Partial Equilibrium Measures of Trade Restrictiveness

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Abstract

This paper examines the new partial equilibrium form of the Trade Restrictiveness Index recently used by the World Bank to measure the average level of tariffs and other restrictions on imports into a country, and the partial equilibrium form of the Mercantilist Trade Restrictiveness Index. The analysis is extended in two directions. First, we consider how non-tariff measures should be incorporated in the indices. This requires new concepts of the welfare-equivalent tariff rate and the import-equivalent tariff rate. Second, we look at the bias due to the neglect of general equilibrium effects. Australian and Japanese tariff data are used to illustrate the computation of the indices.

The problem of how best to measure the average level of tariffs and non-tariff measures which restrict trade in an economy is an important one, as trade restrictions have a substantial influence on the allocation of resources and on the level and distribution of social welfare in a tariff-imposing country. Trade restrictions of course also affect imports from the country's trading partners and, therefore, the welfare in these countries. Commonly, the average tariff in a country is measured either as the ratio of total customs duty to the total value of imports or as the unweighted average. However, it has been known since the work of League of Nations (1927) that the former measure is inadequate as the use of current imports under-weights those items with prohibitive or high tariffs and the latter is plainly an uninformed guess.

A major breakthrough was made in the theory of trade restrictions with the development of the concept of the Trade Restrictiveness Index (TRI) by Anderson and Neary (1994 and 2005). They produced an index of the average levels of restrictions that is a true (utility-constant) index and a general equilibrium measure which takes account of input-output relations and all other inter-relationships across markets in both demand and supply. The TRI is the uniform tariff that yields the same utility as a differentiated structure of tariffs.

As a general equilibrium measure, it has been presumed that a computable general equilibrium (cge) model of the economy is required to calculate the index. This is a severe limitation as it makes the computation complex and, in the absence of cge models associated with a time series of social accounting matrices and protection databases, it precludes the computation of a time series of the TRI. The complexity involved in estimating the index has limited the attempts to compute TRIs. Estimates of the TRI have been made for one or two years for the US (see Anderson and Neary, 2005) and a few other countries.

Feenstra (1995, p. 1562) derived a special case of the Trade Restrictiveness Index, on the assumption that tariffs are the only form of trade restrictions and all import functions are linear functions of own price only. The restrictions on the import functions eliminate all cross-market demand and supply effects of tariffs but it is an index which can be readily calculated without the use of a computable general equilibrium model. Anderson and Neary (2005) develop the analogous partial equilibrium form of the MTRI. The MTRI is the uniform tariff rate that yields the same level of imports as the differentiated structure of restrictions.

Recently, a group of economists at the World Bank has used this form of the TRI to calculate new measures of the TRI for 88 countries in the 1990s (Kee, Nicita and Olarreaga, forthcoming b). This is an audacious but inspired approach to the measurement of the TRI. Following this method, Irwin (2007) has calculated a time series of TRI for the US economy over the period from 1859 to 1961. Although these calculations do neglect general equilibrium effects, nevertheless, they result in measures which are a substantial improvement over standard measures of the average tariff level because they properly measure the welfare loss in own markets of each tariff. Kee, Nicita and Olarreaga (forthcoming b) also estimate the partial equilibrium form of the MTRI.

Section I reviews the partial equilibrium forms of the TRI and the MTRI. Section II shows how the TRI and MTRI should be extended to cover non-tariff measures. This requires new concepts of the welfare-equivalent tariff rate and the import-equivalent tariff rate. Section III presents an expression for the difference between the partial equilibrium and the general equilibrium forms of the TRI. Some of these results are illustrated using Australian and Japanese data in Section IV. Section V summarises the findings.

I

To calculate an average of differentiated levels of trade restrictiveness, we require a scalar index which combines the levels of restriction in all markets. The first issue that must be resolved is the purpose of the index. Is the index intended to measure the average level of restriction of international trade, or the effect on production or the total cost to consumers and producers of the tariffs which distort the border prices? In most countries the debate has been about the costs of protection to the economy. Consequently, the logical choice is a measure which indexes the welfare costs to the economy of a differentiated structure of restrictions, the TRI. However, if the focus is on the effects of the restrictions on other countries, the appropriate measure is the MTRI.

Consider first the partial equilibrium form of the TRI and assume that all trade restrictions are *ad valorem* tariffs restricting imports of at least some of the importable commodities. Assume too that all import demand functions are linear functions of own price alone. Under these assumptions, Feenstra (1995, p. 1562) showed that the TRI reduces to the simple form

$$T = [\sum_{i=1}^{n} t_i^2 w_i]^{\frac{1}{2}} \quad \text{where } w_i = (p_i^{*2} \mathrm{d}m_i / \mathrm{d}p_i) / (\sum_i p_i^{*2} \mathrm{d}m_i / \mathrm{d}p_i) \tag{1}$$

i indexes the goods subject to tariff distortions and t_i is tariff rate on good i. The weights, w_i, are positive and sum to unity. They reflect the shares in the changes in the value of imports induced by the tariffs. It is usual to rewrite the weights as

$$w_i \;=\; \varepsilon_i^* (p_i^* m_i^*) / \sum_i^n \varepsilon_i^* (p_i^* m_i^*) \tag{2}$$

where $\varepsilon_i^* < 0$ are the point elasticities of the import demand function in the free trade situation and ($p_i^*\ m_i^*$) are the values of imports in the free trade situation. These can be recovered from the observed values of trade in the actual tariff situation, given the import elasticities.

Thus, the partial equilibrium TRI can be calculated from data of the observed trade, the tariff rates and the values of the elasticities of import demand. In considering the welfare effects of tariffs, the TRI should be used in place of the standard measures such as the ratio of duty collected to the value of imports. Moreover, the TRI index can be applied to the larger set of all tradeables including exportables. Or it can be applied to a subset of importables; for example, the set of goods produced by some industry.

