Do tariffs protect specific factors?

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Abstract. It is shown that a tariff can lower payment to a productive factor used only in (specific to) the protected industry in a simple production model. This may occur any time the protected sector shares more than one common factor with the rest of the economy, as seems most likely. Intuition based on the well-known specific factors model, where sectors share a single common factor, should be modified. Whether specific factors effectively receive protection from tariffs becomes an empirical issue.

Est-se que les tarifs douaniers protègent des facteurs de production à usage spécifique? A l'aide d'un modèle de production simple, l'auteur montre qu'un tarif douanier peut réduire le paiement à un facteur de production utilisé seulement [i.e. utilisé spécifiquement] dans l'industrie protégée. Cela peut se produire quand le secteur protégé a plus d'un facteur de production en commun avec le reste de l'économie, ce qui est fort probable. On doit donc modifier les intuitions fondées sur le modèle bien connu à propos des facteurs de production spécifiques quand les secteurs ont un seul facteur de production en commun. Quant à savoir si les facteurs spécifiques reçoivent effectivement de la protection des tarifs douaniers, cela reste une question que seules les analyses empiriques peuvent éclairer.

INTRODUCTION

An appealing result from the specific factors (SF) model is that a tariff protects a productive factor used only in the protected industry. The SF model, however, is rather special, since the protected industry shares only a single common factor with the rest of the economy. Do tariffs protect specific factors in more realistic settings where protected industries employ various common factors?

Each sector in the popular version of the SF model employs sector-specific capital while sharing labour. Productive capital cannot be transformed from use in one sector to use in the other in the short run. Jones (1971) notes that factor price equalization

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does not occur between freely trading partners, and he derives magnification effects. Samuelson (1971) shows that free trade with homothetic preferences creates at least movement toward factor price equalization. A tariff increases payments to both specific and common factors (using the other good as numeraire), while payment to the other specific factor falls.

This paper presents the simplest situation with *two* shared factors; so technical complementarity and increased flexibility for mixing factors arise in the sector employing a specific factor. This can be interpreted as an intermediate run, after one of the specific factors has become mobile. Perhaps capital in manufacturing is more malleable than in agriculture; alternatively, skilled labour (land) might find no employment in agriculture (manufacturing). Recent research has examined characteristics of the three-factor, two-good model, where each sector employs all factors. (Examples are Ruffin, 1981; Takayama, 1982; Jones and Easton, 1983; Thompson, 1985, 1986.) Technical structure in the present model, the simplest containing a *single* specific factor, is similar in the sector employing three productive factors.

A tariff in the 2 × 2 Heckscher-Ohlin-Samuelson model raises payment to the factor used intensively in the protected sector, while lowering payment to the other – the Stolper-Samuelson result. If the specific factor in the present model is complementary to the intensive shared factor whose payment rises with a tariff, demand and payment could understandably fall for the specific factor. Conditions leading to this outcome are examined. Insight into the general nature of sector specific inputs is gained with the present model. Whether owners of a specific factor actually enjoy benefits from a tariff becomes an intriguing empirical issue.[1]

THE SINGLE SPECIFIC FACTOR MODEL

The general equilibrium model of production and trade is developed in the literature, notably by Jones and Scheinkman (1977) and Chang (1979). Introducing notation: x_j and p_j are output and price of good j ($j = 1, 2$); v_i and w_i are endowment and payment of factor i ($i = 1, 2, 3$); a_{ij} is the cost-minimizing input of factor i in the production of good j; and $a_{kj}{}^h \equiv \partial a_{kj}/\partial w_h$. Factors and goods are numbered; so factor one is specific to industry one ($a_{12} = 0$), and factor two is used intensively in industry one relative to factor three ($a_{21}/a_{22} > a_{31}/a_{32}$).

