Evaluating the Robustness of Trade Restrictiveness Indices

by

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Abstract

This paper examines the robustness of trade restrictiveness indices (TRIs) and shows they can be quite sensitive to alternative model structures (e.g. specific or mobile factor models). Also, the paper points out that in assessing trade restrictiveness over time, researchers need to be aware that changes in economic structure (e.g. factor accumulation) will alter the calculated values of the TRIs for unchanged trade policy. Therefore, researchers need to adjust the calculated values of TRIs for changes in economic structure if one wants a measure of the restrictiveness of trade policy only.

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I. Introduction

Over the last decade, there has been a great deal of interest in the relationship between a country's degree of openness to international trade and economic growth. A central issue is how to measure openness to trade in an economically meaningful way. In a series of papers and a book, Anderson and Neary (1996, 2005) developed a trade restrictiveness index (TRI) that has a firm foundation in economic theory and that can be implemented in practice. The TRI is defined as the uniform deflator, or scaling factor, applied to the prices of imported goods that would produce the same effect on real income as the country's differentiated structure of tariffs. Alternatively, trade restrictiveness is sometimes measured by computing the uniform tariff rate that is equivalent, in welfare terms, to the country's existing tariff structure—the uniform tariff equivalent (UTE). Anderson and Neary (1994), Lloyd and MacLaren (2002), and O'Rourke (1997) have all calculated TRIs using various types of computable general equilibrium (CGE) models, while Kee, Nicita, and Olarreaga (2009) calculated another type of trade restrictiveness index, the mercantilist trade restrictiveness index (MTRI), using a partial-equilibrium methodology explained in Feenstra (1995). Lloyd and MacLaren (2010) compute TRIs using a methodology that goes beyond the partial equilibrium approach of Feenstra (1995), but they do not employ a fully specified general equilibrium model.

Unfortunately, there has not been much work to date that examines how robust calculated TRIs are to alternative model structures and economic environments. This paper has two purposes. First, it explores the robustness of TRI calculations to different CGE model structures. Anderson and Neary (2005) report TRIs for twenty five countries, using a

CGE model that was identical in structure for each country and that used the same elasticity values, but employed data specific to each country. Their results showed that the values for the TRIs, and the ranking of countries' restrictiveness, were generally insensitive to alternative elasticity values. So far, there has been very little exploration of how alternative model structures affect the calculation of TRIs and this paper addresses this issue. To date, O'Rourke (2002) is the only other paper to address this question, but he explored the sensitivity of TRI calculations to the specification of consumer demand.

The second purpose of this paper is to demonstrate that the calculated value of a TRI can change as a result of economic growth, i.e. factor accumulation, even though tariff rates remain unaltered. Typically, TRIs are estimated for two points in time and the values compared to reach a judgment regarding whether the country has become more or less open to international trade. In doing so, however, analysts typically do not take into account changes in the structure of the economy that may have taken place between the two time periods—changes that would affect the welfare cost of a country's tariffs and therefore, its TRI. It turns out that a country's TRI could rise or fall with factor accumulation, depending, among other things, on the bias of the accumulation. This paper points out that this may be a non-trivial issue for rapidly growing economies, such as China.

II. Robustness of TRI Calculations

This section reports the results of some sensitivity tests on calculated TRIs using a CGE model of a hypothetical economy. The objective is to determine how sensitive the calculated TRIs are to alternative values of the elasticity of substitution among factors of production, and to alternative model structures. Anderson and Neary (1994) examined the sensitivity of TRIs for Colombia to alternative values for the elasticities of final demand, intermediate demand, and transformation and concluded that the calculated values of the TRIs were relatively insensitive to alternative elasticity values. This conclusion was derived from a particular CGE model, one in which there is no local production of the importable good, no domestic consumption of the exportable, and no explicit factor markets. Instead of modeling factor markets explicitly, Anderson's model employed a transformation function between exportables and nontraded goods, and an elasticity of transformation governs how easy it is to shift production between the two types of goods.

O'Rourke (1997) used the same model structure as Anderson to assess how sensitive calculations of TRIs for Britain and France in the 1880s were to alternative specifications of consumer demand. He considered alternative nesting schemes for commodities in consumer demand and found the calculated TRIs to be quite sensitive to alternative commodity groupings and elasticities of substitution. Neither of these papers investigated the sensitivity of the TRI calculations to alternative production structures. This section provides the results from such an exercise.

A. Calculated TRIs and the Elasticity of Substitution Among Factors of Production

This section reports the results from using a CGE model to assess the sensitivity of calculated TRIs to alternative model structures and values for the elasticity of substitution among factors of production. The model consists of three goods: two imported and one exported good. A representative consumer receives all factor income plus tariff revenue and is assumed to maximize a Cobb-Douglas utility function defined over the three goods. The terms of trade are exogenous and the price of the export good is taken as the numeraire. In a sense, this model is quite similar to the standard general equilibrium model used in international trade theory, except that there are three goods instead of just two. Two variants of the model are used to conduct sensitivity tests: one with all factors of production mobile across sectors (three factors of production) and one that assumes that one factor of production is sector-specific, and one factor is mobile across all sectors (four factors of production). This permits an evaluation of the sensitivity of the TRI to alternative values of the elasticity of substitution among factors, as well as with respect to model structure. To keep the model relatively simple, there are no intermediate inputs in either variant.

The model described above differs from the model used by Anderson and Neary (1994) and O'Rourke (1997) in several ways. First, the model used in this section introduces factor markets explicitly, while the others did not. Second, the model allows for consumption of the country's export good, as well as domestic production of the two imported goods. In fact, the model assumes that domestic goods are perfect substitutes for imports, as is common in trade theory. Third, unlike Anderson and O'Rourke, the model has no nontraded goods. Nontraded goods are realistic features of many economies and should be included, but they are excluded here to keep the model as simple as possible and to create a structure that is significantly different from the one used by Anderson and O'Rourke.

