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QUALITY UPGRADING AND ITS WELFARE COST IN U.S. STEEL IMPORTS, 1969-74

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ABSTRACT

In this paper we measure the quality change which has occurred in U.S. steel imports during the 1969-74 VRA, using an index number method. Under this approach, the yearly changes in unit values is broken into three components: a quality-adjusted or pure price index; a quality index, which measures changes in the product mix; and a supplier index, which measures changes in the source of supply. We also derive a measure of welfare cost, which equals the inverse of a Paasche price index minus the inverse of an exact price index. Over the 1969-74 VRA period we find quality upgrading of 7.4 percent in U.S. steel imports, which occurs most strongly in the first year. The welfare cost of quality change varies around one percent of import expenditure during 1970-73. This cost is at least as large as the conventional deadweight loss triangle, but smaller than the transfer of quota rents.

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1. Introduction

During the past two decades, the U.S. government, prompted by the faltering steel industry, has made numerous attempts to restrict the flow of imported steel. The U.S. industry was once the leading steel producer of the postwar period, but by the late fifties that position was challenged by foreign producers, particularly Japan, whose newer industries were more efficient and reliable. A crippling strike by steel workers caused the U.S. to become a net importer of steel for the first time in 1959. As countries such as Brazil and Korea began to increase their steel production, and as the U.S. industry failed to remain competitive, imports continued to erode the domestic producers market share.

In 1950 imported steel accounted for only 1.4 percent of total U.S. steel consumption. In 1968, when the import share had reached 17 percent, the U.S. negotiated a voluntary restraint agreement (VRA) with Japan and the European Community (EC). The agreement limited the total tonnage of steel imports, but not their total value. Existing theoretical work, such as Falvey (1979), Rodriquez (1979), Das and Donnenfeld (1986, 1987) and Krishna (1985, 1987), shows that the imposition of a quantitative restriction, as opposed to an ad-valorem tariff, will likely lead countries to upgrade the quality of their imports within quota categories. This has been demonstrated to have occurred in the automobile industry by Feenstra (1984, 1985, 1988), in the footwear industry by Aw and Roberts (1986, 1988), and in the cheese industry by Anderson (1985, 1988).

In this paper we measure the quality change which has occurred in U.S. steel imports during the 1969-74 VRA, using the same method as Aw and Roberts (1986, 1988).[1] Under this method, the yearly changes in unit values is broken into three components: a quality-adjusted or pure price index; a quality index, which measures changes in the product mix; and a supplier index, which measures changes in the source of supply. In section 2 we theoretically justify this technique as a valid way to measure "quality.[2]" In section 3 we go beyond existing literature by showing how the welfare cost of the quality change in imports can be evaluated.[3] In particular, we derive a measure of welfare cost which depends only on some easily calculated index numbers: the welfare cost equals the inverse of a Paashe price index minus the inverse of an exact price index. So long as producers are minimizing costs, this welfare cost is non-negative.

In section 4 we outline our data and the method of calculating the index numbers, and results are presented in section 6. Over the 1969-74 period of the VRA, we find quality upgrading of 7.4 percent in U.S. steel imports, which occurs most strongly in the first year. This compares with a 1.4 percent quality decline in the following years. The welfare cost of the quality change varies around one percent of import expenditure during 1970-73. We argue that this cost is at least as large as the conventional deadweight loss triangle, but smaller than the transfer of quota rents. Conclusions are given in section 6.

2. Model of Trade Restrictions and Quality Change

Let us assume that inputs into an economy's production function may be separated into M discrete varieties of an imported good, which we shall call steel and denote by the column vector x, and all other inputs (including domestically produced steel) denoted by the column vector z. Let us further assume that imported steel is weakly separable from all other inputs in production.[4] This means that the economy's production function can be written as,

$$y = f[g(x), z], \tag{1}$$

where y denotes output, and g is increasing, concave and homogeneous of degree one in x. The function g(x) can be interpreted as an aggregate of imported steel.

Let p denote the M-dimensional price vector of imported steel, and q the price vector of all other inputs. These are treated as columns unless transposed with a prime. Then since the production function in (1) is separable, the corresponding cost function can be written as (see Blackorby, Primont and Russell, 1978, Theorem 3.8):

$$C\ [\pi(p), q, y], \tag{2}$$

where,

$$\pi(p) \equiv \min_{x} \{p'x \mid g(x) = 1, x > 0\}. \tag{3}$$

That is, the prices of imported steel are separable from q and y in the economy's cost function. From (3), $\pi(p)$ is interpreted as a unit-cost function for imported steel, and is increasing, concave and homogeneous of degree one in p.

Separability of the prices of imported steel means that the relative demand for import varieties depends only on the import prices, and not on q or y. This can be demonstrated by differentiating the cost function with respect to some p_i and p_j to derive the demand functions for two varieties of imported steel, and then examining their ratio:

$$x_i/x_j = C_{p_i}/C_{p_j} = C_\pi \pi_i / C_\pi \pi_j = \pi_i(p)/\pi_j(p),$$

where $\pi_i \equiv \partial\pi/\partial p_i$. One can see that although the absolute demand for an individual variety of imported steel is a function of the prices of all goods and the level of output, the relative demand for any two qualities is a function only of imported steel prices.

