

**WELFARE VERSUS MARKET ACCESS:  
THE IMPLICATIONS OF TARIFF STRUCTURE FOR TARIFF REFORM\***

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**Abstract**

We show that the effects of tariff changes on welfare and import volume are fully characterised by their effects on the generalised mean and variance of the tariff distribution, implying two "cones of liberalisation" in commodity price space. Because welfare is negatively but import volume positively related to the generalised variance, the cones do not intersect, which poses a policy dilemma. We present a new radial tariff reform rule, which implies new results for welfare- and market-access-improving tariff changes. Finally, we show that generalised and trade-weighted moments are mutually proportional when the trade expenditure function is CES.

JEL classification: F13, F15.

Keywords: Concertina rule; Market access; Piecemeal policy reform; Tariff moments; Uniform tariff reductions.

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Welfare and trade volume increase together in a small open economy when only one good is subject to a tariff and that tariff is reduced. Tariff reduction thus serves both domestic and international goals: on the one hand it raises home welfare; on the other hand it increases foreign access to domestic markets as required by multilateral trade obligations under the WTO.<sup>1</sup> However, in the empirically relevant case where there are many tariff-ridden goods, the analytic relationship between changes in tariffs, welfare and trade volume forms a difficult tangle due to cross effects. The theory of the second best noted long ago that cutting a single tariff need not raise welfare, and it is easy to see that it need not improve market access either. What tariff changes do improve welfare? Market access? What is the relationship between the two?

Computation can in principle provide answers to these questions. But computations of the effects of multiple tariff changes from any applied general equilibrium model will always be suspect because of uncertainty about the parameters and specification of the 'true' model of the economy. The theory of piecemeal trade policy reform is a promising alternative which seeks to specify directions of change which can raise welfare or improve market access under plausibly general conditions. However, progress in this research program has been relatively limited thus far. (See Foster and Sonnenschein, 1970; Bruno, 1972; Hatta, 1977; Diewert, Turunen-Red and Woodland, 1989). There are but two results, the uniform radial reduction result (reduce all tariffs by the same proportion) and the "concertina rule" (reduce the highest tariff rate). Each

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<sup>1</sup> Bagwell and Staiger (1999) note that reciprocity, which they interpret as trade policy "concessions" that yield equal increases in market access and so keep world prices constant, is one of the foundational principles of GATT.

characterizes a single welfare-improving path in tariff space, and neither is consistent with trade reforms typically proposed or implemented in negotiations or in applied policy-making advice such as that dispensed by international institutions. Moreover, as usually stated, the concertina rule requires implausibly strong restrictions on the general equilibrium substitution effects matrix. As for the effects of tariff reform on market access, Ju and Krishna (2000) explore the implications of the uniform radial reduction and concertina reforms, and derive a new reform rule which ensures an increase in market access (see Section 3.3 below), but much remains to be done.

This paper takes a new approach to the theory of piecemeal trade policy reform, which yields substantial generalisations of previous results. It provides general characterizations of cones of welfare-improving and market-access-improving trade reforms. Under fairly mild and plausible restrictions, tariff change paths within these cones guarantee improvements in welfare or increases in market access for small open economies. The directions of change within the cones approximate many of the practical tariff-cut formulae of multilateral negotiations. They also contain dispersion-changing directions of change which provide the first formal justification for the World Bank's emphasis on reducing dispersion of tariff structure.

The cones of liberalization are closely related to new concepts of the generalized mean and variance of tariff schedules.<sup>2</sup> Standard atheoretic measures of mean and variance of tariffs are

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<sup>2</sup> Anderson (1995) introduced generalised tariff moments and used them to elucidate the properties of the Trade Restrictiveness Index (TRI) of Anderson and Neary (1996). (He defined them in terms of world prices, whereas it is more convenient for our purposes to define them in terms of domestic prices, since it allows us to make use of the homogeneity restrictions on import demand.) Feenstra (1995, p. 1562) also notes the importance of tariff dispersion in the special case of linear demands. These papers, like ours, consider the moments of the distribution of a cross-section of tariffs in a deterministic framework, whereas Francois and Martin (2004) explore the implications for market access of the moments of a single tariff's distribution over

often used as indexes by the World Bank and other analysts because they appear intuitively to be linked to welfare. There is something right about the intuition, but the weights for the appropriate generalized mean and variance are based on marginal substitution effects rather than on average trade shares.<sup>3</sup> In a special CES case, we show that the generalized mean and variance are proportional to the trade-weighted mean and the trade-weighted variance.

In surprising contrast to the one-good case, the sufficient conditions for welfare increase and market access increase are substantially in conflict. The two cones of liberalization are disjoint except on a single path along which domestic relative prices are constant, so the economy is identical to one in which only a single composite commodity is subject to tariffs. This highlights the inadequacy of the one-good framework: the coincidence between the sufficient conditions for welfare improvements and market-access increases falls apart once we move to the realistic case where two or more goods are subject to tariffs. A key reason for this contrast is that reductions in dispersion are good for welfare but bad for market access. This is not to deny that there exist reforms which ensure an increase in both welfare and market access. However, it implies that identifying such reforms requires more information about the structure of the economy than is usually assumed in the theory of piecemeal policy reform, as we show in some special cases.

Section 1 introduces the economic model and the generalised moments of tariffs. Section 2 shows how changes in the generalised moments affect welfare and market access, and derives

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time in a stochastic framework.

<sup>3</sup> Kee, Nicita and Olarreaga (2004) highlight the importance of taking substitution effects into account when tariffs are non-uniform. They show that, because of the high variance of the U.S. tariff schedule, the simple and trade-weighted average tariffs underestimate the true average tariff (the TRI) for the U.S. by more than any other country in their sample. (The atheoretic average tariffs for the U.S. are about 4%, whereas the TRI uniform tariff is approximately 15%.)

the cones of liberalization. Section 3 presents a new class of tariff reform rules which generalise the uniform radial reduction rule, and shows how different members of this class lie in one or other of the cones and so guarantee an improvement in either welfare or market access. Finally, Section 4 relates generalised to trade-weighted moments in the CES case.

### 1. Generalised Tariff Moments

The economic model we use is standard in the trade reform literature.<sup>4</sup> A competitive small open economy produces and consumes  $n$  imported goods which are subject to a vector of specific tariffs  $t$ . All other traded goods are free of trade restrictions, so their home prices equal exogenously given world prices throughout. Hence they can be aggregated into a single composite commodity whose price is set equal to one by choice of numeraire and suppressed from the arguments of the behavioral functions for convenience.<sup>5</sup> We ignore distributional and political-economy issues in order to focus on the efficiency effects of changes in tariffs. Hence the behaviour of the private sector can be summarised in terms of the trade expenditure function, which equals the difference between an aggregate expenditure function and the GDP function:

$$E(\pi, u) \equiv e(\pi, u) - g(\pi) \tag{1}$$

Here  $u$  is domestic aggregate welfare and  $\pi$  denotes the vector of domestic prices for the  $n$  goods,

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<sup>4</sup> See Neary (1995) and the references given there.

<sup>5</sup> Our "imports" category includes *all* goods which are subject to trade taxes or subsidies. The algebra is consistent with the case where some of the  $n$  goods are exported and/or are subject to trade subsidies rather than taxes, though our discussion in the text focuses on the case of tariff-restricted imports only for simplicity. The trade expenditure function is consistent with the presence of non-traded goods with endogenously determined prices, provided they are not subject to domestic taxes.

which equal world prices  $\pi^*$  plus specific tariffs  $t$ :  $\pi = \pi^* + t$ . The GDP function also depends on technology and factor endowments, but these are constant throughout and so can be suppressed.