B. The Trade Restrictiveness Index

Anderson and Neary derive the TRI using the balance-of-trade function for a small, open economy. The TRI, Δ, is the uniform deflator that when applied to the prices of imported goods *i* in situation 1 (p^1_{Mi}), would leave the consumer as well off as in situation 0, with prices of imports equal to p^0_{Mi}. For the simple case of two import goods each subject to a tariff, the TRI is given implicitly by:

$$B\left(\frac{p^1_{M1}}{\Delta}, \frac{p^1_{M2}}{\Delta}, p^0_E, u^0\right) = B\left(p^0_{M1}, p^0_{M2}, p^0_E, u^0\right) \tag{1}$$

where $B(\cdot)$ is the balance-of-trade function, p_{M1} and p_{M2} are the domestic (tariff-inclusive) prices of the two import goods, p_E is the price of exports, and u^0 is the initial level of utility. The superscript "0" denotes the initial situation, while "1" denotes the new situation.

Totally differentiating the right-hand side of equation (1) and solving for du^0 gives:

$$du^0 = \frac{1}{B^0_u}\left[-B^0_{M1} dp^0_{M1} - B^0_{M2} dp^0_{M2}\right] \qquad (2).$$

Differentiating the left-hand side of equation (1) and using (2) gives the proportional change in the TRI:

$$\hat{\Delta} = \frac{-B_u^{\Delta}}{B_u^0}\left[\frac{B_{M1}^0 dp_{M1}^0 + B_{M2}^0 dp_{M2}^0}{B_{M1}^{\Delta} p_{M1}^{\Delta} + B_{M2}^{\Delta} p_{M2}^{\Delta}}\right] \tag{3}$$

where B_k is the partial derivative of the balance-of-trade function and B^{Δ} denotes the derivative of the balance-of-trade function evaluated at prices $p_{Mi}^{\Delta} = \frac{p_{Mi}^1}{\Delta}$. The term $\left(\frac{B_u^{\Delta}}{B_u^0}\right)$ is a "conversion factor" in that the balance of trade function is evaluated at two different points. An alternative way to write equation (3) is:

$$\hat{\Delta} = \left[\frac{-B_u^{\Delta}}{B_u^0}\frac{B_{M1}^0 p_{M1}^0 + B_{M2}^0 p_{M2}^0}{B_{M1}^{\Delta} p_{M1}^{\Delta} + B_{M2}^{\Delta} p_{M2}^{\Delta}}\right]\left[\frac{B_{M1}^0 dp_{M1}^0 + B_{M2}^0 dp_{M2}^0}{B_{M1}^0 p_{M1}^0 + B_{M2}^0 p_{M2}^0}\right] \tag{4}$$

where the first bracketed term on the right-hand side of (4) is an adjustment coefficient, since the balance-of-trade function is evaluated at two different points, p_{Mi}^0 and p_{Mi}^{Δ}. For small changes, this bracketed term will be close to one.

Using equation (4), the choice of model structure will affect the calculated value of the TRI because model structure affects the composition of each B_{Mi} term. For example, the form of the output supply functions (which are a component of each B_{Mi} term) will be different depending on whether all factors of production are mobile or whether one factor is sector specific. On the other hand, for a given model structure, changes in the elasticity of substitution between factors of production will alter the output supply elasticities, but not change the form of these functions. Thus, while changes in the elasticity of substitution between factors of production alter each B_{Mi}, they have limited impact on the calculated TRI, as they enter both the numerator and the denominator of the right-hand side of equation (4). Thus, changes in model structure would be expected to have more of an impact on calculated TRIs than changes in elasticities of substitution between factors of production. The next section uses a general equilibrium model to generate some numerical examples of how elasticities of substitution and model structure might affect the calculation of the "uniform tariff equivalent", UTE, which is related to the TRI through the relationship:

$\tau = \frac{1}{\Delta} - 1$, where τ is the UTE.

C. Sensitivity Results From a CGE Model

Table 1 presents the calculated UTEs from the model for alternative values of the elasticities of substitution among the factors of production, σ_{M1}, σ_{M2}, and σ_E, in the two import sectors (M1 and M2) and the export sector (E). UTEs are calculated holding two of the elasticities of substitution constant, while varying the third only, from a value of 2.0 to 0.5. Estimates of the UTEs are presented for two cases: one where one of the factors is sector specific and the other where all three factors are mobile across all sectors. The tariff rate on the first import sector is assumed to be 8 percent $(t_{M1} = 0.08)$ and the tariff rate applied to the second import good is assumed to be 2 percent $(t_{M2} = 0.02)$.

Table 1 reveals that the calculated UTEs are generally insensitive to changes in the elasticity of substitution among factors of production for a given model structure, however, the UTEs can be quite sensitive to the choice of model structure. For example, in the specific-factors model, varying the elasticity of substitution among factors does have an impact on the calculated UTE, however, the magnitude of the change is relatively small. As shown in Table 1, altering the elasticity of substitution in the first import sector, σ_{M1}, by 75 percent (from 2.0 to 0.5) results in a decline in the UTE of only about 12 percent. Similarly, the same percentage reduction in σ_{M2} raises the UTE by about 13 percent. The largest impact comes in the export sector: reducing σ_E by 75 percent increases the UTE by 30 percent. In all cases, changes in the elasticity of substitution among factors translate into changes in the UTE that are far less than one-for-one. The responsiveness of the UTE to changes in the elasticity of substitution among factors of production is even smaller in the version of the model in which all factors of production are intersectorally mobile. The production possibilities frontier for the mobile-factors model is flatter than the frontier for the specific-factors model, since it is an "outer envelope" of the latter. This implies that changes in the elasticity of substitution between factors will have a smaller effect when all factors are mobile, compared to a specific-factors model.

