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PRACTICAL GENERAL EQUILIBRIUM ESTIMATION OF RESOURCE PULLS UNDER TRADE LIBERALIZATION

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Abstract

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February 1972

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Practical General Equilibrium Estimation of Resource Pulls Under Trade Liberalization*

1. Introduction

Analysis of the effects on resource allocation of changes in tariff rates has greatly interested applied international economists for several years. Early studies of Effective Rates of Protection (ERP's) were the initial impulse for the current activity; and remarkably enough in a factious discipline, the ERP concept continued until quite recently to universally accepted as the theoretical basis for empirical studies.

In the problem which interests us here--predicting shifts in resources resulting from changes in tariff rates (perhaps to the free trade point) from an initial tariff-ridden situation--one would have applied the ERP methodology by calculating the changes in protection given value-added in each industry under different trade liberation schemes. The industries whose value-added declined most relative to the existing level under any particular scheme would presumably be hardest hit. The Government would decide among the different schemes at least in part on the basis of this kind of information, supplemented by data on supply

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elasticities (or, better, production functions) and consumer and world demand patterns. Even using ERP's, predicting resource pulls would be a fairly data- and computation-intensive process.

Of course, theoreticians have recently shown that partial equilibrium ERP prediction is <u>not</u> an admissible technique for analyzing the effects of tariff changes except under such very strict conditions as no monopoly power in trade and fixed physical input-output coefficients.[1] One must use general equilibrium techniques instead. This path has been followed by few practicing planners, or even by academics who are supposed to experiment with new planning tools. In this paper, we propose to explore it--at least a little way--by sketching out a local, but feasible, method of calculating resource pulls which takes both general equilibrium effects and all relevant data into account. We also do numerical sensitivity analysis on different specifications of our basic model (particularly with respect to the effects of intermediate input substitutability of ERP-based predictions of resource pulls) and discuss briefly the calculation of employment effects of tariff reductions. All this is done with a 35-sector model of Chile--which makes for a fairly realistic exercise.

Simply put, our methodology follows what economists have "always" done when they analyze the effects of endogenous parameter changes on a market or set of markets, allegedly in equilib-

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[1] See Bhagwati and Srinivasan (1971ab) and Bruno (1971). A good description of possible partial equilibrium calculations appears in Grubel and Lloyd (1971).

rium. A set of equations characterizing the equilibrium is written down and totally differentiated, and enough differential changes in exogenous variables are specified to permit inference of differential changes in the endogenous variables by solution of a system of linear equations. Naturally, this works only for "small" changes, but in our problem such changes are relevant--a protectionist country is not likely to remove all its tariffs at once, or even in five years.[2]

In a planning context, one might argue that this method has not been used enough (and conversely, that more expensive programming methods have been used too much). The pioneering (and almost unique) planning model of this type involving a number of sectors is Leif Johansen's (1964, 1968), and we follow his example quite closely.[3] Our basic assumptions are as follows:

(i) Demands for goods by consumers can be described by an aggregate utility function, with the convenient property of separability. This permits application of the Frisch (1959) method for determining all direct and cross-price elasticities from a

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[2] Full solutions of general equilibrium models have been obtained numerically, but getting them with a non-linear model is still a tricky, and therefore impractical, business--see Chenery and Raduchel (1971) and Raduchel (1971). Linear programming models are more immediately feasible but costly. More important, they cannot respond to theoretical doubts about intermediate input substitutability in tariff calculations. Within these limitations, however, some interesting work has been done by, <u>inter alia</u>, Cabezon (1969), Clark (1970), Evans (1971), Lage (1970) and Werin (1965).

[3] See also Saito (1971), whose model resembles our version with a Cobb-Douglas production function for intermediate inputs.

minimum of information about income and direct price elasticities.

(ii) Production takes place under competitive conditions. We adopt various specifications of the production functions for purposes of sensitivity analysis: (a) fixed coefficients for intermediate inputs and Cobb-Douglas functions of labor and capital for value-added; (b) fixed coefficients and C.E.S. value-added functions; (c) Cobb-Douglas functions for primary factors and intermediate inputs.

(iii) A modified small-country assumption is made about trading possibilities: imports are in completely elastic supply, but demand elasticities for exports are less than infinite (though usually quite high).

(iv) Lacking good data, we minimize the role of the government. We assume that it imposes tariffs and indirect taxes, and has an exogenously fixed expenditure vector. The difference between expenditures and tax revenues is covered by direct taxes which are not calculated explicitly. Thus, as in Johansen's model, equations(s) linking factor payments, savings, and total consumption do not appear.

(v) Finally, we work with decreasing returns production functions in only one variable domestic factor of production: labor. The reasons for doing this are described in detail below.

Most of these assumptions could be loosened with more data.

As we will see, they do permit reasonable flexibility in empirical application. Since this is our main goal, we sacrifice some generality for convenience.

2. Fixed Coefficients Specification

Since Johansen-type models are not widely known among trade specialists, we set out the specification in equation form in Tables 1 and 2. In this section, the equations assuming fixed coefficients for inter-industry flows are described. The other variant, based on Cobb-Douglas production functions for intermediate inputs, is described in the next section.

The model incorporates all goods that are imported non-competitively (i.e., not domestically produced) into a single sector (sector 0). In addition, we assume q_1 competitively imported goods, q_2 exports, and q_3 goods that are not traded. Thus of our n goods, $n-1(=q_1 + q_2 + q_3)$ are domestically produced. For brevity, the tables give equations in the log-differential form used in applications. Variables without primes are levels in the base year; the addition of a prime denotes a log-change ($X' = dX/X$).

