production and trade structure. Technology is subject to constant returns to scale and there are at least as many homogeneous (perfect substitutes with domestic products) traded goods and factors as there are nontraded goods and factors. In these circumstances the nontraded goods producer prices are determined by the traded goods and factors producer prices, independently of the consumer prices. Thus $E_{pq} = E_{qp} = 0$ and $\bar{g}'_{Gq} = \bar{g}_{Gp} = 0$. Then $MCF^{\theta} < MCF^{\tau}$ if $R^{q} \geq R > 0$.

> <u>Proposition 2: the Marginal Diamond-Mirrlees Proposition.</u> *A uniform radial marginal replacement of trade taxes with consumption taxes is welfare improving in a normal dependent economy, provided trade and consumption are not initially subsidized.*

These are of course oversufficient conditions. Nevertheless, a part of the significance of Proposition 2 is negative: even quite restrictive conditions do not suffice to guarantee that a replacement of trade taxation with consumption taxation at the margin will be welfare improving.

Proposition 2 contrasts with Abe (1995), who considers welfare improving tariff and consumption tax changes in a dependent economy when both tariffs and taxes change *exogenously* according to a derived rule, and the supply of public goods changes endogenously along with the level of utility. Abe sets the rule such that the net welfare effect of the change in p and q is equal to zero, with the welfare effect of the change coming through the increase in public goods production which is enabled by the revenue increase. In contrast to Proposition 2, Abe's proposition requires a great deal of information to form the weights in the linear tax rule. In further contrast, Diewert, Turunen-Red and Woodland (1989), Theorem 7 and Corollary 7.1 provide conditions under which uniform tariff cuts combined with *unspecified* commodity tax changes will suffice for Pareto improvement. The present analysis uses a uniform radial increase to balance the government budget, but more importantly, it allows taxation of only the non-numeraire goods. In allowing taxation of all goods, Diewert, Turunen-Red and Woodland in effect allow lump sum taxation.[13]

As in section 4, a simple and useful condition signing the welfare effect of the revenue neutral tariff reform is presented. However, part of the significance of Proposition 2 is negative: fairly strong qualifications are needed to guarantee that uniform radial replacement is beneficial.

6. TAXATION OF NONTRADED VS. TRADED GOODS

The first great result of public finance is the Ramsey inverse elasticity principle. It implies that domestic and imported goods should generally be taxed differently, and if import taxes should be higher due to elasticities of demand being lower, liberal trade obligations conflict with fiscal efficiency. Moreover, optimal tax rates will differ across broad product categories, hence there are fiscal inefficiencies in the uniform tariff structure advocated by the World Bank and in trade negotiations. In contrast, the logic of the preceding section applies when domestic and imported goods are perfect substitutes: foreign and domestic suppliers of the same good should face the same tax; i.e. trade should be untaxed.

This section attempts to provide some theoretical insight into how costly is the decision to bind tariff levels in a WTO deal, or a regional trade agreement. First, a simple counter-example is developed in which trade taxation is efficient and the optimal home good tax rate is equal to zero. Second, a general formula for evaluating the replacement of trade taxes with home good taxes is offered. Intuitively, as in (5.6), it comes down to the MCF of home goods taxation vs. the MCF of trade taxation. These are complex expressions, so only very special cases can be signed from theory alone.

6.1. An efficient trade tax example

Efficient input taxes seem likely to exceed efficient final goods taxes on inverse elasticity reasoning, since inputs are likely to be more inelastically demanded than are final goods, and since many developing or small

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[13] A uniform tax on all goods, including the numeraire, is equivalent to a lump sum tax. I thank Peter Neary for this observation on Diewert, Turunen-Red and Woodland.

countries have no substitutes for their imported inputs. The example shows a case where the government collects and redistributes a given revenue from either a consumption tax or a traded input tax, and the trade tax dominates.

The left hand panel of the Figure shows a production function with constant returns to the variable imported input m up to a capacity constraint at P. National aggregate final activity is both consumed and exported, exports of ZY being used to pay for imported inputs m. The right hand panel shows that net final activity is split into two goods, y and x, according to a linear transformation function running from Y through C and C'. Under the input tax, after paying for imports at the international price given by the slope of PY, net national revenue of Y still remains, the sum of the new national income Y' and the tariff revenue R which is returned to the consumer in a lump sum. The consumption point is C. Under a consumption tax (on consumption of good y) which raises as much revenue, C' is the consumption point, which is clearly inferior to C.

Panagariya (1992) considers input tariff increases balanced by final goods tariff decreases in a revenue neutral model and obtains ambiguous results in general. While the models are different, his conclusion about ambiguity holds here as well, since the ranking of the two instruments can be reversed by reversing the substitutability assumption: complete inelasticity in consumption while production has elastic demand. As inputs are usually thought to be more inelastically demanded than are final goods, the logic is to *tax inputs more heavily than final goods*, which will imply trade taxation.