In contrast, calculated UTEs are quite sensitive to model structure. Reading across rows of Table 1, *for given elasticity values*, different assumptions regarding factor mobility significantly alter calculated values for the UTEs in most cases—there are only two cases in which the difference between the UTEs across the two model structures is less than 1 percent. On the other hand, the differences between the values of the UTE for the two models can be substantial, nearly 18 percent, as in the last row of table 1. This finding, although confined to the particular CGE model used here, reinforces the point made by O'Rourke (1997) that care should exhibited in choosing a particular model structure to calculate a UTE for a given country.

The results from this set of sensitivity tests demonstrate the importance of model choice in assessing trade restrictiveness. As the calculated UTEs can differ widely across models, the researcher should choose the type of model to answer the specific question at hand. In particular, for measuring trade restrictiveness over a short time period—defined as period of time for which some factor cannot adjust to new circumstances—then a specific-factors model would be appropriate. UTEs calculated from this type of model should then be thought of as "short-run" UTEs. In contrast, if the purpose is to measure how trade restrictiveness has changed over a long time period, e.g. several decades, then it would be appropriate to use a model in which all factors of production are mobile. UTEs calculated from this type of model can be thought of as "long-run UTEs". Thus, the choice of model structure for analyzing trade restrictiveness should depend on the purpose for which the UTE and TRI will be used. Model choice should also take into account the features of the economy during the period of change in trade policy. That is, was the period characterized by rapid investment, in which a mobile factor model would be appropriate, or by a period of time too short to alter the supply of the factor, in which case a specific-factors model would be appropriate?

Table 1. Sensitivity of the Uniform Tariff Equivalents to Changes in Values of the Elasticity of Substitution Between Labor and Capital

			Fixed Factor Model		All Factors Mobile		Percent Difference
				Percent		Percent	Between Two
σM1	σM2	σE	UTE	Change 1/	UTE	Change 1/	Models
2.00	1.50	1.50	0.05367016		0.05152938		-3.99
1.50	1.50	1.50	0.05208624	-2.95	0.05115417	-0.73	-1.79
1.25	1.50	1.50	0.05114180	-1.81	0.05092261	-0.45	-0.43
0.75	1.50	1.50	0.04880535	-4.57	0.05033853	-1.15	3.14
0.50	1.50	1.50	0.04731791	-3.05	0.04996629	-0.74	5.60
1.50	2.00	1.50	0.05073410		0.05064263		-0.18
1.50	1.50	1.50	0.05208624	2.67	0.05115417	1.01	-1.79
1.50	1.25	1.50	0.05292666	1.61	0.05141959	0.52	-2.85
1.50	0.75	1.50	0.05535122	4.58	0.05197050	1.07	-6.11
1.50	0.50	1.50	0.05754775	3.97	0.05225622	0.55	-9.20
1.50	1.50	2.00	0.04936698		0.05077284		2.85
1.50	1.50	1.50	0.05208624	5.51	0.05115417	0.75	-1.79
1.50	1.50	1.25	0.05387572	3.44	0.05143039	0.54	-4.54
1.50	1.50	0.75	0.05926470	10.00	0.05222511	1.55	-11.88
1.50	1.50	0.50	0.06411704	8.19	0.05278760	1.08	-17.67

Source: Author's simulations. The tariff rate on first import good is 8 percent ($t_{M1} = 0.08$) and the tariff rate on the second import good is 2 percent ($t_{M2} = .02$).

1/ Percentage change is calculated as the percentage difference between the UTEs for a given model structure.

III. Analyzing Trade Restrictiveness Over Time With the TRI

Researchers frequently want to know whether a particular country has become more or less open to international trade over some time period. One reason for this is that there is a great deal of interest in knowing whether there is a causal relationship between greater openness to trade and economic growth. Indeed, there is a rather large literature that explored the relationship between openness to trade and growth by using various measures of openness as explanatory variables in cross-country growth regressions. See Lee (1993), Edwards (1993), and Edwards (1998) for examples of this literature.

One way to determine whether an economy has become more open to trade would be to compute TRIs for the country in question for a number of years and observe how these TRIs changed over time. Indeed, Anderson and Neary (2005) argue that the TRI is the "natural index" for such an investigation and they point out that many atheoretic measures of trade policy restrictiveness have undesirable features. While using the TRI (and UTE) to assess whether an economy has become more open seems straightforward, it requires some qualification. The reason for this is that the computed TRI/UTEs would be affected by factors other than just changes in trade policy—they would be affected by changes in the underlying structure of the economy, such as factor accumulation and technological change, which will alter the computed value of the TRI, even if trade policy remains unchanged. Thus, simply tracking changes in TRIs over time could give a misleading picture of whether an economy's *trade policy* has become more open. Therefore, if one wants to assess how a country's *trade policy* changed over time, it is necessary to decompose the calculated changes in the TRIs into a part that is due to changes in economic structure and a component that captures changes in trade policy alone.[2]

Expanding the discussion of section II, the TRI can be defined implicitly in equation (5) for the illustrative case of two import goods, one export good, a factor of production that is mobile across all sectors (labor) and a sector-specific factor (capital):

$$B\left(\frac{p_{M1}^{*0}(1+t_{M1}^{1})}{\Delta},\frac{p_{M2}^{*0}(1+t_{M2}^{1})}{\Delta},p_E^0,u^0,L^0,K_j^0,\theta_j^0,\beta_i^0\right)=B\left(p_{M1}^{*0}(1+t_{M1}^{0}),p_{M2}^{*0}(1+t_{M2}^{0}),p_E^0,u^0,L^0,K_j^0,\theta_j^0,\beta_i^0\right)(5).$$

The difference between equation (1) and (5) is that in equation (5), the balance-of-trade function, $B(\cdot)$, is shown to depend explicitly on factor endowments (labor L^0 and sectoral capital K_j^0), the international prices of traded goods p_i^{*0}, product-specific technical change denoted by θ_j^0, and technical change biased toward factor *i* denoted by β_i^0. The other parameters in equation (5) are defined as in equation (1). The specification in equation (5) could also include nontraded goods which operate in the background.[3] As before, the superscripts "0" denotes the initial situation, while "1" denotes the post-change situation. In

[2] Irwin (2010) calculates TRIs for the United States for the years 1859, and 1867-1961, using the partial equilibrium method explained in Feenstra (1995), but does not adjust for changes in the TRI that may be due to changes in economic structure over this time period.