Aggregate substitution between factors k and h is described by substitution terms $s_{kh} \equiv \Sigma_j x_j a_{kj}{}^h$, which capture variation in the input of factor k across the economy due to changes in the payment to factor h. Technical complementarity is indicated by negative terms, and substitution by positive. Due to homogeneity of factor mixes, $\Sigma_i w_i s_{hi} = 0$; factors are rescaled, so that payment to each is initially one, and $\Sigma_i s_{hi} = 0$. Symmetry of the negative semi-definite matrix of substitution terms follows from Shephard's lemma.

Given full employment and competitive pricing, the entire SSF is summarized:

1 Recent research by Magee (1980), Grossman (1987), and Grossman and Levinsohn (1987) has turned up some empirical evidence that tariffs protect sector specific inputs.

$$\begin{bmatrix} s_{11} & s_{12} & s_{13} & a_{11} & 0 \\ s_{12} & s_{22} & s_{23} & a_{21} & a_{22} \\ s_{13} & s_{23} & s_{33} & a_{31} & a_{32} \\ a_{11} & a_{21} & a_{31} & 0 & 0 \\ 0 & a_{22} & a_{32} & 0 & 0 \end{bmatrix} \begin{bmatrix} dw_1 \\ dw_2 \\ dw_3 \\ dx_1 \\ dx_2 \end{bmatrix} = \begin{bmatrix} dv_1 \\ dv_2 \\ dv_3 \\ dp_1 \\ dp_2 \end{bmatrix}.$$

Comparative static results are found with Cramer's Rule. Chang (1979) shows the system determinant D is negative with three factors. Symmetry implies Samuelson's reciprocity: $\partial x_m/\partial v_h = \partial w_h/\partial p_m$. Production possibility or $\partial x/\partial p$ terms indicate a locally concave production frontier.

Considering effects of changing endowments on factor payments, general equilibrium diminishing marginal returns are found; each factor payment is negatively related with its own endowment. With Ruffin (1981), factors are called enemies (friends) if an increase in the endowment of one lowers (raises) the other's payment. Factors most intensive in either sector (factors one and three) turn out to be enemies, while middle factor two is the others' friend. These results generalize from the SF model and are found in the three-factor, two-good model as well.

Comparative static solutions of interest are represented by the Rybczynski term $r_{mh} \equiv \partial x_m/\partial v_h$. Cofactors are written in capitals, with D representing the negative system determinant: $R_{mh} = r_{mh}D$. Solving for these terms,

$$\begin{aligned} R_{11} &= -a_{32}c_1 s_{12} + a_{22}c_2 s_{13} - (a_{22} + a_{32})c_3 s_{23}, \\ R_{12} &= -a_{32}c_1 s_{12} - a_{32}c_2 s_{13}, \\ R_{13} &= a_{22}c_1 s_{12} + a_{22}c_2 s_{13}, \\ R_{21} &= a_{31}c_1 s_{12} - a_{21}c_2 s_{13} + (a_{21} + a_{31})c_3 s_{23}, \\ R_{22} &= a_{31}c_1 s_{12} + (a_{11} + a_{31})c_2 s_{13} - a_{11}c_3 s_{23}, \text{ and} \\ R_{23} &= -(a_{11} + a_{21})c_1 s_{12} - a_{21}c_2 s_{13} - a_{11}c_3 s_{23}, \end{aligned}$$

where $b \equiv a_{21}a_{31} - a_{22}a_{31}) > 0$; $c_1 \equiv b + a_{11}a_{32} > 0$; $c_2 \equiv b - a_{11}a_{22}$; and $c_3 \equiv a_{11}(a_{22} + a_{32}) > 0$. For reference, arrange the Rybczynski terms in matrix form,

$$R = \begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \end{bmatrix}.$$

Note that r_{12} and r_{13} have opposite signs. Due to homogeneity, $\Sigma_i a_{i1} r_{2i} = \Sigma_i a_{i2} r_{1i} = 0$; so each row contains at least one positive and at least one negative element. Possible sign patterns in the top row are thus $(+ + -)$, $(+ - +)$, $(- + -)$, and $(- - +)$.