Its properties have been established. Since the weights are all positive, $\partial T / \partial t_i \geq 0$ for all i. Kee, Nicita and Olarreaga (forthcoming b) show that

$$T^2 = \bar{t}^2 + Var[t] + Cov[\tilde{\varepsilon}, t^2] \tag{3}$$

where $\bar{t}^2$ is the square of the arithmetic mean tariff and $\tilde{\varepsilon}$ is the set of normalised elasticities of the import demand curves. The variance term captures the importance of peak and high tariff rates. The covariance term enters because, given the tariff rates and import values, T depends on whether higher values of t_i are associated with higher or lower values of ε_i (see Equations (1) with (2)). Finally and importantly, an increase in the index as tariff rates change must lower the welfare of the economy.

If, instead the index is designed to measure the average level of restrictions of the volume of international trade rather than of the welfare of the tariff-imposing country, the appropriate index is the MTRI. The partial equilibrium form of the MTRI again under the assumptions that import demand is a function of own price alone, was obtained by (Anderson and Neary, 2005, p. 21). It is

$$I = [\sum_{i=1}^{n} t_i \, w_i] \quad \text{where } w_i = (p_i^{*2} \mathrm{d}m_i / \mathrm{d}p_i) / (\sum_i p_i^{*2} \mathrm{d}m_i / \mathrm{d}p_i) \tag{4}$$

This index is a true (import-constant) index of average tariff rates. More precisely, what is held constant is the volume of imports in constant prices. Like the partial equilibrium form of the TRI, this can be readily calculated from observed data.

The properties of this index too are straightforward. It is increasing in t_i for all i. Importantly, an increase in the index as tariff rates change must lower the volume of imports in constant prices.

Comparing the MTRI with the TRI, Anderson and Neary (2005, p.21) noted that the MTRI has the same weights as the TRI. A more informative way of expressing this is to note that the MTRI and the TRI are the means of order 1 and 2 respectively with the same weights.[1] (The mean of order r is $M = \left(\sum_{i=1}^{n} t_i^r w_i \right)^{1/r}$). It follows immediately from the Theorem of the Mean that $I \le T$, with the strict inequality holding provided the tariff rates are not all the same (Hardy, Littlewood and Polya, 1952, p. 26), as we can assume in any country that does not have free trade. Anderson and Neary (1994, 2005) noted that, for the general equilibrium form of the MTRI, the difference (T–I) increases as the dispersion of tariff rates increases. For the partial equilibrium form, this follows immediately by regarding the square of the TRI as the mean of squares of the tariff rates

$$T^2 = [\sum_{i=1}^{n} t_i^2 w_i] = E[t_i^2] = E^2[t] + Var[t] \tag{5}$$

where E denotes the expectation operator. Thus, the difference (T–I) increases as the dispersion (=variance) of tariff rates increases.

II

Before considering non-tariff measures and the possible bias due to the use of a partial equilibrium form, we need to derive the expressions for the TRI and MTRI.

Assume initially that all trade restrictions are *ad valorem* tariffs. Take a small economy which produces and consumes and imports from competitive world markets a fixed number of goods, n. There is one household in the economy. Assume, furthermore, that the import demand for each good, m_i, is a function of the own domestic price alone, $m_i = m_i(p_i)$. In the present context, since the TRI is a utility-constant measure, the import demand functions should be income-compensated demand functions, $m_i(p_i, u)$ where u is the chosen level of utility. In the trade policy context, it is natural to take the utility in the present tariff-distorted situation.

In a partial equilibrium analysis, the deadweight loss of welfare due to the imposition of a tariff t_i on good i, is determined by the function $\mathrm{d}m_i(p_i, u)$. For a non-small tariff on good i, the total loss is the integral

$$L_i = -\int_{p_i^*}^{p_i^*(1+t_i)} \mathrm{d}m_i \mathrm{d}p_i \tag{6}$$

Since, over the interval of integration, $p_i = p_i^*(1 + \tau_i)$, we can change the integrating variable to express the loss as a function of the tariff rate

$$\begin{aligned} L_i &= -\int_0^{t_i} p_i^* \mathrm{d}m_i \mathrm{d}\tau_i \\ &= -\int_0^{t_i} p_i^{*2} \tau_i \mathrm{d}m_i / \mathrm{d}p_i \mathrm{d}\tau_i \end{aligned} \tag{7}$$

This is the exact area of the triangular shape under the import demand curve.

If, however, we assume that the import demand function is linear, the welfare loss is given exactly by the area of the triangle

$$\begin{aligned} L_i &= -\tfrac{1}{2}\Delta m_i \Delta p_i = -\tfrac{1}{2}(\Delta m_i / \Delta p_i p_i^* t_i)(p_i^* t_i) \\ &= -\tfrac{1}{2}(p_i^* t_i)^2 \mathrm{d}m_i / \mathrm{d}p_i \end{aligned} \tag{8}$$

where now $\mathrm{d}m_i / \mathrm{d}p_i = const.$ for each i, and t_i are the actual discrete tariff rates. This is the Harberger Triangle, the sum of the change in producer surplus and consumer surplus net of the tariff revenue. If the import demand functions are not linear, this expression provides an approximation to the loss in Equation (6).

Equation (8) yields the fundamental result that the loss from the tariff is proportional to the square of the tariff rate. This holds because the tariff rate determines both the price adjustment and the quantity response to this adjustment. This insight is usually attributed to Harberger.[2]

With n importable goods each subject to some level of tariff, the aggregate loss is

$$L = -\tfrac{1}{2}\sum_{i=1}^{n}(p_i^* t_i)^2 \mathrm{d}m_i / \mathrm{d}p_i \qquad \mathrm{d}m_i / \mathrm{d}p_i = const. \tag{9}$$

The TRI, T, is the uniform tariff rate that yields the same loss of aggregate welfare. It is defined by the equation

$$-\tfrac{1}{2}\sum_{i=1}^{n}(p_i^* t_i)^2 \mathrm{d}m_i / \mathrm{d}p_i = -\tfrac{1}{2}\sum_{i=1}^{n}(p_i^* T)^2 \mathrm{d}m_i / \mathrm{d}p_i \tag{10}$$

Solving for T, we obtain

$$T = [\sum_{i=1}^{n} t_i^2 w_i]^{\frac{1}{2}} \quad \text{where } w_i = (p_i^{*2} \mathrm{d}m_i / \mathrm{d}p_i) / (\sum_i p_i^{*2} \mathrm{d}m_i / \mathrm{d}p_i) \tag{11}$$

This is of course the same expression as that derived by Feenstra as a special case of the general equilibrium expression. This derivation of the TRI explains why the squared terms appear in the TRI. It is due to Harberger's power of two. In the international trade policy context, this reveals the importance of tariff spikes and peak rates.