[3] Woodland (1982) shows how nontraded goods affect the basic model of international trade and the balance-of-trade function. The presence of nontraded goods alters the general-equilibrium elasticities.

equation (5), the tariffs are assumed to be ad-valorem, rather than specific as in Anderson and Neary (2005).[4] Note that the types of structural changes enumerated above (changes in the terms of trade, factor endowments, and technology) are not the only types of structural changes that might take place. There are others, such changes in consumer preferences, but the ones enumerated above are used to illustrate the issues.

To see how changes in factor endowments, technological change, and changes in the terms of trade affect the TRI, totally differentiate the right-hand side of equation (5) and solve for du^0 gives, choosing p_E as numeraire, which gives:

$$du^0 = \frac{1}{B_u^0}\begin{bmatrix} -B_{M1}^0\left[dp_{M1}^{*0}(1+t_{M1}^0)+p_{M1}^{*0}dt_{M1}^0\right]-B_{M2}^0\left[dp_{M2}^{*0}(1+t_{M2}^0)+p_{M2}^{*0}dt_{M2}^0\right] \\ -B_L^0 dL^0 - B_{K_j}^0 dK_j^0 - B_{\theta_j}^0 d\theta_j^0 - B_{\beta_i}^0 d\beta_i^0 \end{bmatrix} \qquad (6).$$

Totally differentiating the left-hand side of equation (5) and using (6) gives the proportional change in the TRI:

[4] Most countries, except Switzerland, apply tariffs in ad-valorem form. The majority of U.S. tariffs are in ad-valorem form, but some agricultural tariffs are in specific form.

$$\hat{\Delta} = \frac{1}{(B^{\Delta}_{M1}p^{\Delta}_{M1} + B^{\Delta}_{M2}p^{\Delta}_{M2})}\left[\begin{array}{l}
\left(\left(B^{\Delta}_{L} - \left(\frac{B^{\Delta}_{u}}{B^{0}_{u}}\right)B^{0}_{L}\right)L^{0}\right)\hat{L}^{0} + \\
\sum_{j}\left(\left(B^{\Delta}_{K_j} - \left(\frac{B^{\Delta}_{u}}{B^{0}_{u}}\right)B^{0}_{K_j}\right)K^{0}_{j}\right)\hat{K}^{0}_{j} + \\
\left(\left(B^{\Delta}_{\theta_j} - \left(\frac{B^{\Delta}_{u}}{B^{0}_{u}}\right)B^{0}_{\theta_j}\right)\theta^{0}_{j}\right)\hat{\theta}^{0}_{j} + \\
\left(\left(B^{\Delta}_{\beta_i} - \left(\frac{B^{\Delta}_{u}}{B^{0}_{u}}\right)B^{0}_{\beta_i}\right)\beta^{0}_{i}\right)\hat{\beta}^{0}_{i} + \\
\left(B^{\Delta}_{M1}p^{\Delta}_{M1} - \left(\frac{B^{\Delta}_{u}}{B^{0}_{u}}\right)B^{0}_{M1}p^{0}_{M1}\right)\hat{p}^{0^{*}}_{M1} + \\
\left(B^{\Delta}_{M2}p^{\Delta}_{M2} - \left(\frac{B^{\Delta}_{u}}{B^{0}_{u}}\right)B^{0}_{M2}p^{0}_{M2}\right)\hat{p}^{0^{*}}_{M2} + \\
-\left(\left(\frac{B^{\Delta}_{u}}{B^{0}_{u}}\right)B^{0}_{M1}t^{0}_{M1}p^{*0}_{M1}\right)\hat{t}^{0}_{M1} \\
-\left(\left(\frac{B^{\Delta}_{u}}{B^{0}_{u}}\right)B^{0}_{M2}t^{0}_{M2}p^{*0}_{M2}\right)\hat{t}^{0}_{M2}
\end{array}\right] \qquad (7).$$

Equation (7) shows how the TRI changes as a result of changes in economic structure (e.g. changes in factor endowments) and changes in trade policy (e.g. changes in tariffs). The term $(B^{\Delta}_{M1}p^{\Delta}_{M1} + B^{\Delta}_{M2}p^{\Delta}_{M2})$, the sum of the derivatives of the balance-of-trade function with respect to the prices of both import goods, evaluated at prices $p_{Mi}^{\Delta} = \frac{p_{Mi}^{1}}{\Delta}$, could be positive or negative. Expanding this term gives:

$$
\begin{aligned}
&(B_{M1}^{\Delta} p_{M1}^{\Delta} + B_{M2}^{\Delta} p_{M2}^{\Delta}) = \\
&p_{M1}^{\Delta}\left[-(p_{M1}^{\Delta} - p_{M1}^{*})(E_{M1M1} - G_{M1M1}) - (p_{M2}^{\Delta} - p_{M2}^{*})(E_{M2M1} - G_{M2M1})\right] p_{M1}^{*} dt_{M1} \\
&+ \\
&p_{M2}^{\Delta}\left[-(p_{M1}^{\Delta} - p_{M1}^{*})(E_{M1M2} - G_{M1M2}) - (p_{M2}^{\Delta} - p_{M2}^{*})(E_{M2M2} - G_{M2M2})\right] p_{M2}^{*} dt_{M2}
\end{aligned} \qquad (8).
$$

Both $(E_{M1M1} - G_{M1M1})$ and $(E_{M2M2} - G_{M2M2})$ must be negative, but the cross-price terms could be positive or negative depending on whether the two goods are substitutes or complements in production and consumption. As Anderson and Neary (2005) have shown, this term will be positive if the generalized mean tariff is positive. And this will be the case if each of the tariff-protected goods is a substitute for the numeraire good—an oversufficient, yet plausible condition. The following sections discuss the components of equation (7).