The structure of the model is relatively standard, and if the exchange rate is held constant it is almost recursive. Under this assumption, a log-change in the domestic price level of a traded good is set equal to the log-change in one-plus-its-tariff (or subsidy) in the first sets of equations in Table 1 (subject to some feedback from the immediately following equations because the world prices of exported goods are assumed to depend on the volumes actually exported). The traded goods price changes, substituted into the three following sets of equations (i.e. sectoral demands for labor, sectoral production functions, and the overall demand-supply balance for labor), would determine output changes if all goods were traded. Since some goods are not traded, however, we have to bring in their demand-supply balances from the immediately following sets of equations to identify all output and price changes. With these determined, the demand-supply balances for traded goods determine changes in imports, exports and total consumer expenditure. The trade shifts then determine the ultimate effect of the tariff revisions on the balance of payments.

In summary, the major feedbacks from equations far down in Table 1 to those above them when the exchange rate is treated as exogenous are (i) the effect of export volumes on world prices, and (ii) the necessity to take into account demand relationships in determining production levels for non-traded goods. If we also set the log-change in the deficit in the balance of trade (Δ') to some specified value, the exchange rate log-change (r') become endogenous and the model completely non-recursive, since the revaluation necessary to maintain the balance of payments depends on all demand-supply interactions.

The fixed coefficients specification requires one distinctive feature, the use of net prices or value-added (net of indirect taxes),

$$p_j^* = p_j - \sum_i a_{ij} p_i - \theta_i$$

Table 1
Equations in Log-Changes for the Model

Effects of Tariff and Exchange Rate Changes on Domestic Prices

$p'_C - \tau'_0 - r' = 0$ (1 equation for complementary imports)

$p'_j - \tau'_j - r' = 0$ (q_1 equations for competitive imports)

$p'_k - \pi'_k - \phi'_k - r' = 0$ (q_2 equations for exports)

Effects of Export Volumes on World Prices

$E'_k - \eta_k \pi'_k = 0$ (q_2 equations)

Sectoral Demand Equations for Labor

Fixed Coefficients Intermediate Inputs

$$(1 - \sum_{j=0}^{n-1} a_{ji} - \theta_i)^{-1} (p'_i - \sum_{j=0}^{n-1} a_{ji} p'_j - \theta_i \theta'_i) + X'_i - w' - L'_i = 0$$

(n-1 equations)

Cobb-Douglas Intermediate Inputs

$(1 - \theta_i)^{-1} (p'_i - \theta_i \theta'_i) + X'_i - w' - L'_i = 0$ (n-1 equations)

Sectoral Production Relationships

Fixed Coefficients Intermediate Inputs

$X'_i - \alpha_i L'_i = 0$ (n-1 equations)

Cobb-Douglas Intermediate Inputs

$$X'_i(1 - \sum_j \gamma_{ji}) - \alpha_i L'_i + \sum_{j \neq i} p'_j \gamma_{ji} + p'_i[\gamma_{ii} - (1/(1-\theta_i))\sum_j \gamma_{ji}]$$

$$+ (\theta_i/(1-\theta_i))(\sum_j \gamma_{ji})\theta'_i = 0$$ (n-1 equations)

Total Labor Use

$\sum_i L_i L'_i - LL' = 0$ (1 equation)

Demand-Supply Balance for Complementary Imports

Fixed Coefficients Intermediate Inputs

$M_0 M'_0 - \sum_i X_{0i} X'_i - C_0[\sum_i g_{0i} p'_i + g_{0y} Y'] - Z_0 Z'_0 = 0$ (1 equation)

Cobb-Douglas Intermediate Inputs

$$M_0 M'_0 - \sum_{i \neq 0} X_{0i} X'_i - \sum_{i \neq 0} p'_i [X_{0i}(1/(1-\theta_i)) + C_0 g_{0i}] + p'_0[\sum_{i \neq 0} - C_0 g_{00}]$$

$$+ \sum_i \theta'_i X_{0i}(\theta_i/(1-\theta_i)) - C_0 g_{0y} Y' - Z_0 Z'_0 = 0$$ (1 equation)

<u>Demand Supply Balances for Domestically Produced Goods</u>

Fixed Coefficients Intermediate Inputs

$$X_jX_j' - \sum_i X_{ji}X_i' - C_j[\sum_i g_{ji}P_i' + g_{jY}Y'] - Z_jZ_j' \begin{Bmatrix} + M_jM_j' \\ - E_jE_j' \end{Bmatrix} \text{ if necessary } = 0 \quad \text{(n-1 equations)}$$

Cobb-Douglas Intermediate Inputs

$$X_jX_j' - \sum_i X_{ji}X_i' - \sum_{i\neq j} P_i'[X_{ji}(1/(1-\theta_i)) + C_jg_{ji}] + P_j'[\sum_{i\neq j} X_{ji}$$

$$- (X_{jj}\theta_j/(1-\theta_j)) - C_jg_{jj}] + \sum_i \theta_i' X_{ji}(\theta_i/(1-\theta_i)) - C_jg_{jY}Y'$$

$$- Z_jZ_j' \begin{Bmatrix} + M_jM_j' \\ - E_jE_j' \end{Bmatrix} \text{ if necessary } = 0 \quad \text{(n-1 equations)}$$

<u>Balance of Payments</u>

$$\Delta\Delta' + \sum_k \pi_k E_k(\pi_k' + E_k') - \sum_j \pi_j M_j M_j' - \pi_0 M_0 M_0' = 0 \quad \text{(1 equation)}$$