If, instead, the index is designed to measure the average level of restrictions of the volume of international trade rather than of the welfare of the tariff-imposing country, the appropriate index is the MTRI. The partial equilibrium form, *I*, is defined implicitly by the equation

$$\sum_{i=1}^{n} p_i^* m_i(p_i^*[1+t_i]) = \sum_{i=1}^{n} p_i^* m_i(p_i^*[1+I]) \tag{12}$$

Assume again that the import demand function is a linear function of own price $m_i = \alpha_i - \beta_i p_i$, with $\alpha_i > 0, \beta_i > 0$. Substituting this equation in (12) and solving for *I*, we have

$$I = [\sum_{i=1}^{n} t_i w_i] \quad \text{where } w_i = (p_i^{*2}\beta_i)/(\sum_i p_i^{*2}\beta_i) \tag{13}$$

Noting, from Equation (13), that $\beta_i = -\mathrm{d}m_i / \mathrm{d}p_i$, the weights in this equation may be written as

$$w_i = (p_i^{*2}\mathrm{d}m_i / \mathrm{d}p_i)/(\sum_i p_i^{*2}\mathrm{d}m_i / \mathrm{d}p_i) \tag{14}$$

Equation (13) with the weights defined in Equation (14) is the partial equilibrium form of the import-constant MTRI (Anderson and Neary, 2005, p. 21). More precisely, what is held constant is the value of imports in constant prices, that is, the volume of imports.

Now ntms can be incorporated into this framework using the notions of the equivalence and non-equivalence of protective instruments. An ntm and a tariff are “equivalent” if there is a level of an *ad valorem* tariff which replicates the effects of the ntm on *all* endogenous variables. The endogenous variables are the domestic price, the revenue and the quantity imported (and by implication, the quantities consumed and produced domestically). An ntm and a tariff are non-equivalent if there is no level of an *ad valorem* tariff which replicates the effects of the ntm on all endogenous variables.

When the only distortion in the market for some good is an ntm and this ntm is equivalent to a tariff in the sense above, the restrictiveness of the ntm is represented in the index by the equivalent *ad valorem* tariff. Some ntm’s fall into this category; for example, variable levies. Quotas also fall into this category if the conditions required for equivalence are satisfied and if the quota is auctioned or one treats the quota rents accruing to private quota-holders in the same way as revenues accruing to the government under a regime of tariffs only.

When this ntm is non-equivalent to a tariff, the invariable practice is to use the equivalent tariff rate defined as the rate which yields the same increase in the producer price; for example, Kee, Nicita and Olarreaga (forthcoming a) and the papers in Dee and Ferrantino (2005). We can call this rate the *producer price-equivalent* rate. But this practice is not correct in the context of the welfare-constant or import-constant index. By the definition of non-equivalence, this price-equivalent rate cannot replicate the effect on all endogenous variables and, therefore the effects on welfare and imports. Consequently, it is not the appropriate rate.

Consider first the TRI. The correct measure of the price effect for some commodity in this index is the *welfare-equivalent* rate, that is, the tariff rate which results in the same loss of welfare in the market concerned as the ntm creates. Curiously, this concept has not appeared in the literature on ntms as researchers have been content generally to establish equivalence or non-equivalence and, in the event of the latter, to use producer price-equivalence.

When the market for a good is distorted by a combination of measures that distort the consumer and the producer prices differentially, the welfare loss is

$$L_i = -\tfrac{1}{2}\{(p_i^* r_i)^2 dx_i / dp_i - (p_i^* s_i)^2 dy_i / dp_i\} \qquad (15)$$

where r_i is a rate of consumption tax and s_i is a rate of production subsidy and $r_i \neq s_i$. This is the sum of two triangles, on the assumption that the demand (x_i) and supply (y_i) functions are linear. The two effects of the changes in consumer and producer prices capture all of the welfare effects under the usual assumption that the market is competitive.

To derive the welfare-equivalent tariff rate, t_i^E, we set the loss in Equation (15) equal to the loss due to a tariff

$$(p_i^* r_i)^2 \mathrm{d}x_i / \mathrm{d}p_i - (p_i^* s_i)^2 \mathrm{d}y_i / \mathrm{d}p_i = (p_i^* t_i^E)^2 \mathrm{d}m_i / \mathrm{d}p_i$$

Solving this equation for t_i^E, we obtain

$$t_i^E = \{a_i r_i^2 + b_i s_i^2\}^2 \qquad (16)$$

where

$a_i = (\mathrm{d}x_i / \mathrm{d}p_i)/(\mathrm{d}m_i / \mathrm{d}p_i)$ and $b_i = -(\mathrm{d}y_i / \mathrm{d}p_i)/(\mathrm{d}m_i / \mathrm{d}p_i)$

Thus, the welfare-equivalent tariff rate is the mean of order two of the producer price and consumer price distortions, the weights being their share of the import response to the change in price.

