Journal of International Economics 98 (2016) 150–159

Contents lists available at ScienceDirect

Journal of International Economics

journal homepage: www.elsevier.com/locate/jie

# Sufficient statistics for tariff reform when revenue matters☆

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ARTICLE INFO

*Article history:*
Received 12 December 2013
Received in revised form 20 September 2015
Accepted 2 October 2015
Available online 19 October 2015

*JEL classification:*
F13
H21

*Keywords:*
Trade policy reform
Generalized mean and variance of tariffs
Tariff revenue
Piecemeal policy reform

ABSTRACT

What kinds of tariff reform are likely to raise welfare in situations where tariff revenue is important? General conditions for welfare to rise without reducing tariff revenue are opaque. We show that they can be greatly simplified using a small number of sufficient statistics, primarily the generalized mean and variance of tariffs. We present sufficient conditions for a class of linear tariff reform rules that guarantee higher welfare without a loss in revenue. The rules consist of convex combinations of (i) trade-weighted-average-tariff-preserving cuts in dispersion; and (ii) uniform tariff cuts that preserve domestic relative prices among tariff-ridden goods.



## 1. Introduction

What kinds of tariff reform are likely to raise welfare in situations where tariff revenue is important? The question is an important one: despite steady reductions in average tariffs, tariff revenue is still a significant component of total tax revenue, especially in low-income countries. Baunsgaard and Keen (2010) review the empirical evidence on the revenue effects of trade liberalization in recent decades, and conclude that, while middle-income countries have managed to offset reductions in trade tax revenues by increasing their domestic tax revenues, many low-income countries have not. Even in rich countries, the revenue effects of changes in tariffs can be substantial in absolute if not in relative terms, and can be a factor influencing the decision to liberalize trade. The implications of trade reform for revenue have featured prominently in discussions of the EU's association agreements with countries in the Southern Mediterranean region (see Abed, 1998), and even in official discussions of the case for the U.S. joining NAFTA (see Congressional Budget Office, 1993).[1]

Unfortunately, as we shall see, general conditions for welfare to rise without reducing tariff revenue are opaque, and provide little guidance to practical policy-making. Our main contribution is to show that they can be greatly simplified using a small number of sufficient statistics, primarily the generalized mean and variance of tariffs. Reexpressing the general conditions in terms of these sufficient statistics leads to new operational guidelines for tariff reform that guarantee higher welfare without a loss in revenue. The rules consist of convex combinations of cuts in tariff dispersion that preserve the trade-weighted-average-tariff, on the one hand, and uniform tariff cuts that preserve domestic relative prices among tariff-ridden goods, on the other. These guidelines provide a theoretical foundation for the standard World Bank advice to developing country clients that they should reduce dispersion of tariffs while maintaining average tariffs to preserve revenue. In plausible special cases, the rules require only observable data and a small number of aggregate elasticities.

Our approach builds on the sizeable literature on trade policy reform in open economies, stemming in particular from Hatta (1977). Much of this literature provides guidelines for welfare-improving tariff reform when government revenue is not a concern, which amounts to

☆ Earlier versions of this paper were circulated under the title "Revenue Tariff Reform." We are grateful to the editor, Bob Staiger, to two referees, and to Richard Blundell, Ian Crawford, Rod Falvey, Doug Irwin, Udo Kreickemeier, Will Martin, and participants at various seminars and conferences, for their helpful comments. Peter Neary thanks the European Research Council for funding under the European Union's Seventh Framework Programme (FP7/2007–2013), ERC grant agreement no. 295669.

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[1] We are grateful to Doug Irwin for this reference.

http://dx.doi.org/10.1016/j.jinteco.2015.10.001
0022-1996/

assuming that the government has lump-sum tax/transfer power. This approach has been extended to study the interplay of revenue and efficiency considerations in trade policy reform by a number of authors, including Falvey (1994), Emran and Stiglitz (2005), Hatta and Ogawa (2007), and Raimondos-Møller and Woodland (2015). However, these papers either use relatively special low-dimensional models, or do not provide rules that can be easily implementable. An exception is a branch of the literature which advocates replacing border taxes with domestic consumption taxation. (See for example, Hatzipanayotou et al. (1994), Keen and Ligthart (2002), and Kreickemeier and Raimondos-Møller (2008).) The intuitive argument that the base is broader can be supplemented with optimality considerations. Diamond and Mirrlees (1971) demonstrated that it is inefficient to distort productive efficiency when raising revenue with distortionary taxation. Trade taxes, by subsidizing production, drive a wedge between domestic and international marginal rates of transformation. However, Anderson (1999) shows that gradual reform of this type need not improve welfare when uniform radial reductions are used to lower tariffs. The present paper admits a much broader class of trade reforms when wage taxation is the alternative revenue source and provides more optimistic prospects for tariff reforms which reduce dispersion.

The present paper draws on Anderson and Neary (2007), where the approach using generalized moments of the tariff structure was introduced and applied to devising rules for trade policy reform in the conventional setting of no revenue constraint. That paper derived linear welfare-improving reform rules as implications of reform that reduced either or both of two sufficient statistics, the generalized mean and generalized variance of the tariff structure. Here we extend these methods to the case where lump-sum taxes and transfers are not feasible and so the government faces a binding revenue constraint. All government tax changes become costly at the margin because they involve distortions. The same sufficient statistics prove useful in the case of an active revenue constraint, supplemented by some additional aggregate elasticity terms. In a big step toward applicability with very limited information, Anderson and Neary (2007) also showed that, in a special CES case, the generalized mean and variance reduced to the readily observable trade-weighted version of these statistics. A second contribution of the present paper is to demonstrate that observability of generalized moments obtains with weak separability, nesting not only the CES but most other widely-used preference and technology structures. A group of goods such as clothing under separability can contain pairs that are complements (shirts and trousers) and other pairs that are substitutes (cotton and silk shirts). The separable setting also permits a further realistic extension which replaces the representative agent with heterogeneous agents while maintaining feasible operational rules that yield Pareto improvement.

Section 2 sets up the model and derives the general expressions for tariff reform in the presence of revenue constraints. Though insightful, these do not easily lend themselves to practical implementation. The remainder of the paper shows how they can be operationalized using the tariff moments approach introduced in Anderson and Neary (2007). Section 3 reviews and extends that approach, while Sections 4 and 5 use it to analyze trade reform and to derive the main results of the paper. Section 6 extends the results to the case of many households, while Section 7 concludes.

## 2. Equilibrium and the effects of tariffs and taxes

### 2.1. The setting

The tariff reform problem is to advise on directions of change of tariffs from initial values. Full optimization is not feasible by assumption. The setting is a competitive small open economy which raises its revenue with a set of tariffs and with a wage tax. For simplicity we will present the results in terms of a perfectly competitive economy though, as shown in Anderson and Neary (2005), the results also apply to a variety of monopolistically competitive models with fixed entry costs and firm heterogeneity. The wage tax is distortionary because labor supply is variable (due to household choice in an economy where immigration is shut down) and leisure cannot be taxed. Tariffs and the wage tax are initially set sub-optimally. The objective of the reform is to move the taxes gradually toward their optimal (Ramsey) values. This section first describes the economy and then derives general expressions which show how tariff changes affect welfare and tariff revenue. These results are the key building blocks for our results in later sections that are expressed in terms of tariff aggregates.

The representative consumer's net expenditure function is given by $e(\pi, w, u)$. It gives the minimum spending needed to sustain a level of utility or real income $u$ when the representative consumer faces a vector of prices of traded goods subject to tariffs, denoted by $\pi$, and a net-of-tax wage rate denoted by $w$. The domestic prices $\pi$ differ from world prices $\pi^*$ by a vector of specific tariffs $t$. Since the economy is small, the world prices are exogenous, so changes in domestic prices $d\pi$ are equal to changes in tariffs $dt$ throughout. Implicit in the list of arguments of $e$ is the price of a composite export good, which we take as numeraire so its price can be set equal to one. By Shephard's Lemma, $e_\pi$ gives the vector of final demand for traded goods, while $-e_w$ gives labor supply. As for the supply side of the economy, the maximum value of GDP which can be produced given its technology and facing goods prices $\pi$ and a gross wage $w+\tau$, where $\tau$ is the tax on labor income, is given by the GDP function $g(\pi, w+\tau)$. By Hotelling's Lemma, the vector of supply of traded goods (or where appropriate, minus the demand for traded inputs) is given by $g_\pi$ while $-g_w$ gives labor demand.