The key property of the trade expenditure function is that its derivatives with respect to prices are the general-equilibrium net import demand functions:

$$m(\mathbf{p}, u) \equiv E_{\pi}(\pi, u) = e_{\pi}(\pi, u) - g_{\pi}(\pi) \quad (2)$$

This follows from Shephard's and Hotelling's Lemmas, which imply that  $e_{\pi}$  and  $g_{\pi}$  equal domestic demand and supply functions respectively. The matrix of second derivatives  $E_{\pi\pi}$  is therefore the substitution matrix for non-numeraire goods, which we assume is negative definite. As for the cross-derivatives with respect to utility, they are proportional to the Marshallian income derivatives of demand,  $E_{\pi u} = e_{\pi u} = e_u x_i$ , where  $e_u$  is the marginal cost of utility.

In order to characterise changes in the distribution of tariffs, we introduce *generalised* tariff moments. These are equal to weighted moments, where the weights are the elements of the substitution matrix  $E_{\pi\pi}$  normalised by *domestic* prices. For compatibility with these, it turns out to be easiest to work with tariffs which are also deflated by domestic prices. Hence, define the *ad valorem* tariff rate on good  $i$  as  $T_i \equiv t_i/\pi_i = (\pi_i - \pi_i^*)/\pi_i$ . Note that tariff rates defined in this way must lie between zero and one:  $0 \leq T_i < 1$ , which is why  $T_i$  is sometimes called the "power" of the tariff. (See Francois and Martin (2003).) The  $T_i$  are related to tariff rates defined with respect to world prices ( $\tau_i \equiv t_i/\pi_i^*$ ) by:  $T_i = \tau_i/(1 + \tau_i)$ . To express the vector of tariff rates in matrix notation, let  $\underline{x}$  denote a diagonal matrix with the elements of the vector  $x$  on the principal diagonal. Then we can write the vector of tariff rates  $T$  as:

$$T \equiv \underline{\pi}^{-1} t = \mathbf{1} - \underline{\pi}^{-1} \pi^* \quad (3)$$

where  $\mathbf{1}$  denotes an  $n$ -by-1 vector of ones.

Next, define the matrix of substitution effects normalised by domestic prices as:

$$S \equiv -\bar{s}^{-1} \underline{\pi} E_{\pi\pi} \underline{\pi}, \quad \text{where:} \quad \bar{s} \equiv -\pi' E_{\pi\pi} \pi > 0. \quad (4)$$

By construction  $S$  is a symmetric  $n$ -by- $n$  positive definite matrix all of whose elements sum to one:  $\mathbf{1}' S \mathbf{1} = 1$ . We can use  $S_{ij}$  to denote both the individual elements of  $S$  and (when either  $i$  or  $j$  is zero) the corresponding cross-price effects with the numeraire good:

$$S_{ij} = -\bar{s}^{-1} \pi_i E_{ij} \pi_j, \quad i, j = 0, 1, \dots, n. \quad (5)$$

Note the sign convention: the normalised own-price effects  $S_{ii}$  are positive for all  $i$ , while the normalised cross-price effects  $S_{ij}$  are negative if and only if goods  $i$  and  $j$  are general-equilibrium net substitutes. The homogeneity restrictions on  $E_{\pi\pi}$  imply corresponding restrictions on  $S$ :

$$E_{0j} + \sum_{i=1}^n \pi_i E_{ij} = 0 \quad \Leftrightarrow \quad S_{0j} + \sum_{i=1}^n S_{ij} = 0, \quad \forall j = 0, 1, \dots, n. \quad (6)$$

Thus the elements of column  $j$  of  $S$  sum to  $-S_{0j}$ , which is the normalised cross-price effect between the numeraire good and good  $j$ . (By symmetry the elements of row  $i$  of  $S$  sum to  $-S_{i0}$ .)

After these preliminaries, we can define two generalised moments of the tariff structure. The first is the generalised average tariff:

$$\bar{T} \equiv \mathbf{1}' S T, \quad (7)$$

This equals a weighted average of the individual tariff rates, where the weights are the row (or column) sums of  $S$ :

$$\bar{T} = \sum_{j=1}^n \omega_j T_j \quad \text{where:} \quad \omega_j \equiv \sum_{i=1}^n S_{ij} = -S_{0j} \quad (8)$$

(The last equality follows from (6).) The weights must sum to one, since  $\sum_j \omega_j = \sum_i \sum_j S_{ij} = \iota' S \iota = 1$ . However, they need not lie in the  $[0,1]$  interval. It follows that  $\bar{T}$  itself need not lie in the unit interval. Two conditions which are sufficient to ensure that it does are immediate. First,  $\bar{T}$  must lie in the unit interval if tariffs are uniform. In that case  $T = \iota\beta$  ( $0 \leq \beta < 1$ ), so  $\bar{T} = \iota' S \iota \beta = \beta$ . Second, because  $S$  is defined to be positive definite, the weight on a given tariff rate is more likely to be positive the higher the own-substitution effect for that good and the more it is a complement rather than a substitute for other tariff-constrained goods. Equation (8) implies a more succinct condition: the weight attached to the tariff rate on good  $j$  in the expression for  $\bar{T}$  is positive if and only if that good is a substitute for the numeraire. Hence, if all goods are substitutes for the numeraire,  $\bar{T}$  must be positive and less than one. Summarising these results:

*Lemma 1: Sufficient conditions for the generalised average tariff to be positive and less than one are: (a) that all tariff rates are the same; or (b) that all goods subject to tariffs are general-equilibrium substitutes for the numeraire good.*

Clearly, the conditions in Lemma 1 are over-strong.  $\bar{T}$  can only be negative if tariffs are disproportionately higher on goods which are relatively strong complements for the numeraire good, and it can only be greater than one if tariffs are disproportionately higher on goods which are relatively strong substitutes for the numeraire good.

The second generalised moment we introduce is the generalised variance of tariffs:

$$V \equiv (T-\iota\bar{T})'S(T-\iota\bar{T}) = T'ST-\bar{T}^2. \quad (9)$$

Unlike the generalised average tariff,  $V$  is unambiguously positive in sign, since it is a quadratic form in the positive definite matrix  $S$ .

When we come later to consider tariff reform, we will need to have expressions for changes in the tariff rates  $T$  and the generalised moments  $\bar{T}$  and  $V$ . It is convenient to treat domestic prices as the policy instruments. Hence we *define* the changes in tariff rates as the changes in specific tariffs relative to domestic prices:  $dT_i \equiv dt_i/\pi_i$ , or in matrix notation:

$$dT \equiv \underline{\pi}^{-1}dt \quad (10)$$

Note that  $dt$  equals  $d\pi$  since world prices are fixed, and so the vector of changes in  $T$ ,  $dT_i$ , equals the vector of tariff-induced proportional changes in domestic prices,  $d\pi_i/\pi_i$ . As for the changes in the generalised moments, it turns out to be enormously convenient to work with Laspeyres-type approximations to them, which ignore tariff-induced changes in  $\pi$  and  $E_{\pi\pi}$ . Thus we define the change in the generalised mean tariff as follows:

$$d\bar{T} \equiv \iota'SdT = \sum_{j=1}^n \omega_j dT_j \quad (11)$$

The second equality follows from (8) and shows that the generalised mean tariff is increasing in a single tariff if and only if the good in question is a general equilibrium substitute for the numeraire. Similarly, the change in the generalised variance is defined as follows:<sup>6</sup>

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<sup>6</sup> The change in  $V$  can be interpreted as twice the (generalised) covariance between initial tariff rates and their changes:  $dV = 2(T-\iota\bar{T})'S(dT-\iota d\bar{T}) = 2Cov(T,dT)$ .

$$dV \equiv 2(T'SdT - \bar{T}d\bar{T}) = 2T'S(dT - \bar{t}d\bar{T}). \quad (12)$$

As we will see, these changes in generalised moments provide an invaluable intermediate step when we come to assess the effects of changes in actual tariffs on welfare and import volume.