As an example, suppose the production of a good is assisted only by an output-based subsidy. Then the welfare-equivalent rate will be less than the producer price-equivalent rate (= the *ad valorem* subsidy rate). If, further, the domestic demand and supply curves have the same slope (ignoring sign), with a tariff $\mathrm{d}m_i / \mathrm{d}p_i = \mathrm{d}x_i / \mathrm{d}p_i - \mathrm{d}y_i / \mathrm{d}p_i = -2\mathrm{d}y_i / \mathrm{d}p_i$. The welfare-equivalent rate is $t_i^E = (½s^2)^{½}$ $=\sqrt{(1/2)}$a or 0.71 per cent of the subsidy rate. As a second example, suppose a good is assisted by a combination of a 20 per cent tariff and a subsidy of 20 per cent in *ad valorem* terms. The consumer price increases by 20 per cent and the producer price by 40 per cent. If, again, the domestic demand and supply curves have the same slope, the welfare-equivalent rate is 31.62 (=$\{0.5(0.2)^2+0.5(0.4)^2\}^{1/2}$) per cent. This is 79 (31.62/40) per cent of the producer price effect.

The welfare-equivalent rate is less than the producer price-equivalent rate (= the *ad valorem* subsidy rate) in these examples because the tariff reduces welfare both through the increase in the producer price and the associated production loss and through the increase in the consumer price and the associated consumption loss.

Note that, in the second example, the effects of both measures on the producer price is additive. In symbols, let u_i denote the subsidy rate, expressed as a percentage of the world price. Then $p_i = p_i^*(1 + u_i + t_i) = p_i^*(1 + s_i)$ where $s_i = u_i + t_i$ is the proportional rate of change of the producer price. This is the *producer price-equivalent* rate. It is exactly the sum of the separate effects of the subsidy and the tariff rate.

In other cases, the costs of the distortions are not additive. For example, suppose now that the producers are assisted by a 10 per cent tariff and a quota that if applied alone would raise producer and consumer prices by 20 per cent. Now the combined effect of these two measures on producer and consumer prices is only 20 per cent.[3]

If, instead, the tariff rate on the same good is high enough, the quota will not be binding and producer and consumer prices rise only by the margin of the tariff. In still other cases, one measure or a combination of measures may be trade-prohibitive. In these cases, the relevant rate is the prohibitive tariff rate, $t_i^{\dagger}$.

The TRI in the presence of both tariffs and ntms can now be obtained by putting these welfare-equivalent tariff rates and prohibitive tariff rates into Equation (11). That is, Equation (11) can now be read with the tariff rates being t_i in the case of a good protected solely by a tariff, or t_i^E in the case of a good protected by one or more measures or $t_i^{\dagger}$ in the case of a good protected by a prohibitive tariff or ntm, as appropriate.

A similar procedure can be used to derive the import-equivalent tariff rate, t_i^I. When the market is distorted by a combination of measures that distort the consumer and producer prices differentially, the change in imports is

$$\Delta M_i = p_i^{*2} r_i dx_i / dp_i - p_i^{*2} s_i dy_i / dp_i \tag{17}$$

with $r_i \neq s_i$. The import-equivalent tariff is defined by the equality

$$p_i^{*2}(dx_i / dp_i) r_i - p_i^{*2}(dy_i / dp_i) s_i = p_i^{*2}(dm_i / dp_i) t_i^I$$

Hence,

$$t_i^I = a_i r_i + b_i s_i \qquad a_i = (\mathrm{d}x_i / \mathrm{d}p_i)/(\mathrm{d}m_i / \mathrm{d}p_i) \text{ and}$$

$$b_i = -(\mathrm{d}y_i / dp_i)/(dm_i / dp_i) \tag{18}$$

Thus, the import-equivalent tariff rate is a weighted mean of the rates of distortion of consumer and producer prices.

In the first example in which a good is assisted only by an output-based subsidy and the demand and supply curves have the same slope, we find again that the import-equivalent tariff rate is not equal to the producer price-equivalent tariff rate. In fact, t_i^I = ½a. It is exactly one half this rate. The explanation is simple. The import tariff affects both the domestic demand and the domestic supply whereas the subsidy affects on the supply side of the market.

As the second example, the good is assisted by a combination of a 20 per cent tariff and a subsidy of 20 per cent in *ad valorem* terms. If, again, the domestic demand and supply curves have the same slope, the import-equivalent rate is 30 $(= 0.5(0.2) + 0.5(0.4))$ per cent. That is, it is 75 per cent of the producer price effect.

The MTRI in the presence of both tariffs and ntms can now be obtained by putting these import-equivalent tariff rates and prohibitive tariff rates into Equation (11) for those goods subject to ntms.

Thus we find that the tariff rate which is equivalent to an ntm or a combination of measures differs between the TRI and the MTRI. In the first example of a subsidy alone, the import-equivalent rate is ½ the price-equivalent rate, not √½ of it as it was with the welfare-equivalent tariff rate. The tariff rate which has an effect on welfare that is equivalent to a subsidy is once more due to the power of two that operates in the welfare losses. By comparison, in the import losses due to border interventions the power of one operates, so to speak.

In general, when one seeks a tariff rate which is equivalent to an ntm or ntms, the rate will depend on the objective of the comparison; on whether one is examining the effects of ntms and tariffs on welfare or on imports. This result has not appeared in the literature on the equivalence of tariffs and ntms to our knowledge.

III

In order to know whether these partial equilibrium forms of the TRI and the MTRI are reliable indicators of the average levels of trade restrictions, we need to compare the partial equilibrium forms with the general equilibrium forms. The partial equilibrium forms are a drastic simplification as they ignore all general equilibrium effects.

Consider first the TRI. In the partial equilibrium form, the import demand functions are a function of own price alone, $m_i = m_i(p_i, u)$. Equation (7) above gives the exact area of the triangular shape under the import demand curve for one good. With *n* importable goods subject to some level of tariff, the aggregate loss is

$$L = -\sum_{i=1}^{n} \int_0^{t_i} p_i^{*2} \tau_i \mathrm{d}m_i / \mathrm{d}p_i \mathrm{d}\tau_i \tag{19}$$

In the general equilibrium form, the general equilibrium import demand functions are

$$m_i = m_i(p, u) \tag{20}$$

where $p = (p_1, \ldots, p_n)$ is the vector of prices of the *n* goods and *u* is the chosen utility level. When the prices of tradeables change because of a regime of tariffs, the generalised surplus measure is the line integral

$$L = -\int_0^{t} \sum_{i=1}^{n} p_i^{*2} \tau_i \mathrm{d}m_i / \mathrm{d}p_i \mathrm{d}\tau_i \tag{21}$$

where the upper limit of the integration, *t,* is the set of tariff rates in the tariff-distorted situation.