Before examining the effects of trade policy on the type of steel products imported, we need to have a suitable definition of "quality." Let n denote a column vector of one's with dimension M, and let $X \equiv x'n$ denote the summed quantity of steel imports. We are supposing that the varieties of steel imports are measured in some common unit (i.e. tons), but the summation is still objectionable since we are adding rods, sheets, stainless steel, etc. The purpose of our "quality" measure is to turn the objectionable magnitude X (tons of imported steel) into a meaningful aggregate. To this end we use the following:

Definition 1

The quality of steel imports is $Q \equiv g(x)/X$.

Thus, given data on X the researcher would multiply it by quality Q to obtain the aggregate imports g(x). However, this definition of quality is only useful if it can be computed relatively easily. The following result shows that this is the case.

Proposition 1

Let $x^0 \neq 0$ denote the cost-minimizing choice of imports given (p,q,y), with $X^0 = n'x^0$. Then $Q = (p'x^0/X^0)/\pi(p)$.

Proof:

Let $\lambda = g(x^0) > 0$. Then using a slight change of notation in (3) we can write:

$$\pi(p) = \min_x \{p'(x/\lambda) \mid g(x/\lambda) = 1, (x/\lambda) \geq 0\}$$

$$= \min_x \{p'(x/\lambda) \mid g(x) = \lambda, x \geq 0 \}$$

since g in homogeneous of degree one,

$$= (1/\lambda) \min_x \{p'x \mid g(x) = \lambda, x \geq 0 \}$$

$$= (1/\lambda)\ p'x^0 = p'x^0/g(x^0)$$

by definition of x^0 and λ^0.

Thus, we have $g(x^0) = p'x^0/\pi(p)$ and so the proposition follows directly from the definition of Q. QED

Proposition 1 states that the quality of imported steel can be obtained as a ratio of the unit value $(p'x^0/X^0)$ and the unit-cost $\pi(p)$. Let us denote the former by UV. Now consider evaluating the change in quality between two time periods, labelled 0 and 1. We have:

$$\ln Q^1 - \ln Q^0 = \ln(UV^1/UV^0) - \ln[\pi(p^1)/\pi(p^0)]. \quad (4)$$

In this formula, $\pi(p^1)/\pi(p^0)$ can be measured by an exact price index (see Diewert, 1976, and section 4). Thus, (4) states that the change in quality can be measured by the difference of the growth in the unit value and an exact price index between two periods. This is precisely the method used by Waldorff (1979), Chinloy (1980), Aw and Roberts (1986, 1988), and others.[5]

Our next step is to determine how the quality of imports is affected by trade restrictions. A quota (or VRA) limits the total amount imported as measured by X (i.e. tons of steel). As argued by Falvey (1979), we expect this restriction to cause the same specific or dollar increase in all varieties of the import, since if the specific markups on two varieties differed there could be profits earned by lowering (raising) imports with the low (high) markup, keeping total imports constant.[6] Letting $\sigma > 0$ denote the specific increase in the price of imported steel due to a quota, and p denote the exogenous international prices, the import prices after the quota are $p + \sigma n$. In contrast, an ad valorem tariff of τ leads to the same percentage increase in all import prices, resulting in a price vector of $p(1+\tau)$.

The effect of the quota or ad valorem tariff on the quality of imports is given by:

Proposition 2

(a) A quota leads to an increase in import quality whenever $p_i \neq p_j$ for some i and j and π_{pp} is of rank (M-1).

(b) An ad valorem tariff leads to no change in import quality.

Proof:

(a) We evaluate the change in quality using (4), with $p^0 = p$ and $p^1 = p + \sigma n$. Note that $UV = p'x/X = p'C_\pi \pi_p / C_\pi \pi_p' n = \pi_p' p / \pi_p' n = \pi(p)/\pi_p' n$, since π is homogeneous of degree one. Substituting the expressions for p^0, p^1 and UV into (4) and cancelling terms, we obtain

$$\ln Q^1 - \ln Q^0 = \ln[\pi_p'(p)n] - \ln[\pi_p'(p+\sigma n)n].$$

Since the natural log is an increasing function, the sign of this expresssion is identical to the sign of $[\pi_p'(p)n - \pi_p'(p+\sigma n)n]$. Define $\psi(\lambda) = \pi_p'[\lambda p+(1-\lambda)(p+\sigma n)]n$. Then from the mean-value theorem we have,

$$\begin{aligned}\pi_p'(p)n - \pi_p'(p+\sigma n)n &= \psi(1) - \psi(0) \\ &= \psi'(\lambda^0) \text{ for some } \lambda^0 \in [0, 1] \\ &= -\sigma n' \pi_{pp} [\lambda^0 p + (1-\lambda^0)(p+\sigma n)]n \\ &> 0, \end{aligned} \tag{5}$$

where the last inequality follows since π is concave, so that π_{pp} is negative semi-definite. We know in general that $\pi_{pp}(p)p = 0$ and, given our rank assumption, there is no vector other than kp which can be multiplied with $\pi_{pp}(p)$ to yield zero. Thus, (5) is zero if and only if $[\lambda^0 p+(1-\lambda^0)(p+\sigma n)] = kn$ for some $k>0$, which implies that $p = [k-(1-\lambda^0)\sigma]n$ so $p_i = p_j$ for all i and j.