A further result limits outcomes. If output of industry two is negatively related with the endowment of its intensive factor three, it cannot be positively related with endowments of both other factors. This is proved for the 3 × 2 model by Jones (1985) and Thompson (1985); a proof based specifically on the present model appears in the first section of the appendix.

An increased endowment must raise some output, or the factor would have a negative marginal value product. Since factor payments are non-negative, each column of R must have at least one positive element.

Using all these properties, six comparative static sign patterns are possible:

$$\begin{matrix} - & + & - \\ + & - & + \end{matrix} \quad \begin{matrix} + & + & - \\ + & - & + \end{matrix} \quad \begin{matrix} + & + & - \\ - & - & + \end{matrix} \quad \begin{matrix} + & + & - \\ - & + & + \end{matrix} \quad \begin{matrix} + & - & + \\ - & + & + \end{matrix} \quad \begin{matrix} + & - & + \\ - & + & - \end{matrix} .$$

(a) (b) (c) (d) (e) (f)

Looking at the first columns, increased endowment of specific-factor one may cause either or both outputs to rise. Looking at the first row, a tariff on good one may lower or raise payment to any factor. In pattern (a) increased endowment of the specific factor contracts its industry, and a tariff on good one lowers payment to the specific factor.[2]

CONDITIONS FOR A TARIFF TO EXPOSE THE SPECIFIC FACTOR

Results hinge upon relationships of intensity and substitution among the productive factors. There are obviously no necessary conditions for r_{11} to be negative (R_{11} to be positive). A relatively simple sufficient condition is found after goods are rescaled; so $p_1 = p_2 = 1$. By competitive pricing, $p_j = \Sigma_i w_i a_{ij} = \Sigma_i a_{ij}$; so $a_{11} + a_{21} + a_{31} = a_{22} + a_{32} = 1$. The result in R_{11} can then be manipulated to concentrate on factors one and two:

$$R_{11} = a_{22}(a_{22} - a_{21})s_{11} + (a_{11}a_{22} + a_{22} - a_{21})s_{12} + a_{11}s_{22}.$$

If $a_{11}a_{22} + a_{22} > a_{21} > a_{22}$, a positive R_{11} would follow from a high enough degree of substitution between factors one and two. If $a_{21} > a_{22} > a_{11}a_{22} + a_{22}$ and the specific factor is complementary enough with factor two, R_{11} would be positive.

This is only one approach to finding sufficient conditions, which are impossible to pin down. Some understanding of the economics involved can be obtained through the following stories.

SIX SCENARIOS

Conditions that favour each sign pattern are developed. Considering increased factor endowments, different degrees of substitution and complementarity determine the output effects; factor intensity is the same throughout. Remember that the conditions developed are only one set of sufficient conditions; others can be readily found. Model simulations corresponding to the discussion appear in the second section of the appendix.

Strong complementarity between shared factors can result in pattern (a). Increased (endowment of) factor three causes its payment to fall. Complementary factor two is

2 Batra and Casas (1976) incorrectly claim this cannot occur in their Theorem 7 when all three factors are weak substitutes.

attracted to sector two; so x_2 rises ($r_{23} > 0$) and x_1 falls ($r_{13} < 0$). Since some of an increase in factor two is employed in sector one, x_1 rises ($r_{12} > 0$); since factor two wants complementary factor three, whose endowment is fixed, x_2 falls ($r_{22} < 0$). Specific factor one is a strong substitute for the others; an increase in its endowment lowers its payment, causing firms to substitute strongly away from the others, which are released to sector two. As a result, x_1 falls as x_2 rises ($r_{11} < 0$ and $r_{21} > 0$).

Pattern (b) is found as substitution with the specific factor weakens, with factors two and three remaining weakly complementary. Compared with (a), a change occurs in the effect of an increase in specific factor one. With decreased substitution, less of the other factors is released from sector one; so both outputs rise (r_{11}, $r_{21} > 0$).