This line integral in Equation (21) can be compared with the sum of the integrals for the independent demand curves in Equation (19), which are based on the assumption of zero cross-price effects. In Equation (21), $\mathrm{d}m_i = \mathrm{d}m_i(p, u)$. As the tariff rates on other goods are increased over the path of the integration,[4] the demand curves as a function of own price will shift. They will shift to the right (left), causing the surplus to increase (decrease), as $\partial^2 m_i / \partial p_i \partial p_j > (<)\ 0$ for $j \neq i$; that is, as the goods *i* and *j* are trade substitutes (complements). If all goods are trade substitutes (at all prices), all cross-price effects are positive and they increase the loss of surplus from a given set of tariffs, just as substitution relations increase the generalised surplus in demand theory (see, for example, Ng, 1983, p.95).

Some pairs of goods are net substitutes in both production and consumption and, therefore, are substitutes in trade. However, this restriction is extremely strong if applied to all goods. In production, many goods are used as intermediate inputs in the production of other goods. In such cases the pairs of goods are net complements unless the substitutability in demand is strong. Furthermore, the introduction of taxes on inputs and the possibilities of fragmented production introduce additional costs. The output of the final goods now depends on the effective rates of protection which are generally much higher than the nominal rates, and if intermediate inputs are themselves produced domestically, protection of these goods adds further deadweight losses. In general some of the additional general equilibrium terms will be negative and some positive.

Understatement (overstatement) of the welfare losses from trade restrictions does not, however, imply that the value of the general equilibrium index is understated (overstated) by the partial equilibrium index. This index, G, is defined implicitly by the equation

$$\int_0^t \sum_{i=1}^{n} p_i^{*2} \tau_i \mathrm{d}m_i / \mathrm{d}p_i \mathrm{d}\tau_i = \int_0^T \sum_{i=1}^{n} p_i^{*2} G \mathrm{d}m_i / \mathrm{d}p_i \mathrm{d}\tau \tag{22}$$

The understatement (overstatement) affects the right-hand side of this equation too because the general equilibrium effects increase the welfare loss from a uniform tariff.

The partial equilibrium TRI, in this general (linear or non-linear) case, is defined by the equation

$$\sum_{i=1}^{n} \int_0^{t_i} p_i^{*2} \tau_i \mathrm{d}m_i / \mathrm{d}p_i \mathrm{d}\tau_i = \sum_{i=1}^{n} \int_0^{t_i} p_i^{*2} T \mathrm{d}m_i / \mathrm{d}p_i \mathrm{d}\tau_i \tag{23}$$

If the import functions are linear in own price, the partial equilibrium equation reduces to that in Equation (10) above:

$$\sum_{i=1}^{n} (p_i^* t_i)^2 \mathrm{d}m_i / \mathrm{d}p_i = \sum_{i=1}^{n} (p_i^* T)^2 \mathrm{d}m_i / \mathrm{d}p_i \tag{10}$$

Comparing Equations (10) and (22), the general equilibrium equation can be rewritten as

$$\sum_{i=1}^{n} (p_i^* e_i t_i)^2 \mathrm{d}m_i / \mathrm{d}p_i = \sum_{i=1}^{n} (p_i^* e T)^2 \mathrm{d}m_i / \mathrm{d}p_i$$

where e_i is the adjustments to the tariff rates required to equate each of the terms in the left-hand of Equations (10) to that of (22) and e is the adjustment to the uniform rate required to equate the right-hand sides of the two equations. Hence, the general equilibrium form of the TRI can be written as

$$G = \left(\sum_{i=1}^{n} \tilde{e}_i t_i^2 w_i \right)^{1/2} \tag{24}$$

$\tilde{e}_i = e_i/e$ is the normalised difference between the general equilibrium assessment of the effect on the market for good *i* and the partial equilibrium assessment, an error term. We can regard $\tilde{e}$ and t^2 as jointly distributed "random variables" with observed values of $\tilde{e}_i$ and t_i^2. Following the same steps as used in the derivation of Equation (9) above, we get[5]

$$\begin{aligned} G^2 &= E[\tilde{e}]\{\bar{t}^2 + Var[t]\} + Cov[\tilde{e}, t^2] \\ &\simeq \bar{t}^2 + Var[t] + Cov[\tilde{e}, t^2] \end{aligned} \tag{25}$$

if E[$\tilde{e}$] $\simeq$ 1. By contrast, *T* is obtained from Equation (24) with $\tilde{e}_i = 1$ for all *i*. Hence, the difference between the two forms is due to the covariance between $\tilde{e}$ and t^2. The general equilibrium form of the TRI will be understated (overstated) by the partial equilibrium form if and only if the error terms for each good and the squares of the tariff rates are positively (negatively) correlated.

A similar line of argument applies to the MTRI. As with the general equilibrium form of the TRI, we can rewrite the equation defining the general equilibrium form of the MTRI as

$$\sum_{i=1}^{n} p_i^* m_i(p_i^*[1 + u_i t_i]) = \sum_{i=1}^{n} p_i^* m_i(p_i^*[1 + uI]) \tag{26}$$

On the left-hand side of this equation, if all pairs of goods are trade substitutes, the partial equilibrium analysis (with $\tilde{u}_i = 1$ for all i) will understate the magnitude of the fall in international trade if trade substitutability predominates.