Table 2

Glossary of Variables, Base-Year Values and Parameters

Variables		Number
p_0', p_j', p_k'	Changes from base-year domestic price levels of unity	n
τ_0', τ_j'	Log-changes in the level of one-plus-sector-tariff	q_1+1
ϕ_k'	Log-changes in one-plus-sector-export-subsidy	q_2
π_k'	Log-changes in world prices of export goods	q_2
E_k'	Log-changes in export volumes	q_2
r'	Log-change in the exchange rate	1
θ_i'	Log-changes in sector indirect tax rates	n-1
X_i'	Log-changes in sector production levels	n-1
w'	Log-change in the wage rate	1
L_i'	Log-changes in sector employment levels	n-1
L'	Log-change in total employment	1
Y'	Log-change in total consumer expenditure	1
Z_0', Z_j'	Log-changes in exogenous final demands	n
M_0'	Log-change in complementary imports	1
M_j'	Log-changes in levels of competitive imports	q_1
Δ'	Log-change in level of capital inflows	1

Base-Year Levels

All of the above log-changes when written without primes, and

X_{0i}, X_{ji} — Intermediate uses by sector i of complementary imports (X_{0i}) and goods produced domestically or imported competitively by sector j (X_{ji})

C_0, C_j — Base year levels of consumption of complementary imports (C_0) or domestically produced goods (C_j)

Parameters

η_k — Inverse values of world demand elasticities for exports

a_{ji} — Input-output coefficients: volume of sector j product required per unit output of sector i (assumed constant in fixed coefficients specification).

γ_{ji} — Share of value of sector j input in total value of output of sector i, net of indirect taxes (assumed constant in Cobb-Douglas specification for intermediate inputs).

α_i — Share of labor payments in value added net of indirect taxes (fixed coefficients specification), or value of output net of indirect taxes (Cobb-Douglas specification for intermediate inputs).

g_{ji} — Elasticity of consumer demand for the j-th commodity with respect to the i-th price.

g_{jy} — Elasticity of consumer demand for the j-th commodity with respect to total expenditures.

as the producer price variables in the labor demand equations. Also, if we were to treat capital as a variable factor and assume that all production functions had constant returns, then we would have to add a capital demand-supply balance and sectoral capital demand equations of the following form to Table 1,

$$(p_i^*)' + X_i' - s' - K_i' = 0 \qquad \text{(n-1 equations)} \qquad (1)$$

where s' is the log-change in the economy-wide rate of return to capital, K_i' is the log-change in sector i's capital stock, and $(p_i^*)'$ is shorthand for the expression appearing first in Table 1's labor demand equation. (Note that we implicitly follow Johansen in assuming the base year domestic producers' prices are all equal to one).

However, this specification would lead to a substantial loss of freedom in specifying tariff changes. We can see this by dropping subscripts to indicate appropriate vector and matrix quantities and using the circumflex accent (ˆ) for a column vector written as a matrix with its components along the main diagonal and zeroes elsewhere. In this notation, log-changes of net prices (or costs) are related to log changes of factor prices by

$$(\hat{p}^*)^{-1}[(I-A)^T p' - \hat{\theta}\theta' - a_0 p_0'] = \alpha w' + (h-\alpha)s' \qquad (2)$$

where $(I-A)^T$ is a transposed matrix of net domestic input-output coefficients, a_0 is a column vector of input coefficients for non-competitive imports, and h is a column vector of ones. This system has as many equations as there are produced goods in the economy. Yet after inversion of the input-output matrix the log-change of each price is a function of s', w', and p_0' (ignoring indirect taxes). Hence the price changes of only three competitively traded goods can be determined independently. These determine factor price changes, which in turn determine price changes of the other goods. Investigation of tariff changes for a large number of sectors is fruitless--in effect all but three of the competitively traded goods would cease to be produced after most sets of tariff changes.

On the other hand, following Table 1 and treating labor as the only variable factor means that we can drop the K_i' term in (1) and replace s' by s_i', leaving n-1 equations (not appearing in Table 1) to determine changes in profit rates in all sectors as residuals, dependent on but not affecting price and output changes. In equations (2), this amounts to putting a "hat" over s'. The result is a linear system with more equations than variables, in which we can impose price changes as we wish. Naturally, this greater flexibility has a cost: all calculations are necessarily "short-run" in nature.[4/] With Cobb-Douglas production functions and the

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[4/] Several comments (in part due to Leif Johansen) are in order: first, in point of fact the linear programming models of the effects of tariff changes cited in footnote 2 are also short-run in our sense, since they work with only one variable factor. For calculation this seems to be the simplest hypothesis. However, it misses the important points that capital is at least partially shiftable between sectors and that still there are probably more industries operating than there are factors of production available in most countries. Hence our use of decreasing returns to generate many degrees of freedom for changing tariffs may be unrealistic insofar as these degrees of freedom will not be used in practice. Purposeful avoidance of specialization natural price-scaling assumption that the log-change in the wage rate (w') is equal to zero, sectoral supply changes in the fixed coefficients intermediate input model reduce to the familiar partial equilibrium formula[5/]

$$x_i' = \frac{\alpha_i}{1-\alpha_i} (p_i^*)', \qquad (3)$$

This equation states that the log-change in output from sector i will equal the log-change in the sector's net price (or value added) multiplied by its supply elasticity. It holds <u>within</u> the fixed coefficients model, but could be used directly to predict supply responses either if the exchange rate were fixed (so that log-changes in prices of traded goods would equal log-changes of the tariffs-plus-one), or if its revaluation in response to tariff revisions could be predicted without going through all the computation-intensive apparatus we have set

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[4/]limits possible price variation in the long run, but it keeps more sectors operating to satisfy policy-makers' desires for much industry (an important fact of life in less developed countries, at least) or to minimize risks from fluctuations of international prices, sudden unavailability of crucial imports, etc. These same factors also reduce competitive pressures to close down non-profitable industries as investments flow toward those with higher rates of return, at least in part the fruit of comparative advantage in trade. One would like to capture all these dynamic forces in a computable model, but it is hard to imagine how.