6.2. Trade taxation vs. home good taxation

When trade taxes are high and home good taxes are very low it usually (but see the counter-example) pays to switch at the margin. Symmetrically, with low trade taxes and high home good taxes it pays to switch at the margin. The intuition is that a uniform radial replacement policy lowers the tax needed on each initially taxed good while raising it on each initially untaxed good. Since MCF is quadratic, rising more than in proportion to the tax, the replacement policy marginally tends to reduce loss. Cross effects qualify the insight with nonzero initial taxation of both sets of goods.

The home good consumption price vector is h and the home good producer price vector is h*. The specific tax t = h-h* is an instrument. The numeraire (including at least one export good) price is constant. For simplicity, restricted imports are confined to final goods only. Under these restrictions, the expenditure function is e(p,h,G,u) and the gross domestic product function is g(h*,G). Equilibrium in the home good markets determines h*(t,p,G,u) as a function of t,p,G,u implicitly in:

(6.1) $e_h(p, h^* + t, G, u) - \bar{g}_h(h^*, G) = 0$.

The private and the government budget constraints are:

(6.2) $e(p, h, G, u) - \bar{g}(h^*, G) + G\bar{g}_G = 0$

(6.3) $[p - p^*]' e_p + [h - h^*]' e_h + \bar{g}_G(h^*, G)G = 0$.

Now consider uniform radial replacement of parametric trade taxes with revenue neutral endogenous home good taxes:

(6.4) $dp = (p - p^*)d\alpha \qquad dt = (h - h^*)d\eta$

In the nontraded good market, dt implies h* changes by h_t^* while h changes by $I + h_t^*$ both obtained by implicit differentiation of (6.1).

Using the same methods as before,

$$\text{(6.5)}\quad \mu^{-1}E_u \frac{du}{d\alpha} = \left(\frac{MCF^{\eta}}{MCF^{\alpha}} - 1\right)R^p, \qquad \text{where}$$

$$MCF^{\alpha} = \frac{R^p}{R^p + l^p}, \qquad MCF^{\eta} = \frac{R^h}{R^h + l^h},$$

$$R^p = e_p^{'}(p - p^*) + G\overline{g}_{Gh^*}^{'}h_p^*(p - p^*), \quad R^h = e_h^{'}(h - h^*) + G\overline{g}_{Gh^*}^{'}h_t^{'}(h - h^*),$$

$$l^p = (p - p^*)'\left(e_{pp} + e_{ph}h_p^*\right)(p - p^*) + (h - h^*)'\left(e_{hp} + e_{hh}h_p^*\right)(p - p^*),$$

$$l^h = (h - h^*)'\, e_{hh}[I + h_t^*](h - h^*) + (p - p^*)'\, e_{ph}[I + h_t^*](h - h^*).$$

When might MCF^{η} be less than MCF^{α} in (6.5)?

> <u>Proposition 3: The Wider Base Proposition</u> *With consumption taxes initially equal to zero, a uniform proportional rise in consumption taxes combined with a uniform radial reduction in trade taxes is welfare improving provided traded goods are not perfectly inelastically demanded.*

For this case, MCF^{η} is equal to one, while MCF^{α} is greater than one. By continuity, welfare should continue to rise with small home goods taxation. The reasoning is symmetrical: a regime with no taxation of imperfectly substitutable imports can always improve welfare with at least a bit of trade taxation. Proposition 3 is the formal counterpart to the intuitive notion that at the margin it always pays to add new goods to the tax base.

General results for switching between trade and home good taxation from interior positions are not possible, as the MCF expressions depend on the entire substitution effects matrix interacted with the tax structure.

7. TOWARD OPERATIONALITY

This paper stresses the importance of the MCF of trade taxes relative to that for domestic taxes. Thus it concludes with illustrative estimates of MCF^{θ} and MCF^{τ} for a stylized small scale CGE model of the Korean economy in 1963, found in the public domain GAMS (General Algebraic Modeling System) software library. For more details, see Chenery et al. (1986).

There are 3 sectors, agriculture, manufacturing and services. Each sector has an import available at fixed international price competing with a domestic product which is an imperfect substitute in demand via a CES preference structure. The CES aggregate consumption bundles are substitutes with each other according to a Cobb-Douglas preference structure. Each sector exports at fixed international price a product which is an imperfect substitute in supply for the domestic product according to a CET joint output technology. Each sector produces its output with intermediate goods with fixed coefficients, while the value added technology has a CES form. Agricultural labor is not mobile and sectoral capital is fixed in the short run. There is in effect a representative consumer who receives all sources of income.[14] Government consumption is modeled as absorbing revenue but not supplying a public good. Imports are subject to tariffs, and indirect taxes apply to all domestic transactions. Income taxes in the model are equivalent to lump sum taxes, as labor supply is inelastic. The model is fully Walrasian.

