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AN EMPIRICAL ANALYSIS OF THE COMPOSITION OF MANUFACTURING EMPLOYMENT IN THE INDUSTRIALIZED COUNTRIES

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The paper seeks to identify empirically, using pooled regression estimation, the role that resource variables and resistance factors, tariffs in particular, play in determining employment patterns in manufacturing. Cross-section data were utilized pertaining to 20 industries and 18 industrialized countries for 1970. The possible primary impact of post-Kennedy Round (1972) tariff reductions on employment by industry and country can be calculated on the basis of the tariff elasticities presented.

1. Introduction

The purpose of this paper is to identify empirically the factors that determine employment patterns in the manufacturing sector in the major industrialized countries, with a particular focus on the role that tariffs play. By assumption, the fraction of a country's total employment of labor allocated to a given industry can be explained partly by a set of resource variables that determine the special productive capacities of the country and partly by a set of 'resistance' factors, such as tariffs and transportation costs that determine the country's access to international markets. The importance of the various determinants of industry employment shares is assessed by pooled regression estimation,

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making use of cross-section data pertaining to 20 industries and 18 countries for 1970.

The paper proceeds as follows. In section 2, we establish briefly our theoretical framework of how factors of production are allocated within a country. We then discuss in section 3 the impact of tariffs on output and employment in a given industry for countries with different resource endowments, our choice of functional form, the data utilized, and the results of our estimating equations. In section 4, we indicate how our results might be used in assessing the possible effects of tariff reductions on employment by industry for the countries being studied. We offer some concluding remarks in section 5.

2. The determinants of trade and the allocation of factors

The general equilibrium model of international trade focuses on the relationship between factor endowments and the structure of trade. The allocation of factors among industries is determined in the process, but it is not an issue of central concern. Here, the allocation of a specific factor – labor – is the object of our interest, and we recognize that there are two alternative approaches that could be used. One possibility is to determine the effects of tariffs on imports and exports, as has been done by Leamer (1974), and to link these output effects to factor allocations. Although that approach has some appeal, we have chosen to explore the direct linkage between tariffs and employment. It was our expectation at the outset that countries with relatively high tariffs on a particular industry would tend to have relatively high employment in that industry.

Our basic model can be written symbolically as

$$E_{ik}/E_{i.} = l_k(V_i), \qquad i = 1, \ldots, n, \tag{1}$$

where E_{ik} is the labor allocation to industry k in country i; country i's total manufacturing employment is $E_{i.} = \sum_k E_{ik}$; and l_k is some function (common to all countries) of various country characteristics – such as factor and resource endowments, tariffs, and transport costs – included in the vector V that determine both trade and factor allocation – in our case, industry k's share of country i's employment.

3. Estimation procedure, data, and empirical results

The empirical presumption upon which our investigation rests is that the industry composition of manufacturing employment differs significantly among the major industrialized countries. Since we are especially interested in the role of tariffs in determining this composition, we first consider the problem that arises if tariffs are endogenous. We then posit a functional form that may enable us to distinguish among countries with respect to the influences of tariffs. Next, we describe our data and thereafter we report our empirical results based upon pooled estimation methods.

3.1. The simultaneity problem if tariffs are endogenous

Given that policy-makers use commercial policy to protect employment, the observed relationship between tariff levels and employment will then be partly determined by their actions. Consider the set of three different countries illustrated in fig. 1. The world price P_w and the domestic demand are assumed the same for all countries. The supply curves are assumed to differ due to comparative cost differences arising from the different relative scarcity of some critical resource. The resultant responsiveness of output to tariff levels is depicted for each country in the right-hand graphs of fig. 1.

Now suppose that policy-makers choose tariffs just high enough to prevent totally any imports. If we were to graph the resulting tariff and output levels, we would obtain the points plotted in fig. 2. A cross-section regression of outputs on tariffs would then yield a negatively sloped 'supply' curve. In the very best of circumstances, if tariffs were allocated completely randomly (i.e., with no simultaneity bias), we would obtain a scatter of points as depicted in fig. 3.

The sets of points that are connected by the lines in fig. 3 represent countries with identical supply functions, that is, with identical resources. Within each set, the countries are assumed to have different tariff levels. For the exporting 'A' type countries, tariffs have no effect on output, whereas, over some range, tariffs have a positive effect on output for the 'B' and 'C' type countries. Practically speaking, however, if we were to observe a general scatter of points like fig. 3, the tariff effect would be obscured because a given level of tariffs would be consistent with many levels of outputs, depending on the availability of resources. If we expect to obtain a reasonable estimate of the tariff effect, it is essential therefore that our model have the power to identify a particular country as an 'A', 'B', or 'C' country. That is, it must fully take into account the resources that determine differences in comparative costs and therefore differences in the supply schedules for given industries in individual countries.

3.2. Choice of functional form

After experimenting with various functional forms that permit the industry supply curve to be shifted according to different levels of a resource variable, we selected the following form that seemed on the whole to have desirable properties:

$$\ln Q = \alpha + \beta x + (\gamma + \delta x)/(1+t), \qquad (2)$$

where ln Q is the natural logarithm of output, x is the level of the resource variable, and t is a measure of the tariff.