## 2. Welfare, Market Access and Changes in Tariff Moments

We begin with the effects of changes in the tariff moments on welfare. The equilibrium condition for our small open economy is that the trade expenditure function (which from (1) gives the excess of expenditure over GDP at domestic prices) should equal tariff revenue:

$$E(\pi, u) = t'E_{\pi}(\pi, u) \quad (13)$$

Totally differentiating this gives the basic equation which links tariff changes to welfare (equation (10) from Hatta (1977) in our notation):

$$\mu^{-1} e_u du = t'E_{\pi\pi} dt. \quad (14)$$

Here  $\mu \equiv (1 - t'x_j)^{-1}$  is the tariff multiplier, or the "shadow price of foreign exchange". This conveniently subsumes all the income effects in the economy into a single scalar expression, and following standard practice we assume it is positive.<sup>7</sup> We can rewrite (14) in terms of the normalised substitution matrix by using (3) and (10) to replace specific tariffs by  $T$ :

$$(\mu\bar{s})^{-1} e_u du = -T'SdT. \quad (15)$$

Both  $\mu$  and  $\bar{s}$  are positive, so the change in welfare has the same sign as the right-hand side of

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<sup>7</sup> A positive value for  $\mu$  can be justified by assuming either that the initial equilibrium is stable, or that income effects are not perverse, or that public policy embodies a minimal degree of rationality. See Neary (1995) for further discussion and references.

(15). Using (12) we can express this in terms of the changes in the generalised tariff moments:

$$(\mu\bar{s})^{-1} e_u du = -\bar{T}d\bar{T} - \frac{1}{2}dV. \quad (16)$$

Equation (16) shows that the change in welfare is related in a particularly simple way to the changes in the generalised moments of the tariff structure. It is not too surprising that welfare is a decreasing function of the generalised mean tariff provided  $\bar{T}$  itself is positive. More significant is the result that it is always decreasing in the generalised variance. This provides a partial rationalisation for the common practice of viewing increases in the variance of tariffs as harmful (only partial because in general  $V$  is not observable and its relation to the observable trade-weighted variance is indeterminate, except in a special case as we show in Section 4).

We turn next to see the effects of changes in the tariff moments on the volume of imports:  $M \equiv \pi^* . m$ . (Note that imports are measured at world prices: we shall see later that this seemingly innocuous convention has important implications.) The change in import demand can be expressed in terms of income and substitution effects as follows:

$$dM = \pi^* . dm = \pi^* . (E_{\pi\pi} d\pi + x_f e_u du). \quad (17)$$

However, from (14), the income effect is itself related to tariff changes via the substitution matrix  $E_{\pi\pi}$  in general equilibrium. Substituting from this gives the basic equation which links tariff changes to import volume (equation (15) from Ju and Krishna (2000) in our notation):

$$dM = (\pi^* + M_b t)' E_{\pi\pi} dt. \quad (18)$$

Here  $M_b$  is the marginal propensity to spend on importables, defined as follows:<sup>8</sup>

$$M_b \equiv \mu \pi^* \cdot x_I = \frac{\pi^* \cdot x_I}{\pi^* \cdot x_I + x_{0I}} \quad (19)$$

where  $x_{0I}$  is the income derivative of demand for the numeraire good. Hence  $M_b$  must lie between zero and one provided only that both the tariff-constrained goods as a whole and all other traded goods as a whole (i.e., the numeraire) are normal in demand, a very mild restriction.

The next step is to express equation (18) in terms of changes in the generalised moments. As before, we first rewrite it in terms of the normalised substitution matrix:<sup>9</sup>

$$\bar{s}^{-1} dM = - [1 - (1 - M_b) T]' S dT. \quad (20)$$

which leads to the desired expression:

$$\bar{s}^{-1} dM = - [1 - (1 - M_b) \bar{T}] d\bar{T} + \frac{1}{2} (1 - M_b) dV. \quad (21)$$

This shows that, as with the change in welfare in equation (16), the change in import volume is fully determined by the changes in the two generalised moments. However, a key difference is that the volume of imports is usually *increasing* in the generalised variance, for a given level of the generalised mean. The contrast between the effects of the generalised variance on welfare and import volume given in equations (16) and (21) is one of the central results of the paper.

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<sup>8</sup> To derive the right-hand side of (19) we use the adding-up constraint on income derivatives at domestic prices:  $\pi' x_I + x_{0I} = 1$ . Substituting into the inverse shadow price of foreign exchange gives  $1 - t' x_I = \pi^* \cdot x_I + x_{0I}$ . The latter expression is sometimes called the "Hatta normality term".

<sup>9</sup> The coefficient in parentheses in (18) becomes:  $\pi^* + M_b t = \pi - (1 - M_b) t = \underline{\pi} [1 - (1 - M_b) T]$ .

The implications of these equations can be summarised as follows:

*Proposition 1: The effects on welfare and import volume of an arbitrary small change in tariffs are fully described by its effects on the generalised mean and variance of tariffs. An increase in  $\bar{T}$  (with  $V$  constant) lowers welfare if  $\mu$  and  $\bar{T}$  are positive, and lowers import volume if and only if  $(1-M_b)\bar{T}$  is less than one. An increase in  $V$  (with  $\bar{T}$  constant) reduces welfare if and only if  $\mu$  is positive and raises import volume if and only if  $M_b$  is less than one.*

In the case of two tariffed goods the implications of this result can be illustrated in commodity price space as in Figure 1. Points  $A$  and  $F$  represent the initial distorted equilibrium and free trade respectively. Any change in initial tariffs will in general change both the generalised mean and variance. Consider those paths along which either one of them does not change. From (11), the generalised tariff will remain constant along a curved locus such as  $EAG$ , which is downward-sloping provided both goods are substitutes for the numeraire.<sup>10</sup> Similarly, from (12), the generalised variance is constant along the ray  $OBA$  from the origin to  $A$ .<sup>11</sup> These two loci therefore divide the space of non-negative tariffs into four regions, depending on whether the generalised mean and variance rise or fall for movements away from  $A$ . The regions denoted  $I$

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<sup>10</sup> Using (11), and recalling from (10) that  $d\pi_i=dt_i=\pi_i dT_i$ , the slope of this locus in  $\{\pi_1, \pi_2\}$  space is  $-\pi_2\omega_2/\pi_1\omega_1$ . From (8) the weights  $\omega_i$  are positive if and only if good  $i$  is a general-equilibrium substitute for the numeraire. In the special case of linear demands and zero cross-substitution effects the slope equals  $-\pi_2 E_{22}/\pi_1 E_{11}$ , which is always negative and becomes smaller in absolute value as relative prices approach the free-trade ratio  $\pi_1^*/\pi_2^*$  along  $AE$ .

<sup>11</sup> Recalling (12),  $dV$  is zero (for arbitrary initial tariffs and when  $S$  is of full rank) only when  $dT=\alpha d\bar{T}$ , i.e., when  $dT=\alpha d\alpha$  (where  $d\alpha$  is an arbitrary scalar which may be positive or negative).

and  $II$  are of particular interest. In Region  $I$ , bounded by  $AEFB$ , both the generalised moments fall, so from (16) welfare definitely rises, while in Region  $II$ , bounded by  $ABG$ , the generalised mean falls but the generalized variance rises, so from (21) the volume of imports definitely rises. Hence we can call these regions *Cones of Welfare- and Market-Access-Increasing Liberalisation* respectively.<sup>12</sup> It should be stressed that there is a whole half-space of small changes from  $A$  which will raise either welfare or market access. The cones give sufficient conditions only, whereas necessary and sufficient conditions are given by the iso-welfare and iso-import-volume loci through  $A$ . The dashed lines in Figure 1 illustrate some possible configurations of these loci, but determining their shapes in general requires much more information than is generally assumed to be available in the theory of piecemeal trade policy reform.<sup>13</sup> In the remainder of the paper we therefore concentrate on showing how the cones  $AEFB$  and  $ABG$  can yield new results on welfare- and market-access-increasing reforms.