(b) We follow the same procedure as in (a), where now $p^0 = p$ and $p^1 = p(1+\tau)$. Then expression (4) becomes,

$$\ln Q^1 - \ln Q^0 = \ln[\pi_p'(p)n] - \ln[\pi_p'(p(1+\tau))n].$$

Since π is homogeneous of degree one in p, π_p is homogeneous of degree zero. It follows that $\pi_p(p) = \pi_p(p(1+\tau))$, and so the above expression equals zero. QED

The assumption that $p_i \neq p_j$ in Proposition 2(a) simply means that some varieties of imported steel have different prices, since otherwise the specific price increase from a quota would be equivalent to an ad valorem tariff. The assumption that π_{pp} is of rank (M-1) rules out a Leontief production function g(x), for example, since the corresponding cost function $\pi(p)$ is linear and $\pi_{pp} = 0$. In the Leontief case the varieties of steel would be imported in fixed proportions x_i/x_j, and a quota has no effect on import composition. But aside from this case, we expect the specific price increase to shift import demand towards the varieties with higher initial prices, since those varieties experience a lower relative price increase. It is this shift in the composition of imports which is captured by our measure of "quality." Since the ad valorem tariff leaves relative import prices unchanged, it leads to no shift in the composition of imports.

Proposition 2 should be regarded as a generalization of the results in Falvey (1979), and certainly depends on our assumption of separability of steel imports.[7] New results are obtained when we consider the welfare effect of quality change, which we turn to next.

3. Welfare Cost of Quality Change

To evaluate the welfare cost of a quota or ad valorem tariff, we shall use the conventional deadweight loss definition (Diamond and McFadden, 1974): the difference between the rise in production costs due to the trade restriction, and the revenue or rents generated from it.[8] Letting L_σ and L_τ denote the deadweight loss due to the quota and ad valorem tariff, respectively, we have:

$$L_\sigma = C[\pi(p+\sigma n), q, y] - C[\pi(p), q, y] - C_\pi \pi_p'(p+\sigma n)\sigma n, \tag{6a}$$

$$L_\tau = C[\pi(p(1+\tau)), q, y] - C[\pi(p), q, y] - C_\pi \pi_p'(p(1+\tau))\tau p. \tag{6b}$$

The first two terms in (6a) and (6b) are production costs with and without the trade restriction, and the third terms are quota rents or tariff revenue, respectively, where $C_\pi \pi_p(\cdot)$ is the vector of import purchases.[9] If the quota rents are obtained by foreigners, then the third term in (6a) should be omitted when calculating the social cost of the quota.

In this study we wish to focus on the "excess" cost of the quota due to the quality upgrading. Our analysis is complementary to Crandall (1981), Congressional Budget Office (1984), Tarr and Morkre (1984), Hufbauer, Berliner and Elliot (1986), and other studies which estimate the price increase due to the steel quota, the corresponding reduction in aggregate imports, and then calculate the deadweight loss triangle. We will provide an additional welfare cost due to the quality change itself, which can be added to the conventional deadweight loss triangle, and to the rectangle of quota rents (see section 5.2).

To isolate the welfare effect of the quality change, let us consider an ad valorem tariff which has the same effect on the aggregate import price as the quota, i.e. which satisfies:

$$\pi(p(1+\tau)) = \pi(p+\sigma n). \qquad (7)$$

If the quota led to no change in the composition of imports (e.g. if the production technology was Leontief), then the tariff and quota satisfying (7) would have the same deadweight loss. Then a natural way to isolate the welfare effect of the quality change is to consider the difference between L_σ and L_τ when (7) holds. Formally, we state:

Definition 2

The welfare cost of quality upgrading due to the quota is $W \equiv (L_\sigma - L_\tau)/C_\pi\pi(p+\sigma n)$, where (7) holds.

Several points should be noted. First, in this definition the term $C_\pi\pi(p+\sigma n)$ is the total expenditure on imports with the quota, and we measure the welfare cost relative to this expenditure. Second, we have referred to W as a "cost" without yet proving it is positive; this is the point of our next proposition. Third, the ad valorem tariff and quota satisfying (7) can be thought of as "price-equivalent." The welfare cost of the quota is equal to the welfare cost of the price-equivalent tariff (L_τ) plus W (before dividing by import expenditure). An alternative comparison of tariffs and quotas can be made by considering those which are "quantity-equivalent" as defined by X, i.e. leading to the same tonnage of steel imports. This approach is taken by Krishna (1987), and will be considered at the end of this section.