The trade expenditure function for this economy is defined as the excess of domestic expenditure over GDP, with the added constraint that the labor market clears in the background:[2]

$$E(\pi, \tau, u) = \max_{w} \; [e(\pi, w, u) - g(\pi, w+\tau)]. \tag{1}$$

$E$ gives the net transfer to the private sector needed to support utility $u$ when domestic prices of traded goods are set at $\pi$ and the wage tax is set at $\tau$. Its derivative with respect to $\pi$, $E_\pi$, is the vector of excess demand for traded goods, which equals the vector of net imports $m$; while its derivative with respect to $\tau$, $E_\tau = -g_w$, is equilibrium employment, where the maximization with respect to $w$ ensures that the labor market clears: $e_w = g_w$.

Since $e$-$g$ is concave in $(\pi, w, \tau)$, $E$ is concave in $(\pi, \tau)$: compensated net import demand functions are downward-sloping, and a higher wage tax reduces employment.

The private-sector budget constraint is:

$$E(\pi, \tau, u) - s = 0. \tag{2}$$

Here, $s$ is the transfer from the government to the private sector. If the government has lump-sum power, $s$ is an active policy instrument. Otherwise, it is an exogenous transfer, which also serves as a useful analytic link between the private-sector and government budget constraints.

The government budget constraint expresses the requirement that a given amount of revenue must be raised net of subsidies. Taxes are collected on tradable goods at rates $t = \pi - \pi^*$ and on labor at the rate $\tau$. The government budget constraint is therefore given by:[3]

$$R(\pi, \tau, u, s) \equiv t'E_\pi + \tau E_\tau - s \geq R^0. \tag{3}$$

Here, $R^0$ represents the government's revenue requirement, to fund public goods, repay foreign loans, or finance some other goal which does not directly affect private-sector decisions. Extending the model to

[2] See Anderson and Neary (2007) for a discussion of the trade expenditure function when labor supply is fixed, and for further references.

[3] All vectors are column vectors and a prime denotes a transpose.

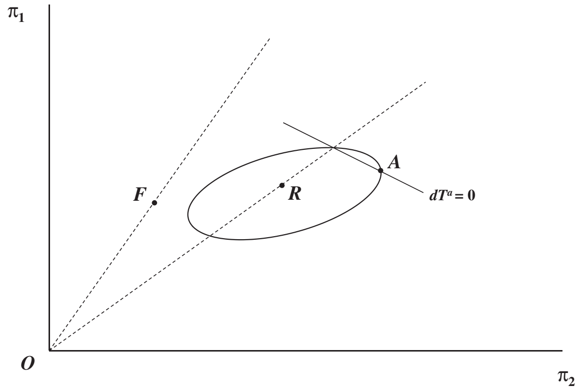


**Fig. 1.** The tariff reform problem. $A$ is the initial point, $F$ is free trade, and $R$ is the Ramsey optimum.

endogenize this revenue requirement is straightforward, along the lines of Atkinson and Stern (1974), or, in a trade context, Abe (1992). We do not pursue this approach here, since it distracts from our primary focus, using summary statistics to simplify the guidelines for tariff and tax reform.

To clarify the implications of this setup, contrast it with the standard setting in the theory of piecemeal trade policy reform, where it is implicitly assumed that any revenue change is actively transferred in a lump-sum way between the private-sector and government budgets. Then the transfer $s$ is endogenous, and we can combine the private-sector budget constraint (2) with the government budget constraint (3) to form the social budget constraint, which is also the balance of trade constraint with the rest of the world: net expenditure by the private sector must be matched by tax revenue less government spending:

$$E(\pi, \tau, u) = s = t' E_\pi + \tau E_\tau - R^0. \tag{4}$$

In this case, the government's revenue requirement is not an independent constraint on policy-making because the transfer $s$ adjusts endogenously. This makes a crucial difference for evaluation of tariff reform: Eq. (4) leads to the standard results of piecemeal trade policy reform, augmented to allow for an exogenous wage tax. (See Appendix A for details.)

In the setting considered in the rest of the paper, by contrast, lump-sum transfers are infeasible, so the gradual reform problem is to determine welfare-improving directions of change in the set of reformable tariffs $t$, equivalent to changes in $\pi$, while at the same time not decreasing revenue. One class of reforms takes the wage tax as given and looks for tariff reforms that raise both welfare and revenue. A more ambitious class of tariff reforms permits the wage tax to vary endogenously in order to maintain government revenue. We consider each of these classes in turn.

### 2.2. The problem

A diagram illustrating the three-good case, two of them subject to tariffs, aids intuition. In Fig. 1, initial tariffs are such that domestic prices equal $\pi^A$, corresponding to point $A$. Point $F$ represents free trade, but of course that yields zero revenue. Optimal revenue-raising tariffs imply Ramsey-optimal prices $\pi^R$, corresponding to point $R$. The tariff reform problem is to devise rules that will improve welfare locally; directions of change for $\pi$ starting from $A$ that bring the economy closer to $R$ in the sense of attaining a higher iso-welfare contour.[4] However, the shape of the iso-welfare contours depends on the policy instruments available to the government. The line though point $A$ labeled $dT^a = 0$ shows combinations of domestic prices that keep the trade-weighted average tariff $T^a$ constant. As we will see below, it is also an iso-welfare locus for the case where the wage tax is given: i.e., it is implicitly defined by the private-sector budget constraint (2) for given $u$, $\tau$, and $s$. By contrast, the elliptical locus drawn through point $A$ shows combinations of domestic prices that keep welfare constant when the wage tax adjusts to maintain revenue: it satisfies both the private-sector budget constraint (2) and the government budget constraint (3) for given $u$ ($s$ is now irrelevant) and with $\tau$ adjusting endogenously. This locus is one of a family of iso-welfare curves centered around $R$: each raises the same amount of revenue but yields successively higher levels of welfare as $R$ is approached. As drawn, the locus encloses a convex set of $\pi$'s and is upward-sloping at $A$, but these properties are not guaranteed. To determine more precisely the location of these iso-welfare contours and hence the desired direction of tax reform away from $A$, we need to develop a more formal analysis.

### 2.3. Tariff changes only

Consider first the case where the wage tax is given. Differentiating the private budget constraint (2) with $\tau$ and $s$ fixed shows that real income measured in expenditure units is directly reduced by increases in tariffs:

$$E_u du = -E'_\pi dt. \tag{5}$$

Similarly, differentiating the government budget constraint (3) and using Eq. (5) to eliminate $E_u du$ yields an expression linking the change in government revenue to changes in tariffs:

$$dR = R'_\pi d\pi + R_u du = (1 - R_I) E'_\pi dt + (t' E_{\pi\pi} + \tau E_{\tau\pi}) dt. \tag{6}$$

The coefficient of the first term on the right-hand side, $1 - R_I$, is the "Hatta (1977) normality term" or the inverse of the "shadow price of foreign exchange." Here, $R_I$ denotes the derivative of revenue with respect to nominal income given the tax structure:

$$R_I \equiv \frac{R_u}{E_u} = t' \frac{E_{\pi u}}{E_u} + \frac{\tau E_{\tau u}}{E_u}. \tag{7}$$

We will assume that this term lies in the unit interval:

**Assumption 1.** $R_I$ is positive and less then one.

A host of arguments has been given in the literature on piecemeal policy reform to defend this assumption. Normality suffices, as does homotheticity or a standard stability condition.[5] Violation of the assumption would be perverse indeed, since it would imply that a gift of foreign exchange to the private sector, enabling a rise in real income, would at constant prices $\pi$ either reduce government revenue or raise it by more than the value of the gift. In the presence of lump-sum redistribution, moreover, a negative value of $R_I$ would imply that gifts make the economy worse off.

Comparing the first term on the right-hand side of Eq. (6) with Eq. (5) reveals the tension between private and public spending:

$$dR + (1 - R_I) E_u du = (t' E_{\pi\pi} + \tau E_{\tau\pi}) dt. \tag{8}$$

The left-hand side suggests a clear presumption that more for the government means less for the private sector. However a positive value for the term on the right-hand side can offset this presumption,

[4] Atkinson and Stern (1974) show in a similar setting that, as the permitted level of lump-sum taxation rises, there exists a path from $R$ to the first-best optimum $F$ along which welfare increases steadily. Here we are interested in characterizing the desired direction from an arbitrary initial point $A$ toward $R$.