The fact that import volume is usually increasing in  $V$  is an important and surprising finding, which has a major influence on the results to be presented below. To get some intuition for this finding, and to deduce some further implications of it, note that, from (14), the change in welfare following any change in tariffs is proportional to  $(\pi - \pi^*)' E_{\pi\pi} dt$ . However, from the definitions of  $S$  and  $d\bar{T}$  in (4) and (11),  $\pi' E_{\pi\pi} dt$  is zero whenever  $d\bar{T}$  is zero. Combining these expressions shows that the change in welfare is proportional to  $-\pi^* \cdot E_{\pi\pi} dt$ , which can be interpreted as minus

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<sup>12</sup> Rigorously speaking, the regions are not cones, since one of their boundaries is not linear and they are defined only for rays from  $A$  which lie above  $FG$  and to the left of  $OF$ .

<sup>13</sup> Neary (1995) explores the properties of the iso-welfare loci. If all traded goods are substitutes and only two are subject to tariffs, the locus has the shape shown in Figure 1 when point  $A$  corresponds to the optimal second-best tariff on good 1, conditional on the initial tariff  $\pi_2^0 - \pi_2^*$  on good 2.

the compensated change in import volume. Thus welfare and compensated import volume move in opposite directions when  $d\bar{T}$  is zero. Income effects complicate this argument but are unlikely to reverse it. To see this, recall from (15) that  $-T'SdT$  is proportional to the change in utility, so we can rewrite equation (20) as follows:

$$(1-M_b)\mu^{-1}e_u du + dM = -\bar{s}d\bar{T} \quad (22)$$

Hence, if  $d\bar{T}$  is zero (i.e., for any generalised- mean-preserving change in the variance of tariffs), welfare and import volume must move in opposite directions, provided  $\mu$  is positive and  $M_b$  is less than one.

Equation (22) also yields a generalisation of Proposition 4 in Ju and Krishna:<sup>14</sup>

*Proposition 2: Provided  $\mu$  is positive and  $M_b$  is less than one, both welfare and the value of imports cannot fall following a reduction in tariffs, defined as a fall in  $\bar{T}$ .*

When combined with the result in (11) that a reduction in an arbitrary tariff lowers  $\bar{T}$  if and only if the good in question is a substitute for the numeraire good, we have a corollary of Proposition 2: if all goods are net substitutes for the numeraire, then *any* reduction in tariffs must lower  $\bar{T}$ , as a result of which either  $M$  or  $u$  or both must rise.

Before leaving the positive relation between import volume and tariff variance, it is worth noting that it does *not* hold if import volume is measured in domestic prices, which we denote

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<sup>14</sup> Ju and Krishna assume that all goods are normal and are substitutes for each other. Proposition 2 dispenses with the second assumption and relaxes the first by requiring that it hold only in an average sense: importables should not be so inferior that  $\mu$  is negative, nor so superior that  $M_b$  exceeds one.

by  $\tilde{M} \equiv \pi' m$ . A series of derivations similar to those which led to (21) above now yields:

$$\begin{aligned}
d\tilde{M} &= m'd\pi + \pi'dm \\
&= m'dt + (\pi + \tilde{M}_b t)' E_{\pi\pi} dt \\
&= (m'/\pi^*) d\tau^a - \bar{s} (1 + \tilde{M}_b T)' S dT \\
&= (m'/\pi^*) d\tau^a - \bar{s} (1 + \tilde{M}_b \bar{T}) d\bar{T} - \frac{1}{2} \bar{s} \tilde{M}_b dV
\end{aligned} \tag{23}$$

This shows that the change in  $\tilde{M}$  consists of two components. The first,  $m'd\pi$ , is a valuation effect, which is proportional to the change in the trade-weighted average tariff  $d\tau^a$  (defined as  $m'dt/m'\pi^*$ ). The second,  $\pi'dm$ , is the change in import volume at constant domestic prices, which is *negatively* related to both  $\bar{T}$  and  $V$  (provided  $\tilde{M}_b$  is positive). Indeed, it is affected by changes in  $\bar{T}$  and  $V$  in a very similar manner to the level of welfare.<sup>15</sup> Unfortunately, however, the results for tariff reform which this implies are not of great interest. As far as trade negotiations are concerned, market access matters primarily from the perspective of *exporters* to the economy under consideration. Hence it is import volume at world rather than at domestic prices which is the main focus of interest, and we concentrate on it from now on.<sup>16</sup>

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<sup>15</sup> Compare (23) with (16). A minor difference from the earlier case is that the marginal propensity to spend on importables in (23),  $\tilde{M}_b \equiv \mu\pi'x_j$ , is measured at domestic rather than world prices. Unlike  $M_b$ , this could be greater than one if tariffs are sufficiently high, even if all goods are normal in demand. The difference between the two marginal propensities depends directly on the size of the tariff multiplier:  $\tilde{M}_b - M_b = \mu - 1$ .

<sup>16</sup> A different reason for being interested in import volume at domestic prices is that the difference between it and import volume at world prices equals tariff revenue:  $R = t'm = \tilde{M} - M$ . Hence the change in tariff revenue is:  $dR = d\tilde{M} - dM$ . Substituting from (18) and (23) yields a particularly simple expression:  $dR = m'dt + e_u du$ . This is important in discussions of trade policy reform subject to a tariff revenue constraint, where it leads to a version of the Ramsey Rule for tariff rates, an application we do not pursue further here. See for example Falvey (1994).

### 3. A General Tariff Reform Rule

The results of Section 2 show that changes in the generalised moments are useful summary measures of any arbitrary change in tariffs. However, these results do not directly contribute to the theory of piecemeal policy reform, since changes in the generalised moments can only be calculated if the substitution matrix is known. In this section we present a general tariff reform rule and show how the results of Section 2 can be used to deduce its implications for welfare and market access.

#### 3.1 Radial Tariff Reforms

Our new general radial tariff reform rule implies an equiproportionate change in the gap between all tariff rates and an arbitrary uniform tariff rate, denoted by  $\beta$ :<sup>17</sup>

$$dT = -(T - \beta) d\alpha \quad (24)$$

This is a generalisation of the uniform radial reduction rule discussed in the introduction, for which  $\beta$  is zero and  $d\alpha$  is positive. Substituting from (24) into (11), the changes in the generalised moments become:

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<sup>17</sup> This bears a superficial resemblance to a result of Fukushima (1979), but the results are different. Fukushima shows that a welfare change of the form  $d\tau = -(\tau - \gamma)d\alpha$ ,  $d\alpha > 0$ , raises welfare for *all* values of  $\gamma$ . However, a key difference is that Fukushima includes in the vector  $\tau$  the distortions on *all* traded goods; i.e., unlike our model his does not allow for a numeraire traded good which is not subject to tariffs. As a result his model is in a free-trade equilibrium whenever  $\tau = \gamma$  for *all*  $\gamma$ , since a uniform distortion affecting all traded goods (both exports and imports) does not change relative prices from their free-trade values, and so it yields no revenue and imposes no welfare cost. Fukushima's result is thus a restatement rather than a generalisation of the uniform radial reduction result. See Neary (1998) for further discussion.

$$d\bar{T} = -(\bar{T} - \beta)d\alpha \quad \text{and} \quad dV = -2Vd\alpha. \quad (25)$$

From Proposition 1, we know that, subject only to mild restrictions on  $\mu$ ,  $\bar{T}$  and  $M_b$ , any change which reduces both generalised moments must raise welfare, and any change which reduces the generalised mean and increases the generalised variance must improve market access. Combining this with (24) gives a whole family of results which can be stated formally as follows:

*Proposition 3: Following a tariff reform such as (24):*

- (i) *Welfare must rise when  $d\alpha > 0$  and  $\beta \leq \bar{T}$ , provided  $\mu$  and  $\bar{T}$  are positive.*
- (ii) *Import volume must rise when  $d\alpha < 0$  and  $\beta \geq \bar{T}$ , provided  $M_b$  and  $(1 - M_b)\bar{T}$  are less than one.*

To see the wide range of results the proposition implies, we consider some special cases.