[5/]Of course, one just multiplies the right side of (3) by the elasticity of substitution between capital and labor when it differs from unity to get the supply response in this case.

up.[6] Given its value-added basis, this would essentially be an ERP prediction of the impact on sector outputs of tariff changes, except that in practice one would base finite difference approximations to log-changes in net prices on the tariff-ridden as opposed to the free-trade point, since all available production and demand data refer to the former. The accuracy of this type of prediction, as opposed to full use of the model, is discussed below in numerical terms. For the moment, we note that its applicability depends crucially on proper assessment of the demand-supply interactions which determine the exchange rate response to tariff reduction (the main non-recursive interaction in the full model) and on the assumption of fixed coefficient production. This hypothesis permits the use of net prices in sector supply functions, a simplification which lies at the heart of ERP calculations, but which is not justifiable when there is intermediate input substitutability.[7] It is obviously desirable to test the results of the fixed coefficients specification against some alternative, and the next section sets out an applicable model.

3. Cobb-Douglas Specification

The major problem with not assuming fixed input-output coefficients is that there has been little econometric work on

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[6] In applying (3) in practice, one has to worry about declining world prices of export goods, changing prices of non-traded goods, etc. See footnote 13 for details on our approaches to these problems.

[7] For more discussion, see the papers cited in footnote 1 and our empirical sections below.

short-run production functions which depend on both primary factors and intermediate inputs. By all odds the simplest specification, originally proposed by Klein (1953) and later given empirical support by Tilanus (1965) and Watanabe (1961), is that the value share of expenditures on a given intermediate input is constant, i.e. that the production function is Cobb-Douglas in intermediate inputs. As a test of the fixed coefficients specification, we adopt this assumption in what follows.

If we also assume that primary factors enter the production function in Cobb-Douglas fashion, then it takes the form $X_i = A_i L_i^{\alpha_i} K_i^{\beta_i} X_{ji}^{\gamma_{ji}}$, and the derived demand equations of a competitive producer in sector i with fixed capital become

$$(1 - \theta_i)^{-1}[p_i' - \theta_i \theta_i'] + X_i' = \begin{cases} w' + L_i' & \text{(1 equation)} \\ p_j' + X_{ji}' & \text{(n equations).} \end{cases}$$

The log-change of output itself is given by

$$X_i' = \alpha_i L_i' + \sum_j \gamma_{ji} X_{ji}',$$

which differs from the fixed coefficients case in that log-changes in intermediate uses (X_{ji}') affect production levels.

These equations, if written explicitly, would require us to carry all the X_{ji}' terms in the calculation. However, we can use the derived demand equations for intermediate inputs to substitute these out in the sectoral demand-supply balances and production function. The results appear in Table 1. We note that

(i) The price terms in the demand-supply balances have more complicated coefficients in the Cobb-Douglas model, reflecting its wider range of potential substitution;

(ii) The production function appears in "semi-dual" form, since X_i' depends on physical inputs of labor, but on prices of intermediate inputs. Bruno (1971) calls such a representation a value-added function; some years before, Samuelson (1966) pointed out the potential usefulness of such hybrids in planning applications.

4. Analysis of the Equation System

Before continuing with an empirical application, a few remarks may clarify the interpretation of the systems of linear equations in log-changes of variables which we have derived.

First--it is inelegant but nonetheless reassuring to count up equations and variables whenever one is working with a large system. We have $9+7q_1+8q_2+5q_3$ variables with log-changes listed in Table 2, for both specifications. The Table 1 equations number $4+4q_1+5q_2+3q_3$. Subtraction informs us that $5+3q_1+3q_2+2q_3$ log-changes "should" be specified exogenously to determine the remainder. Do this many naturally exogenous variables exist?

Some thought about the roles different variables play indicates that this question can be answered in the affirmative. The following log-changes are naturally tagged as exogenous: final demands Z_i', forces of tariffs τ_j', forces of export subsidies ϕ_k', total supply of labor L' (or the exchange rate r'), indirect tax rates θ_i', and capital inflow Δ' (or the exchange rate r' for the almost recursive model). There are $4+3q_1+3q_2+2q_3$ variables in this set, and all of them may be assumed to be under the control of either the government or the gods. As mentioned above, it is convenient to follow Johnasen and scale price changes by assuming that the wage w remains constant, which gives enough exogenous variables to close the system.[8/]

Second--suppose we group all the endogenous log-changes in a vector a and the exogenous changes in vector b. Then our equations can be written in a general matrix form as $Ma + Nb = 0$. Formally, this system is solved as $a = -M^{-1}Nb$. Can this inversion be done in practice? A little calculation indicates that the answer is "yes." For our Chilean application (which might be typical) we work with 19 competitive import sectors, 6 export sectors, and 10 non-traded sectors. In this case, the matrix M is of order 175 x 175. Inverting a matrix of this size is not trivial, but the task is quite standard and requires only a few minutes on computers which frequently are available in developing countries.[9/]

Third--data gathering for a model of the size considered here requires much work, but it has already been done in many

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[8/] Endogenous variables are import changes M_i', exports E_k', production changes X_i', total consumption Y', domestic prices p_i', world prices of exports π_k', and sectoral employments L_i'.