A. TRI and Factor Accumulation

As shown in equation (7), the impact of a change in factor endowments on the TRI will depend on the derivatives of the balance-of-trade function with respect to the factor endowments. In the example above, the impact of a change in the supply of labor is given by:

$$
\hat{\Delta} = \frac{1}{(B_{M1}^{\Delta} p_{M1}^{\Delta} + B_{M2}^{\Delta} p_{M2}^{\Delta})} \left(\left(B_{L}^{\Delta} - \left(\frac{B_{u}^{\Delta}}{B_{u}^{0}} \right) B_{L}^{0} \right) L^{0} \right) \hat{L}^{0} \qquad (9)
$$

and the impact of changes in the capital supplies by sector is:

$$\hat{\Delta} = \frac{1}{(B^{\Delta}_{M1}p^{\Delta}_{M1} + B^{\Delta}_{M2}p^{\Delta}_{M2})}\sum_{j}\left(\left(B^{\Delta}_{K_j} - \left(\frac{B^{\Delta}_{u}}{B^{0}_{u}}\right)B^{0}_{K_j}\right)K^{0}_{j}\right)\hat{K}^{0}_{j} \tag{10}$$

where:

$$B_L = -\left[G_L - t_{M1}p^{*}_{M1}G_{M1L} - t_{M2}p^{*}_{M2}G_{M2L}\right] \quad \text{and} \tag{11}$$

$$B_{K_j} = -\left[G_{K_j} - t_{M1}p^{*}_{M1}G_{M1K_j} - t_{M2}p^{*}_{M2}G_{M2K_j}\right] \tag{12}$$

The exact form of the derivatives in equations (11) and (12) will depend on model structure, such as whether factors are mobile or sector specific. When the number of factors equals the number of goods, outputs will respond to changes in factor supplies (at constant prices) according to factor intensities, as described by the Rybczynski theorem in the case of two goods and factors.

In the context of the specific-factors model, it is possible to reach some more definite conclusions regarding the signs of B_L and B_{K_j}. Equations (11) and (12) can be re-written to show that both B_L and B_{K_j} are equal to (minus) the change in outputs of each good, valued at world prices:

$$B_L = -\left[p_E^* G_{EL} + p_{M1}^* G_{M1L} + p_{M2}^* G_{M2L} \right] \quad \text{and} \tag{13}$$

$$B_{K_j} = -\left[p_E^* G_{EK_j} + p_{M1}^* G_{M1K_j} + p_{M2}^* G_{M2K_j} \right] \tag{14}.$$

Assuming that labor is perfectly mobile across sectors, while capital is sector specific, an increase in the supply of labor will cause outputs of all goods to rise—($G_{EL} > 0, G_{M1L} > 0, G_{M2L} > 0$)—so the term in brackets in equation (13) is positive. Welfare rises as a result of an increase in the supply of labor in the Ricardo-Viner model. Regarding B_{K_j}, it a well-known feature of the Ricardo-Viner model that an increase in K_j will raise the output of sector *j*, but reduce the output of every other sector. It is easy to show, using equations (12) and (14) that an increase in the supply of capital specific to the export sector must raise welfare, while an increase in the supply of capital specific to either of the tariff-protected sectors could cause welfare to either rise or fall.[5] Welfare could decline if factor accumulation, i.e. an increase in K_{M1} or K_{M2}, causes output of one of the tariff-protected goods to rise by a sufficiently large magnitude.

B. TRI and Technological Change

This section shows how two different types of technological change—product specific and factor biased—will affect the TRI. The treatment of technological change is

[5] Johnson (1967) showed that growth biased toward a tariff-protected sector could leave a country worse off at unchanged terms of trade in the context of a two-good, two-factor model in which both factors are intersectorally mobile.

based on Dixit and Norman (1980) and focuses on how technological change affects the economy's GDP function. Alternatively, Jones (1965) showed how technological change in could be introduced into a simple general equilibrium model. As he demonstrated, product-specific technological change is mathematically equivalent to the effects of an output-price change, while factor-specific technological change is mathematically equivalent to the effects of a change the supply of a factor of production.

1. Product-Specific Technical Change

Dixit and Norman (1980) demonstrate that technological change that is product or sector specific is equivalent to a price change. In particular, for the case of two imported goods and one export good, the GDP function can be written as:

$$G = G(\theta_{M1} p_{M1}, \theta_{M2} p_{M2}, \theta_E p_E, v) \tag{15}$$

where θ_j is a measure of technology in the production of good j, and v represents a vector of factor supplies. An increase in θ_j means that the value of output will be higher without the use of any additional inputs. As a consequence, a one-percent change in θ_j has the same impact on GDP as a one-percent change in p_j. Therefore:

$$\theta_j \left(\frac{\partial G}{\partial \theta_j} \right) = p_j \left(\frac{\partial G}{\partial p_j} \right) \qquad (16).$$

Differentiating equation (16) with respect to p_r

$$\theta_j\left(\frac{\partial^2 G}{\partial\theta_j\partial p_r}\right)=\left(\frac{\partial G}{\partial p_r}\right)_{j=r}+p_j\left(\frac{\partial^2 G}{\partial p_j\partial p_r}\right) \tag{17}$$

Finally, choosing units such that $p_j = 1$ and assuming that $\theta_j = 1$ initially, equations (16) and (17) become:

$$\left(\frac{\partial G}{\partial\theta_j}\right)=\left(\frac{\partial G}{\partial p_j}\right) \tag{18}$$

$$\left(\frac{\partial^2 G}{\partial\theta_j\partial p_r}\right)=\left(\frac{\partial G}{\partial p_r}\right)_{j=r}+\left(\frac{\partial^2 G}{\partial p_j\partial p_r}\right) \tag{19}$$