The general equilibrium form of the MTRI, J, can be written as

$$J = [\sum_{i=1}^{n} \tilde{u}_i t_i \, w_i] \quad \text{where } w_i = (p_i^{*2} \beta_i)/(\sum_i p_i^{*2} \beta_i) \tag{27}$$

$\tilde{u}_i = u_i/u$ is the normalised error between the general equilibrium assessment of the effect on the market for good *i* and the partial equilibrium assessment, an error term. Now, this general equilibrium form of the MTRI can be written as

J = E[$\tilde{u}$ *t*] = E[$\tilde{u}$] E[*t*] + Cov[*t*]

$$\simeq \ \mathrm{E}[t] + \mathrm{Cov}[t] \qquad \text{if } E[\tilde{e}\ ] \simeq 1 \qquad\qquad (28)$$

In the case of the MTRI, it is the tariff rates, not the tariff rates squared, that enter the index. The bias due to the neglect of general equilibrium effects will, therefore, depend on the covariance between the understatement or overstatement of the effects on imports in each market and the tariff rates.

IV

The use of the partial equilibrium forms of the TRI and the MTRI can be illustrated from data on tariff rates. Computation of the partial equilibrium forms requires data on imports and duty collected by tariff level and the elasticities of import demand. The tariff revenue and import data should be disaggregated to the level of the tariff line, which is the level at which the tariff classification determines the tariff rate that is applied. If the data are collected at a more aggregated level, the TRI will be underestimated as it will omit the intra-group variance of tariff rates.

As an example, Australia publishes import data at the tariff item level. Currently the level at which the tariff rates are specified is the 8-digit level of the Harmonised System. To examine the effect of using a TRI in place of the standard arithmetic mean index of tariff levels, we consider the data for one year, 2001-2002.

The relative frequency distribution of tariff rates is shown in Figure 1. The distribution is bimodal. The first and highest mode is the zero rate; 58 per cent of imports by value entered duty-free in that year (2001-02). The second mode is 5 per cent which accounts for 22 per cent of imports by value.

For this year we compute various estimates of the average level of tariffs in this distribution. We start with the usual statistic of the average duty, obtained by dividing the total duty collected by the total value of all actual import clearances and expressing the quotient as a percentage.[6] By simple rearrangement of terms, this is

$$T = \sum_{i=1}^{n} (V_i) t_i / \sum_{i=1}^{n} V_i$$
$$= \sum_{i}^{n} t_i u_i \qquad \text{where } u_i = V_i / \sum_{i}^{n} V_i \tag{29}$$

$V_i t_i$ is the value of duty collected and V_i is the import value of good *i* at world prices. This measure is, as is well-known, the weighted arithmetic mean of the tariff rates, using current period weights.

To obtain the TRI, we need to make two adjustments to this crude average. The first is to the weights. The second adjustment is the calculation of the mean of order 2, the TRI, in place of the arithmetic mean.

Free trade import shares cannot be observed. It is possible to rewrite the weights in terms of the elasticities and the values of imports in the *protected* trade situation. Using the relation between the domestic price and the world price, $p_i = p_i^*(1 + t_i)$, and the definition of the elasticities, the weights in Equation (2) can be rewritten as

$$w_i \;=\; [\varepsilon_i/(1+t_i)](p_i^* m_i) / \sum_{i}^{n} [\varepsilon_i/(1+t_i)](p_i^* m_i) \tag{30}$$

Here ε_i and $(p_i^* m_i)$ are the elasticities and the values of imports (at world prices), respectively, in the protected trade situation. In the absence of any information about the elasticities, the assumption can be made that the import demand elasticities are the same for all commodities. The weights then reduce to

$$w_i \;=\; [(p_i^* m_i)/(1+t_i)] / \sum_{i}^{n} [(p_i^* m_i)/(1+t_i)] \tag{31}$$

This expression for the weights has the considerable advantage that the import values are the observed values.

The second adjustment is to calculate the mean of order 2, the TRI, rather than the mean of order 1. This is done using both the actual protected trade import shares and the actual protected trade import shares adjusted for the tariff rates (Equation (31)). By calculating estimates of the average level of tariff for both the arithmetic mean and TRI with the distorted trade weights and with the adjusted protected trade situation weights, we can isolate the effects of changing the weighting system from those of changing the formula for the mean.

Four estimates of the average rate of duty for all imports into Australia in the year 2001–02 were calculated (Table 1). The estimate in row 1 of 2.7 per cent is the crude statistic calculated by simply dividing total duty collected by the total value of all import clearances. This is the figure usually cited for the average tariff.

With both adjustments, the average tariff in row 4 is now 5.0 per cent. This is a much higher number. Although their calculations differ in some respects from those in Table 2, Kee, Nicita and Olarreaga (forthcoming b) and Irwin (2007) also obtained TRI estimates which were much larger than the conventional arithmetic mean measures.

The other rows allow us to break this difference into a component due to the tariff adjustment of the weights and a component due to the use of the mean of order 2 rather than the mean of order 1. Row 2 provides the arithmetic mean calculated using the tariff-adjusted protected trade weights (i.e., the estimated free trade weights) rather than the actual protected trade weights. The estimate is 2.5 per cent. Thus, using the tariff-adjusted (or corrected) distorted trade weights makes little difference.

This adjusted rate is actually the MTRI. The MTRI is closely approximated by the standard measure of the average tariff level.

Comparing Row 3 with Row 1, or Row 4 with Row 2, the effect of using the mean of order 2 rather than the mean of order 1 can be seen. In the first comparison (with protected trade weights) the average is almost doubled and in the second (with protected trade shares adjusted for the tariff rates) it is doubled. Thus, the adjustment for the formula used to calculate the average produces the larger changes in the average tariff levels. This calculation shows the vital importance of entering the tariff rates properly.

The difference between these two components is to be expected. In general, the mean of order two is more sensitive to errors in the rates of distortions than to errors in the weights. Indeed, partially differentiating *T* with respect to ε_i and then t_i , one finds that the elasticity of *T* with respect to t_i is twice that with respect to ε_i . Consequently, more effort should be put into calculation of the rates of distortion.