As factors one and two become moderate substitutes, pattern (c) occurs; factors two and three may be either weak complements or weak substitutes, as may one and three. An increase in the specific factor attracts others from sector two; so x_2 falls ($r_{21} < 0$). This occurs since their marginal productivities are enhanced by the additional factor one.

Uniform substitution generally favours pattern (d), the 'normal' SF pattern. The simulation involves weak complementarity between factors one and three. An increase in factor two still raises x_1 ($r_{12} > 0$) but x_2 rises as well ($r_{22} > 0$). In the SF model, middle factor two is shared by both sectors; its payment would fall as the ratio of the shared to the specified factor rises in each sector.

With factors one and two weak complements, pattern (e) yields two changes. An increase in factor three is split between sectors; so both outputs rise as w_3 falls and w_2 rises. Firms in sector one then use (i) more factor three, substituting for factor one, and (ii) less factor two, also dropping the input of complementary factor one. In this scenario, a_{11} must fall; since $v_1 = a_{11}x_1$ and v_1 is constant, x_1 must rise ($r_{13} > 0$). Similarly, additional factor two causes w_2 to fall and w_3 to rise, inducing a higher a_{11}, so x_1 must fall ($r_{12} < 0$).

Pattern (*f*) is found as factors one and two become stronger complements. A surprise occurs in that increased endowment of factor three lowers output of sector two where it is used intensively ($r_{23} < 0$). Factors two and three are such strong substitutes that enough factor two is released from sector two with the falling w_3 that x_2 falls.

CONCLUSION

A tariff may lower payment to an input specific to a protected industry sharing more than one input with other industries. This is favoured by complementarity (i) between shared factors, or (ii) between the specific factor and the factor intensive in its sector. No single set of necessary or sufficient conditions for this outcome are to be found, even in the simplest model.

Intuition regarding specific factors based on the popular but starkly simple SF model may prove misleading under realistic conditions. On the other hand, results in

TABLE A1
Simulations

	Sign Patterns						
	(a)	(b)	(c)	(c)	(d)	(e)	(f)
Substitution terms							
s_{12}	3	1.75	1.25	0.75	0.25	−0.25	−1
s_{23}	−2	−0.75	−0.25	0.25	0.75	1.25	2
s_{13}	6.0875	1.4	0.4	−0.1	−0.1	0.4	2.0875
Partial derivative terms							
r_{11}	−2	0.5	1.5	2.5	3.5	4.5	6
r_{12}	6	3.5	2.5	1.5	0.5	−0.5	−2
r_{13}	−6	−3.5	−2.5	−1.5	−0.5	0.5	2
r_{21}	3	0.5	−0.5	−1.5	−2.5	−3.5	−5
r_{22}	−5	−2.5	−1.5	−0.5	0.5	1.5	3
r_{23}	7	4.5	3.5	2.5	1.5	0.5	−1

most respects similar to those in the SF model are expected over a range of factor intensity and substitution.

An interesting empirical question comes to mind:

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APPENDIX

Sign pattern proof

Assume pattern (+ + −) for the bottom row of R. This means $R_{23} > R_{21}$ and $R_{23} > R_{22}$, which together imply (i) $c_1 s_{12} < -c_3 s_{23}$ and (ii) $c_1 s_{12} < -c_2 s_{13}$. Since only one of s_{12}, s_{13}, and s_{23} can be negative, (s_{12} s_{23}) must be either (+ +), (− +), or (+ −).

(+ +): since c_1 and c_3 are positive, (i) is inconsistent.

(− +): principal minors of the substitution matrix are positive; so $s_{12} > -s_{13}s_{23}/(s_{13} + s_{23})$. Substitute this into (i) and (ii) to obtain (iii) $c_2 s_{13} s_{23} > c_3 s_{23}^2$ and (iv) $c_3 s_{13} > s_2 s_{13}^2$. Divide (iii) by a positive s_{23} and (iv) by a positive s_{13} to find a contradiction.