The next result shows that W can be measured by a comparison of index numbers.[10] We suppose that import prices and quantity before and after the quota are available to the researcher. The Paasche price index measures the change in import expenditure using the post-quota quantities:

$$P_a(p,\ p+\sigma n) \equiv C_\pi \pi_p'(p+\sigma n)(p+\sigma n)/C_\pi \pi_p'(p+\sigma n)p$$
$$= \pi_p'(p+\sigma n)(p+\sigma n)/\pi_p'(p+\sigma n)p. \qquad (8)$$

In contrast, an exact price index (see Diewert, 1976, and section 4) uses the price and quantity data to measure the true change in the aggregate import price:

$$P_e(p,\ p+\sigma n) \equiv \pi(p+\alpha n)/\pi(p). \qquad (9)$$

We then have:

Proposition 3

$$W = [1/P_a(p,\ p+\sigma n)] - [1/P_e(p,\ p+\sigma n)] > 0.$$

Proof:

Since π is homogeneous of degree one we have $\pi_p'(p)p = \pi(p)$ and $\pi_p(p(1+\tau)) = \pi_p(p)$. Then substituting (7) into (6) and cancelling terms, we obtain,

$$L_\sigma - L_\tau = C_\pi[\pi_p'(p(1+\tau))\tau p - \pi_p'(p+\sigma n)\sigma n]$$

$$= C_\pi[\pi_p'(p+\sigma n)p - \pi_p'(p(1+\tau))p]$$

since $\pi_p'(p(1+\tau))p(1+\tau) = \pi_p'(p+\sigma n)(p+\sigma n)$ from (7)

$$= C_\pi[\pi_p'(p+\sigma n)p - \pi(p)].$$

From (3), this expression must be non-negative, since the quantities $x = \pi_p(p+\sigma n)$ are feasible to produce $g(x) = 1$ but not cost-minimizing with prices p. Dividing this expression by $C_\pi \pi(p+\sigma n) = C_\pi \pi_p'(p+\sigma n)(p+\sigma n)$ and using (8) and (9), we obtain the proposition. QED

The result that $W > 0$ in Proposition 3 means that the quota has greater deadweight loss than a "price-equivalent" tariff, as defined by (7). Note that this quota and tariff also lead to equivalent aggregate imports, given by $g(x) = C_\pi(\pi(p(1+\tau)), q, y) = C_\pi(\pi(p+\sigma n), q, y)$. However the quantity of imports as measured by X (tonnage of steel) certainly differ between the quota and ad valorem tariff, since the former leads to quality upgrading. Indeed, from Definition 1 we have that $X = g(x)/Q$, and since Q rises with the quota but not the tariff, we see that imports X are lower with the quota than with a "price-equivalent" ad valorem tariff.

In some policy situations, planners might be interested in limiting X, so it is relevant to compare the welfare cost of instruments which achieve this goal, as in Krishna (1987). Since $X = C_\pi \pi_p' n$, we can define an ad valorem tariff and quota to be "quantity-equivalent" if,

$$C_\pi[\pi(p(1+\tau)), q, y]\ \pi_p'(p(1+\tau))n$$
$$= C_\pi[\pi(p+\sigma n), q, y]\ \pi_p'(p+\sigma n)n. \quad (10)$$

A comparison of the deadweight loss for the tariff and quota is then possible with the following result:

Proposition 4

For the ad valorem tariff and quota satisfying (10), $\pi(p(1+\tau)) > \pi(p+\sigma n)$, with strict inequality when $p_i \neq p_j$ for some i and j and π_{pp} is of rank (M-1).

Proof:

Since π_p is homogeneous of degree zero, $\pi_p(p(1+\tau)) = \pi_p(p)$. Then using (5) and (10) we obtain,

$$C_\pi[\pi(p(1+\tau)), q, y] < C_\pi[\pi(p+\sigma n), q, y],$$

with strict inequality under the hypotheses of Proposition 2(a). Concavity of the cost function means that $C_{\pi\pi} < 0$, and so the proposition follows. QED

From this result we can assert that the deadweight losses L_σ and L_τ, for the "quantity-equivalent" quota and tariff in (10), cannot be ranked in general. The reason is that the quota always leads to the welfare cost W due to upgrading. A "quantity-equivalent" tariff, however, leads to a larger deadweight loss triangle due to the higher import price π. The welfare costs of the quality upgrading versus the higher import price cannot be compared in general, and so neither can L_σ and L_τ.[11]

In this study we shall focus on the quality change in imports and the corresponding welfare cost W. In the next section we outline the calculation of index numbers needed to measure the upgrading and welfare cost.

4. Calculation of Index Numbers

We obtained annual, seven digit TSUSA data on the quantity (X) and value (V) of steel imports by country of origin, from the U.S. Bureau of the Census (1968-1978). The countries used accounted for virtually all the steel imported into the U.S. One hundred sixteen product categories are included; all steel products other than pipe and tube. Overall, this group of products represents about 95 percent of U.S. steel imports in 1968. Denoting varieties of steel by m and countries by c, the rate of growth of a unit value (ΔUV) of steel imports can be measured as follows:

$$\Delta UV^t = \ln UV^t - \ln UV^{t-1}, \tag{11}$$

where,

$$UV^t = \frac{\sum_m \sum_c V^t_{mc}}{\sum_m \sum_c X^t_{mc}} .$$

Superscripts denote time periods, while subscripts identify the particular product-country combination.