### 3.2 Tariff Reforms which Raise Welfare

In Figure 2 (which repeats the essential features of Figure 1), any reform of the type given in Proposition 3(i) with  $d\alpha > 0$  and  $\beta \leq \bar{T}$  can be represented by a movement along a line from the initial point  $A$  towards a point on the ray  $OFE$  from the origin through  $F$ . The location of the point depends on  $\beta$ . For example, if  $\beta$  equals zero the point coincides with  $F$ , since (24) is just the uniform radial reduction rule. If  $\beta$  equals the minimum tariff rate  $T_1$  the point is given by  $D$ , which is horizontally aligned with  $A$ : with more than two goods subject to tariffs, this can be called a "super-concertina" reform, where *all* tariffs are reduced equiproportionally towards the lowest tariff rate. A sufficient condition for it to raise welfare (with  $\mu$  positive) is that  $\bar{T}$

exceeds the minimum tariff rate. Indeed, these conditions are sufficient for *any* reform in the sub-cone  $DAB$  to raise welfare, so we can call  $DAB$  a "minimal-information" cone of welfare-increasing liberalisation.

When  $\beta$  is negative, the interpretation is easier if we replace it by  $-(1-\gamma)/\gamma$ , where  $\gamma=1/(1-\beta)$ , so  $\gamma$  lies between zero and one. The radial reform rule (24) now becomes:

$$dT = -[\gamma T + (1-\gamma)t] \frac{d\alpha}{\gamma}, \quad 0 < \gamma \leq 1. \quad (26)$$

With  $d\alpha$  positive, this is a weighted average of a uniform radial reduction in tariffs,  $dT=-Td\alpha$ , and a uniform *absolute* reduction in tariffs,  $dT=-td\alpha$ . (The effects of these and other tariff reforms to be considered below are summarised in Table 1.) The former reduces tariffs by the same proportion however they are measured (whether in nominal units, or relative to either home or world prices), and the equilibrium moves along  $AF$ . The latter reduces specific tariffs  $t$  in proportion to domestic prices,  $dt = -\pi d\alpha$ , so domestic relative prices are unchanged, and the equilibrium moves along  $AB$  towards the origin  $O$ . Hence (26) moves the equilibrium along a ray from  $A$  in the sub-region  $FAB$  of the welfare-improving cone. From Proposition 3, a sufficient condition for any reform of this kind to raise welfare (assuming, as always, that  $\mu$  is positive) is that  $\bar{T}$  is positive (which with  $\beta$  negative also ensures that  $\beta < \bar{T}$ ), so  $FAB$  is a minimal-information cone of welfare-increasing liberalisation even less restrictive than  $DAB$ .

While a value of  $\bar{T}$  which is positive and greater than  $\beta$  is sufficient for a welfare improvement from Proposition 3, it is clearly far too strong. To see this, substitute from (24) into (15) to get an explicit expression for the change in welfare implied by the general radial

reform rule (with  $d\alpha$  positive):<sup>18</sup>

$$(\mu\bar{s})^{-1} e_u du = [\bar{T}(\bar{T} - \beta) + V] d\alpha. \quad (27)$$

Equation (27) shows that a value of  $\beta$  equal to zero (i.e., the uniform radial reduction rule) is the only value which guarantees a welfare improvement irrespective of the pattern of substitutability between goods. More constructively, it also shows that a positive variance of tariffs always contributes towards a welfare improvement under the linear reform rule (24), irrespective of whether  $\bar{T}$  is positive or negative. Recalling from Lemma 1 that  $\bar{T}$  must be positive when  $V$  is zero (i.e., tariffs are uniform), we can be confident that for values of  $\beta$  close to zero a welfare improvement is assured.

To conclude this section, note that part (i) of Proposition 3 substantially increases the scope of what is known about the welfare effects of across-the-board cuts in tariffs. It is particularly important since successive trade rounds under the GATT and the WTO have considered many different types of tariff-cutting formula. (Laird and Yeats (1987), Panagariya (2002) and Francois and Martin (2003) review the different approaches under consideration in the current and previous rounds.) Many of these formulae can be closely approximated by (24), and so Proposition 3 makes it likely that they increase welfare given reasonable restrictions on the

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<sup>18</sup> From (27), a necessary and sufficient condition for a welfare improvement is that *either*  $\bar{T} > 0$  and  $\beta < (\bar{T}^2 + V)/\bar{T}$  *or*  $\bar{T} < 0$  and  $\beta > (\bar{T}^2 + V)/\bar{T}$ . However, this does not throw any more light on tariff reform rules which are operational without knowledge of the substitution matrix. Note that a negative value of  $\bar{T}$  may arise if trade restrictions are predominantly subsidies (including export subsidies).

degree of complementarity between the tariff-constrained goods and the numeraire.<sup>19</sup>

### 3.3 Tariff Reforms which Raise Market Access

Consider next the implications of the second part of Proposition 3. We begin with the case where  $\beta$  is less than one. When  $d\alpha$  is negative and  $\beta$  lies between zero and one, the general radial reform rule (24) implies a uniform change in tariffs such that the equilibrium moves away from  $A$  in Figure 2 along a path which lies in a cone bounded by  $AH$  and by the line  $FA$  extended northeastward from  $A$ . In the normal case where both  $M_b$  and  $\bar{T}$  are less than one, many such paths lie in the sub-region  $HAG$  of the cone of market-access-increasing liberalization as shown. One special case is where  $\beta$  equals the maximum tariff rate. This is denoted by  $AJ$  in Figure 2 and we can call it an "anti-concertina" reform, since it reduces *all* tariffs, except the highest, in proportion to their difference from the highest tariff. Provided  $\bar{T}$  is less than the maximum tariff and  $M_b$  is less than one, this variance-increasing reform is guaranteed to increase import volume. By analogy with the corresponding condition for a "super-concertina" reform in the last section, a value of  $\bar{T}$  less than the maximum tariff (with  $M_b$  less than one) is sufficient for *any* reform in the sub-cone  $BAJ$  to raise welfare, so we can call  $BAJ$  a minimal-information cone of market-access-increasing liberalisation.

When  $\beta$  is greater than one, equation (24) with  $d\alpha$  negative corresponds to a reduction in tariffs along a ray in the sub-cone  $BAH$ . In this case another change of variables is helpful.

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<sup>19</sup> Most of the formulae under consideration imply larger cuts in high than in low tariffs, and so fall in the  $DAF$  region of Figure 2. The best-known is the "Swiss formula," which relates new tariffs  $\tau_1$  to old ones  $\tau_0$  by:  $\tau_1 = a\tau_0/(a+\tau_0)$ . (In the Tokyo Round the value of  $a$  was set between 0.14 and 0.16.) This is a non-linear reform rule, but can be approximated by the discrete version of (24), which implies:  $\tau_1 = [1-(1-\beta)\alpha]\tau_0 + \beta\alpha$ .

Replace  $\beta$  by  $1/(1-\delta)$ , where  $\delta=(\beta-1)/\beta$  and lies between zero and one. The radial reform rule (24) now becomes:

$$dT = [\delta\iota + (1-\delta)(\iota-T)] \frac{d\alpha}{1-\delta}, \quad 0 \leq \delta < 1. \quad (28)$$

Once again this is a weighted average of two simple reforms. (Keep in mind that  $d\alpha$  is *negative* in this sub-section.) One is a uniform absolute reduction in  $T$ ,  $dT=\iota d\alpha$ ,  $d\alpha<0$ , which as we have seen in Section 3.2 moves the equilibrium along  $AB$ . The other is a uniform absolute reduction in  $\tau$ , the tariff rates measured with respect to *world* prices, since  $dT=(\iota-T)d\alpha$  implies  $d\tau=\iota d\alpha$ . This moves the equilibrium along  $AH$ . The rule given by (28) therefore moves the equilibrium along a path in the sub-region  $BAH$ . With  $\beta$  greater than one, any such reform must raise import volume from Proposition 3 provided  $M_b$  and  $(1-M_b)\bar{T}$  are less than one, so  $BAH$  is a minimal-information cone of market-access-increasing liberalisation even less restrictive than  $BAJ$ . The implications of (28) are clearer when expressed in terms of domestic prices:

$$d\pi = dt = \underline{\pi}dT = [\delta\pi + (1-\delta)\pi^*] \frac{d\alpha}{1-\delta}. \quad (29)$$

Hence (28) implies reducing domestic prices in proportion to a weighted average of domestic and world prices, where  $\delta$  is the weight attached to domestic prices.