According to equation (7), the impact of technical change in a particular sector on the TRI is given by:

$$\hat{\Delta}=\frac{1}{(B^{\Delta}_{M1}p^{\Delta}_{M1}+B^{\Delta}_{M2}p^{\Delta}_{M2})}\left(\left(B^{\Delta}_{\theta_j}-\left(\frac{B^{\Delta}_{u}}{B^{0}_{u}}\right)B^{0}_{\theta_j}\right)\theta^0_j\right)\hat{\theta}^0_j,$$

which depends on the derivative of the balance-of-trade function with respect to θ_j. For the case of technical change in the first import sector:

$$B_{\theta_{M1}} = -G_{\theta_{M1}} + (p_{M1} - p^*_{M1})G_{M1\theta_{M1}} + (p_{M2} - p^*_{M2})G_{M2\theta_{M1}} \quad (20).$$

Using the results of equations (18) and (19), equation (20) becomes:

$$B_{\theta_{M1}} = -G_{M1} + (p_{M1} - p^*_{M1})\left[G_{M1} + G_{M1M1}\right] + (p_{M2} - p^*_{M2})G_{M2M1} \quad (21)$$

or

$$B_{\theta_{M1}} = -G_{M1}\left[1 - t_{M1}p^*_{M1} - \left(\frac{t_{M1}}{1+t_{M1}}\right)\varepsilon_{M1}\right] + (p_{M2} - p^*_{M2})G_{M2M1} \quad (22)$$

where ε_{M1} is the price elasticity of supply of the first import good, M1. Assuming that the two import goods are general-equilibrium substitutes in production, output of M2 will fall when the price of M1 rises, so $G_{M2M1} < 0$. Thus, the sign of equation (22) depends on the sign of the bracketed term, which is ambiguous. However, the larger the tariff on good M1, or the larger the price elasticity of supply of M1, the greater the likelihood that technical progress specific to the first import good will reduce welfare.

2. *Factor-Biased Technical Change*

As noted, the effects of technical change biased toward the use of a particular factor of production are similar to the impact of an increase in the supply of that factor. In particular, let β_i be a measure of the productivity of factor *i*. Then:

$$\beta_i\left(\frac{\partial G}{\partial \beta_i}\right) = v_i\left(\frac{\partial G}{\partial v_i}\right) \tag{23}$$

where v_i is the supply of factor *i*. Differentiating equation (23) with respect to the price of good j:

$$\beta_i\left(\frac{\partial^2 G}{\partial \beta_i \partial p_j}\right) = v_i\left(\frac{\partial^2 G}{\partial v_i \partial p_j}\right) \qquad (24).$$

Finally, choosing units such that $v_i = 1$ and assuming that $\beta_i = 1$ initially, equations (23) and (24) become:

$$\left(\frac{\partial G}{\partial \beta_i}\right) = \left(\frac{\partial G}{\partial v_i}\right) \tag{25}$$

$$\left(\frac{\partial^2 G}{\partial \beta_i \partial p_j}\right) = \left(\frac{\partial^2 G}{\partial v_i \partial p_j}\right) \qquad (26).$$

Equation (7) shows that the impact of technical change biased toward a particular factor of production on the TRI is given by:

$$\hat{\Delta} = \frac{1}{(B_{M1}^{\Delta} p_{M1}^{\Delta} + B_{M2}^{\Delta} p_{M2}^{\Delta})}\left(\left(B_{\beta_i}^{\Delta} - \left(\frac{B_u^{\Delta}}{B_u^0}\right) B_{\beta_i}^0\right)\beta_i^0\right)\hat{\beta}_i^0,$$

which depends on the derivative of the balance-of-trade function with respect to β_i. Using the results in equations (25) and (26), the derivatives of the balance-of-trade functions are:

$$B_{\beta_L} = -G_L + (p_{M1} - p_{M1}^*)G_{M1L} + (p_{M2} - p_{M2}^*)G_{M2L} \tag{27}$$

and

$$B_{\beta_{K_j}} = -G_{K_j} + (p_{M1} - p_{M1}^*)G_{M1K_j} + (p_{M2} - p_{M2}^*)G_{M2K_j} \qquad (28).$$

Equations (27) and (28), which are identical to equations (11) and (12), reveal that the impact of technical progress biased toward a factor of production depends on how outputs of the tariff-protected goods respond to changes in factor supplies—the Rybczynski elasticities or, using duality, the Stopler-Samuelson elasticities. In the context of the specific factors' model in which labor (L) plays the role of the mobile factor and capital stocks (K_j) are sector specific, the results are clear cut, as an increase in the supply of the mobile factor must raise outputs of all goods. Rewriting equation (27):

$$B_{\beta_L} = -w\left[1 - \left(\frac{t_{M1}}{1+t_{M1}}\right)S_{L,P_{M1}} - \left(\frac{t_{M2}}{1+t_{M2}}\right)S_{L,P_{M2}}\right] < 0$$

or

$$B_{\beta_L} = -w\left[\frac{1+t_{M2}(1-S_{L,P_{M2}})+t_{M1}(1-S_{L,P_{M1}})+t_{M1}t_{M2}(1-S_{L,P_{M2}}-S_{L,P_{M1}})}{1+t_{M2}+t_{M1}+t_{M1}t_{M2}}\right] < 0 \qquad (29)$$

where *w* is the wage rate (equal to the derivative of the GDP function with respect to *L*), and $S_{L,P_{M1}}$ and $S_{L,P_{M2}}$ are the elasticities of the wage with respect to the prices of the two import goods. In the specific factors' model, $S_{L,P_{M1}}$ and $S_{L,P_{M1}}$ each lie between zero and one and $(S_{L,P_{M1}} + S_{L,P_{M2}} + S_{L,P_E} = 1)$. Therefore, $(S_{L,P_{M1}} + S_{L,P_{M2}} < 1)$. Using these results, the bracketed term in equation (29) must be positive, so $B_{\beta_L} < 0$. Alternatively, changes in sectoral capital stocks have an ambiguous impact on B_{K_j} because welfare could rise or fall. In equation (28), if the supply of capital used in sector M1 rises, then $G_{M1K1} > 0$, but $G_{M2K1} < 0$. In sum, in the specific factors model, (i) technical progress biased toward the specific factor in the export sector must raise welfare and reduce $B_{\beta_{K_E}}$; (ii) technical progress biased toward the specific factors in one of the tariff-protected sectors could raise or lower welfare, so the signs of $B_{\beta_{K_{M1}}}$ and $B_{\beta_{K_{M2}}}$ are ambiguous; and (iii) technical progress biased toward the mobile factor (labor) must raise welfare and reduce B_{β_L}.