Non-tariff measures are important in several sectors of the economy but especially so in agriculture. To illustrate the insight provided through Equation (16) on the correct value of the tariff equivalent, WTO and OECD data for Japan were used. Applied tariff rates, and specific tariffs were obtained for the year 2005 on nine commodities at the HS6 level from the WTO database (WTO, 2008). From the OECD PSE/CSE database (OECD, 2008), nominal rates of protection were obtained for producers and consumers. Nominal rates of assistance were calculated using the producer support estimates from that database.[7]

A comparison of the applied tariff rates and the nominal rates of assistance provided an indication of which commodities were supported by domestic instruments in addition to tariffs. Of the nine commodities chosen, three were assisted by *ad valorem* tariffs only (beef and veal, poultry meat and mandarin oranges), one was supported by a domestic subsidy only (soyabean) and five were supported by a combination of tariffs and domestic instruments (cabbage, wheat, rice, strawberries and onions). For wheat and rice, the tariffs imposed are both *ad valorem* and specific. The latter were converted to *ad valorem* equivalents using the prevailing border prices.

The tariff equivalents of border and domestic support were calculated using Equation (16) for the five commodities subject to a mixture of tariff and ntms and the one commodity subject to a domestic instrument only. In place of the slopes of the domestic demand, supply and import functions, the corresponding elasticities were[8] used. The elasticities of the domestic functions were obtained from an UNCTAD database (UNCTAD, 2008) and the import elasticity was calculated as $\varepsilon_i = \delta_i x_i / m_i - \sigma_i y_i / m_i$, where, for the *i*th commodity, δ_i is the price elasticity of domestic demand, x_i is the quantity demanded, σ_i is the price elasticity of domestic supply, y_i is the quantity supplied and m_i is the quantity imported.

The values for r_i and s_i (in Equation (16)) were the values for the nominal rates of assistance to consumers and producers, respectively, that were calculated from the OECD database (see Table 2). The observed (distorted) values of production, consumption and imports were taken from the OECD database and adjusted using the procedure in Equation (30). The computed values of t_i^E for the six commodities, and the applied tariff, t_i, for the remaining three commodities are shown in Table 2. It should be noted, following from the discussion in section II above, that the tariff-equivalent rate for soyabean is not the domestic subsidy rate, s, of 1.11, but a rate of approximately one half of that value, namely, 0.57.

Making use of Equations (11) and (13), provides the TRI and the MTRI, respectively, for this subset of agricultural products (Table 2). The value of the TRI is 1.57. This means that the uniform, *ad valorem* tariff rate that is welfare-equivalent to all forms of intervention is 157 per cent. On the other hand, the value of the MTRI is 0.84, meaning that the uniform, *ad valorem* tariff rate that is import-equivalent to all forms of support is 84 per cent.

To investigate the sensitivity of these results to the values of the elasticities, the weights were re-calculated using Equation (31) in which the elasticities do no appear in the calculation of the weights. The resulting values for the TRI and the MTRI were 1.38 and 0.69, respectively. Hence, the TRI is more sensitive than is the MTRI to the elasticities and, thus, the weights. The more important conclusion that has been illustrated again by these data is that, if the welfare effect of intervention at the border and behind the border is the variable of interest, then it is vital to use the mean of order 2 and not the mean of order 1. The mean of order 1 grossly underestimates the welfare losses generated by the policy instruments of intervention.

V

International trade theory indicates that empirical researchers should use the TRI to measure average levels of tariffs and other trade restrictions if they are concerned with the welfare losses due to a regime of trade restrictions. They should use the MTRI if they are concerned with the effects on imports.

Other writers have shown that the partial equilibrium form of the TRI can be derived under the assumption that all import demand functions are linear. It turns out to be the mean of order two, not the arithmetic mean. This mean incorporates Harberger's power of two, the result that the welfare loss from a tariff is proportional to the square of the tariff rate. This feature captures the much larger welfare losses associated with tariff spikes and peaks. The partial equilibrium form of the MTRI is the mean of order one, the ordinary arithmetic mean of the distortion rates. The partial equilibrium forms of the TRI and the MTRI can be calculated from observed data of tariff rates and the actual imports shares in the protected situation.

Multilateral organisations such as the WTO and the World Bank compare tariffs and ntms across countries, at time for all imports and at times for commodity groups. Other multilateral organisations make comparisons across countries of the average height of trade restrictions in sectors: for example, the OECD annually monitors the height of restrictions on agricultural trade in OECD countries. In all of these cases a partial equilibrium TRI is preferable to standard average measures because it recognises the power of two.

In the presence of ntms, we show that the TRI and the MTRI can each be calculated in two stages. The first stage is, in the case of the TRI, to calculate the welfare-equivalent tariff rate in each market and, in the case of the MTRI, to calculate the import-equivalent tariff rate in each market. Then these rates are inserted in the standard expression for the TRI and the MTRI, whichever is being used. Thus, these indices can readily accommodate ntms. However, these commodity-specific equivalent rates are not the producer-price equivalent rate, as usually supposed. Moreover, we find that, for markets in which one or more measures result in differential producer and consumer price effects, the welfare-equivalent and the import-equivalent tariff rate are not the same.

The partial equilibrium form may either underestimate or overestimate the general equilibrium forms. The bias depends on the covariance between the normalised error terms and the tariff rates.

For a sample of Australian tariff data in 2001-02, adjusting the order of the mean from 1 to 2 increases the measured levels of the average tariff while adjusting the weights decreases it marginally. The effect of using the mean of order two is particularly great. Both adjustments together almost double the measured level of the average tariff compared to the arithmetic mean with actual import weights. However, the MTRI is closely approximated by the standard measure of the average tariff level. Some examples of ntms using Japanese data for selected agricultural commodities indicate that the calculation of the welfare-equivalent tariff or the import-equivalent tariff rate, as appropriate in place of the standard producer price-equivalent rate is crucial as these rates diverge considerably.