[9/] On the IBM 360/65 at Harvard, it took 5.4 minutes of C.P.U. time, using a standard Gauss-Jordan double precision matrix inversion routine. Also note that if capital inflows are made endogenous (and the exchange rate exogenous) one could take advantage of the model's recursive structure to solve it on a small computer.

developing countries. The basic ingredients (available for Chile only in 1962) are an interindustry flow table including a breakdown of value added, employment data, data on volumes of imports and exports and their world prices, and some notion of income and a few price elasticities of consumer demand (which are sufficient under the Frisch-Johansen additivity assumptions to generate all cross-price elasticities). This is not a small package (as some of the scrambling we undertook to get it--described in Black (1971)--will attest) but it in principle exists wherever input-output, effective protection and consumer budget studies have been undertaken. The importance of general equilibrium effects in sector responses described in the next two sections suggests that gathering and using this data as described herein would be a worthwhile exercise whenever extensive tariff changes are seriously considered.

5. Effects of Tariff and Subsidy Changes with Fixed Labor Supply

In this section, we describe a series of experiments with the model under the assumption that the labor force is fixed at the 1962 employment level in Chile. To equalize the number of variables and equations, the exchange rate is treated as endogenous. Since the other major factor price in the system, the wage, is held constant, price changes should be interpreted with respect to this variable.

Table 3 presents some aggregate indicators of the impact on the economy (under various model specifications) of ten per-

Table 3

Effects of a Ten-Percent Cut in all Tariffs and Subsidies on Aggregate Magnitudes in a Full-Employment Model

Variable	Fixed Coeff. Intermed. Inputs: C-D Value Added	Fixed Coeff. Intermed. Inputs: C.E.S. Value Added	Cobb-Douglas Int. Inputs & Value Added
Consumption Expenditures	-0.42%	0.84%	0.21%
Exchange Rate	3.10%	4.01%	3.04%
Export Volume	4.75%	4.90%	7.27%
Largest Output Increase	8.50% (Nitrates)	8.60% (Nitrates)	8.81% (Nitrates)
Largest Output Decrease	-4.97% (Food)	-3.18% (Food)	-10.29% (Food)

cent cuts in the levels of all tariffs and trade subsidies.[10] From the Table, it can be seen that the response of aggregate consumption expenditure in base-year prices to these reductions is quite small, and indeed is negative in one case.[11] On the other hand, export volume and production levels in the most affected industries have absolute response elasticities to the tariff cuts ranging between one-half and one. The exchange rate, interpreted as the price of Chilean Escudos in terms of the dollar, rises as tariffs are cut with an elasticity of 0.3 or 0.4. Such a short-run response of an overvalued exchange to a reduction in protection is of course to be expected.[12]

Against this aggregate background, it is interesting to compare the full model's predicted changes in output levels to partial equilibrium ERP predictions based on formula (3). Table 4 gives detail on log-changes in outputs of the traded sectors

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[10] That is, a 20 percent tariff was reduced two points to 18 percent. Since export subsidies in 1962 were very small, essentially a tariff-cutting policy is described.

[11] This is a common result in neoclassical models--aggregate welfare indicators are not responsive to policy changes. The small effect of tariff cuts on aggregate consumption dissuaded us from calculating the more elaborate consumers' and producers' surplus welfare indicators which have often been employed by international economists.

[12] The magnitude of the devaluation in response to tariff cuts is surprisingly close to estimates made for Chile by Selowsky (1970) and Taylor and Bacha (1971) using partial equilibrium models. In these exercises, however, the 30% devaluation was interpreted as a long-run response. Present results would indicate that this interpretation was erroneous.

predicted by these two methods.[13] Two specifications of the model--fixed coefficient and Cobb-Douglas production functions for intermediate inputs with primary factors entering the production function in Cobb-Douglas fashion--were tested with twenty percent reductions in tariffs exceeding 100 percent, and ten percent reductions in other tariffs and subsidies. A third version--with fixed coefficient intermediate inputs and C.E.S. primary factors--was tried with ten percent reductions in all tariffs and subsidies.[14] The results of the first two calculations are also depicted in Figures 1 and 2.

From the first two columns of Table 4 and Figure 1, it is apparent that prediction based on formula (3) is indeed quite accurate in the model from which it was derived. With the exception of one or two sectors where domestic price changes have some impact and supply elasticities are high, the predictions of the general equilibrium model and the ERP formulas lie close to the 45-degree line.

This close fit is in sharp comparision to the results for the model where intermediate inputs enter production in

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[13] Formula (3) was modified according to the world demand elasticity in the case of export goods. For both exports and imports, the change in the exchange rate from the full model was used in calculating price changes of traded goods used as intermediate inputs, and prices of non-traded goods were assumed not to change. The (p*)' term in (3) was approximated by a finite difference based on initial tariffs.

[14] The solutions are not strictly comparable, since some adjustments in world demand elasticities, etc., were made between them. Behrman (1970) is the source of elasticity of substitution data in aggregated form--we applied his aggregate elasticities to each appropriate disaggregated sector.