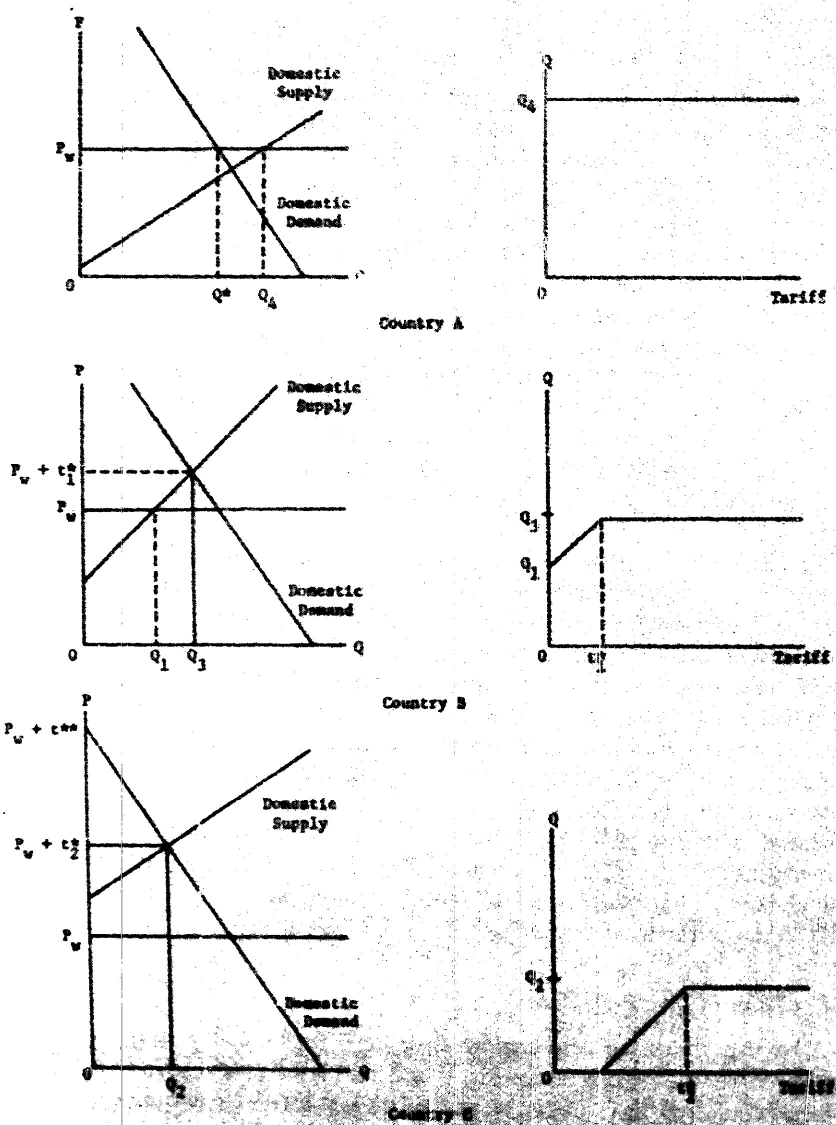

Fig. 1. Hypothetical output-tariff functions.

The asymptotic value of Q as t increases is $\exp(\alpha+\beta x)$. At $t=0$, the value of Q is $\exp(\alpha+\beta x+\gamma+\delta x)$. Depending on the values of β, γ and δ, this function generates two different families of curves indexed by x, alternative levels of the resource variable. The derivative of $\ln Q$ with respect to x is $\beta+\delta/(1+t)$, which

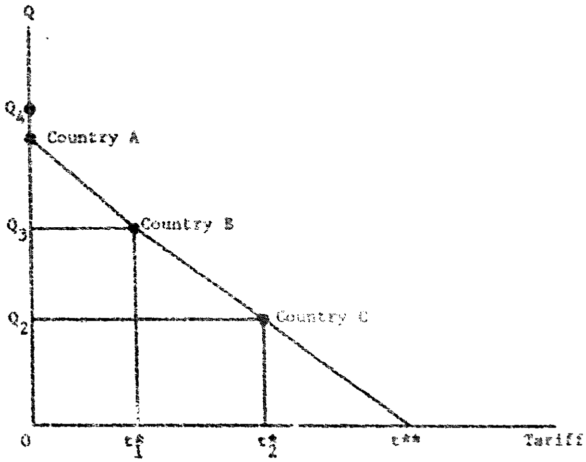

Fig. 2. Hypothetical output–tariff scatter with prohibitive tariffs.

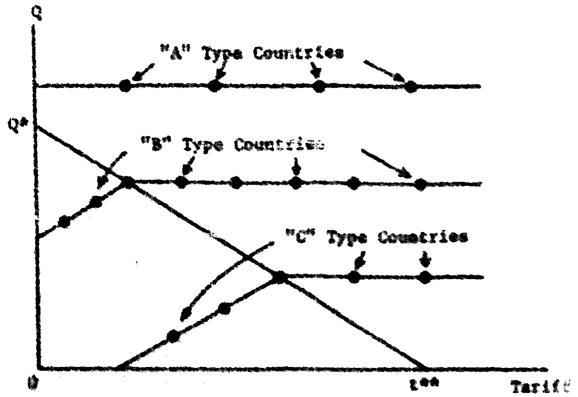

Fig. 3. Hypothetical output–tariff scatter with random non-prohibitive tariffs.

is zero for $t^* = -(\beta+\delta)/\beta$. If $t^* < -1$, that is, if δ and β have the same sign, the desirable family of curves depicted in fig. 4a results, each curve representing a different level of the resource. Curves labelled 1, 2, and 3 jointly form a graph similar to fig. 3. Curves 4 and 5, which suggest a negative effect of tariffs on output, will be interpreted as describing A type countries that are natural exporters, with employment insensitive to tariff rates. These curves bend up at the origin only in order that they can 'pick up' the several countries that have very low tariff rates and relatively high output levels.