[5] See, for example, Foster and Sonnenschein (1970), Bruno (1972), and Hatta (1977), and the discussion in Section 3.1 below. In the homothetic case, $R_I = R_u/E_u$ reduces to $T^a \pi' e_\pi / e - T^w (w + \tau) g_w / e$, the average tax rate on goods and employment as a share of total expenditure.

permitting a rise in both real income and revenue. This possibility arises from reforms that remove inefficiency in the tariff structure. Below, we characterize such possibilities in terms of tariff moments.

### 2.4. The marginal cost of funds

When we turn to consider choices between different forms of taxation, it is useful to express our results in terms of the marginal cost of funds (MCF) of different instruments. Consider the cost to the government of supporting the representative agent's real income $u$ with a hypothetical subsidy $ds$ when the wage tax $\tau$ changes to raise revenue $R$ by one dollar.

From the private-sector budget constraint (2), the hypothetical compensating subsidy is $ds = E_\tau d\tau$; while from the public-sector budget constraint (3), the required change in the wage tax is $d\tau = \frac{1}{R_\tau} dR$. Combining these gives $\frac{ds}{dR} = \frac{E_\tau}{R_\tau}$ which we define as $\mu^\tau$, the marginal cost of raising a dollar of public funds using the wage tax $\tau$. Similar operations define the marginal cost of funds for any other policy instrument such as $\pi_i$. That is, raise a marginal dollar of public funds by increasing the tariff on a single good $t_i$, implicitly requiring a tax change $\frac{1}{R_{\pi_i}}$, with compensating hypothetical subsidy $ds$ to the representative agent of $\mu_i^\pi$. The outcome is a marginal cost of funds for that tariff instrument equal to $\frac{E_{\pi_i}}{R_{\pi_i}}$.

What is the likely magnitude of the marginal cost of funds? In the case of the wage tax, we assume that $\mu^\tau$ is positive, since otherwise the problem of how to cut tariffs without reducing revenue is trivial; the numerator $E_\tau$ is the tax base, while the denominator $R_\tau$ is positive provided the economy lies below the maximum of the Laffer Curve. From Eq. (3), the full expression for $R_\tau$ is:

$$R_\tau = E_\tau + t' E_{\pi\tau} + \tau E_{\tau\tau}. \tag{9}$$

Recalling that $E$ is concave in $\tau$, the direct substitution effect of a wage tax on labor supply $E_{\tau\tau}$ tends to reduce $R_\tau$ below $E_\tau$, and so encourages a value for the social cost of funds greater than one. This could be offset by the cross effect: if leisure is a complement for imports, so $E_{\pi\tau}$ is positive, a rise in the wage tax $\tau$ increases tariff revenue, encouraging a value for the social cost of funds less than one. However, values greater than one are typically found in applied studies and must be considered the norm. Similar considerations, *mutatis mutandis*, apply to the magnitude of the marginal cost of funds of any other tax instrument.

### 2.5. Tariff changes compensated by wage tax changes

Armed with the concept of the marginal cost of funds, we can now consider our second approach to tariff reform. This ensures revenue neutrality by adjusting the wage tax to compensate for any reduction in revenue arising from tariff changes. Thus we analyze reforms of tariffs, i.e., changes in prices $\pi$, compensated by changes in the wage tax $\tau$ that keep government revenue at its initial level $R^0$. Differentiating the private-sector budget constraint (2), the change in utility now depends, unlike Eq. (5), on the change in the wage tax as well as on changes in tariffs:

$$E_u du = -E_\pi' dt - E_\tau d\tau. \tag{10}$$

Similarly, unlike Eq. (6), the change in the wage tax is determined implicitly by the requirement that the government budget constraint (3) must bind:

$$R_\pi' dt + R_\tau d\tau + R_u du = dR_0. \tag{11}$$

Eliminating the endogenous change in the wage tax, $d\tau$, from Eqs. (10) and (11) gives the expression for welfare change in this case:

$$(1 - \mu^\tau R_I) E_u du = -\mu^\tau dR^0 - (E_\pi' - \mu^\tau R_\pi') dt \tag{12}$$

where $\mu^\tau = E_\tau / R_\tau$ is the marginal cost of funds raised by the wage tax.

Although we will hold revenue fixed, it is insightful to include the change in the revenue requirement $R^0$ in Eq. (12), since it allows us to interpret the coefficient of the welfare change on the left-hand side. Consider the effect of a hypothetical transfer to the government which reduces the revenue requirement $R^0$ by one unit. The impact effect of this on welfare is equal to the marginal cost of funds $\mu^\tau$. In an economy with tariff and wage tax distortions this impact effect has multiplier repercussions, which are measured by the inverse of the coefficient of $E_u du$. This shows that the term $1 - \mu^\tau R_I$ is the inverse of the shadow price of foreign exchange modified for the endogeneity of the wage tax. Moreover, as with the corresponding term in Section 2.3, we are justified in assuming that it is positive: a negative value would imply that a gift to the economy, which relaxes the revenue requirement $R^0$, would lower real income.[6]

With income effects taken care of, we are free to concentrate on the substitution effects of the tariff change, summarized by the coefficient of $dt$ in Eq. (12). (We can also ignore the change in the revenue requirement, so we set $dR^0$ equal to zero from now on.) Unfortunately, while this lends itself to useful intuitive interpretations, it does not lead to easily operational rules for tariff reform. A first approach is to consider Eq. (12) on a commodity-by-commodity basis. Factoring out the scalar elements of $E_\pi$, and using $\mu_i^\pi \equiv E_{\pi_i} / R_{\pi_i}$, Eq. (12), becomes:

$$(1 - \mu^\tau R_I) E_u du = -\sum_i (1 - \mu^\tau / \mu_i^\pi) E_{\pi_i} dt_i. \tag{13}$$

The intuitive implication of Eq. (13) is that reducing tariffs on all goods for which $\mu_i^\pi > \mu^\tau$ and increasing tariffs on all goods for which the inequality is reversed will produce a surplus. This in turn causes an increase in real income, provided the shadow price of foreign exchange is positive.

An alternative approach to Eq. (12) is to write the term $R_\pi'$ in full, using Eq. (7) and the definition of the marginal cost of funds from Eq. (9):

$$(1 - \mu^\tau R_I) E_u du = \left[ (\mu^\tau - 1) E_\pi' + \mu^\tau (t' E_{\pi\pi} + \tau E_{\tau\pi}) \right] d\pi. \tag{14}$$

This provides an insightful contrast with the usual expression for welfare change in the theory of piecemeal tariff reform when lump-sum taxes are available (see Eq. (34) in Appendix A), and it reduces to it when labor supply is fixed so a wage tax is effectively lump-sum ($\mu^\tau = 1$ and $E_{\tau\pi} = 0$). However, saying more about the tariff reform problem using Eq. (14) as it stands is challenging. To make progress with this problem, we turn in the next section to extend the method of tariff moments developed in Anderson and Neary (2007) to the present context.

## 3. Tariff moments

### 3.1. Summary statistics for the structure of tariffs

The key intermediate step in the analysis of trade reform is a decomposition of the effect of tariff changes into their effect on various moments of the distribution of tariffs. Anderson and Neary (2007) examine welfare-improving directions of tariff reform in the case where revenue considerations are unimportant, so $\mu^\tau = 1$. Here we

[6] Empirically, requiring $(1 - \mu^\tau R_I)^{-1}$ to be positive is more demanding than before, given that $\mu^\tau$ is likely to be greater than one. On the other hand, empirical studies typically find relatively low values of the labor supply elasticity, hence low $\mu^\tau$ is plausible.

**Table 1**
Notation.

| Name | Symbol | Explanation |
|---|---|---|
| Government revenue function | $R$ | $(\pi-\pi^*)'E_\pi+\tau E_\tau-s$ |
| Substitution effects matrix | $E_{\pi\pi}$ | Negative definite |
| Substitution weights matrix | $S$ | $\frac{\underline{\pi}E_{\pi\pi}\underline{\pi}}{\pi' E_{\pi\pi}\pi}$ (positive definite) |
| Generalized mean tariff | $\overline{T}$ | $\iota' ST$ |
| Trade-weighted average tariff | $T^a$ | $\frac{E_\pi' t}{E_\pi'\pi}$ |
| Cross-weighted average tariff | $T^\theta$ | $\frac{E_{\tau\pi}t}{E_{\tau\pi}\pi}$ |
| Own elasticity | $\eta$ | $-\frac{\pi' E_{\pi\pi}\pi}{E_\pi'\pi}$ |
| Cross elasticity | $\theta$ | $\frac{E_{\tau\pi}\pi}{E_\tau}$ |
| Employment elasticity | $\omega$ | $-\frac{d\log E_\tau}{d\log(w+\tau)}$ |
| Wage-Tax revenue relative to value of imports | $\lambda^\tau$ | $\frac{\tau E_\tau}{E_\pi'\pi}$ |
| MCF for wage tax | $\mu^\tau$ | $\frac{E_\tau}{R_\tau}=(1-T^w\omega+T^\theta\theta)^{-1}$ |
| MCF for scalar $T$ reform | $\mu^T$ | $\frac{E_\pi'\pi}{R_\pi'\pi}=(1-\eta\overline{T}+\lambda^\tau\theta)^{-1}$ |

extend their moments decomposition technique to the revenue tariff problem. Table 1 summarizes the notation.