The rate of growth of a discrete *Divisia* price index (ΔP_d) of imported steel may be written as:

$$\Delta P^t_d = \sum_m \sum_c S^t_{mc} \left[\ln \left[\frac{V^t_{mc}}{X^t_{mc}} \right] - \ln \left[\frac{V^{t-1}_{mc}}{X^{t-1}_{mc}} \right] \right] , \tag{12}$$

where,

$$S^t_{mc} = 1/2 \left[\frac{V^t_{mc}}{\sum_m \sum_c V^t_{mc}} + \frac{V^{t-1}_{mc}}{\sum_m \sum_c V^{t-1}_{mc}} \right] .$$

As shown above, the Divisia price index weights the individual price change of each type of steel, from each country, by its average share in the total value of steel imports over the two periods. It will not change simply because of a change in the product or country mix. This index is an exact price index if the import expenditure function is translog (Diewert 1976), and as such is a good choice as the true price index.

The difference between ΔUV and ΔP_d is an index of the change in product and supplier mix. It captures the rate of growth of steel import prices which is not due to the price increase of any particular product from a particular country. It may be written as follows:

$$\Delta Q_d^t = \Delta UV^t - \Delta P_d^t \,. \tag{13}$$

Partial Divisia indexes may also be constructed to measure changes in product and country mix individually. This is done by aggregating over one factor, either treating products as homogeneous to measure changes in the source of supply, or treating suppliers as homogeneous to measure changes in the product mix. A partial Divisia index is not a pure index, because it contains one source of aggregation bias. However, the difference between the rate of growth of a unit value index, and the rate of growth of a partial Divisia index, may be interpreted as a product quality index only (Q_m) or a supplier index only (Q_c). To create a product quality index, we first create a partial Divisia index treating countries as homogeneous. The rate of growth of this index ΔP_m is:

$$\Delta P_m^t = \sum_m S_m^t \left[\ln \left[\frac{\sum_c V_{mc}^t}{\sum_c X_{mc}^t} \right] - \ln \left[\frac{\sum_c V_{mc}^{t-1}}{\sum_c X_{mc}^{t-1}} \right] \right] , \tag{14}$$

where

$$S_m^t = 1/2 \left[\frac{\sum_c V_{mc}^t}{\sum_m \sum_c V_{mc}^t} + \frac{\sum_c V_{mc}^{t-1}}{\sum_m \sum_c V_{mc}^{t-1}} \right] .$$

If this index is then subtracted from ΔUV constructed previously, we get a measure of product quality change or quality index, corresponding to Proposition 1 and (4):

$$\Delta Q_m^t = \Delta UV^t - \Delta P_m^t . \qquad (15)$$

If a partial Divisia index treating goods rather than countries as homogeneous is constructed, then the difference between ΔUV and the rate of growth of that partial Divisia index (ΔP_c) is a supplier index, measuring the change in import prices due to different foreign suppliers:

$$\Delta Q_c^t = \Delta UV^t - \Delta P_c^t . \qquad (16)$$

The composite quality and supplier index in (13) is not necessarily equal to the sum of (15) and (16), because substitution may take place toward more expensive products from more expensive countries; see Aw and Robert (1986).

Finally, we need to calculate the cumulative Paasche and exact indexes to measure the welfare cost W. Using 1968 as the base year, the cumulative Paasche price index is calculated as;

$$P_a^t = \frac{\sum_m \sum_c V_{mc}^t}{\sum_m \left(\sum_c V_{mc}^{68} / \sum_c X_{mc}^{68} \right) \sum_c X_{mc}^t} . \qquad (17)$$

Note that in this index we are treating countries as homogeneous, and therefore measuring the change in product prices only. This corresponds to our treatment of countries in the quality index. The cumulative Divisia index treating countries as homogeneous is calculated from (14) as,

$$P_m^t = \exp\left(\sum_{\tau=69}^{t} \Delta P_m^{\tau}\right). \tag{18}$$

The welfare cost corresponding to Proposition 3 is given by,

$$W_d^t = (1/P_a^t) - (1/P_m^t), \tag{19}$$

where the subscript "d" is used to emphasize that a (partial) Divisia index has been used as the exact index.

Since it will be apparent that the welfare cost is sensitive to the choice of the exact index, we shall also report results using the Fisher (1922) Ideal price index, which is exact for a linear, Leontief and quadratic production function (Diewert, 1976). The cumulative Ideal index (P_i^t) is obtained by first calculating the Laspeyres price index (P_ℓ^t) with 1968 as the base year, and then taking the geometric mean of the Paasche and Laspeyres indexes:

$$P_\ell^t = \frac{\sum_m \left(\sum_c V_{mc}^t \,/\, \sum_c X_{mc}^t\right) \sum_c X_{mc}^{68}}{\sum_m \sum_c V_{mc}^{68}} \tag{20}$$

$$P_i^t = (P_a^t \; P_\ell^t)^{1/2} . \tag{21}$$

In these formulae we are again treating countries as homogeneous. The welfare cost W using the Ideal index is given by,

$$W_i^t = (1/P_a^t) - (1/P_i^t). \tag{22}$$

5. Effects of the 1969-74 VRA in Steel

5.1 Estimates of Quality and Supplier Changes

When the VRA was first negotiated by the Johnson Administration in 1968, the decision was made to limit overall steel imports to 12.7 million tons (including pipe and tube). Forty-one percent was allocated to each of Japan and the European Community (EC) and 18 percent was allocated to the rest of the world. The VRA was agreed to formally, however, only by Japan and the EC. It was to begin in 1969 and last three years, with a five percent growth rate in imports allowed each year.