In the event that $t^* > -1$, that is, if δ and β differ in sign, an alternative family of curves depicted in fig. 4b results. The difficulty here is that for values of

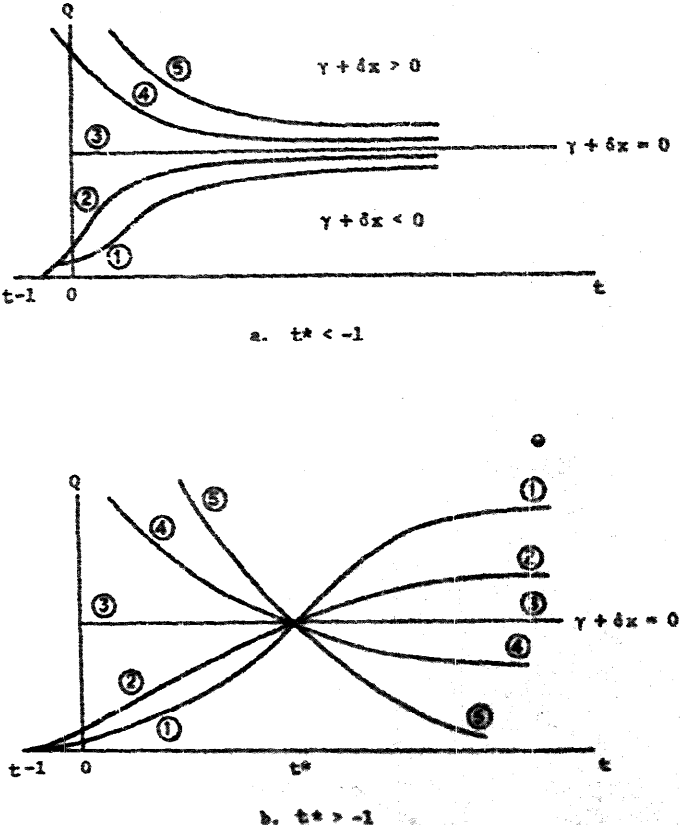

Fig. 4. Family of functional forms.

t greater than t^*, countries 1 and 2 that have the lowest levels of the resource and are therefore natural importers, now have the highest levels of output, whereas the opposite is the case for countries 4 and 5 with the highest levels of the resource. The region greater than t^* defines a 'reverse' effect of resource levels on output. Unfortunately, we were not able to devise an alternative functional form to avoid this effect, and, as will be noted below, our estimation results for certain industries suggest that some countries may fall in this reverse region.

In what follows, we shall assume that the preceding analysis which referred to the relationships involving resource levels, tariffs, and output can be applied to factor inputs. This is the counterpart of our earlier discussion, which presumed that the determinants of trade could, in turn, be taken also as the determinants of inputs, employment in the present circumstances. Thus, our estimation of equation (2) will proceed with a measure of employment as the dependent variable.

3.3. *The data*

We designate the level of employment by industry in the major industrialized countries as E_{ik}. For purposes of analysis, we have selected the world's 18 major industrialized countries ($i = 1, \ldots, 18$). The reason for this choice was the compilation of detailed information on ad-valorem tariffs for these countries, in both printed and machine-readable form, by the General Agreement on Tariffs and Trade (GATT) in *The Basic Documentation for the Tariff Study* (1974). The information was compiled on a line-item basis according to the Brussels Tariff Nomenclature (BTN), with the post-Kennedy Round (1972) tariff expressed in percentage form. The 18 countries covered, including the mnemonics utilized in our study, are as follows:

ALA	– Australia	IT	– Italy
ATA	– Austria	JPN	– Japan
BLX	– Belgium–Luxembourg	NL	– Netherlands
CND	– Canada	NZ	– New Zealand
DEN	– Denmark	NOR	– Norway
FIN	– Finland	SWD	– Sweden
FR	– France	SWZ	– Switzerland
GFR	– West Germany	UK	– United Kingdom
IRE	– Ireland	US	– United States

Our employment data were obtained from the United Nations, *The Growth of World Industry*, which is published annually. The latest data available at the time of writing were for 1970. These data refer to the total number of employees by industry, based on the 3-digit International Standard Industrial Classification (ISIC). Although data were available for 25 3-digit ISIC industries for 1970, we reduced this number to 20 in order to obtain comparability over time due to changes in industry definitions.[1] In view of differences in national reporting

[1]Changes in manufacturing employment over time are analyzed in Edward E. Leamer, Robert M. Stern, and Christopher F. Baum, 'Characteristics of manufacturing employment in the industrialized countries, 1958–70', in process.

systems, we also had to make approximations for some countries when data were too aggregative or incomplete.[2]

The 20 industries ($k = 1, \ldots, 20$) that we have chosen for analysis are as follows:[3]

ISIC Group	Description
321	Textiles
322	Wearing apparel, except footwear
323	Leather and leather and fur products
324	Footwear
331	Wood products, except furniture
332	Furniture and fixtures, except metal
341	Paper and paper products
342	Printing, publishing
35A	Industrial chemicals (351); Other chemical products (352)
35B	Petroleum refineries (353); Misc. products of petroleum and coal (354)
355	Rubber products
36A	Pottery, china and earthenware (361); Other non-metallic mineral products (369)
362	Glass and glass products
371	Iron and steel basic industries
372	Non-ferrous metal basic industries
381	Metal products, except machinery, etc.
382	Machinery, except electrical
383	Electrical machinery, apparatus, etc.
384	Transport equipment
38A	Plastic products, n.e.c. (356); Professional, photographic goods, etc. (385); Other manufacturing industries (390)

As already mentioned, our general hypothesis is that countries economize on their relatively scarce resources by producing relatively large amounts of the goods that use relatively little of these scarce resources. This hypothesis should be true even without international trade, peculiarities in consumption perhaps causing exceptions. Trade should then induce further specialization since deficiencies in the output of goods that require the scarce resources can be alleviated through trade. Thus, the abundance or scarcity of resources and

[2]The detailed employment [illegible] and procedures followed are available upon request from the authors.

[3]Food, beverages, and tobacco have been excluded from consideration.

the openness of the countries under consideration should jointly determine the allocation of production and labor inputs across industries.

In principle, we may divide resources into two major groups: accumulatable and natural. The chief accumulatable resource under consideration here is the manufacturing labor force in each country, $E_{i.}$, which we shall take as given in the sense that the allocation between manufacturing and non-manufacturing sectors is not analyzed. The other accumulatable resources comprise the various forms of capital: physical, human, and knowledge.

The resource variables that we have identified are listed below, together with their mnemonics. They refer generally to 1970. The details, including the variety of data sources used, are available upon request.