We begin by defining "tariff factors," tariffs measured as a proportion of domestic prices: $T_i \equiv \frac{t_i}{\pi_i}=\frac{\pi_i-\pi_i^*}{\pi_i}$. These can be written in matrix form as: $T=\underline{\pi}^{-1}(\pi-\pi^*)$, where $\underline{\pi}$ denotes a diagonal matrix formed from the vector $\pi$. The analog for the wage tax is $T^w \equiv \frac{\tau}{w+\tau}$. Following Anderson and Neary (2007), we define the generalized mean tariff $\overline{T}$ and the generalized variance of tariffs $V$ as a weighted average and variance respectively of the tariff factors $T$:

$$\overline{T}\equiv\iota' ST=\frac{\pi' E_{\pi\pi}t}{\pi' E_{\pi\pi}\pi},\quad V\equiv\left(T-\iota\overline{T}\right)'S\left(T-\iota\overline{T}\right). \tag{15}$$

The weights are normalized elements of the substitution effects matrix $E_{\pi\pi}$: the positive definite weighting matrix $S$ is defined by $S\equiv-\bar{s}^{-1}\underline{\pi}E_{\pi\pi}\underline{\pi}$, where $\bar{s}\equiv-\pi' E_{\pi\pi}\pi>0$ is the normalization coefficient for the substitution effects matrix, and $\iota$ is a vector of ones. The normalization implies that $\iota' S\iota=1$. The focus in the present paper on the revenue constraint and endogenous labor supply requires that we define two further average tariffs: the trade-weighted average tariff and the cross-weighted average tariff, where the weights in the latter are the cross-responses between leisure and each good:

$$T^a\equiv\frac{E_\pi' t}{E_\pi'\pi},\quad T^\theta\equiv\frac{E_{\tau\pi}t}{E_{\tau\pi}\pi}. \tag{16}$$

As for changes in trade policy, we define the changes in tariff moments as Laspeyres-type approximations, using initial trade shares and responses as weights:

$$d\overline{T}\equiv\iota' SdT,\quad dV\equiv 2T' SdT-2\overline{T}d\overline{T},\quad dT^a\equiv\frac{E_\pi'\underline{\pi}dT}{E_\pi'\pi},\quad dT^\theta\equiv\frac{E_{\tau\pi}d\pi}{E_{\tau\pi}\pi}, \tag{17}$$

where $dT\equiv\underline{\pi}^{-1}dt=\underline{\pi}^{-1}d\pi$.

Except for the trade-weighted average tariff $T^a$, these generalized moments and their changes are complicated functions of consumer and producer behavior. Nonetheless, they summarize the implications of the full matrices of aggregate demand and supply responses in an intuitive and parsimonious way. In this respect, they are analogous to the shadow price of foreign exchange introduced by Hatta (1977): it allows all income effects to be summarized in terms of a single convenient aggregate statistic, whereas earlier work typically made strong assumptions about income effects on a commodity-by-commodity basis, such as requiring all goods to be normal.[7] In the same way, the generalized tariff moments provide a set of sufficient statistics for the substitution effects in the economy. As we will show, analytic expressions in changes in generalized means and variances help formulate linear tariff change rules that guarantee welfare improvement even in the absence of detailed information about substitution effects.

Notice that whereas the trade-weighted average tariff $T^a$ is positive so long as imports are not heavily subsidized, the generalized mean tariff need not necessarily be positive even with all positive tariffs. Being able to assume a positive generalized mean turns out to be important for our approach to the assessment of the welfare implications of tariff changes when information is limited. Fortunately, a negative generalized mean is an unlikely perverse case.[8] In the remainder of this paper we assume that the generalized mean tariff is positive.

### *3.2. Tariff moments with general equilibrium separability*

An important special case of preferences and technology provides a very illuminating and convenient illustration of the generalized moments and their relationship to the observable trade-weighted average tariff. Suppose that the group of goods with price vector $\pi$ enters preferences and technology separably:[9]

**Definition 1.** The trade expenditure function is implicitly separable in tariffed goods and leisure when:

$$E(\pi,\tau,u)=F[\phi(\pi,u),\tau,u], \tag{18}$$

where the function $\phi(\pi,u)$ is concave and homogeneous of degree one in $\pi$.

Separability is a very common assumption in applied work with both econometric and simulation modeling. Appendix B shows that all our present argument can be applied to any separable group while more general substitution possibilities continue to govern relationships between groups. The payoff to assuming separability is that it implies that both generalized average tariffs equal the observable trade-weighted average tariff:

**Proposition 1.** *Under separability as in* Eq. (18), *both the generalized mean tariff and the cross-weighted average tariff are equal to the trade-weighted average tariff:* $\overline{T}=T^\theta=T^a$.

**Proof.** In the separable case, linear homogeneity of $\phi$ implies that $\pi'\phi_\pi=\phi$ and $\pi'\phi_{\pi\pi}=0$. Hence, differentiating Eq. (18) twice with respect to $\pi$, we have: $E_\pi=F_\phi\phi_\pi$ and $E_{\pi\pi}=F_\phi\phi_{\pi\pi}+F_{\phi\phi}\phi_\pi\phi_\pi'=F_{\phi\phi}\phi\phi_\pi'$. It follows that the generalized mean tariff from Eq. (15) becomes:

$$\overline{T}=\frac{\pi' E_{\pi\pi}t}{\pi' E_{\pi\pi}\pi}=\frac{F_{\phi\phi}\phi\phi_\pi' t}{F_{\phi\phi}\phi\phi_\pi'\pi}=\frac{\phi_\pi' t}{\phi_\pi'\pi}=T^a. \tag{19}$$

Similarly, differentiating Eq. (18) twice with respect to $\tau$, gives: $E_\tau=F_\tau$ and $E_{\tau\pi}=F_{\tau\phi}\phi_\pi'$. Hence the cross-weighted average tariff from Eq. (16) becomes:

$$T^\theta=\frac{E_{\tau\pi}t}{E_{\tau\pi}\pi}=\frac{F_{\tau\phi}\phi_\pi' t}{F_{\tau\phi}\phi_\pi'\pi}=\frac{\phi_\pi' t}{\phi_\pi'\pi}=T^a. \tag{20}$$

□

[7] Foster and Sonnenschein (1970) assumed that all goods were normal, which we now know is far stronger than needed to obtain results about piecemeal policy reform. Bruno (1972) seems to have been the first to appreciate that income effects could be summarized in a single parameter.

[8] Anderson and Neary (2007) show that $\overline{T}$ is positive if all tariff rates are equal or if all goods subject to tariffs are general-equilibrium substitutes for the numéraire (which, with variable labor supply, must be extended to general-equilibrium substitutes for the composite commodity made up of the numéraire and leisure). With a zero wage tax, a negative value of $\overline{T}$ implies that $\mu^T$, the marginal cost of funds for the group of tariff-ridden goods, defined in Eq. (24) below, is less than one. This means that welfare increases with a rise in the tariff because marginal deadweight loss is actually negative. Replacing lump-sum taxes with a uniform absolute rise in tariffs would be welfare-increasing in such a case. If exports or imports are heavily subsidized, the perverse case becomes more likely, but this perversity is also likely to show up in a negative value for $T^a$.

[9] See Anderson and Neary (1992) for further discussion.