Table 4

Log-Changes of Sectoral Outputs in Response to Tariff and Subsidy Reductions and ERP-Based Predictions of Log-Changes Under Various Specifications

	Twenty percent reductions of tariffs exceeding 1.0; Ten percent reductions of other tariffs and subsidies				Ten percent reductions in all tariffs and subsidies	
	Fixed coeffs. inter. inputs C.-D. Value added Functions		C.-D. Inter. inputs and Value added Functions		Fixed coeff. inter. inputs C.E.S. value added Functions	
Sector	Actual	Predicted	Actual	Predicted	Actual	Predicted
Agriculture	0.0066	0.0054	0.0077	0.0053	0.0017	0.0044
Elect. Mach.	-0.0386	-0.0413	-0.0683	-0.0412	-0.0062	-0.0095
Other Min.	0.0013	-0.0020	-0.0031	-0.0012	-0.0008	-0.0044
Trade	0.0309	0.0306	0.0427	0.0310	0.0054	0.0281
Food	-0.0358	-0.0455	-0.0778	-0.0463	-0.0318	-0.0499
Machinery	-0.0086	-0.0115	-0.0132	-0.0113	-0.0096	-0.0154
Chemical	-0.0123	-0.0149	-0.0253	-0.0192	-0.0115	-0.0175
Metal Prod.	0.0093	0.0064	0.0160	0.0065	0.0023	0.0004
Oil & Coal Der.	0.0033	0.0028	0.0153	0.0018	0.0022	0.0025
Textiles	-0.1001	-0.1064	-0.1708	-0.1143	-0.0232	-0.0335
Ftwr., Cloth.	-0.0471	-0.0500	-0.0757	-0.0471	-0.0120	-0.0164
Trans. Mach.	-0.0047	-0.0070	-0.0060	-0.0068	-0.0063	-0.0103
Non-met. Min.	-0.0581	-0.0628	-0.0964	-0.0630	-0.0118	-0.0179
Misc. Manf.	-0.0261	-0.0279	-0.0640	-0.0283	-0.0049	-0.0074
Bas. Met.	-0.0076	-0.0177	-0.0150	-0.0280	-0.0122	-0.0227
Rubber	-0.0317	-0.0339	-0.0756	-0.0372	-0.0048	-0.0074
Leather	-0.0244	-0.0216	-0.1949	-0.0916	-0.0071	-0.0258
Furniture	-0.0839	-0.0931	-0.1313	-0.0924	-0.0160	-0.0258
Beverages	-0.0684	-0.0734	-0.1915	-0.0735	-0.0151	-0.0223
Wood Prod.	-0.0126	0.0115	-0.0366	0.0120	-0.0016	0.0089
Paper & Pulp	0.0043	-0.0062	-0.0030	-0.0012	-0.0004	-0.0082
Nitrates	0.1060	0.1155	0.1118	0.1032	0.0860	0.1081
Trans. & Com.	0.0122	0.0768	0.0113	0.0768	0.0095	0.0713
Iron Min.	0.0303	0.0306	0.0372	0.0299	0.0228	0.0293
Copper Min.	0.0194	0.0206	0.0333	0.0245	0.0191	0.0263

Cobb-Douglas fashion. As shown in Figure 2, the ERP calcualtion clearly under-predicts (in absolute value) most log-changes, in some cases by a factor of two or more. Since the Watanabe and Tilanus studies cited above indicate that a Cobb-Douglas specification of the way intermediate inputs enter production is probably more realistic than fixed coefficients, the normal ERP formula appears inappropriate.[15/]

Of course, one can derive modified ERP formulas to take into account intermediate input substitutability in partial equilibrium form. However, such formulas would be unsatisfactory even in the simple one-factor model considered here. The exchange rate responds in general equilibrium (depending on both supply and demand factors) to commercial policy, having an elasticity with respect to single changes in the forces of tariffs and subsidies as large as 0.29 in absolute magnitude in the model with fixed coefficients intermediate inputs. ERP predictions ignoring this devaluation in response to tariff cuts would clearly overestimate output changes in absolute terms. For accuracy, the model has to be solved to get the new exchange rate to plug into the ERP formulas--even with fixed coefficients. Naturally, with more primary factors and/or intermediate input substituta-

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[15/] If fixed coefficients do apply, but not Cobb-Douglas production functions for value-added, ERP predictions fare better. They only err insofar as the elasticity of substitution differs from one, and the last two columns of Table 2 indicate that this error is not great when Behrman's estimated elasticities for Chile are used.