Accumulatable Resources

$E_{i.}$	Total employment in manufacturing
NPTO%POP	Number of professional and technical workers as percentage of population
GNP/POP	Per capita GNP
G DOM PR	Gross domestic product in mining and manufacturing
NET INV	Gross fixed capital formation less depreciation
WG+SAL	Manufacturing wages and salaries
ELEC	Electric generating capacity
R&D	Expenditures on research and development

Natural Resources

FOR LAND	Forest land
CONI PROD	Coniferous roundwood production
BRLF PROD	Broadleaf roundwood production
HIDESKIN	Production of cattle hides and skins
ARA LAND	Arable land
CATTLE	Number of cattle
WOOD PRD	Wood production
OIL PROD	Crude oil production
RUB PROD	Synthetic rubber production
IRONCOAL	Price-weighted index of iron and coal production
ORES	Price-weighted index of non-ferrous metal production (bauxite, copper, lead, tin, and zinc)

The foregoing variables are meant to be interpreted as proxies for the different resources. Thus, we take the relevant labor force to be measured by $E_{i.}$.

Physical capital may be approximated alternatively by our measures of per capita GNP, gross domestic product, net investment, and electric generating capacity. Human capital may be measured by the number of professional and technical workers or by wages and salaries per employee, which may be indicative of differential returns to human capital. Knowledge capital may be measured by the number of professional and technical workers or by expenditures on R&D. These divisions into the different kinds of capital are only suggestive, however, since there may be a substantial overlap for some of the measures.

The measures of natural resources must also be intepreted in the sense of proxies. There is a further difficulty in that we have used measures of outputs of natural resources as if they were measures of resources themselves. Like wages and salaries per employee, these output measures are jointly determined with our dependent variable E_{ik} and a simultaneity problem may affect our results.

We may now turn to an examination of the tariff data. As already mentioned, post-Kennedy Round nominal tariffs were available on a line-item basis according to the Brussels Tariff Nomenclature (BTN) together with 1970 imports by country of origin for the 18 countries. We had planned originally to use pre-Kennedy Round (1967) tariffs as perhaps being more representative of the patterns of protection afforded to employment in 1970, especially in view of any time lags involved. It proved impossible to compile the pre-Kennedy Round tariffs, however, because of incomplete documentation and incomparabilities of the available computer tapes so that the only choice we had was to use the post-Kennedy Round (1972) data.

Our investigation was hampered on two other counts. The first was our inability to represent the interindustry effects of tariffs on intermediate goods because of the unavailability of detailed and systematic data on effective rates of protection for the countries being studied. This is an important limitation because of the differential employment effects that may result from tariffs that are escalated depending upon the stage of processing in the industries involved. The second difficulty was that we could not take non-tariff barriers (NTB's) into account. The widespread existence of NTB's has been well documented, but systematic and comparable data do not exist that would permit these various NTB's to be expressed in terms of their ad-valorem tariff equivalents.

Before we could use the post-Kennedy Round (1972) tariff data, several adaptations were required. Briefly, we first had to aggregate the imports and tariff levels within individual 4-digit BTN categories, with a number of imputations for missing data. These efforts produced a set of BTN records for each of the individual countries, including the nine members of the European Community (EC) combined. The next step was to aggregate the detailed BTN entries to correspond to the 3-digit ISIC industry classes and, in the process, to obtain 'world' import-weighted tariffs for the individual industries in each country. The industry tariffs (t_{ik}) and technical details involved are available upon request.

In principle, tariff rates on all commodities in all countries will affect employment in *every* industry. Empirically, it is the case that the tariffs facing each country's exports do not vary significantly across countries, so that these rates may be neglected. Two relatively small countries, Australia and New Zealand, do have significantly higher tariffs than the rest of the countries. It would be erroneous to conclude that these countries thereby provide relatively high protection to all industries, since when protecting one industry, labor must be drawn from another. A reasonable empirical approximation is to measure industry tariffs (t_{ik}) around the employment-weighted country mean,

$$\bar{t}_i = \sum_k E_{ik} t_{ik} \Big/ \sum_k E_{ik}. \tag{3}$$

Our tariff measure is thus $(t_{ik} - \bar{t}_i)$, so that industries with tariffs higher than the country average will have relatively higher protection than industries below the country average.

Distance-to-markets is a factor that plays a role similar to tariffs in impeding trade and thus affecting the pattern of employment specialization. Ideally, data on transport costs would indicate these effects. In the absence of such data, we have approximated these costs by compiling a matrix of air distances between principal cities. The measure used was D_i, defined as a GNP-weighted average of the air distances D_{ij} between major cities of the countries i and j, in statute miles.

3.4. Estimation results

Estimation of the model requires the specification of resource variables, industry by industry. Since we did not know a priori which resource variables were important for individual industries, we began our empirical procedure by testing a single resource over all industries. The estimating equation, based upon the functional form noted above in eq. (2), was

$$\ln(E_{ik}/E_{i.}) = \alpha + (\gamma/\tau_{ik}) + \beta x_i + (\delta x_i/\tau_{ik}), \tag{4}$$

where

$E_{ik}/E_{i.}$ = the fraction of country i's employment allocated to industry k;
τ_{ik} = $1 + (t_{ik} - \bar{t}_i)$, one plus the industry tariff deviation from the weighted country mean;
x_i = the level of the resource in country i;
$\alpha, \gamma, \beta, \delta$ = parameters to be estimated.