An important special case of (28) is where  $\delta$  equals the marginal propensity to spend on importables,  $M_b$ . This is identical to a rule proposed by Ju and Krishna (2000), so we call it the

"Ju-Krishna Rule".<sup>20</sup> It plays a similar role in relation to market access as the uniform radial reduction rule plays in relation to welfare. We saw in Section 3.2 that a uniform radial reduction in tariffs is in the interior of the cone of welfare-increasing liberalization, and has the special feature that it ensures a welfare gain irrespective of the pattern of substitutability between goods. Similarly, the Ju-Krishna Rule lies in the interior of the cone of market-access-increasing liberalization, and does not require any restrictions on substitutability. To see this, substitute from (24) into (20) to get an explicit expression for the effect on import volume of the radial reform rule:

$$\bar{s}^{-1} dM = \left[ \{1 - (1 - M_b) \bar{T}\} (\bar{T} - \beta) - (1 - M_b) V \right] d\alpha. \quad (30)$$

Replacing  $\beta$  by  $1/(1-\delta)$ , this can be rewritten as follows:

$$\bar{s}^{-1} dM = - \left[ \{1 - (1 - M_b) \bar{T}\}^2 + (1 - M_b)^2 V \right] \frac{d\alpha}{1 - M_b} - \{1 - (1 - M_b) \bar{T}\} \frac{\delta - M_b}{(1 - \delta)(1 - M_b)} d\alpha. \quad (31)$$

In the Ju-Krishna case, the second expression on the right-hand side vanishes, and so imports unambiguously rise since  $d\alpha$  is negative.

### 3.4 Tariff Reforms Outside the Cones of Liberalization

In general we can say relatively little about the consequences of tariff reforms outside the cones of liberalisation. We can get some understanding of the effects of such reforms by noting a remarkable duality between two results which answer questions that appear *a priori* to be

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<sup>20</sup> Ju and Krishna present this result in a rather different form and without the weighted average interpretation: see the first part of their Proposition 1. In our notation, they write the reform rule in terms of changes in specific tariffs:  $dt = (\pi^* + M_b t) d\alpha$ ,  $d\alpha < 0$ . Substituting this into (18) yields minus a quadratic form in  $E_{\pi\pi}$ , which must be positive.

unrelated. Consider first a uniform radial reduction in tariffs, which we know must raise welfare, and ask how it affects import volume. It is clear from (18) that if only one good is subject to tariffs then import volume rises monotonically as the tariff is reduced towards zero. However, it does not follow that import volume must rise following a uniform radial reduction when many goods are subject to tariffs. The reason is that, as we have already seen, both  $\bar{T}$  and  $V$  fall in this case. Since, from (21),  $\bar{T}$  and  $V$  have opposite effects on import volume, we would therefore expect the overall effect to be ambiguous. To see this explicitly, substitute from the uniform radial reduction rule  $dT = -Td\alpha$ ,  $d\alpha > 0$ , into (20) and rewrite in terms of the generalised moments, so the change in import volume becomes:

$$\bar{s}^{-1}dM = \left[ \{1 - (1 - M_b)\bar{T}\}\bar{T} - (1 - M_b)V \right] d\alpha \quad (32)$$

(This is identical to equation (30) with  $\beta$  equal to zero.) Even when  $M_b$  and  $\bar{T}$  lie between zero and one, the expression on the right-hand side can be either positive or negative. With  $d\alpha$  positive, a high generalised mean tariff  $\bar{T}$  encourages an increase in imports, but this can be offset if the initial variance is high.

Next, consider the dual to this reform. We know from (31) that the Ju-Krishna reform (equation (28) with  $\delta$  equal to  $M_b$  and  $d\alpha$  negative) must raise import volume. Consider instead its effect on welfare. Substituting into the expression for welfare change (15) yields:

$$(\mu\bar{s})^{-1}e_u du = - \left[ \{1 - (1 - M_b)\bar{T}\}\bar{T} - (1 - M_b)V \right] d\alpha \quad (33)$$

Remarkably, this is exactly the same condition as (32), recalling that  $d\alpha$  is positive in (32) and negative here. We can combine these results and state them formally as follows:

*Proposition 4: Provided  $\mu$  is positive, the necessary and sufficient conditions for a uniform radial reduction in tariffs to raise import volume and for a Ju-Krishna reform to raise welfare are identical. Both these outcomes are encouraged, ceteris paribus, by low values of  $V$  and high values of  $M_b$  (assuming that  $M_b$  and  $(1-M_b)\bar{T}$  are less than one.)*

We can illustrate Proposition 4 using Figures 1 and 2. It implies that, if and only if the uniform radial reduction path  $AF$  lies in the half-space of import-volume-increasing movements from  $A$  (i.e., below the iso-import-volume locus denoted  $dM=0$  in Figure 1), then the Ju-Krishna path  $AC$  must also lie in the half-space of welfare-increasing movements from  $A$  (i.e., to the left of the iso-welfare locus denoted  $du=0$  in Figure 1). The intuition for this is clear in the special case where the initial tariffs are uniform.<sup>21</sup> Now the generalised variance  $V$  is initially zero, and the uniform radial reduction and Ju-Krishna reforms coincide with each other and with a uniform absolute reduction in  $T$ . Hence the  $du=0$  and  $dM=0$  curves coincide and there is no conflict between reforms which raise welfare and those which raise import volume. Higher values of  $V$  make a conflict more likely, as equations (32) and (33) show.

Figure 3, drawn in  $\{V, \bar{T}\}$  space, shows how the marginal propensity to spend on importables,  $M_b$ , interacts with the generalised variance  $V$  in Proposition 4. Each curve in the figure shows the values of  $V$  and  $\bar{T}$  which set the coefficient of  $dM$  in (32) and (33) equal to zero, with higher curves corresponding to higher values of  $M_b$ . Thus, for a given value of  $M_b$ , all points above the

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<sup>21</sup> Ju and Krishna (2000), in the second part of their Proposition 1, show that a uniform radial reduction in tariffs must raise import volume in this case. It corresponds to the horizontal axis in Figure 3.

corresponding curve show combinations of  $V$  and  $\bar{T}$  for which a uniform radial reduction in tariffs lowers import volume, and a Ju-Krishna reform lowers welfare.<sup>22</sup>

To conclude, it should be repeated that each cone shows only those regions in which an unambiguous increase in the target of interest is guaranteed. Identifying which special cases of the general reform rule (24) lie in one or other cone therefore yields tariff reforms that can be recommended to attain either target subject to mild assumptions about the values of  $\beta$ ,  $\bar{T}$ , and (in the case of import volume)  $M_b$ . If additional information is available then it may be possible to identify further tariff changes which can attain the desired goal. For example, Proposition 4 shows that if we have some information about the magnitude of  $M_b$ ,  $\bar{T}$  and  $V$  then we can predict whether import volume will rise following a uniform radial reduction in tariffs, and its dual, whether welfare will rise following a Ju-Krishna reform. In the absence of such additional information, there is likely to be a conflict between the objectives of raising welfare and increasing market access. The only tariff change which is guaranteed to achieve both goals, with no assumptions other than that  $\bar{T}$  and  $M_b$  lie between zero and one, is a uniform absolute reduction in  $T$  (i.e., a movement along  $AB$  in Figure 2), which reduces domestic prices proportionally.