The MCF is a compensated implicit derivative. It is built up from two separate simulations of the change in money metric utility with respect to a small *external* transfer. In the first, the government budget is balanced by a uniform radial tax change while in the second it is balanced by a lump sum transfer. The results are not very sensitive to the size of the perturbation or to variation in the size of elasticities of substitution, so the sensitivity analysis is not reported. The computational methods are described in the Appendix.

The simulation of the model at the base values of the substitution parameters yields the MCF for tariffs of around 1.57 while the MCF for indirect taxes is around 1.74. (The MCFs are calculated based on a uniform radial change in tariffs and in indirect taxes respectively.) These values appear reasonable, based on two sorts of check. First, reports of estimates of MCF for income and commodity taxes combined range from 1.32 to 1.47 for the US while an estimate for Sweden is recorded at 2.2 (Devarajan et al, 1995).

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[14] For the intertemporal aspect of the model, there are different marginal propensities to save out of different sources of income. This divergence from the representative consumer story does not affect the static properties of the model.

Ballard, Shoven and Whalley (1985) report MCF estimates for the US ranging from 1.17 to 1.57. Second, the values of both MCFs for Korea are consistent with the tax rates and simulated values of the general equilibrium (uncompensated) elasticities in the model. This observation is based on a crude use of the general formula for MCF in which diagonal terms only are used.

Significantly, the MCF for tariffs is lower than that for indirect taxes. This is a surprise because indirect taxes are relatively low --- less than or equal to 5%, in contrast to tariffs ranging from 8% to 22%. The finding illustrates the practical importance of the theoretical ambiguity: replacing trade taxes with domestic taxes is not necessarily beneficial.[15]

The results should probably not be taken too seriously as a description of the payoff to marginal trade reform in the Korean economy of 1963. Instead, they illustrate the principles of the paper and their applicability to the calculation of the key MCF variables under the discipline of using real world tariffs, domestic taxes, public expenditure and production/consumption shares. In future work, it would be very useful to modify the model to permit MCF calculations for distortionary income taxation, and to extend the set of countries for which MCF calculations exist.

This paper casts doubt on the desirability of trade reform for convex competitive economies with active government budget constraints. No general theoretical presumption in favor of liberalization can be established in the highly plausible case where foreign and domestic goods are imperfect substitutes. Indeed, some trade taxation will almost always be desirable. The empirical application illustrates this problem strikingly, as the results show that tariff cuts matched by revenue neutral indirect tax rises would lower Korean welfare.

[15] Regrettably, in the CGE model used, there is no labor supply decision; hence income taxes are equivalent to lump sum taxes and it is not possible to evaluate trade reform paid for with realistic distortionary income taxation.

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9. Appendix: CALCULATION OF MCF IN CGE MODELS

The calculation of the Marginal Cost of Funds (MCF) in Computable General Equilibrium (CGE) models is done in a three step procedure, since as it is a 'compensated equilibrium' concept, it does not fall out of a CGE model in a single step. (See Anderson and Martin, 1995 for more details, including reasons for preferring the compensated to the uncompensated version of MCF).

9.1. Calculation

The first step is to run the CGE experiment which calculates the rate of change of money metric utility with respect to an external transfer offset by a change in the distortionary taxes of interest. (In the text these are tariffs and domestic consumption taxes.) For the first step, perform the following operations:

- Transfer an *external* exogenous amount dβ into the government budget,
- offset by an endogenous proportionate change in the tax vector of interest; e.g., (p-p*)dα, where dα is the endogenous scalar; and
- calculate the change in money metric utility which arises from this experiment ($E_u$du and dα are endogenous, the government budget constraint and the private budget constraint are the two equations which determine them). This is denoted $E_u$du/dβ(1). It is the uncompensated marginal cost of funds for the taxes of interest.

The second step is to run the CGE experiment which calculates the shadow price of foreign exchange, also called the fiscal multiplier by Anderson and Martin (1995).

- Transfer the same exogenous external amount dβ into the government budget,
- offset by a lump sum transfer dρ from the government to the private sector.
- Calculate the rate of change in money metric utility which results. This value is the shadow price of foreign exchange for experiment 2.

The third step is to calculate MCF^p using the results of the first two steps. Based on the simple case of the text, this involves dividing the result of the first experiment by the result of the second. Unfortunately, a complicating factor is that some CGE models (including the Korean model of the text) apply a tax rate to external transfers. Call this rate τ, so that a proportion τ of the external transfer goes to the government, the proportion (1-τ) going to the private sector. Also, some CGE models have savings as a part of intertemporal structure. These complications necessitate a bit more elaborate derivation.