Table 1

Pooled regression estimates of employment patterns by industry; $\ln E_{it}/E_{i.} = \alpha + \beta/\tau_{it} + \gamma x_i + \delta_1 D_i + \delta_2\,\mathrm{GNP/POP}_i + \delta_3\,\mathrm{NPTO\%POP} + \delta_4\,\mathrm{ELEC}_i + \lambda_1 x_i/\tau_{it} + \lambda_2 D_i/\tau_{it} + \lambda_3\,\mathrm{GNP/POP}_i/\tau_{it} + \lambda_4\,\mathrm{NPOP\%POP}_i/\tau_{it} + \lambda_5\,\mathrm{ELEC}_i/\tau_{it}$ (standard errors in parentheses).[a]

ISIC	x_i	α	β	γ	δ_1	δ_2	δ_3	δ_4	λ_1	λ_2	λ_3	λ_4	λ_5	R^2 (ESS)
Textiles	GNP/POP	−13.41	12.53	3.08	−0.44	−0.22	0.44	−0.06	−3.45	0.30	0.19	−0.47	0.05	0.81
			(5.09)	(1.20)	(0.57)	(0.62)	(0.38)	(0.16)	(1.23)	(0.57)	(0.60)	(0.39)	(0.16)	(0.42)
Wearing apparel	GNP/POP	−7.92	6.54	2.16	−0.51	−0.22	0.50	0.04	−2.56	0.03	0.19	−0.51	−0.06	0.67
			(3.49)	(1.11)	(0.53)	(0.62)	(0.36)	(0.13)	(1.23)	(0.62)	(0.60)	(0.40)	(0.15)	(0.64)
Leather & prod.	CATTLE	−9.47	4.80	−0.64	−0.51	−0.22	0.45	−0.02	0.74	0.18	0.19	−0.45	0.01	0.77
			(3.49)	(1.80)	(0.58)	(0.62)	(0.39)	(0.18)	(1.71)	(0.57)	(0.59)	(0.38)	(0.18)	(0.52)
Footwear	HIDESKIN	−8.88	5.89	1.28	−0.58	−0.24	0.37	−0.08	−0.93	0.08	0.18	−0.48	0.10	0.62
			(4.27)	(1.31)	(0.57)	(0.61)	(0.37)	(0.14)	(1.45)	(0.59)	(0.60)	(0.40)	(0.16)	(2.49)
Wood Prod.	CONI PROD	−5.89	1.65	−0.19	−0.30	−0.23	0.48	−0.05	0.35	0.53	0.18	−0.42	0.05	0.55
			(5.02)	(1.99)	(0.59)	(0.62)	(0.40)	(0.20)	(1.85)	(0.59)	(0.16)	(0.38)	(0.18)	(2.95)
Furniture & fixtures	FOR LAND	−4.25	0.69	−0.32	−0.44	−0.24	0.43	−0.04	0.34	0.27	0.18	−0.46	0.06	0.40
			(5.02)	(2.02)	(0.58)	(0.61)	(0.39)	(0.18)	(2.18)	(0.61)	(0.60)	(0.39)	(0.18)	(0.96)
Paper & prod.	CONI PROD	−6.01	2.57	0.37	−0.42	−0.26	0.46	−0.06	−0.17	0.29	0.17	−0.44	0.07	0.91
			(4.17)	(1.37)	(0.58)	(0.62)	(0.39)	(0.19)	(1.30)	(0.60)	(0.60)	(0.38)	(0.18)	(0.34)
Printing, publishing	FOR LAND	0.01	−3.18	−2.62	−0.36	−0.25	0.48	−0.07	2.47	0.42	0.17	−0.42	0.09	0.51
			(4.80)	(2.23)	(0.58)	(0.62)	(0.40)	(0.19)	(2.12)	(0.57)	(0.59)	(0.38)	(0.18)	(1.35)
Chemicals	NPTO%POP	−0.68	−1.85	−0.30	−0.42	−0.14	0.49	−0.03	0.26	0.33	0.26	−0.45	0.02	0.54
			(3.30)	(0.71)	(0.58)	(0.60)	(0.42)	(0.16)	(0.70)	(0.56)	(0.60)	(0.40)	(0.16)	(0.46)
Petroleum & prod.	OIL PROD	−7.25	2.23	0.60	−0.42	−0.23	0.47	−0.06	−0.49	0.31	0.19	−0.44	0.06	0.17
			(5.08)	(3.14)	(0.58)	(0.62)	(0.40)	(0.19)	(2.85)	(0.60)	(0.60)	(0.38)	(0.18)	(5.41)

Rubber prod.	RUB PROD	−5.85	1.60	2.61	−0.36	−0.28	0.48	−0.06	−2.29	0.40	0.15	−0.44	0.66	0.33
			(4.03)	(2.02)	(0.57)	(0.61)	(0.38)	(0.19)	(1.82)	(0.59)	(0.60)	(0.39)	(0.19)	(1.19)
Pottery, china, etc.	GNP/POP	−5.27	2.49	−0.64	−0.41	−0.23	0.46	−0.07	0.53	0.31	0.19	−0.44	0.06	0.39
			(9.00)	(2.74)	(0.58)	(0.62)	(0.40)	(0.19)	(2.75)	(0.59)	(0.60)	(0.39)	(0.19)	(0.66)
Glass & prod.	GNP/POP	−6.14	2.53	0.02	−0.42	−0.22	0.44	−0.08	−0.12	0.31	0.19	−0.46	0.06	0.37
			(8.74)	(2.79)	(0.58)	(0.62)	(0.39)	(0.19)	(2.89)	(0.60)	(0.60)	(0.39)	(0.19)	(1.94)
Iron & steel	IRONCOAL	−0.84	−1.26	3.21	−0.40	−0.29	0.42	−0.10	−2.00	0.33	0.14	−0.49	0.10	0.53
			(4.72)	(2.12)	(0.58)	(0.61)	(0.39)	(0.19)	(1.81)	(0.59)	(0.60)	(0.38)	(0.18)	(2.84)
Non-ferr. met.	ELEC	−9.07	4.49	0.47	−0.35	−0.18	0.42	−0.06	−0.40	0.42	0.23	−0.46	0.06	0.50
			(7.23)	(0.45)	(0.59)	(0.62)	(0.40)	(0.25)	(3.43)	(0.56)	(0.59)	(0.38)	(0.24)	(3.11)
Metal prod.	GNP/POP	−1.22	−1.68	0.16	−0.37	−0.22	0.47	−0.06	−0.07	0.38	0.19	−0.45	0.06	0.41
			(8.93)	(2.88)	(0.58)	(0.62)	(0.39)	(0.19)	(2.89)	(0.60)	(0.60)	(0.39)	(0.19)	(0.45)
Machinery, excl. elec.	GNP/POP	−4.02	1.23	0.16	−0.37	−0.09	0.45	−0.06	−0.11	0.40	0.29	−0.46	0.04	0.38
			(11.32)	(1.21)	(0.58)	(0.62)	(0.42)	(0.19)	(1.19)	(0.57)	(0.60)	(0.40)	(0.19)	(2.32)
Electrical mach.	IRONCOAL	−7.14	5.05	−0.02	−0.41	−0.19	0.44	−0.08	0.24	0.33	0.22	−0.45	0.06	0.34
			(7.97)	(2.75)	(0.58)	(0.62)	(0.39)	(0.19)	(2.94)	(0.60)	(0.60)	(0.39)	(0.19)	(0.88)
Transport equip.	NPTO%POP	0.57	−3.16	−0.69	−0.31	−0.31	0.45	−0.14	0.77	0.50	0.12	−0.45	0.14	0.31
			(8.00)	(0.86)	(0.57)	(0.61)	(0.42)	(0.18)	(0.88)	(0.59)	(0.60)	(0.40)	(0.18)	(1.49)
Other man.	NPTO%POP	−2.48	−0.09	0.02	−0.40	−0.22	0.45	−0.06	−0.03	0.32	0.19	−0.46	0.06	0.06
			(12.79)	(2.77)	(0.58)	(0.62)	(0.42)	(0.20)	(2.77)	(0.61)	(0.60)	(0.40)	(0.19)	(2.22)