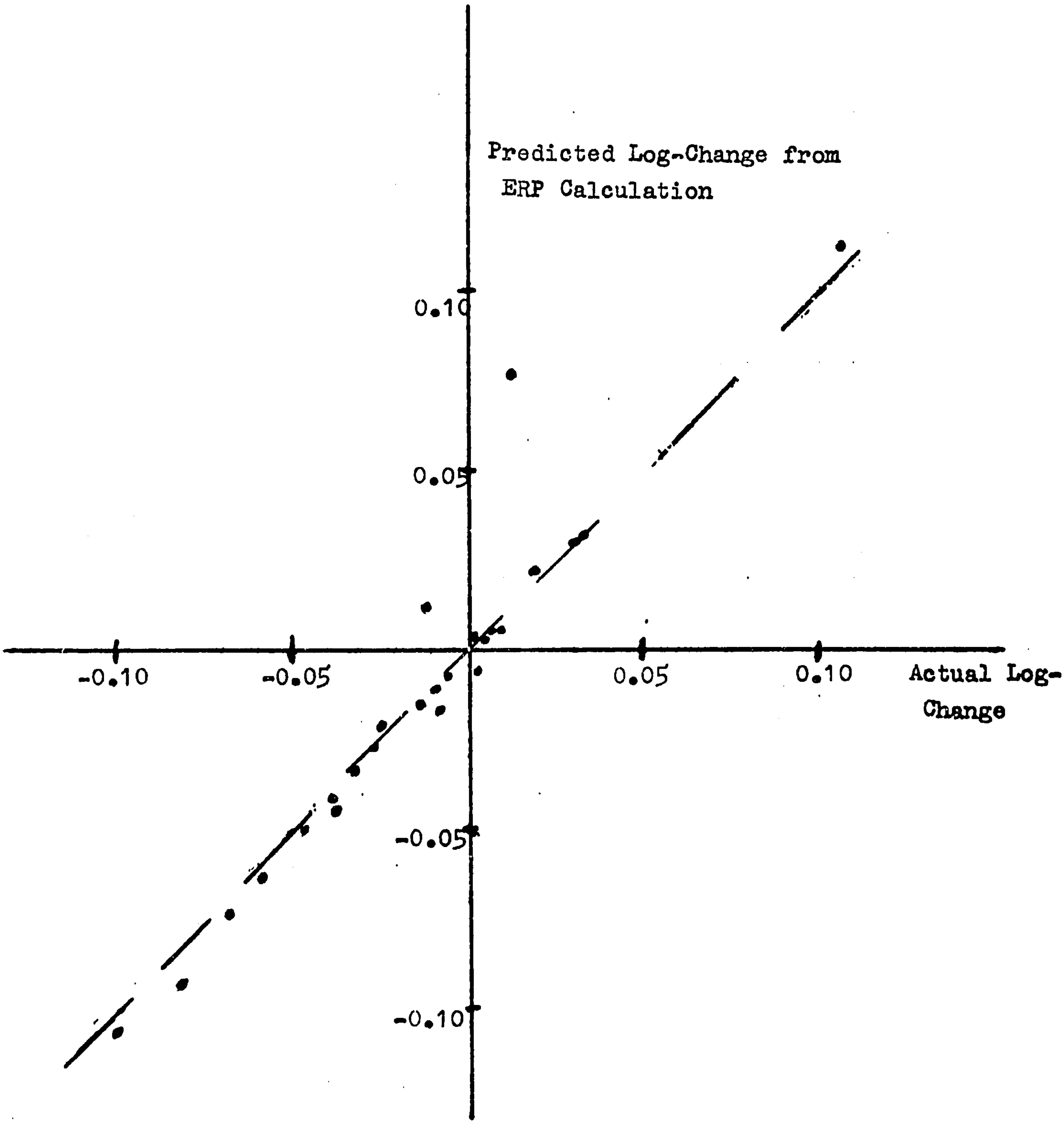

Figure 1

Actual and Predicted Log-Changes of Sectoral Outputs: Fixed Coefficient Intermediate Inputs, Cobb-Douglas value added functions, 20% reductions in Tariffs Exceeding One, 10% reductions in Other Tariffs and Subsidies.