9.2. Derivation

The derivation of the MCF and shadow price of foreign exchange μ functions is based on the 2 equation system of the government and private sector budget constraints:

(A.1) $\tau\beta + (p-p^*)' E_p + (q-q^*)' E_q - \pi G - \rho = 0$ government constraint,

(A.2) $E - (1-s)(1-\tau)\beta - (1-s)\rho = 0$ private constraint,

where *E(p,q,G,u)* is the private net expenditure on private goods, G is the government good obtained at external price π (for simplicity), ρ is the transfer from the government to the private sector, β is the external transfer, τ is the tax rate on transfers, p is a domestic price vector for the class of goods we are interested in for MCF purposes and q is a domestic price vector for some other class of goods subject to distortions. For a model with savings, there is also a macroeconomic balance equation $s[(1-\tau)\beta + \rho]$ = Investment, where Investment causes demand links to the general equilibrium structure which need not be detailed here.

9.2.1. MCF Experiment

The domestic price vector p will change according to $dp = (p-p^*)d\alpha$, where α is a scalar. $d\beta$ is the exogenous shift parameter, and $d\alpha$ and du are endogenous changes which satisfy the two constraints in changes. ρ, G, q and τ are constant. First solve first from the government budget constraint for $d\alpha/d\beta$:

$$\text{(A.3)}\quad \frac{d\alpha}{d\beta} = \frac{-\tau - \{(p-p^*)' E_{pu} + (q-q^*)' E_{qu}\}du/d\beta}{(p-p^*)' E_p + (p-p^*)' E_{pp}(p-p^*) + (q-q^*)' E_{qp}(p-p^*)}.$$

Substituting into the differential of the private budget constraint:

$$\text{(A.4)}\quad \{1 - MCF^p[(p-p^*)' E_{pu}/E_u + (q-q^*)' E_{qu}/E_u]\}E_u du = (1-\tau)(1-s) + \tau MCF^p$$

where

$$MCF^p = \frac{E_p'(p-p^*)}{E_p'(p-p^*) + (p-p^*)' E_{pp}(p-p^*) + (q-q^*)' E_{qp}(p-p^*)}.$$

Solving for the money metric utility rate of change:

$$\text{(A.5)}\quad E_u \frac{du}{d\beta}(1) = \mu(1-\tau)(1-s) + \mu\tau MCF^p,$$

where μ is the inverse of the coefficient multiplying $E_u du$ on the left hand side of (A.4):

$$\text{(A.6)}\quad \mu = \frac{1}{\{1 - MCF^p[(p-p^*)' E_{pu}/E_u + (q-q^*)' E_{qu}/E_u]\}}.$$

With τ equal to one, equation (A.5) gives the money metric or uncompensated version of the marginal cost of funds. The left hand side of (A.5) is calculated from a CGE model.

9.2.2. Shadow Price of Foreign Exchange Experiment

The redistribution ρ changes endogenously along with u in response to an exogenous change in the external transfer β, to satisfy the two constraints in changes. The variables p, G, τ and q are constant. Solving the government budget constraint for $d\rho/d\beta$:

$$\frac{d\rho}{d\beta} = \tau + [(p-p^*)' E_{pu} + (q-q^*)' E_{qu}]du/d\beta.$$

Substituting into the differential of the private budget constraint:

$$\{1-(1-s)[(p-p^*)' E_p + (q-q^*)' E_q]\}E_u du/d\beta = (1-s)[(1-\tau)+\tau] = 1-s.$$

Therefore, solving for the rate of change in money metric utility:

$$\text{(A.7)}\quad E_u \frac{du}{d\beta}(2) = \frac{1-s}{\{1-(1-s)[(p-p^*)' E_p + (q-q^*)' E_q]\}} = \mu(2).$$

The left hand side of (A.7) is calculated from the CGE experiment. Note that the shadow price of foreign exchange in this experiment is not the same as that for the MCF experiment, $\mu(2)$ is not equal to μ. The relation between them is:

$$\text{(A.8)}\quad \frac{1}{\mu} = 1 + \left(\frac{1}{\mu(2)} - \frac{1}{1-s}\right)MCF^p.$$

9.2.3. Solving for MCF

Divide equation (A.5) through by μ:

$$\frac{E_u \dfrac{du}{d\beta}(1)}{\mu} = (1-s)(1-\tau) + \tau MCF^p.$$

Then use equation (A.8) to substitute for $1/\mu$ and solve for MCF^p:

$$\text{(A.9)} \quad MCF^p = \frac{E_u \dfrac{du}{d\beta}(1) - (1-\tau)(1-s)}{\tau + E_u \dfrac{du}{d\beta}(1)\left(\dfrac{1}{1-s} - \dfrac{1}{\mu(2)}\right)}.$$

The right hand side of equation (A.9) is in terms of observables and the two calculated values from the two CGE experiments.

FIGURES AVAILABLE ON REQUEST FROM THE AUTHOR

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