*$E_{ki}/E_{.i}$ = employment share of industry k in country i;
τ_{ki} = $[1+(t_{ki}-\bar{t}_i)]$, where $t_{ki}-\bar{t}_i$ measures the post-Kennedy Round tariff on industry k in country i less 1970 employment-weighted country average;
x_i = single best resource;
D_i = GNP-weighted distance variable;
GNP/POP$_i$ = per capita GNP in country i;
NPTO%POP$_i$ = percentage of professional and technical workers in population of country i;
ELEC$_i$ = electric generating capacity in country i;
ESS = error sum of squares of equation (in parentheses below R^2).

For estimating purposes, we chose per capita GNP as the resource variable (x_i), since this variable has been commonly used to explain development patterns as a proxy for the capital–labor ratio, or, alternatively, market size. The ordinary least squares (OLS) results, which are not reported here, were relatively poor for most industries, with the notable exception of textiles. We decided therefore to experiment with the other resource variables listed earlier and selected the 'best' ones based upon R^2 maximization. While some improvements were obtained for particular industries, it was evident that single-resource-variable explanations were not adequate for our purpose.

Accordingly, we posited a general model with N resources and began by estimating it with $N = 2$, selecting particular resource variables based upon simple regressions, with the constraint that the second variable measured something qualitatively different from the first. While still further improvements were thereby obtained for some industries, multicollinearity caused estimation difficulties in several instances. The question then was what to do if we wanted to include a larger number of resource variables, having already run up against collinearity constraints.

One possibility was to constrain the coefficients to be equal across equations. On the face of it, this seemed undesirable since we were interested in determining the ways in which the industries differed from one another in resource use. We dealt with this problem by utilizing a statistical technique discussed in Lindley and Smith (1972) which amounts to 'pooled' regression estimation. It asserts only that the coefficients are similar (in a probabilistic sense), based upon Bayesian assumptions of 'prior knowledge'. The effect of the technique is to impose the equality constraints only 'loosely', and the coefficients, rather than being constrained to be identical, will be adjusted only part way toward their common mean, variable by variable. The technical details of our procedure are available upon request.

The usefulness of the pooled estimation procedure is that it allows estimation of the process in situations when the number of observations and the degree of collinearity preclude the use of the more traditional procedures. We were thus able to include in our pooled estimation several general resource variables together with our 'best' resource variable identified earlier. In addition, we introduced explicitly our measure of distance to markets, D_i.

The actual estimating equation, detailed results by industry, and the variable mnemonics are recorded in table 1. The estimation was set up so that the coefficients on the single best resource variables (x_i) were relatively 'free'. The values that they assume are nearly the constrained OLS values, subject to constraints on the other coefficients. The other coefficients were constrained to be almost identical across equations, reflecting the use of a 'system' method which estimated the coefficients of all equations simultaneously.

Several comments may be made about the results in table 1:

(1) The international pattern of employment resists explanation in the sense that the R^2's are generally low. The notable exceptions are paper and paper products ($R^2 = 0.91$), textiles ($R^2 = 0.81$), and leather and leather products ($R^2 = 0.77$). We conclude from perusal of these R^2's that the total employment in commodity classes that make heavy use of identifiable non-transportable inputs, such as labor or pulp, can be reasonably well explained. The commodity classes that most resist explanation have higher ISIC numbers and probably mix many resources in complex manufacturing processes, thereby disguising from us the *raison d'etre* of their patterns of employment.

(2) Because of the relatively complex functional form, the signs of the resource and tariff derivatives are not easily read from table 1. We reserve for the next section a discussion of the tariff effects. The resource derivatives are

$$\partial \ln E_{ik}/E_{i.}/\partial x_i = \gamma + \lambda_1/\tau_{ik}. \tag{5}$$

At zero tariff levels, $\tau_{ik} = 1$, so that this derivative becomes $\gamma + \lambda_1$. Thus, for textiles, the effect of per capita GNP is seen to be negative: in this case $(\gamma + \lambda_1 + \delta_2 + \lambda_3) = 3.08 - 3.45 - 0.22 + 0.19 = -0.40$, since the key resource also enters the equation as a separate variable. [If this separate entry is ignored, the magnitude is virtually unchanged: $(\gamma + \lambda_1) = 3.08 - 3.45 = -0.37$.] This figure suggests that countries with high per capita GNP's tend not to allocate large portions of their labor force to textile production. Incidentally, this may mean that production is less, or it may mean that production is relatively capital intensive. In general, the signs of the particular key resource derivatives are consistent with prior information. The effects of the other resources may be computed in a similar manner as above but are not reported here.