C. TRI and Changes in World Prices

To assess the impact of changes in world prices on the TRI, differentiate the balance of trade function with respect to p_j^*. For example, in the case of a change in p_{M1}^*:

$$B_{p^*_{M1}} = (E_{M1} - G_{M1}) - t_{M1} p^*_{M1} \left[(1+t_{M1})(E_{M1M1} - G_{M1M1})\right] - t_{M2} p^*_{M2} \left[(1+t_{M2})(E_{M2M1} - G_{M2M1})\right] \qquad (30).$$

Although $(E_{M1} - G_{M1}) > 0$ and $(E_{M1M1} - G_{M1M1}) < 0$, the sign of equation (30) is ambiguous, because $(E_{M2M1} - G_{M2M1})$ could be positive or negative, depending on whether imports of M2 are a substitute or a complement for M1. If $t_{M2} = 0$, then $B_{p^*_{M1}} > 0$, since an increase in p^*_{M1} reduces welfare.

The last two terms in equation (7) correspond to the impact of changes in ad-valorem tariff rates alone on the TRI, which is the object of interest in knowing whether trade policy has become more or less restrictive. An alternative method for answering this question would be to compute the total change in the TRI, as given in equation (7), and then subtract the contributions from changes in all of the structural factors discussed above (e.g. changes in factor endowments, technological change, and changes in the terms of trade) from the change in the overall TRI.

IV. Simulations Using a CGE Model

A. Some Numerical Simulations

This section presents the results of some simulations using a simple general equilibrium model to demonstrate how changes in exogenous variables (e.g. factor accumulation, technological change, and changes in the terms of trade) might affect the calculated values of TRIs.

Briefly, the model consists of four sectors (an export good, two import goods, and a nontraded good). This is the same model used in previous sections, except nontraded goods are included. Output of each sector is produced using labor, which is mobile across all sectors and a sector-specific factor. Thus, the wage rate is the same in every sector, but the return to capital differs. The country is taken to be "small", and thus, unable to influence its terms of trade through changes in tariff rates. The model is used to demonstrate that in assessing whether an economy has become more open to trade over time, it is very important to recognize that the underlying structure of the economy is changing and this will affect the calculated values of the TRIs independently of changes in trade policy. The simulation results are presented in Table 2.

The first row of table 2 reports the UTEs for a hypothetical economy in four different years. The tariff rates in year 1 are 10 and 5 percent and only the top rate is assumed to change over time, rising to 25 percent in year 4. At the same time, the economy is assumed to undergo structural changes. In particular, the amount of the sector-specific factor used in the export sector is expected to grow by 5 percent a year, the terms of trade are assumed to improve by 5 percent a year, and there is labor-saving technical improvement in the export sector of 5 percent a year. Taking into account the change in the highest tariff rate and structural changes, the UTE for each year is given in row 1 of table 2. The UTE ranges from 7.9 percent in year 1 to 17.9 percent in year 4.

Row 2 of table 2 reports the calculated UTEs taking into account the assumed changes in tariff rates, but assumes that the structure of the economy remains unchanged.

Table 2. The Importance of Changes in Economic Structure in Calculating TRIs

Calculated Uniform Tariff Equivalents (in percent)

	Year 1	Year 2	Year 3	Year 4
	$t_{M1} = 10$ $t_{M2} = 5$	$t_{M1} = 15$ $t_{M2} = 5$	$t_{M1} = 20$ $t_{M2} = 5$	$t_{M1} = 25$ $t_{M2} = 5$
Changes in Tariffs and Economic structure	7.918	11.347	14.697	17.916
Changes in Tariffs Only	8.058	11.952	16.009	20.078
Percent deviation from UTEs above (row 1)	1.8	5.3	8.9	12.1
	$t_{M1} = 10$ $t_{M2} = 5$	$t_{M1} = 10$ $t_{M2} = 5$	$t_{M1} = 10$ $t_{M2} = 5$	$t_{M1} = 10$ $t_{M2} = 5$
Changes in Economic Structure only (tariffs constant) (increase in capital used in the export sector (5%), terms of trade improvement (5%), and labor specific technical change in the Export sector (5%))	7.918	7.803	7.713	7.646

Source: Model simulations

This calculation generates UTEs that are uniformly higher than the UTEs in row 1, with the deviation rising from 2 to 12 percent by year 4. The UTEs calculated assuming that the structure of the economy remains unchanged are higher because the assumed structural changes all work to reduce output of the tariff-protected sectors and expand output of the export sector and these tend to raise welfare. Thus, these structural changes act to reduce the calculated UTEs, independently of changes in tariff rates, and this is shown in the bottom section of table 2, which presents the calculated UTEs absent any changes in tariff rates. Had the structural changes and the factor accumulation been biased toward the sector with the highest tariff, the calculated UTEs would have grown, as the factor accumulation would be making the distortion worse—a second-best result. This exercise demonstrates that structural changes in an economy can significantly influence the calculated values of the TRI and UTE, and thus, affect the values of the TRI/UTE over time. In order to gain a perspective on how trade policy alone changes over time, it is necessary to adjust calculated UTEs for structural change.