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<sup>22</sup> Figure 3 can also be used to illustrate the effects on welfare of a uniform absolute reduction in  $\tau$ , which as we have seen moves the equilibrium along  $AH$ . This lowers the generalised mean tariff provided  $\bar{T}$  is less than one. However, it *raises* the generalised variance. The net effect on welfare is proportional to  $(1-\bar{T})\bar{T}-V$ , or  $(1-\bar{T})ST$ , which cannot be unambiguously signed even when all goods are substitutes. Hence this type of tariff reform is not helpful from a welfare perspective, though as we have seen, it is very important from the perspective of import volume. It is represented by the lowest curve in Figure 3 (that labelled  $M_b=0.0$ ), which shows that it is likely to reduce welfare unless  $V$  is very low.

#### 4. Relating Generalised to Observable Moments

So far we have shown how changes in welfare, market access and trade restrictiveness can be expressed in terms of the generalised mean and variance of the tariff schedule. These two generalised moments serve in effect as sufficient statistics for the whole  $n$ -by-one vector of tariff rates. Of course, the generalised moments are not independent of the structure of the economy: on the contrary, they are defined in terms of the general-equilibrium substitution matrix. But there is clearly a huge economy of information from the fact that everything that is relevant to small changes in welfare and market access can be summarised in terms of changes in the two moments. However, there is no guarantee that the generalised moments are closely related to the standard moments which can be calculated using only information on the tariff schedule and the levels of imports. In this section, we show that the generalised moments coincide with the standard moments in an interesting special case, where preferences take a homothetic constant-elasticity-of-substitution (CES) form, and where imports are imperfect substitutes for home-produced goods. The latter assumption follows Armington (1969) and is made in the vast majority of CGE models. Hence our result greatly enhances the usefulness of the generalised moments and the results based on them presented in previous sections.<sup>23</sup>

The trade expenditure function in this case can be written as follows:

$$E(\pi_0, \pi, u) = e(\pi_0, \pi, u) - g(\pi_0) = u\Pi(\pi_0, \pi) - g(\pi_0). \quad (34)$$

Here we have made explicit the dependence of both the expenditure function  $e$  and the GDP function  $g$  on the price of the numeraire good  $\pi_0$ , which as before is an aggregate of the prices

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<sup>23</sup> Anderson (1995) showed that generalised moments defined with respect to world prices coincide with standard moments when the trade expenditure function is Cobb-Douglas.

of all traded goods not subject to tariffs. Expenditure is linear in  $u$  because preferences are homothetic, and it is a separable function of the prices of all  $n+1$  goods, mediated through  $\Pi$ , which is a constant-elasticity-of-substitution aggregate price index defined over both  $\pi_0$  and  $\pi$ :

$$\Pi(\pi_0, \pi) = \left( \sum_{i=0}^n \beta_i \pi_i^{1-\sigma} \right)^{\frac{1}{1-\sigma}}, \quad \sum_{i=0}^n \beta_i = 1 \quad (35)$$

As for GDP, it is independent of  $\pi$  because of the assumption that imports are non-competing.

The key implication of this specification is the following:<sup>24</sup>

*Lemma 2: Given (34) and (35), the generalised or marginal trade weights  $\omega_i$  used in the construction of  $\bar{T}$  and  $V$  equal average trade weights  $\phi_i = \pi_i E_i / M$ .*

We can now state the main result of this section:

*Proposition 5: When the trade expenditure function takes the form given by (34) and (35), the generalised average tariff is equal to the trade-weighted average tariff, and the generalised variance of tariffs is proportional to the trade-weighted variance, both evaluated at domestic prices.*

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<sup>24</sup> To prove this, note that expenditure on a single good  $i$  is  $E_i = u \beta_i (\pi_i / \Pi)^{-\sigma}$  and expenditure on all goods is  $e = u \Pi$ . Hence average import shares are  $\phi_i = \pi_i E_i / v e = (\beta_i / v) (\pi_i / \Pi)^{1-\sigma}$ , where  $v$  is the share of imports in aggregate expenditure:  $v \equiv M / u \Pi$ . As for marginal import shares, differentiating the demand functions yields:  $\pi_i E_{ij} \pi_j = -\sigma M \phi_i (\delta_{ij} - v \phi_j)$ , where  $\delta_{ij}$  is the Kronecker delta (equal to one when  $i=j$  and zero otherwise). Recalling the definition of the elements of the normalised substitution matrix from (5), we can now express them as:  $S_{ij} = \phi_i (\delta_{ij} - v \phi_j) / (1-v)$ ; or in matrix form:  $S = (\Phi - \Phi v \Phi') / (1-v)$ . It follows that  $\omega_i = \sum_j S_{ij} = \phi_i$ .

The proof is immediate. The generalised average tariff becomes:

$$\bar{T} \equiv \iota' S T = \Phi' T = \frac{t'm}{\pi'm}. \quad (36)$$

which is simply the standard atheoretic trade-weighted average tariff at domestic prices. As for the generalised variance of tariffs, it becomes:

$$V = T' S T - \bar{T}^2 = \frac{T' \Phi T - \bar{T}^2}{1-\nu}. \quad (37)$$

The numerator of the final expression is the trade-weighted variance of tariffs at domestic prices:

$$\tilde{V} \equiv (T - \iota \bar{T})' \Phi (T - \iota \bar{T}) = T' \Phi T - \bar{T}^2. \quad (38)$$

This proves the proposition.

*Q.E.D.*

## 5. Conclusion

In this paper, we have developed a new approach to characterising the structure of tariff rates. Practical researchers have often attempted to summarise such structure in terms of the mean and variance of tariffs, but, to date, this approach has had no theoretical justification. Empirical measures which only use data on tariff levels and import shares fail to give an adequate picture because they ignore marginal responses. To deal with this problem, we drew on Anderson (1995) to introduce two generalised moments of the tariff structure. The generalisation involves weighting actual tariff rates by the elements of the substitution matrix, so the generalised moments incorporate information on marginal responses by construction. The central contribution of this paper is to show that the effects of tariff changes on welfare and import volume can be

fully characterised by their effects on the generalised mean and variance of the tariff distribution. The generalised moments thus serve as sufficient statistics for the vector of tariff rates.<sup>25</sup>

These generalised tariff moments are of interest in themselves. For example, they provide a partial rationale for the common practice of viewing increases in actual tariff variances as welfare-reducing. They also provide an invaluable intermediate step in assessing the effects of actual tariff changes on welfare and market access. In particular, we showed that their implications can be conveniently illustrated in terms of two "cones of liberalisation" in price space, one showing directions which are guaranteed to raise welfare and the other showing directions which are guaranteed to raise market access.

The other main contribution of the paper was to introduce a new radial reform rule for tariffs, which generalises the well-known uniform radial reduction rule by assuming that tariffs are moved uniformly towards or away from an arbitrary uniform tariff rate (not necessarily zero).<sup>26</sup> This rule allows high and low tariff rates to be changed at different rates, in the same way as many of the rules which have been proposed and applied in actual trade reform programmes. By characterising which members of our class of reforms lie in either of the two cones of liberalisation, we obtained many new results for the theory of trade policy reform. In particular,

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<sup>25</sup> The generalised moments can be viewed as index numbers which jointly summarise the tariff distribution. This raises the question of how they relate to the index numbers which we have introduced elsewhere, the Trade Restrictiveness Index (TRI) which gives the uniform tariff that is welfare-equivalent to a given tariff structure, and the Mercantilist Trade Restrictiveness Index (MTRI) which gives the uniform tariff that is import-volume-equivalent to a given tariff structure. (See Anderson and Neary (1996, 2003).) In the longer version of this paper we show that changes in the TRI and MTRI can be related to changes in the two generalised moments. Under very general conditions, small changes in tariffs raise the TRI uniform tariff  $\tau^\Delta$  by more than the MTRI uniform tariff  $\tau^\mu$  if and only if the generalised variance of tariffs rises.

<sup>26</sup> In the longer version of this paper we show that our approach also throws additional light on the concertina rule.

we showed that many different types of tariff reduction guarantee an increase in either welfare or market access, given only the assumptions that goods are not inferior on average and are not complementary with untariffed goods on average. Just as the tariff multiplier subsumes all the income effects in the economy into a single scalar, so the generalised average tariff subsumes all the cross-substitution effects.