(+ −): eliminate c_2 from R_{21} and R_{23} to find (v) $c_1(a_{21}s_{13} - a_{31}s_{12}) > c_3(a_{21}s_{13} + (a_{21} + a_{31})s_{23})$ and (vi) $c_1((a_{11}a_{21})s_{12} + a_{21}s_{13}) < c_3(a_{21}s_{13} - a_{11}s_{23})$. Isolate c_3 in (vi), noting that $a_{21}s_{13} - a_{11}s_{23} > 0$, and substitute for c_3 in (v). A negative principal minor is implied.

Model simulations

Table A1 reports simulations corresponding to scenarios in the text. Partial derivative sign patterns can be easily found by assuming $a_{21} = a_{22} = a_{32} = 0.5$ and $a_{11} = a_{31} = 0.25$, so $c_2 = 0$. With $s_{12} + s_{23} = -s_{22} = 1$, an example of each sign pattern is found by varying substitution and complementarity. Negative semidefiniteness of the substitution matrix is demonstrated with a negative s_{11}, a positive principal minor $(s_{11}s_{22} - s_{12}^2)$, and a zero determinant. It would be possible to assume a particular form for the production function (Cobb-Douglas for instance) to derive production functions implicit in each simulation.

Since factors have been rescaled so that $w_i = 1$ and goods so that $p_j = 1$, the partial derivative terms are elasticities of factor payments with respect to prices: $r_{mh} \equiv \partial x_m/\partial v_h = \partial w_h/\partial p_m = (p_m/w_h)(\partial w_h/\partial p_m)$. A 10 per cent tariff on good one leads to a 20 per cent reduction in the payment to factor one in simulation (a).

REFERENCES

Batra, R. and F. Casas (1976) 'A synthesis of the Heckshcr-Ohlin and neoclassical models of international trade.' *Journal of International Economics* 6, 21–38

Chang, W. (1979) 'Some theorems of trade and general equilibrium with many goods and factors.' *Econometrica* 47, 709–26

Grossman, G. (1987) 'The employment and wage effects of import competition.' *Journal of International Economic Integration* 2, 1–23

Grossman, G. and J. Levinsohn (1987) 'Import competition and the stock market return to capital.' Princeton University Discussion Papers in Economics #131.

Jones, R. (1971) 'A three-factor model in theory, trade, and history.' In J. Bhagwati, R. Jones, R. Mundell, and J. Vanek, eds, *Trade, Balance of Payments, and Growth* (Amsterdam: North-Holland)

— (1985) 'A theorem on income distribution in a small open economy.' *Journal of International Economics* 18, 171–6

Jones, R. and S. Easton (1983) 'Factor intensities and factor substitution in general equilibrium.' *Journal of International Economics* 15, 65–99

Jones, R. and J. Scheinkman (1977) 'The relevance of the two-sector production model in trade theory.' *Journal of Political Economy* 85, 909–35

Magee, S. (1980) 'Three simple tests of the Stolper-Samuelson theorem.' In P. Oppenheimer, ed, *Issues in International Economics* (Stocksfield: Oriel Press)

Ruffin, R. (1981) 'Trade and factor movements with three factors and two goods.' *Economics Letters* 7, 177–82

Samuelson, P. (1971) 'Ohlin was right.' *Scandinavian Journal of Economics* 4, 365–84

Takayama, A. (1982) 'On theorems of general competitive equilibrium of production and trade – a survey of some recent developments in the theory of international trade.' *Keio Economic Studies* 19, 1–37

Thompson, H. (1985) 'Complementarity in a simple general equilibrium model.' This JOURNAL 18, 616–21

— (1986) 'Free trade and factor-price polarization.' *European Economic Review* 30, 419–25