This proposition is a significant generalization of Anderson and Neary (2007), who showed that $\overline{T}$ equals $T^a$ in a special case where tariffed imports are final goods imperfectly substitutable with domestic production, and preferences are CES. Separability is a considerably weaker sufficient condition.[10]

## 4. Tariff changes only

With tariff reform restricted to tariff changes only, the task is to find directions of improvement that raise welfare and/or revenue without lowering either one. We reexpress the differentials of the private and government budget constraints (5) and (6) in terms of the generalized moments of the tariff structure:[11]

$$\frac{E_u du}{E_\pi \pi} = -dT^a \tag{21}$$

$$\frac{dR}{E'_\pi \pi} = (1-R_I)dT^a - \eta\left(\tfrac{1}{2}dV + \overline{T}d\overline{T}\right) + \lambda^\tau \theta dT^\theta. \tag{22}$$

Here we introduce two new elasticities, which summarize the effects of a uniform change in goods prices: $\eta \equiv -\frac{\pi' E_{\pi\pi}\pi}{E'_\pi \pi} = \frac{\overline{s}}{E'_\pi \pi}$ is the own-elasticity of the $\pi$ group with respect to an equiproportionate change in $\pi$; while $\theta \equiv \frac{E_{\tau\pi}\pi}{E_\tau}$ is the cross-elasticity of employment with respect to an equiproportionate change in $\pi$. We also use $\lambda^\tau \equiv \frac{\tau E_\tau}{E'_\pi \pi}$ to denote wage-tax revenue relative to the value of imports.

Eqs. (21) and (22) show how the informational requirements for tariff reform with an arbitrary number of goods subject to tariffs are reduced to only six parameters (not counting the easily observable $T^a$ and $\lambda^\tau$): a major economy of information relative to the full matrices needed to interpret and calibrate Eqs. (5) and (6). Eq. (21) implies that the change in money metric utility as a percent of trade expenditure is equal to minus the change in the trade-weighted average tariff. Eq. (22) reveals that revenue must fall with a fall in $T^a$, unless compensated by changes in the other tariff moments.[12] What type of tariff structure changes can induce both welfare and revenue to rise?

Reductions in the generalized variance must always increase revenue, all else equal. Mean-preserving reductions in dispersion are thus attractive if it is feasible to preserve all three means $(T^a, \overline{T}, T^\theta)$. When the group of tariff-ridden goods being reformed enters preferences or technology separably, the three first moments are all equal, from Proposition 1. This gives our first result for tariff reform:

**Proposition 2.** *Under separability as in* Eq. (18)*, cuts in tariff dispersion which leave the trade-weighted average tariff unchanged raise revenue while not harming welfare.*

Consider next reductions in average tariffs. Anderson and Neary (2007) show that a uniform absolute cut in tariff rates, $dT = -\iota d\alpha$, is attractive because it raises both welfare and market access (the value of imports at world prices).[13] Unfortunately, it ordinarily must reduce revenue. To see this, note that such a reform leaves dispersion unchanged ($dV = 0$) and reduces all three average tariffs by the same proportion: $dT^a = d\overline{T} = dT^\theta = -d\alpha$. These results do not depend on separability; they arise because a uniform absolute cut in tariff rates $T_i$ brings about a uniform proportional reduction in domestic prices, $d\pi = -\pi d\alpha$, so imported goods constitute a Hicksian composite commodity. As a result, from Eq. (22), revenue changes by:

$$\frac{dR}{E'_\pi \pi} = -(1-R_I-\eta\overline{T}+\lambda^\tau\theta)d\alpha = -\left(\frac{1}{\mu^T}-R_I\right)d\alpha. \tag{23}$$

Here we use $\mu^T$ to denote the marginal cost of funds for the group of tariff-ridden goods, which, by the composite commodity theorem, can be treated as if it were a single good when prices move equiproportionately:

$$\mu^T \equiv \frac{E'_\pi \pi}{R'_\pi \pi} = \left(1-\eta\overline{T}+\theta\lambda^\tau\right)^{-1}. \tag{24}$$

As discussed in Section 2.4, there is a presumption that the marginal cost of funds is greater than one for each individual good, so it must be considered highly unlikely that this marginal cost of funds of a composite group could be less then one. We also expect $R_I$, the effect of a unit gift of foreign exchange on government revenue, to lie between zero and one, as discussed in Section 2.3. Given this, the sign of the right-hand side of Eq. (23) is ambiguous, although there is a presumption that the direct price effect $1/\mu^T$ outweighs the income effect $R_I$: uniform absolute reductions ordinarily imply that revenue falls: [14]

**Proposition 3.** *Uniform absolute reductions in T raise both welfare and market access, but raise revenue if and only if the inverse of the marginal cost of funds for all tariff-ridden goods, $\mu^T$, is less than the income responsiveness of revenue, $R_I$.*

Summarizing this section, given that very large dispersion is common in tariff structures, even in countries that raise a substantial portion of government revenue from tariffs, Proposition 2 implies considerable scope for efficiency improvement from dispersion cuts. On the other hand, Proposition 3 implies that absolute tariff cuts with constant dispersion decrease revenue, which creates a presumption against average tariff reductions as part of a reform package when tariff revenue is important (i.e., when tariffs are the only instrument).

## 5. Tariff reform with compensating wage tax changes

### 5.1. Tariff reform rules in terms of generalized moments

Tariff reform advice has more scope for efficiency gains when the wage tax $\tau$ can be changed so as to hold revenue constant. As we saw in Section 2.5, the general expression for welfare change given by Eq. (14) is not so informative in this case. However, reexpressing it in terms of tariff moments gives more insight:

$$\frac{1-\mu^\tau R_I}{E'_\pi \pi}E_u du = (\mu^\tau-1)dT^a - \mu^\tau\eta\left(\tfrac{1}{2}dV + \overline{T}d\overline{T}\right) + \mu^\tau\lambda^\tau\theta dT^\theta. \tag{25}$$

The first term on the right-hand side of Eq. (25) is increasing in the trade-weighted average tariff provided that $\mu^\tau > 1$. This term gives the revenue effect of the tariff change at constant quantities demanded, without substitution effects. The second term gives the effect of tariff changes acting through within-group substitution effects, all multiplied by the own-price elasticity of the composite imported good, $\eta$. It is decreasing in the generalized variance and, provided $\overline{T} > 0$, in the generalized mean. The third term gives the cross effect on revenue due to the

[10] As shown in Anderson and Neary (2007), the CES case also yields a simple observable expression for the generalized variance of tariffs. No such simplification is possible for the much wider class of weakly separable preferences or technology, but none is needed for our purposes.

[11] To derive Eq. (22) from Eq. (6), we use: $t'E_{\pi\pi}d\pi = T'\underline{\pi}E_{\pi\pi}\underline{\pi}dT = -\overline{s}T'SdT = -\overline{s}(\frac{1}{2}dV + \overline{T}d\overline{T}) = -\eta(\frac{1}{2}dV + \overline{T}d\overline{T})E'_\pi \pi$.

[12] In contrast, Anderson and Neary (2007) show that welfare and "market access" (trade volume) are moved in the same direction by changes in $\overline{T}$ but in opposite directions by changes in variance $V$.

[13] Such a uniform absolute cut in the tariff rates $T_i$ implies that tariffs are reduced in proportion to domestic prices: $\frac{dt_i}{\pi_i}$ is the same for all $i$. This preserves domestic relative prices, unlike the more familiar uniform radial reduction in tariffs, which implies that tariffs are reduced in proportion to their initial values: $\frac{dt_i}{t_i}$ is the same for all $i$. See Anderson and Neary (2007), especially Table 1 and Fig. 2, for further details.

[14] In the neighborhood of zero taxation, $\mu^T = 1$ and $R_I = 0$, implying that quite substantial levels of tariffs and taxes are necessary for revenue to rise.

change in the cross-weighted average tariff $T^\theta$ multiplied by $\theta$, the cross-elasticity between leisure and goods.