B. Application to China

This section reports the results of decomposing uniform tariff equivalents (UTEs) into the portion due to changes in tariff policy and the portion due to changes in economic structure for the case of China. In particular, a 57-sector numerical general equilibrium model was used to calculate uniform tariff equivalents (UTEs) for China for the years 1997, 2001, and 2004. These particular years were chosen because they correspond to years for which full datasets were available for China from various versions of the GTAP database.[6]

[6] The Global Trade and Analysis Project (GTAP) produces detailed datasets for a number of countries needed to implement numerical general equilibrium models. The most recent, publically available dataset is for the year 2004. Documentation for the 2004 version of the database is contained in Badri and Walmsley (2008).

The maximum number of sectors for which data are available is 57, so data at the most disaggregated level were used in order to capture the differences in tariff rates across sectors, which is of central importance in the calculation of UTEs. The structure of the model is essentially a multi-sector version of the model presented in Anderson and Neary (2005) and therefore will not be presented in detail.

The model is also extremely similar to the models used in earlier sections of this paper with one some exceptions. First, it allows for imperfect substitutability. That is, the model treats imports into China as imperfect substitutes for Chinese goods—the "Armington Assumption"—and it treats goods exported by China as differentiated from the goods produced and sold domestically on the Chinese market.[7] Second, the model includes a distortion other than tariffs, namely a production tax in each sector. Finally, the model allows for the use of intermediate inputs in production, both imported and domestic. Each sector is assumed to use a factor of production that is mobile across all sectors (labor), plus a sector-specific factor. Table 3 reports the calculated UTEs for China for each year: 1997, 2001, and 2004.

The main results are contained in rows (e) and (f) of Table 3. Row (e) of table 3 shows the calculated UTEs for China for 1997, 2001, and 2004 using the actual tariff rates in

[7] This assumption essentially means that the model uses a constant elasticity of substitution (CES) function to aggregate imports and domestically produced goods, and a constant elasticity of transformation (CET) function to allocate production between export and domestic markets, as in Anderson and Neary (2005).

Table 3. China: Calculation of Uniform Tariff Equivalents

	1997	2001	2004
a. Simple average tariff (in percent)	17.1	11.1	5.7
b. Import-weighted tariff (in percent)	14.0	11.6	5.6
c. Standard deviation	30.9	21.1	8.2
d. Welfare Effects of Removing Tariffs		(millions of U.S. dollars)	
Equivalent Variation	2,375.0	1,740.0	1,624.9
Percent of GDP	0.29	0.17	0.10
e. Uniform Tariff Equivalent (in percent) (current-year tariff rates)	19.6	14.0	8.2
f. Uniform Tariff Equivalent (in percent) (1997 tariff rates)	19.6	15.8	15.2

Source: Author's calculations using versions 5, 6, and 7 of the GTAP database. See Badri and Walmsley (2008) for details of version 7 (2004) of the database.

each of those years, as well as the structure of the Chinese economy. As shown in row (e), the calculated UTEs range from 19.6 in 1997 to 8.2 in 2004. From simply inspecting these calculations, one might be tempted to conclude there was a substantial reduction in *trade restrictiveness* in China between 1997 and 2004, since the UTE declined by 58 percent!

The principal reason why this conclusion would be incorrect is that between 1997 and 2004, there were changes in the structure of the Chinese economy in addition to changes in tariff rates—changes that would alter the calculated values of UTEs even if tariff rates had remained unchanged. Row (f) of table 3 presents the calculated UTEs for China for 1997, 2001, and 2004 using the structure of the Chinese economy in each of those years, but keeping tariff rates unchanged at their 1997 levels. Therefore, the difference between the UTEs in rows (e) and (f) of table 3 shows how the restrictiveness of tariff policy changed in a given year.

By construction, the calculated UTEs for 1997 are the same—both 19.6. For 2001, the calculated UTE declines to 14.0 when allowing for changes in both tariff rates and the structure of the Chinese economy, such as changes in factor supplies, technology, and the terms of trade. However, when using the structure of the Chinese economy as it was in 2001, but with 1997 tariff rates, the calculated UTE was 15.8. Thus, of the total change in the calculated UTE from 19.6 to 14.0 between 1997 and 2001, 1.8 percentage points (or 32 percent of the total change in the UTE) was due to changes in tariff rates and the remaining 3.8 percentage points (68 percent of the total change in the UTE) was due to structural change in the Chinese economy. From this exercise it becomes clear that although the UTE declined by quite a lot between 1997 and 2001, only a relatively small portion was due to changes in tariff policy. The bulk of the reduction in the UTE between 1997 and 2001 was due to changes in the structure of the Chinese economy.

A somewhat different picture emerges when expanding the period under consideration to 2004. Between 1997 and 2004, the calculated UTE declined from 19.6 to 8.2. Of this total change, about 60 percent is due to changes in tariff policy and the rest due to changes in the structure of the Chinese economy. This analysis indicates that between the years 2001 and 2004, the restrictiveness of China’s tariff policy declined significantly, in contrast to the period between 1997 and 2001 when most of the decline in China's UTE was accounted for by structural change.

IV. Conclusions

This paper has made two principal contributions. First, it evaluates how sensitive calculated measures of trade restrictiveness (UTEs) are to alternative productions structures. The simulations show that UTEs are relatively insensitive to changes in the elasticity of substitution between factors of production, but quite sensitive to alternative model structures. For example, the simulations compared the calculated UTEs under two types of production structures—mobile factors and specific factors—and found that the calculated UTEs can differ markedly. This finding highlights the importance of the model structure used to assess trade restrictiveness. In particular, short-run UTEs can differ significantly from long-run UTEs.

Second, there is a great deal of interest in knowing whether a country has become more open to trade over time. The TRI and UTE are well-suited for answering this question, but with an important caveat. Typically, the structure of an economy changes over time and this will affect the calculated values of the TRI and UTE, even if trade policy does not change. If one wants a measure of changes in trade *policy* only, then it would be incorrect to allow changes in economic structure to affect the calculated values of the TRI and UTE. The second part of the paper demonstrated how changes in economic structure could affect the calculated values of the UTEs. In general, one needs to adjust calculated UTEs for changes in structure to obtain an accurate measure of how trade policy changed over time.

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