As seen in Table 1, from 1968 to 1970 the quantity of steel imports fell from 15.7 million tons, with a unit value of $105 per ton, to 10.8 million tons, with a unit value of $143 per ton. In Table 2, the aggregate unit value change is decomposed into a Divisia index, and using partial Divisia indexes, into quality and supplier indexes.

During the first year of the VRA the unit value of steel imports rose 14.7 percent, with about half of that increase due to product quality upgrading. In the second year of the VRA the unit value rose 16.1 percent, with about two percentage points of that increase due to importing higher quality products. The agreement broke down in 1971 when the Nixon administration placed a 10 percent surcharge on all imported products. The Europeans and the Japanese claimed that this violated the quota agreement.

They responded by increasing steel exports to a level which exceeded their alloted quotas. As a result of this, the quantity of imports rose by about 50 percent in 1971, reaching 15.5 million tons. The unit value of steel imports fell to $139 per ton that year. However, since the exact price (Divisia) index actually rose by 2.3 percent, the entire decline in the unit value index can be attributed to changes in the product and country mix to include more low quality steel products, imported from Japan and the EC.

In May 1972, after over a year of negotiation, the agreement was renewed, with more specific restrictions placed on high valued products, specifically stainless steel and alloy tool steel (so called specialty steel). There was a renewed pledge by countries to maintain the product mix of imports, and annual import growth rates were reduced from 5 percent to 2.5 percent. In 1973, there was a dramatic increase in world steel demand which caused the agreement to become superfluous. It lapsed in 1974. During the time the renegotiated VRA was in place, from mid-1972 to 1974, there was some additional quality upgrading. However, because the agreement was binding with the EC only in 1973, and was not binding with Japan in either 1973 or 1974, it is not surprising that further quality upgrading was small.

Over the entire five year period of the VRA, the unit value of steel imports rose by 53 percent, an average increase of 10 percent per year. About one-seventh or 7.4 percentage points of that increase was due to product quality upgrading. Since 1971 is included, this is a conservative estimate. The upgrading is most apparent in the first year of the VRA. There was virtually no movement, however, toward importing steel from higher priced producers. Since the VRA was based on historic market shares, this result follows naturally.

In order to see how instrumental the VRA was in the occurrence of this quality upgrading, we compare the VRA period 1969 to 1973 (this is the last year the agreement was binding), to a period when there were relatively few restrictions, 1975 to 1978. In the latter years, there were no formal quantitative restrictions on carbon steel imports, although there were quantitative restrictions on specialty steel imports between 1976 and 1980.

The industry went through a period of strong demand worldwide in 1973 and 1974. In 1974, 13.3 million tons of steel with a unit value of $305 were imported into the U.S. Although imports increased dramatically, the share of imports in total domestic steel consumption fell from about 17 percent to about 13 percent. Therefore, import penetration was not a major concern. In 1975 and 1976, the situation reversed. Steel prices fell and producers, who had expanded in the previous two years, were left with enormous levels of excess capacity. In addition, because the decline in demand was viewed as temporary, the industry was relectant to retire its older facilities, exacerbating the problem. Steel imports fell by 30 percent in 1975, reaching their lowest level of 9.6 million tons. However, the import share rose slightly.

In order to maintain employment levels in their domestic steel industries, many countries subsidized steel production and/or dumped imports into the U.S. This led to a disintegration in the price structure and added to the crisis already facing the domestic steel industry. Increased imports of low priced foreign steel once again spurred action by the domestic industry, in the form of anti-dumping and countervailing duty lawsuits. By 1978, when the quantity of steel imports has risen to 17 million tons, a new method of curbing steel imports - the trigger price mechanism - was introduced.

From 1975 to 1978, the Divisia price index of imported steel rose erratically by about five percent, but the unit value rose by less than one percent. That is because the product quality index fell by 1.4 percent, and the supplier index fell by 3.5 percent. This is a reversal of the previous period, with lower quality products being imported from lower pricing countries.

In summation, product quality seemed to be affected by the imposition of the VRA. Quality upgrading was most pronounced during the first year of the VRA, when it accounted for one-half of the unit value increase. Product quality increased by 7.4 percent, overall, when the VRA was in effect. This compares to a 1.4 percent quality decline in the following years.

Although supplier changes seemed less dramatic, this may be explained by the smaller differential in the prices among suppliers ($70 to $375 per ton) as compared to the differential in product prices ($41 to $2,387 per ton). The supplier index indicates that there was a greater movement toward buying products from lower pricing countries when the VRA was removed (-.1 percent during 1969-73, compared to -3.5 percent after the VRA). Therefore, even if the agreement did not cause an increase in import purchases from high priced suppliers, because it preserved historic market shares, the agreement may have prevented the increase in purchases from lower priced suppliers.