(3) Distance should have the effect of reducing the tariff elasticity. The tariff elasticity can be computed from eq. (2) as

$$\partial \ln Q/(\partial \tau/\tau) = -\tau(\gamma + \delta x)/(1+\tau)^2. \tag{6}$$

The derivative of this elasticity with respect to x is $-\delta/(1+\tau)^2$ which has the sign of $-\delta$. Thus, the impact of distance on the tariff elasticity has the sign of $(-\delta_2)$ in table 1: negative for all commodity classes, as is to be expected.

4. Tariff reductions and effects on employment

The model that has been described and estimated might be used to compute the employment impacts by industry and country of alternative reductions in post-Kennedy Round (1972) tariffs. Unfortunately, the restrictions that have been imposed to make the model empirically workable limit its use in computing tariff effects.

An unrestricted model would express employment in industry k as a function of four tariff variables: t_{ik}, country i's tariff on commodity k; $\bar{t}_i$, country i's tariff average on other commodities; t_{wk}, the rest-of-world's tariff average on commodity k; and $\bar{t}_w$, the rest-of-world's average tariff on other commodities. The last two variables describing tariff levels facing the country's exports are essentially constant in our sample and cannot be included in our regression equation. Thus, there is no evidence in our data about the domestic effects of foreign tariff changes. Furthermore, the variable $\bar{t}_i$ is also essentially a constant, except for Australia and New Zealand. The use of $\bar{t}_i$ as a variable is empirically equivalent to the use of a dummy variable for these two countries, which in turn is equivalent to excluding the $\bar{t}_i$ variable and averaging these two countries into a single composite observation. An alternative, which is reported above, is to use the single variable $(t_{ik}-\bar{t}_i)$ which in effect adjusts the tariffs of Australia and New Zealand to be comparable with the other countries. It should be noted that $\bar{t}_i$ refers here to a weighted average country tariff with weights based upon industry employment, as in eq. (3) above. The logic of the $(t_{ik}-\bar{t}_i)$ constraint is that it is impossible to protect all industries since employment gains in one industry must be at the expense of others. This seems acceptable for import industries. But it means that the effect of a tariff reduction (t_{ik}) on an export industry is nil, whereas an export industry is in fact likely to expand when tariffs are lowered on other commodities. Thus, the constraint that one effect is the negative of the others is not acceptable.

Both methods were experimented with and the one reported above yielded slightly better results. The interpretation that seems warranted, given the lack of variability of $\bar{t}_i$, is that we have learned something about the initial release of employees from industries which experience tariff reductions. We have learned very little about where these released employees are likely to find jobs. We have learned nothing about the effects of foreign tariff reductions. Tariff elasticities corresponding to the initial impacts are now to be discussed.

On the basis of the pooled estimates, we calculated tariff elasticities with respect to employment shares for each industry in our 18-country sample, with the function evaluated at observed levels of the resource variables, x_i, and the tariff deviations, τ_{ik}. The results are given in table 5. It is evident that a number of the estimates were incorrectly signed, especially in the cases of leather and leather products (323), footwear (324), pottery, etc. (36A), electrical machinery (383), and transport equipment (384). The signs were all positive, however, for wearing apparel (322), chemicals (35A), rubber products (355), iron and steel basic industries (371), non-ferrous metal basic industries (372), metal products (381), non-electrical machinery (382), and miscellaneous manufactures (38A).

The negatively signed elasticities imply that an increase in the industry's tariff in relation to the country average will decrease the industry's employment share. This possibility of such a reverse effect was pointed out earlier in fig. 4b in discussing the properties of the functional form that we selected. We noted

Table 2
Estimated tariff elasticities from pooled regressions.