A feature of our results is that the two cones of liberalisation do not intersect, except along one boundary, because welfare is negatively but import volume positively related to the generalised variance. This is not to say that there are no reforms which meet both objectives, since the cones give only sufficient, not necessary, conditions for meeting one or other goal. However, they cannot be characterised without more information on the structure of the economy than is usually assumed to be available in the theory of piecemeal trade policy reform. For practical policy-making, this can create a conflict between the two aims of any reform: negotiations on trade liberalisation face a difficult choice between tariff-cutting formulae which guarantee an improvement in domestic welfare and formulae which ensure an increase in market access (and so are likely to be acceptable to foreign exporters).

The generalised tariff moments depend on the general-equilibrium substitution matrix, which at best is observable with a lot of error. Hence applying them in practice requires care and judgement. Of course, if a computable general equilibrium model has been estimated for the economy, then they can be calculated explicitly. Alternatively, we can try to establish the properties of the generalised moments under special assumptions about the structure of the economy. This is the approach adopted in Section 4, where we showed that, if the trade expenditure function takes a CES form, the weights reduce to trade weights and the generalised

moments are proportional to observable trade-weighted moments. The CES form is extremely special of course. Nevertheless this result provides further insight into the role of inter-commodity substitution in mediating the effects of tariff changes, and also provides a partial justification for the practical use of trade-weighted tariff moments.

Type of	Effect on			
	$dt (= d\pi)$	$dT (\equiv \underline{\pi}^{-1}dt)$	$d\tau (\equiv (\underline{\pi}^*)^{-1}dt)$	$d\bar{T}$
Tariff Change				$dV$
Uniform Radial Reduction	$-td\alpha$	$-Td\alpha$	$-\tau d\alpha$	$-\bar{T}d\alpha$
Uniform Absolute Reduction in $T$	$-\pi d\alpha$	$-td\alpha$	$-(1+\tau)d\alpha$	$-d\alpha$
Uniform Absolute Reduction in $\tau$	$-\pi^* d\alpha$	$-(1-T)d\alpha$	$-td\alpha$	$-(1-\bar{T})d\alpha$
General Radial Reform	$-(t-\pi\beta)d\alpha$	$-(T-1\beta)d\alpha$	$-[\tau-(1+\tau)\beta]d\alpha$	$-(\bar{T}-\beta)d\alpha$
				$-2Vd\alpha$

**Table 1: Alternative Tariff Reform Rules**

Type of	Effect on
Tariff Change	$(\mu s)^{-1} e_u du$ $\bar{s}^{-1} dM$
Uniform Radial Reduction	$(\bar{T}^2 + V)d\alpha$ $[\{1 - (1 - M_b)\bar{T}\}\bar{T} - (1 - M_b)V]d\alpha$
Uniform Absolute Reduction in $T$	$\bar{T}d\alpha$ $[1 - (1 - M_b)\bar{T}]d\alpha$
Uniform Absolute Reduction in $\tau$	$[\bar{T}(1 - \bar{T}) - V]d\alpha$ $[\{1 - (1 - M_b)\bar{T}\}(1 - \bar{T}) + (1 - M_b)V]d\alpha$
General Radial Reform	$[\bar{T}(\bar{T} - \beta) + V]d\alpha$ $[\{1 - (1 - M_b)\bar{T}\}(\bar{T} - \beta) - (1 - M_b)V]d\alpha$

**Table 1: Alternative Tariff Reform Rules (cont.)**

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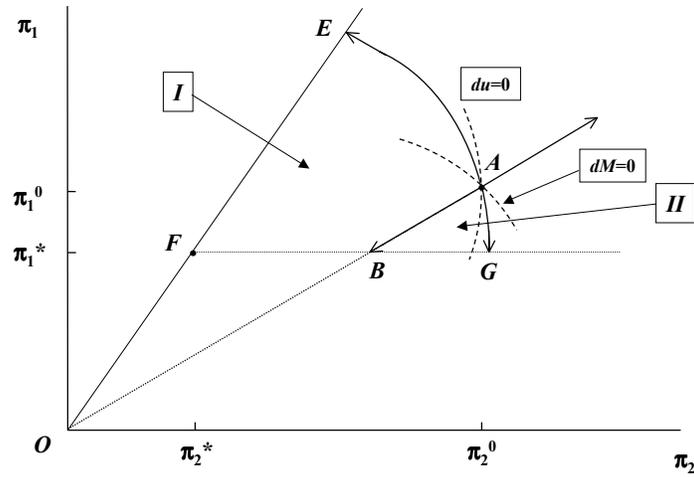
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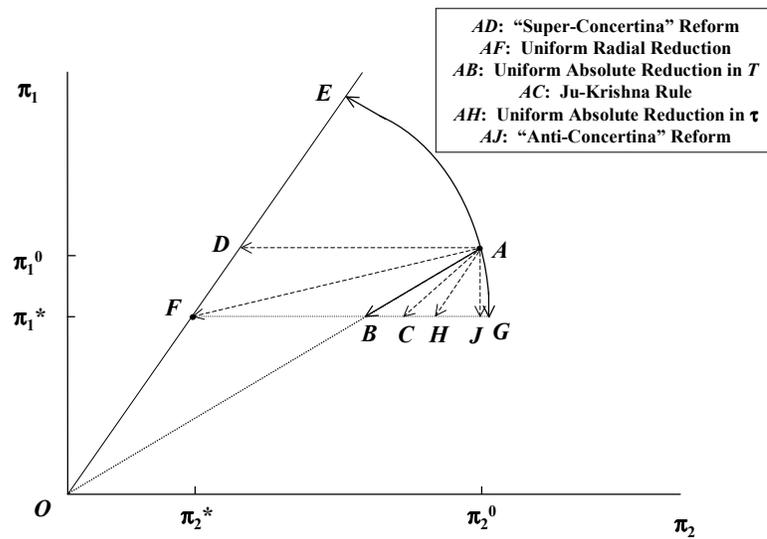
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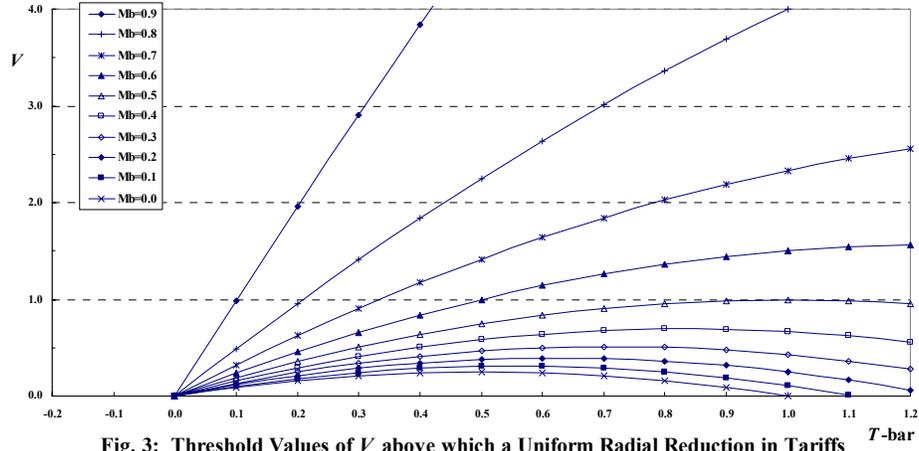
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**Figure 1: The Cones of Welfare-Increasing (I) and Market-Access-Increasing (II) Liberalisation.**  
 (Dashed lines denote iso-welfare and iso-import-volume loci.)



**Figure 2: Radial Reform Rules and the Cones of Liberalisation**



**Fig. 3: Threshold Values of  $V$  above which a Uniform Radial Reduction in Tariffs Lowers Import Volume and a Ju-Krishna Reform Lowers Welfare**