5.2 Welfare Cost of Quality Upgrading

In Table 3 we report the welfare cost of quality change, focusing on the 1969-74 period of the VRA.[12] We first show the cumulative Paasche and Laspeyres price indexes with 1968 as the base year. The Ideal index is calculated as the geometric mean of these, while the cumulative (partial) Divisia can be computed from Table 2 using (15) and (18). Then the welfare costs using the Divisia and Ideal indexes are obtained from (19) and (22), and are shown in the last two columns of Table 3.

In 1969, the first year of the VRA, the welfare cost was 0.42 and 0.21 percent of import expenditure using the Divisia and Ideal indexes, respectively. From Table 1 import expenditure was \$1.64 billion, so the deadweight loss of the quality change is \$6.9 and 3.4 million using the two indexes. The welfare cost rises to exceed one percent of import expenditure in 1970, or about \$15.5 million. After this the welfare cost using the Divisia index falls below one percent of import expenditure, while the welfare cost from the Ideal index fluctuates around one percent. While the magnitude of these welfare costs differ somewhat, the yearly directions of change are the same.

It is useful to compare the welfare cost due to upgrading with the other welfare costs arising from the VRA: the conventional deadweight loss triangle from increased domestic production and reduced consumption; and the transfer of quota rents to foreigners. From Hufbauer, Berliner and Elliot (1986, case M-12), the VRA is estimated to have increased the price of imported steel by 7.3 percent, which is also a median estimate from Crandall (1981, pp. 105-6). Expressed as a percentage of import expenditure _after_ the quota, the conventional deadweight loss triangle is approximately $(1/2)\ \eta(0.073/1.073)^2$, where η is the elasticity of import demand.[13] Hufbauer _et al_. use an import demand elasticity of 2.5, whereas Crandall reports a range of estimates for various products ranging from 2.1 to 5. If we use $\eta = 2.5$, then we obtain a conventional deadweight loss of 0.58 percent of import expenditure, which is _below_ the welfare costs of upgrading reported in Table 3 for 1970-73. Even with a high value of $\eta = 4.5$, as used by Crandall, we obtain a deadweight loss of 1.04 percent, which lies between the welfare costs in Table 3 for 1970-73. Thus, for the VRA in steel, the cost of quality upgrading is at least as large as the conventional deadweight loss.

Considering the transfer of quota rents to foreigners, the 7.3 percent increase in the import price induced by the VRA corresponds to quota rents of (0.073/1.073) 100 = 6.8 percent of import expenditure after the quota. Since the welfare cost of upgrading fluctuates around one percent during 1970-73, we can see that it is considerably smaller than the transfer of quota rents.

6. Conclusions

In this study we have examined the quality upgrading which occurred in U.S. steel imports during the 1969-74 VRA. Quality change is measured by a comparison of unit values with exact price indexes, as was theoretically justified in section 2. We also derived a measure of the welfare cost of quality change, which equals the inverse of the Paasche price index minus the inverse of an exact price index. So long as producers are minimizing costs, this welfare cost will be non-negative.

Empirically, we found quality upgrading of 7.4 percent in U.S. steel imports during the VRA, with most of the upgrading occurring during 1969. This compares with a 1.4 percent quality decline in the following years. The welfare cost of the quality change varies around one percent of import expenditure during 1970-73. The measured cost is somewhat sensitive to the choice of exact index number, with the Ideal index giving a higher welfare cost in several years than the Divisia index.

We should stress that it would be valid to take our measure of the cost of quality upgrading, and simply add it on to the conventional deadweight loss and transfer of quota rents obtained from other studies, such as Crandall

(1981) and Hufbauer, Berliner and Elliott (1986). This procedure gives the total welfare cost of the VRA. The reason it is valid is that the earlier studies convert the quota into price-equivalent tariff, as in (7), before calculating the deadweight loss. This means that the earlier studies are really calculating the loss L_τ rather than L_σ. From Definition 2 we have that $L_\sigma = L_\tau + WC_{\pi\pi}(p+\sigma n)$, and so given the deadweight loss L_τ we can simply add on the additional welfare cost of upgrading to obtain L_σ. Applying this procedure to the 1969-74 VRA, we have argued that the cost due to upgrading is at least as large as the conventional deadweight loss, so that L_σ is twice as large as L_τ. However, the transfer of quota rents is considerably larger than either of these welfare costs.

Finally, it is useful to compare our results with those that could be obtained for later time periods. American steel producers and the government certainly became aware that quality upgrading was a response of foreign producers to the 1969-74 VRA, and later protection attempted to limit upgrading by specifying quotas on very detailed product categories. Boorstein (1987) finds that these programs were partially effective in limiting upgrading: the magnitude of upgrading during the 1976-80 specialty steel quota, or the 1982-85 EC agreement covering specific carbon and alloy products, is less than we have found for the 1969-74 VRA. This means that the welfare cost of quality change is also smaller. However, even in cases where the U.S. has imposed very detailed restrictions, some amount of upgrading is often observed, so the economic forces we have identified in this study are still operative.