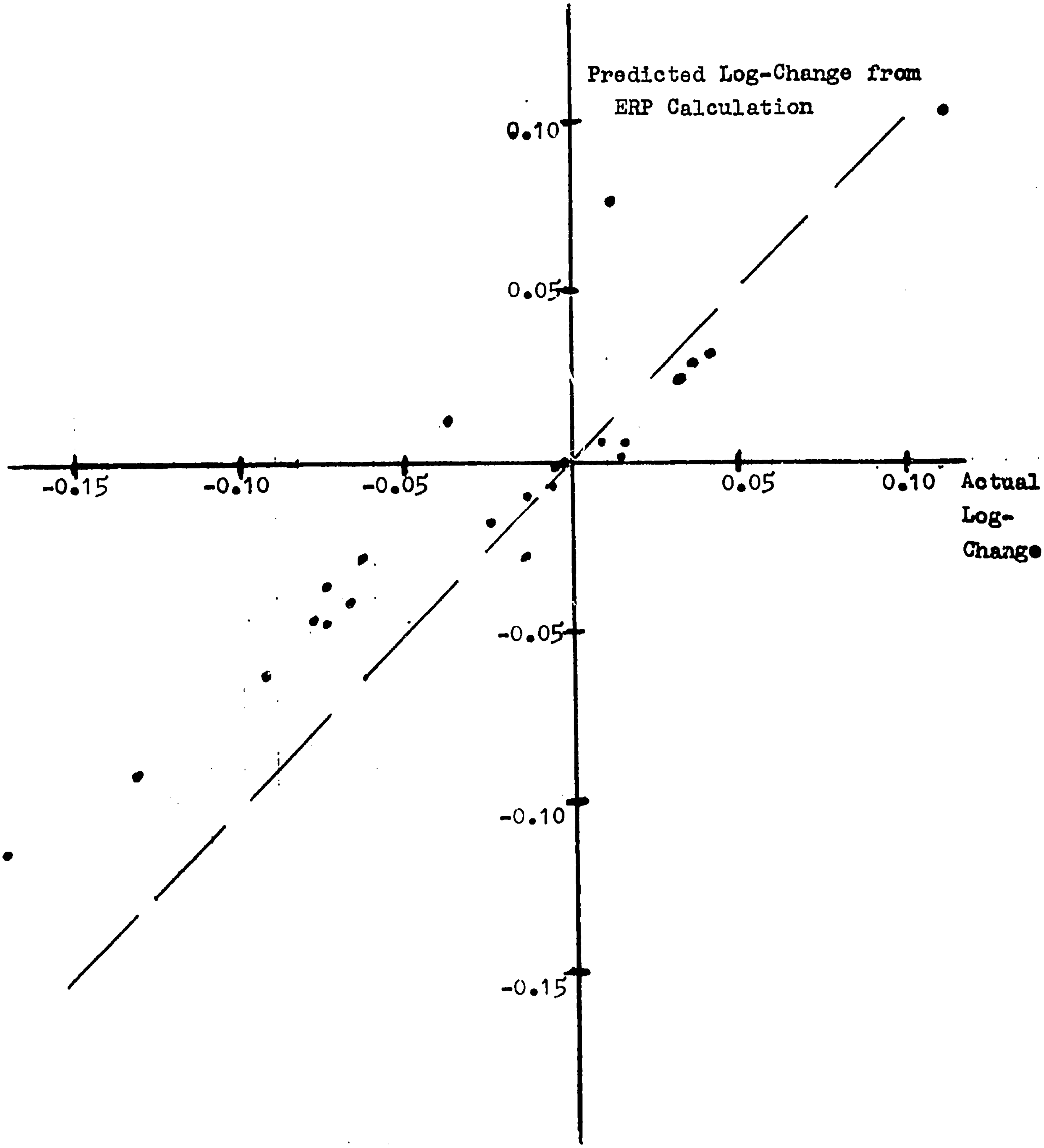

Figure 2

Actual and Predicted Log-Changes of Sectoral Outputs: Cobb-Douglas Production Functions in Intermediate Inputs and Primary Factors, 20% Reduction in Tariffs exceeding One, 10% Reduction in Other Tariffs and Subsidies ability the situation is far more complex.

6. Effects of Commercial Policy on Employment

In this section, mainly to illustrate the uses to which Johansen-type models can be put, we work with a "demand-determined" specification: total employment is made an endogenous variable, while the exchange rate becomes exogenous--to be used along with tariffs as an instrument of policy in raising employment. The use of general equilibrium models (and the exchange rate) for such calculations (and policy purposes) has recently been discussed with reference to Colombia by Richard Nelson (1970). The reader may be interested in comparing our approach with his, since both focus on the employment effect of reducing the real wage via devaluation-induced price increases.

Not too surprisingly, sectoral elasticities of substitution have decisive importance in determining employment responses. When Cobb-Douglas production functions for value added are assumed, the elasticity of total employment with respect to the exchange rate is 1.69 with fixed coefficients intermediate inputs, and 1.74 with Cobb-Douglas inputs. This is the result one would get from an aggregate Cobb-Douglas production function with a labor share of about 0.40 (somewhat less than the level in Chile). By contrast, the elasticity falls to 0.87 (fixed coefficients case) when Jere Behrman's estimated elasticities of substitution, which range between about 0.2 and 0.8, are used. The importance of this difference becomes apparent when it is realized that the Cobb-Douglas specification implies that the exchange rate only has to be increased by two or three percent to reduce Chile's seven percent unemployment rate to three percent. The C.E.S. specification would require a five or six percent devaluation (and a corresponding reduction in the real wage via general price increases of the same five or six percent for traded goods and a bit less for non-traded goods in the face of a constant money wage).[16/] One can entertain doubts about the viability of this policy in a country with powerful unions.

Such worries about general wage cutting become less serious when we consider the impacts of tariff or subsidy increases in specific sectors on total employment. Unfortunately, the problems raised by misspecification of sectoral elasticities of substitution do not disappear, so that the employment increases resulting from isolated ten-point sectoral tariff or subsidy increases shown in Table 5 should only be taken as indicative. These results are calculated from the model with Cobb-Douglas production functions for primary factors and intermediate inputs, and reflect general equilibrium effects. In light of last section's results, we did not consider it worthwhile to compare the Table 5 predictions with more naive forecasts from partial equilibrium.

[16/] Nelson ventures that "Colombia's problems would have been significantly fewer had the exchange rate been, say, twenty percent higher." This may be due to Colombia's far more severe unemployment problem, and his model with only two goods and three factors. Our results, on the other hand, may be biased because we do not take into account Chile's numerous import quotas. Including these would in effect increase the number of non-traded sectors, in which employment is less sensitive to exchange rate policy.

The results themselves indicate that subvention of Chile's export industries (listed beginning with wood products) is unlikely to relieve unemployment. Nor, for that matter, is the trade sector very promising--imports are not large and a shift to exporting is unlikely. On the other hand, protection of agriculture and food processing may well generate significant employment increases, particularly since other results show that the former sector is capable of exporting when general tariff cuts are made at full employment. Employment increases from higher tariffs for other sectors (particularly the highly protected import substituting textile, clothing, rubber and leather industries) are not large.

7. Conclusion

Obviously, there is much more about numerical results that could be said--a large general equilibrium model of the type considered here provides almost limitless opportunities for experimentation. However, space limitations and the antiquity of our basic data are not conducive to more detailed analysis at this time.

The main thing we want to stress in conclusion is that with the type of model described here, one can get local, general equilibrium predictions of resource pulls resulting from changes in commercial policy with scarcely more computational and data gathering effort than is required for a standard effective pro-

Table 5

Effects of a Ten Percent Increase in Single Tariffs or Subsidies Given Traded Goods Sectors on Total Employment in Thousands

Sector	Increase	Sector	Increase
Agriculture	71.9	Misc. Manf.	1.8
Elect. Mach.	2.2	Bas. Met.	0.6
Other Min.	3.6	Rubber prod.	-2.5
Trade	84.1	Leather prod.	0.9
Food	25.5	Furniture	6.4
Machinery	3.3	Beverages	2.0
Chemicals	2.6	Wood prod.	0.5
Metal prod.	8.9	Paper & pulp	0.5
Oil & Coal Deriv.	-3.1	Nitrates	3.9
Textiles	1.8	Trans. & Com.	11.2
Ftwr., Cloth.	8.3	Iron Min.	1.8
Trans. Mach.	4.0	Copper Min.	7.2
Non-Met. Min.	3.0		

Note: The employed Chilean labor force in 1962 was 2.04 millions.

tection study. From our point of view, the now traditional ERP approach is no longer to be recommended, even on the basis of its last line of defense: practicality. The heretofore ignored strength of Johansen-type models is their applicability to real problems. Practitioners should take advantage of this.

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