What combinations of assumed information and rules for tariff changes are likely to improve welfare in this case? The general expression (25) provides useful clues. First, variance reduction is useful, all else equal. Second, the uniform absolute reduction reform is once again an important benchmark. Proposition 3 shows that it usually reduces revenue. Can a wage-tax increase compensate and still permit a real income gain? In this case Eq. (25) reduces to:

$$\frac{1-\mu^\tau R_I}{E_\pi' \pi}\frac{E_u du}{d\alpha} = 1-\frac{\mu^\tau}{\mu^T}. \tag{26}$$

As discussed in the last section, $\mu^T$, the composite marginal cost of funds of the group of tariff-ridden goods, is presumptively positive: recall Eq. (24). What of $\mu^\tau$, the marginal cost of funds of the employment tax? Using Eq. (9), we can write it in terms of generalized moments as:

$$\mu^\tau \equiv \frac{E_\tau}{R_\tau} = \left(1-\omega T^W + \theta T^\theta\right)^{-1}, \tag{27}$$

where $\omega \equiv -\frac{d\log E_\tau}{d\log(w+\tau)}$ is the general-equilibrium elasticity of employment with respect to the tax $\tau$.[15] General results on the sign of $1-\frac{\mu^\tau}{\mu^T}$ are not possible and empirical evidence is sparse.[16] However, it seems plausible that $\frac{\mu^\tau}{\mu^T}<1$, i.e., that a tariff is less efficient than the alternative distortionary tax. For example, this is the finding of Erbil (2004) in a simulation exercise comparing the marginal cost of funds of trade taxes with consumption taxes for a number of countries. From Eq. (26), this is all we need to assume to be confident that combining reductions in dispersion with scalar cuts in tariffs offers room for welfare- and revenue-improving reforms that are robust to our very substantial uncertainty about economic structure.

For more general results that can cover more of the complexity of actual tariff changes, it is very helpful to consider a more general radial tariff reform rule introduced by Anderson and Neary (2007), $dT = -(T - \beta\iota)d\alpha$. This implies an equiproportionate change in the gap between all tariff rates and an arbitrary uniform tariff rate, denoted by $\beta$. A rise in $\alpha$ always lowers variance and will lower any average tariff provided it is greater than $\beta$.[17] This general linear path is a combination of uniform absolute and uniform proportional changes in tariffs. It is also a convex combination of uniform absolute tariff changes and trade-weighted mean-preserving variance changes.[18] Along the linear path:

$$\frac{1-\mu^\tau R_I}{E_\pi' \pi}\frac{E_u du}{d\alpha} = (1-\mu^\tau)(T^a-\beta) + \mu^\tau \eta V + \mu^\tau\left[\eta\overline{T}(\overline{T}-\beta) - \lambda^\tau\theta\left(T^\theta-\beta\right)\right]. \tag{28}$$

Then using $\mu^T > 1$ (so $\eta\overline{T} > \lambda^\tau\theta$) and additionally supposing that $\overline{T} \geq T^\theta \geq \beta$, the expression in square brackets must be positive. In particular, setting the tariff change rule such that $\beta = T^a$, welfare rises with $\alpha$ whenever $\overline{T} \geq T^\theta \geq T^a = \beta$. Summarizing:

**Proposition 4.** *Welfare improves with:*

(i) *Trade-weighted mean-preserving reductions in tariff variance, when $\overline{T} \geq T^\theta \geq T^a$ and $\mu^T > 1$;*
(ii) *Uniform absolute tariff reductions, when $1 < \mu^\tau < \mu^T$;*
(iii) *Convex combinations of uniform absolute tariff cuts and trade-weighted mean-preserving dispersion cuts, $\beta \leq T^a$, under the conditions of (i) and (ii).*

**Proof.** (i) and (ii) have already been proved. To prove (iii), rearrange the right-hand side of Eq. (28) and divide by $T^a - \beta > 0$ to obtain:

$$\frac{E_u du}{d\alpha} \propto 1-\mu^\tau\left[1-\eta\overline{T}\frac{\overline{T}-\beta}{T^a-\beta} + \theta T^w\frac{T^\theta-\beta}{T^a-\beta}\right] + \mu^\tau\eta\frac{V}{(T^a-\beta)}. \tag{29}$$

The square bracket term is smaller than the inverse of $\mu^T$ under the conditions of (i), and hence the entire expression is positive under the condition of (ii). □

The condition $\overline{T} \geq T^\theta \geq T^a$ is problematic, depending on two unobservable average tariffs. However, it is guaranteed if separability holds, from Proposition 1. It follows that Proposition 4 holds with separability and $1 < \mu^\tau < \mu^T$. In the future, more insight into the behavior of the unobservables will be generated by examining simulations with a variety of models and data for different countries.

The separable case shows that mere substitutability is not important in ranking $\overline{T}$ and $T^\theta$ relative to $T^a$. Substitution effects within classes of tariff-ridden goods are irrelevant, complementarities are admissible along with highly asymmetric substitution effects. For example, it is natural to think of an aggregate like clothing as a goods class, entering preferences separably but having complex substitution effects within class: shirts and trousers may be complements while silk and chambray shirts may be substitutes. What does matter for the ranking is that nonseparability admits varying substitution effects between tariff-ridden goods and the numeraire. Using the standard algebra of covariance, $\overline{T}-T^a = Cov(\omega, T) - Cov(\omega^a, T)$, where the covariance uses arithmetic (equal) weights. The generalized weights $\omega$ differ from the trade share weights $\omega^a$ only if the goods are non-separable and $\overline{T}<T^a$ with non-separability if numeraire substitution effect shares $\omega$ are more sensitive to high tariffs than are trade shares $\omega^a$.

Proposition 4 can readily be extended to many classes of separable tariff-ridden goods. Let $T^{ka}$ denote the trade-weighted average tariff in separable goods class $k$, while $T^a$ continues to denote the overall trade-weighted average tariff and $\overline{T}$ continues to denote the overall generalized mean tariff.

**Proposition 5.** *Welfare improves with:*

1. *Trade-weighted mean-preserving dispersion cuts within separable goods classes;*
2. *Any convex combination of such dispersion cuts and a uniform absolute tariff change across as well as within classes that decreases tariffs when they are over-utilized or increases them when they are under-utilized.*

Proposition 5 is proved in the Appendix. The key element is that, from Proposition 1, the condition of Proposition 4 is met under separability. The proposition is quite useful because separability is a ubiquitous assumption in applied work. Faced with some ten thousand tariff lines, aggregation is inevitable for any econometric or simulation work. The proposition guarantees that trade-weighted average preserving dispersion cuts within classes are welfare-improving without detailed knowledge of substitution effects (either parameter values or specification) within goods classes. National tariff schedules are full of dispersion in detailed product classes, so there is a lot of room in practice for

[15] In general equilibrium, the wage tax affects employment both directly and by changing the wage. Applying the implicit function theorem to the labor-market clearing condition $e_w(\pi, w, u) = g_w(\pi, w + \tau, v)$ yields $dw/d\tau = g_{ww}/(e_{ww} - g_{ww})$. A rise in the wage tax alters employment $E_\tau = -g_w$ by $dE_\tau/d\tau = -g_{ww}(1 + dw/d\tau)$. Then $-d\ln E_\tau/d\ln(w+\tau) = (w+\tau)(g_{ww}e_{ww})/[g_w(e_{ww} - g_{ww})] > 0$ by the concavity of $e$, convexity of $g$, and $g_w = -E_\tau < 0$.

[16] An important benchmark is optimality, the solution to the Ramsey problem. This requires that the marginal cost of funds be equal for all $\pi$, and equal to the marginal cost of funds for the alternative source of tax revenue, in this case the wage tax.

[17] $dT^a = -(T^a - \beta)d\alpha$, and similarly for $d\overline{T}$ and $dT^\theta$; while $dV = -2Vd\alpha$.

[18] $(T - \beta\iota)d\alpha = [\omega(T - T^a\iota) - (1 - \omega)\delta\iota]d\gamma$ where $d\gamma = d\alpha/\omega$ and $\beta = T^a + \delta(1 - \omega)/\omega$ for $1 \geq \omega \geq 0$. The scalar $\delta$ can be positive or negative.

beneficial cuts. It is worth noting that, under separability, a trade-weighted mean-preserving tariff dispersion cut improves welfare strictly by raising government revenue; trade expenditure remains constant under this reform.

Note finally that, from Eqs. (24) and (27), the separable case where $\overline{T} = T^\theta = T^a$ yields directly useful expressions for $\mu^T$ and $\mu^\tau$ that can be used to calculate the relative under- or over-utilization of tariffs:

$$\mu^T = \left(1 - \eta T^a + \theta\lambda^\tau\right)^{-1}, \quad \mu^\tau = \left(1 - \omega T^w + \theta T^a\right)^{-1}. \tag{30}$$

$T^a$, $\lambda^\tau$ and $T^w$ are observable, so it is relatively easy to test the sensitivity of $\frac{\mu^\tau}{\mu^T}$ to alternative values of the elasticities $\eta$, $\theta$ and $\omega$ which are not known with certainty.