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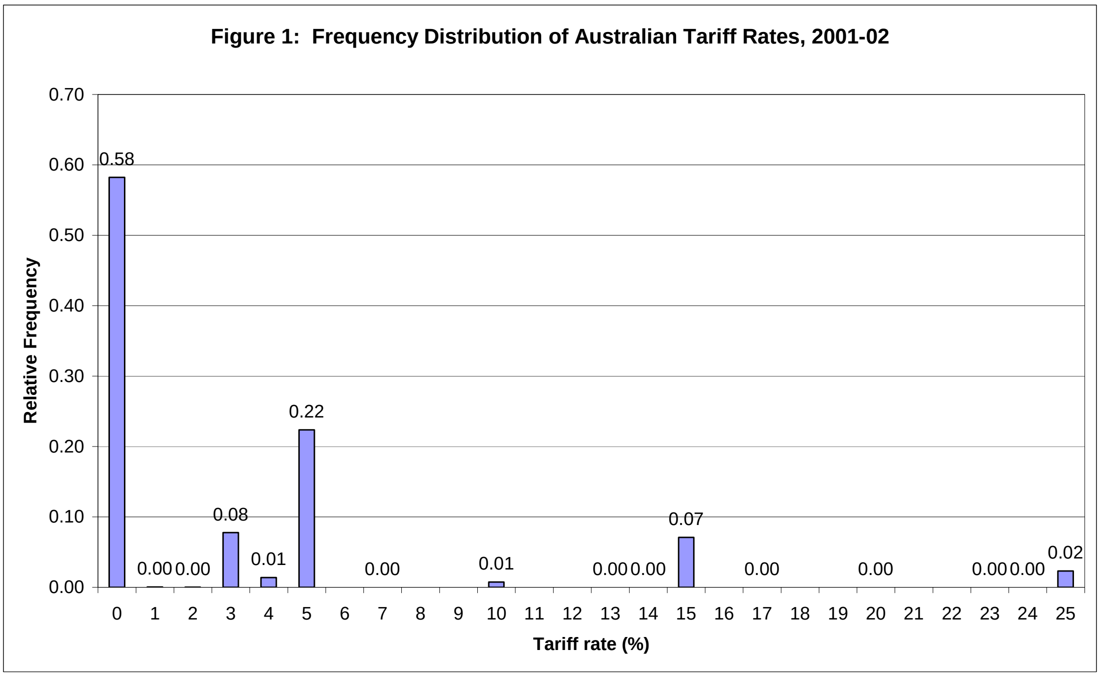

Note: There is a tariff rate of 62 per cent that has a relative frequency of 0.00008 and which has not been shown in the Figure.

Table 1: Estimates of the Average Tariff Rate, Australia, 2001-02

		(%)
1.	Arithmetic mean (Duty collected/total import clearances)	2.7
2.	Arithmetic mean with tariff-adjusted protected trade weights (MTRI)	2.5
3.	Mean of order 2 using actual import weights	5.3
4.	Mean of order 2 using tariff-adjusted protected trade weights (TRI)	5.0

Table 2: Estimates of the Average Tariff Equivalent of Tariffs and NTMs:

Selected Agricultural Commodities in Japan

HS6 code	**Product**	**Nature of Support**	**Tax/subsidy rates[a]**			**Welfare tariff-equivalent**	**Import tariff-equivalent**
			t	*r*	*s*		
020110	beef and veal	tariff	0.39	0.39	0.39	0.39	0.39
070490	cabbage	tariff plus domestic support	0.04	2.19	2.20	2.19	2.19
100190	wheat	specific and *ad valorem* tariffs plus domestic support	0.44	0.44	4.72	2.02	1.19
100620	rice	specific and *ad valorem* tariffs plus domestic support	4.26	4.26	4.42	4.38	4.38
120100	soyabean	domestic support	0	0	1.11	0.57	0.06
020718	poultry meat	*ad valorem* tariff	0.12	0.12	0.12	0.12	0.12
080520	mandarin oranges	*ad valorem* tariff	0.17	0.17	0.17	0.17	0.12
081010	strawberries	*ad valorem* tariff plus domestic support	0.06	0.11	0.11	0.11	0.11
070310	onions	*ad valorem* tariff plus domestic support	0.07	3.11	3.11	3.10	3.10
						TRI	**MTRI**
						1.57	0.84

Note: a *t* is the *ad valorem* equivalent of the applied tariff rates; *r* is the consumer tax equivalent of tariffs and domestic intervention; and *s* is the producer subsidy equivalent of tariffs and domestic support

ENDNOTES

[1] By changing the trade weights to welfare weights, the mean of order 2 can be written as a mean of order 1. The weights in this arithmetic mean are the marginal effects on welfare of a change in the tariff rate. They are themselves an increasing linear function of the tariff rate. This is the partial equilibrium analogue of the result obtained for the general equilibrium form by Anderson and Neary (1994, Equation (6)).

[2] In fact, the square result was discovered by Dupuit (1844), more than 100 years before Harberger, while analysing the welfare loss resulting from commodity taxation. In his words, "the loss of utility increases as the square of the tax." (Dupuit, 1844, p. 281). Dupuit's contribution to consumer surplus and welfare analysis is considered in Humphrey (1992).

[3] However, if the quota is auctioned, the price effects of the quota and the tariff are additive.

[4] This integration is not path-dependent because the import demand functions are income-compensated.

[5] One can expect that E[$\tilde{e}_i$] $\simeq$ 1. Note that the weights used in the derivation of this equation are different than those in Equation (3).

[6] One correction was made to the statistics. In Australia, some imported goods are subject to tariff rates which match the domestic rate of excise duty levied on like goods produced in Australia. There is therefore no protective margin. For the purpose of computing levels of protection, customs duties collected on these goods should be, and were, excluded.

[7] The nominal rate of assistance for producers is defined as [($PSE/Q.P_b$) + 1] and the nominal rate of assistance for consumers is defined as [($CSE/Q_c.P_b$) + 1], where *PSE* is the producer support estimate, QP_b is the value of production at border prices, Q_cP_b is the value of consumption at border prices (OECD, 2006, pp. 19-20).