ISIC	ALA	ATA	BLX	CND	DEN	FIN	FR	GFR	IRE	IT	JPN	NL	NZ	NOR	SWD	SWZ	UK	US
Textiles	−0.60	−3.72	0.08	3.58	1.64	−2.35	1.84	1.16	−4.87	−4.90	−4.07	−0.24	−2.15	0.64	8.41	2.30	−1.14	6.75
Wearing apparel	4.25	2.16	4.84	9.61	6.67	2.73	6.50	5.44	1.48	1.09	1.66	5.17	3.88	8.60	13.06	7.25	4.34	10.77
Leather & prod.	−4.20	−2.96	−1.63	−1.30	−1.99	−2.57	−0.62	−1.86	−6.39	−3.31	−2.53	−1.13	6.66	−0.46	2.47	−1.30	−1.00	−1.22
Footwear	−1.44	−3.26	−2.16	−2.39	−2.22	−3.30	−0.98	−2.51	−0.42	−3.66	−3.36	−1.25	0.34	−3.46	0.88	−2.55	−1.99	−1.93
Wood prod.	0.21	−0.53	1.10	−0.87	0.95	−1.90	2.14	0.91	0.75	−0.62	−0.44	1.60	−0.88	0.08	2.91	0.97	1.52	0.85
Furniture & fixtures	1.11	1.03	2.90	−3.36	2.39	0.97	3.62	2.22	2.05	0.68	1.12	3.00	1.14	1.40	5.48	2.34	2.93	2.34
Paper & prod.	−0.16	−0.74	0.46	0.93	0.31	0.31	1.58	0.24	−0.02	−1.36	−0.87	0.87	0.38	−0.30	4.57	0.37	0.81	0.62
Printing, publishing	0.49	4.15	6.09	−40.35	5.64	−2.08	4.87	5.88	5.41	3.99	4.52	6.47	−0.03	0.44	5.19	5.55	6.43	3.22
Chemicals	2.22	2.34	2.54	2.44	2.43	2.39	2.97	2.32	2.61	1.95	1.99	2.77	2.53	2.39	3.87	2.54	2.79	2.26
Petroleum & prod.	1.31	0.44	0.90	8.94	0.94	−0.12	2.12	0.82	0.50	−0.82	−0.46	1.75	1.30	0.53	4.49	0.89	1.35	1.62
Rubber prod.	1.29	0.26	2.41	4.01	1.51	0.51	3.77	2.05	1.10	0.63	1.33	2.05	22.09	1.20	4.91	1.58	2.67	4.21
Pottery, china, etc.	−1.54	−1.77	−0.88	−1.64	−1.23	−1.65	0.14	−1.34	−0.57	−2.14	−1.89	−0.26	−1.14	−1.58	1.79	−1.24	−0.21	−1.83
Glass & prod.	0.38	−0.44	0.91	0.89	0.88	−0.13	2.06	0.72	0.15	−0.96	−0.50	1.37	0.42	0.37	4.41	0.97	1.27	1.25
Iron & steel	10.20	3.55	5.49	6.37	4.40	3.60	6.94	5.26	4.10	2.60	3.39	5.32	4.57	4.00	10.27	4.48	6.17	6.59
Non-ferr. met.	3.94	2.81	1.73	11.94	4.22	2.60	3.07	1.02	2.35	1.24	−0.08	3.67	8.31	16.47	9.98	3.69	2.90	7.87
Metal prod.	4.07	3.44	4.94	4.88	4.89	3.85	6.06	4.64	4.44	3.14	3.52	5.41	4.21	4.60	8.44	4.92	5.30	5.21
Machinery, excl. elec.	2.99	1.54	2.93	3.66	3.00	1.85	4.34	2.51	2.54	0.83	1.16	3.66	2.67	3.57	7.38	3.10	3.50	3.60
Electrical mach.	−2.70	−3.20	−2.10	−2.44	−2.12	−2.99	−1.02	−2.35	−2.39	−3.77	−3.38	−1.54	−2.45	−2.67	1.06	−2.11	−1.72	−2.24
Transport equip.	−3.11	−1.34	−1.62	−6.32	−2.78	−1.71	−2.49	−1.40	−1.40	−0.84	−0.86	−2.30	−4.15	−8.04	−6.22	−2.84	−2.09	−5.32
Other man.	3.05	2.24	3.53	3.66	3.44	2.52	4.69	3.21	3.06	1.65	2.06	4.04	3.10	3.32	7.29	3.59	3.93	3.81

that export industries are likely to have low tariffs and high $E_{ik}/E_{i.}$. Our functional form can turn up at the origin to capture these conditions in the estimation process. For these countries, it is legitimate to set the negative estimates to zero. In other cases, negative estimates may result from sampling error and/or misspecification.

The elasticities reported in table 2 may be used, with the caveats discussed above, to compute estimates of the initial 'release' of employees from industries which experience tariff reductions. For instance, the textile elasticity estimate for the U.S. is 6.75, implying a 6.75% decline in the U.S. textile employment share following a 1% decrease in tariffs [or, more properly, in $\tau_{ik} = (1+t_{ik}-\bar{t}_{.})$]. This decline in the employment share must take into account the initial share, $E_{ik}/E_{i.}$,

$$0.06736 = \frac{\text{1,113 thousand textile workers}}{\text{16,524 thousand U.S. workers}},$$

suggesting that 6.736% of the U.S. workers were employed in textiles in 19?0. A 10% tariff reduction would thus yield (assuming linearity) a 67.5% reduction in the employment *share*: from 6.736% to 2.189%. If assumptions of a fixed total labor force are made (and, with presumed 'release' in all but five U.S. industries, which, as noted above, may be a questionable assumption), this would represent a change in the textile work force from 1,113 thousand to 361 thousand workers: a decline of 67.5%. However, as noted earlier, this is only an initial estimate, relating the magnitude of tariff cuts to the presumed first-round 'release' of employment, and does not involve a mechanism for reallocating 'released' workers. This comprehensive set of elasticities may be used, though, to make relative comparisons among the countries and industries studied with regard to their responsiveness to tariff changes. For this purpose, one needs data on the employment shares and levels by industry. These data, which are not reproduced here, are available upon request.

Granting the shortcomings of our model and limitations of data together with the possibility that certain industries may in fact be unresponsive to tariff changes, our results constitute the most comprehensive set of tariff elasticities presently available by industry for the major industrialized countries. It must be admitted, however, that these estimates are computed with great uncertainty. In most cases, they are subject to large standard errors and are sensitive to the form of the specification. We conclude therefore that it is difficult to infer tariff impacts from the cross-section data set used, although there are several noteworthy exceptions among the commodity classes examined.

5. Conclusion

The objective of our paper has been to investigate the determinants of employment patterns in manufacturing industries in the major industrialized countries, with particular focus upon the role of tariffs. In this connection, we placed great emphasis upon the role of resource endowments, both accumulatable and natural, in determining employment patterns. After experimenting with estimating equations based upon a single 'best' resource and pair of resources, we resorted to a pooled estimation technique that made it possible to deal with the collinearity constraints arising from the inclusion of several resource variables. The empirical results were mixed, with reasonably good fits being obtained for some industries while others resisted explanation.

We had hoped initially in undertaking our research to obtain tariff elasticities that could be used in assessing the complete impact on employment of alternative tariff reductions. This was not possible, however, because there was not enough variation in the tariffs facing the export industries of the countries included. We resorted therefore to a formulation in which tariffs were measured around their country average, and export industries either had a zero elasticity or one that was negative and set to zero. Thus, our estimated tariff elasticities could be used to estimate the primary employment effects of own-country taiff reductions. But estimation of the expansionary effects on employment due to the stimulation of exports requires further attention.

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