### 5.2. The CES special case

Clearly the conditions derived so far are only sufficient, and additional restrictions on either the structure of the economy or the type of trade reform permitted would allow some strengthening of them. Specialization to the CES case with zero cross-effects between goods and leisure ($\theta = 0$) is insightful since in this simple but canonical setting the marginal cost of funds for each individual tariff can be derived independently of all others:[19]

$$\mu_i^\pi = \left[1 - \eta T^a - \sigma\left(T_i - T^a\right)\right]^{-1}. \tag{31}$$

The CES expression (31) for the marginal cost of funds reveals that the focus of Propositions 4 and 5 on convex combinations of mean-preserving tariff cuts and dispersion-preserving mean cuts does indeed capture all the relevant characteristics of welfare-improving revenue tariff reform which can be guaranteed without full knowledge of substitution effects. If exact values of $\eta$ and $\sigma$ are assumed to be known, it is of course possible to improve welfare with tariff reforms outside the cones based on Eq. (31).[20] As substitution possibilities range more widely beyond the CES, more welfare-improving revenue tariff reforms can be found which are not within the cones of Propositions 2, 3, and 4. But again, showing that these reforms raise welfare depends on information that this paper assumes, realistically, that the analyst is unlikely ever to have with any certainty.

Note that the CES expression sheds light on the esoteric possibility that some tariffs may actually have a marginal cost of funds less than one. From Eq. (31), the necessary and sufficient condition for $\mu_i^\pi < 1$ is $(1 - \eta/\sigma)T^a > T_i$. The sufficient condition requires either that $\eta/\sigma < 1$, substitution elasticities within the separable group exceed substitution elasticities between that group and all other goods, or that good $i$ is subject to an import subsidy, so $T_i < 0$. Normally neither condition would be met.

### 5.3. The desirability of dispersion cuts

Further analysis of the desirability of trade-weighted mean-preserving dispersion cuts is useful, since it seems to argue for uniformity in contrast to the intuition of the Ramsey principle. The sufficiency condition $\overline{T} \geq T^a$ appears to be puzzlingly powerful.

Returning to Fig. 1, the ray *OR* through the Ramsey optimal tariff point *R* divides the domestic price space into half spaces. Starting at point *R*, consider a mean-tariff-preserving line (not drawn) to the uniform tariff ray *OF*. For points on this line between the uniform tariff ray *OF* and the optimal tariff ray *OR*, trade-weighted mean-preserving dispersion increases are welfare-improving. For points in the space below ray *OR*, dispersion increases are welfare-decreasing. If the cone *FOR* is small, the World Bank intuition about the desirability of dispersion reduction holds for most of the tariff space.

Next, consider the initial tariffs *A*, lying on an iso-utility locus as shown. Recall that the line labeled $dT^a = 0$ gives the mean-preserving tariff change path. As drawn, decreases in dispersion raise welfare, implying $\overline{T} > T^a$. A line tangent to the iso-utility locus at point *A* represents the situation where $V + \overline{T}(\overline{T} - T^a) = 0$. If the locus $dT^a = 0$ is steeper than the tangent line to $G^A$ at *A*, a reduction in dispersion lowers welfare. With separability, $\overline{T} = T^a$, hence welfare rises for mean-preserving changes in dispersion. This implies that the Ramsey-optimal tariff is uniform in the separable case (Guesnerie, 1995); i.e., point *R* lies on *OF*. Extending separability to multiple classes as in Proposition 5, uniformity of tariffs within classes is optimal. This benchmark case suggests that optimal departures from uniformity may be small for a fairly wide class of reasonable general equilibrium structures.

The desirability of dispersion cuts becomes less surprising when we recall that the linear reform rule restricts outcomes relative to the starting point. The full optimum *R* is not attainable. The optimal tariff structure implied by the linear reform rule $dT = (T - \beta\iota)d\alpha$ is, for mean-preserving dispersion changes $\beta = T^a$, consistent with $V = -\overline{T}(\overline{T} - T^a)$. Fig. 2 illustrates a case where the mean-preserving dispersion cut line *AU* is associated with increases in welfare relative to $u^A$ for each point on the path to the uniform tariff ray *OF*. Nevertheless, the full optimal tariff point *R* is non-uniform and yields still higher welfare.[21] Moreover, there is a best tariff subject to the linear rule and the initial condition $T^A$ which lies somewhere on the path from *A* to *U*, and this tariff is non-uniform unless it lies at *U*. $\overline{T} < T^a$ is necessary for a movement from *A* to *U* not to raise welfare relative to $u^A$ for each point on the path.

## 6. Many households

The preceding expressions extend with appropriate modification to the case of many households. The government budget constraint continues to hold using *E* for the aggregate trade expenditure function and its derivatives, while $E^h$ denotes the individual household *h* trade expenditure function.

To economize on notation, we express the change in welfare in terms of the hypothetical subsidy that must be made to each agent *h* to maintain their real income. By definition $ds = \sum_h ds^h$, the aggregate subsidy is the sum of subsidies needed to maintain each agent's real income. The budget constraint for agent (household) *h* yields:

$$ds^h = E_\pi^h \cdot \pi dT^{a,h} + E_\tau^h (w + \tau) dT^w, \tag{32}$$

where $T^{a,h}$ is the trade-weighted average tariff using the trade weights of agent *h*. $dT^w$ is endogenously generated from the government revenue constraint to compensate for the exogenous tariff changes. Solving that aggregate constraint as before, substituting into the equation above and rearranging yields:

$$ds^h = E_\pi^h \cdot \pi dT^{a,h} - \left(\frac{E_\tau^h}{E_\tau} E_\pi \cdot \pi\right)\mu^\tau dT^a - \left(\frac{E_\tau^h}{E_\tau} E_\pi \cdot \pi\right)\mu^\tau \left[\eta dV/2 + \overline{T} d\overline{T} - T^w \theta dT^\theta\right]. \tag{33}$$

Summing over households *h*, the first two terms cancel out. The condition that reform be beneficial in the aggregate (representative agent) case is that the third term be negative. Propositions 4 and 5 apply.

The potential for individual loss is confined to the deviation due to the balance of the first two terms. Agents can differ in their tastes for

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[19] In the CES case, $\phi_{ij} = \sigma(-\delta_{ij} + w_j) w_i \frac{\phi}{\pi_i \pi_j}$.

[20] In the CES case the half space of welfare-improving reforms is defined by tariffs such that $\{\iota - [\mu^\tau(1 - \eta T^a)\iota - \mu^\tau \sigma(T - T^a \iota)]\}' d\pi < 0$. The condition that $\mu^\tau / \mu^T > 1$ is equivalent to $\mu^\tau(1 - \eta T^a) < 1$. Mean-preserving dispersion cuts reduce government costs, dispersion-preserving mean cuts (uniform absolute cuts) reduce government costs, convex combinations of these also reduce costs. But many other cuts lie in the half space below the constraint.

[21] The Ramsey-optimal tariff vector is given by $T^0 = \frac{\mu^\tau - 1}{\mu^\tau \overline{s}} S^{-1} \underline{\pi} E_\pi$, where all variables are evaluated at the Ramsey optimum.

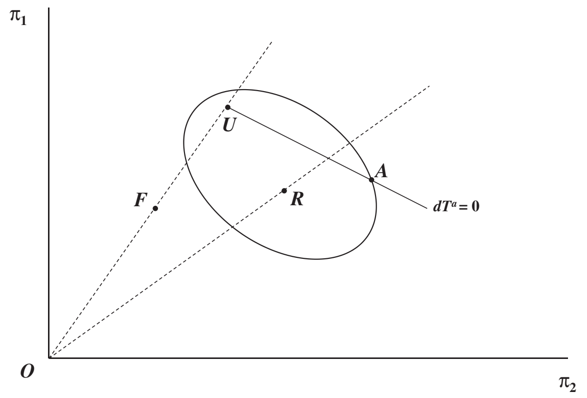


**Fig. 2.** Welfare-improving dispersion cuts. On path *AU*, trade-weighted-mean-preserving tariff cuts raise welfare font = small. On path *AO*, uniform absolute tariff cuts first raise welfare, then lower it.

work vs. consumption, generating differences in the aggregate weights attached to the average tariff differentials, and they can differ in their consumption patterns within the tariffed goods bundle when faced with the same price vectors. The latter results in $dT^{a,h} \neq dT^a$ while the former results in $E_\pi^h \cdot \pi \neq (E_\tau^h/E_\tau)E_\pi \cdot \pi$.