Footnotes

[1]This method has also been used to measure changes in labor quality by Waldorff (1973) and Chinloy (1980), and more generally, is related to the literature on technological change such as Jorgenson and Griliches (1967), Christensen and Jorgenson (1969, 1970).

[2]Note that the concept of "quality" used here refers only to the composition of imports across products. An alternative concept arises when firms change the content of products, as with Japanese exporters sending larger, more powerful cars to the U.S. In that case "quality" can be measured using hedonic regressions, as in Feenstra (1984, 1985, 1988).

[3]Anderson (1985, 1988) measures the welfare cost of inefficient allocation of quotas to U.S. cheese imports. We contrast our approach to his in footnote 10.

[4]The concept of weak separability we use is from Blackorby, Primont and Russell (1978, Lemma 3.3a). Crandall (1981, pp. 46-69) discusses why domestic and imported steel should not be considered perfect substitutes; see also Tarr and Morkre (1984). Note that separability is an assumption in Falvey's (1979) model.

[5]Note that these authors simply define quality change according to an equation like (4). In contrast, we have used the more primitive Definition 1, and then related it to existing techniques using Proposition 1. We hope this clarifies what is meant by "quality."

[6]This statement does not hold if there are limits on the ability to arbitrage between sources of supply, as when the quota specifies the maximum amount exported from various countries. The effect of the VRA in steel on sources of supply is captured by our "supplier index," discussed in sections 4 and 5.

[7]A generalization which allows for nonseparability of imports, leading to ambiguous effects of a quota, is in Dinopoulos and Koo (1986).

[8]Recent analyses of deadweight loss in an open economy are provided by Diewert (1983, 1985).

[9]Note that in all expressions of the form $C_{\pi}\pi_p(\cdot)$ the arguments of C_{π} are $C_{\pi}[\pi(\cdot), q, y]$.

[10]If a researcher actually had estimates of the cost functions C and π, then the deadweight loss of the quota could be evaluated directly from (6a). This is the approach taken by Anderson (1985, 1988), who estimates a translog expenditure function over nine imported (and six domestic) cheese varieties. In our study we have over one hundred categories of imported steel, necessitating the use of index numbers.

[11]Using the conventional approximation for deadweight loss, it is possible to express L_{σ} and L_{τ} in terms of the aggregate elasticity of import demand, extent of quality upgrading, and W. By inserting different values for these variables, it is apparent that L_{σ} and L_{τ} cannot be ranked for the "quantity-equivalent" quota and tariff. These formulae are omitted for brevity but available on request.

[12]Results for later years, and specific countries, will be included in future work.

[13]To derive this formula, we define the ad valorem tariff which is "price-equivalent" to the quota by (7). Then (6b) is the conventional deadweight loss. Dividing (6b) by $C_{\pi}\pi(p(1+\tau))$, and using the approximation $C[\pi(p),q,y] \doteq C[\pi(p(1+\tau)),q,y] - C_{\pi}\pi(p)\tau + (1/2)\, C_{\pi\pi}\pi(p)^2\tau^2$, we obtain $L_{\tau}/C_{\pi}\pi(p(1+\tau)) \doteq (1/2)\, \eta[\tau/(1+\tau)]^2$ where $\eta = -C_{\pi\pi}\pi(p(1+\tau))/C_{\pi}$.

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Table 1: U.S. Steel Imports

	Quantity (million tons)	Unit Value (dollars/ton)
1968	15.68	104.7
1969	11.71	121.3
1970	10.78	142.5
1971	15.46	139.1
1972	14.69	151.9
1973	12.50	178.1
1974	13.33	304.6
1975	9.56	301.2
1976	11.41	263.5
1977	15.76	269.5
1978	16.91	305.5

Table 2: U.S. Steel Import Indexes

	Unit Value Index (ΔUV)	Divisia Index (ΔP_d)	Quality Index (ΔQ_m)	Supplier Index (ΔQ_c)
1969	14.7	8.0	6.9	-0.1
1970	16.1	13.4	1.9	0.7
1971	-2.4	2.3	-4.1	-1.7
1972	8.8	7.6	1.2	0.7
1973	15.9	13.3	1.5	0.3
1974	53.7	52.1	0.0	-1.0
1975	-1.1	-1.3	0.8	-0.3
1976	-13.4	-11.5	-0.9	0.1
1977	2.3	5.4	-1.8	-1.2
1978	12.5	12.4	0.5	-2.1

Note: All indexes are expressed as percentage yearly changes, i.e., equations (11), (12), (15), and (16) multiplied by 100.

Table 3: Welfare Cost of Quality Upgrading

	Paasche Index (P_a)	Laspeyres Index (P_ℓ)	Welfare Cost (Using Divisia) (W_d)	Welfare Cost (using Ideal) (W_i)
1969	1.076	1.081	0.42	0.21
1970	1.229	1.262	1.10	1.08
1971	1.255	1.285	0.71	0.92
1972	1.352	1.391	0.82	1.05
1973	1.557	1.621	0.86	1.27
1974	2.698	2.799	0.04	0.68

Note: The Paasche and Laspeyres indexes are cumulative as in (17), (20). The deadweight losses are expressed as a percentage of import expenditure, i.e., equations (19) and (22) multiplied by 100.