What minimal information is needed to specify welfare-improving rules for each household (Pareto superior rules)? Tariffs are widely levied on intermediate goods. In this case there is no household-specific weighting, $T^{ai} = T^a$, so dispersion cuts are Pareto-superior. As for final goods, assume that imported goods in a separable goods class have no domestic perfect substitute, and that household expenditure patterns $E_\pi^h$ are observable. The former is a widely used empirical assumption because the perfect substitutes assumption yields implications wildly at variance with the trade data. The observability of household expenditure patterns is a more problematic assumption but it is satisfied for a number of countries.

Under these assumptions, the $\beta^h$ parameters can be set equal to the household level trade-weighted average tariff $T^{a,h}$ to implement the mean preserving dispersion cut: $dT^h = (T - T^{a,h})d\alpha$. The mechanism is a uniform deviation from the common tariff cut rule for each household: $dT^h - dT = (T^{a,h} - T^a)\iota d\alpha$. All tariffs are changed according to $dT = (T - T^a\iota)d\alpha$. Implementation of the household specific deviations could presumably take place at the retail level (as with food stamps or senior citizen discounts), supplemented by some governmental identification system. Doing so, for example, all clothing tariffs change according to the common rule, then each household receives or pays its household specific deviation $(T^{a,h} - T^a)d\alpha$. Alternatively, the implementation could be done through income tax credits. To avoid shirking, the common rule could be set around the highest $T^{a,h}$, so that all households with lower average tariffs receive a rebate.

In this scheme of tariffs, the real income of each household is maintained, the individual variation of $\beta^h$ is revenue neutral since $\sum_h (T^{a,h} - T^a)\pi' E_\pi^h = 0$, and the government revenue will rise due to the revenue-increasing cut in dispersion. Thus dispersion cuts are a Pareto-superior reform. As for uniform absolute cuts in tariffs, the requirement of Propositions 2 and 3 that 'tariffs are over (under) utilized' becomes extremely stringent because it requires that the marginal cost of funds of the alternative revenue source be less (more) than *each* individual agent's marginal cost of funds of tariffs. This is seldom likely to appear plausible to analysts evaluating potential reforms.

The implication is that the Pareto-superiority of dispersion cuts holds in the many household case under the separability assumption, understanding that trade-weighted average tariffs must be calculated and applied at the household level. The separability assumption is plausible for some goods classes and not for others. Still, this discussion suggests the surprisingly wide desirability of dispersion cuts.

## 7. Conclusion

This paper has derived rules for welfare-improving trade reform that permit confident policy advice despite the (assumed partial) ignorance of analysts about the true structure of the economy. Dispersion-reducing trade reform is surprisingly widely beneficial: whenever households have implicitly separable preferences with respect to the same partitions of goods, dispersion of tariffs within separable groups is inefficient. Cuts in average tariffs are efficient when the marginal cost of funds of such tariffs is greater than the marginal cost of funds from alternative revenue sources. Convex combinations of uniform absolute cuts and mean-preserving dispersion cuts are beneficial under these conditions. Over and above these specific results, we have shown the value of reexpressing complex results for multi-dimensional policy reform in terms of a small number of summary statistics. This approach should prove useful both in guiding empirical work and in allowing an intuitive focus on the key parameters that matter for policy evaluation.

## Appendix A. Piecemeal policy reform with lump-sum transfers

We assume in the body of the paper that the government cannot impose lump-sum taxes or grant lump-sum subsidies. By contrast, the standard theory of piecemeal trade policy reform assumes that lump-sum transfers are available. In that case, as noted in Section 2.1, the private-sector and government budget constraints, Eqs. (3) and (2), can be combined to give the balance of trade constraint, Eq. (4). Differentiating this yields:

$$(1-R_I)E_u du = -dR^0 + [t'E_{\pi\pi} + \tau E_{\tau\pi}]dt + [t'E_{\pi\tau} + \tau E_{\tau\tau}]d\tau \quad (34)$$

where $R_I$, the income responsiveness of revenue, is defined in Section 2.3. The coefficient of the change in real income, $1 - R_I$, is the inverse of the shadow price of foreign exchange discussed there. Assuming it is positive, the right-hand-side terms in Eq. (34) lead to the standard results of piecemeal tariff reform, allowing in addition for a labor tax. In the special case where there is no labor tax (so $\tau = E_{\pi\tau} = 0$), Eq. (34) reduces to a result which is familiar from Hatta (1977) and subsequent work:

$$(1-R_I)E_u du = -dR^0 + t'E_{\pi\pi}dt. \quad (35)$$

Comparing this with Eq. (5) in the text shows how the welfare effects of changes in tariffs are sensitive to whether or not the government has the power to make lump-sum transfers.

## Appendix B. Proof of Proposition 5

The separable case gives rise to useful simplifications of the model. Here the logic is extended to many separable classes.

Suppose that the tariff-ridden group of goods forms an implicitly separable class in the trade expenditure function: $E(\pi, p, \pi_0, u) = F[\phi(\pi, u), p, \pi_0, u]$, where $\phi$ is concave and homogeneous of degree one in $\pi$. When imported goods form separable classes indexed by $k$, such as $\eta^k(\pi^k)$, the logic of the text yields $\overline{T}^k = T^{ak}$ with the natural extension of notation. Mean-preserving dispersion reduction is desirable within classes. When combined with overall uniform tariff change, the tariff change policy rule is given by

$$dT^k = -\left(T^k - \beta^k \iota^k\right)d\alpha, \quad \forall k \quad (36)$$

where $\iota$ is understood to be the vector of ones with dimension appropriate to goods class $k$ and $\beta^k$ is a scalar for goods class $k$. The combination of trade-weighted mean-preserving change with uniform absolute change overall requires $\beta^k = T^{ak} + \beta$. As for overall mean tariffs, we define $T^a = \sum \omega_k^a T^{ak}$, where $\omega_k^a = \frac{E_{\eta^k}\eta^k}{\sum E_{\eta^k}\eta^k}$, the trade weights for the classes of imports. The generalized mean overall tariff is defined by $\overline{T} = \sum \omega_k T^{ak}$, where the generalized weights are defined as in the text, but using the price aggregators $\eta^k$ as the individual prices.

Define the row vector $b' \equiv \{\beta^1 \iota^1, \ldots, \beta^K \iota^K\}$. The trade-weighted average of $b$ is $b^a = T^a + \beta$, while the generalized average of $b$ is $\overline{b} = \overline{T} + \beta$. Using these properties to simplify the expression for welfare change from Eq. (12) with $dR^0 = 0$ in terms of tariff moments gives, instead of Eq. (25):

$$\frac{1-\mu^\tau R_I}{E'_\pi \pi}\frac{E_u du}{d\alpha} = (1-\mu^\tau)(T^a - b^a) + \frac{\mu^\tau \overline{s}}{E'_\pi \pi}\left\{V + \overline{T}\left(\overline{T} - \overline{b}\right) - Cov(T,b)\right\}. \quad (37)$$

Here, $Cov(T, b)$ denotes the generalized covariance $(T-\overline{T})' S(b-\overline{b})$.

In the separable case, the covariance is equal to zero. Covariation within classes is obviously equal to zero because the elements of $b$ within class do not vary. Between classes, the class-mean-preserving element of $\beta^k$ implies no change in price aggregates while the mean shift element of $\beta^k$ implies a uniform shift which gives no variation. Applying the other implications of the structure of $b$ yields:

$$\begin{aligned}\frac{1-\mu^\tau R_I}{E'_\pi \pi}\frac{E_u du}{d\alpha} &= -\beta(1-\mu^\tau) + \frac{\mu^\tau \overline{s}\overline{T}}{E'_\pi \pi}\left(\frac{V}{\overline{\overline{T}}} - \beta\right) \\ &= -\beta\left(1 - \frac{\mu^\tau}{\mu^T}\right) + \mu^\tau\left(1 - \frac{1}{\mu^T}\right)\frac{V}{\overline{\overline{T}}}.\end{aligned} \quad (38)$$

The substitutions from the first to the second line use the fact that $\frac{\overline{s}\,\overline{T}}{E'_\pi \pi} = 1 - \frac{1}{\mu^T}$. Jointly sufficient conditions for Eq. (38) to be positive, so welfare is increased by the policy rule Eq. (36), are that $\frac{\mu^\tau}{\mu^T} < 1$ and $\beta < 0$. This is the case of over-utilized tariffs and uniform tariff increases combined with increases in trade-weighted mean-preserving dispersion. Thus we have proved Proposition 5.

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