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Statistics Canada
Input-Output Division

Statistics Canada's Price Model:

A Detailed Description of the Structure

and Simulation Capacities

By

René Durand

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August 1988

1. INTRODUCTION

This technical note presents the input-output price model of Statistics Canada. It updates and superdsedes all former documentation. The note includes the standard price model and alternative optional formulations. The standard model is a static cost push type model in which final output prices are determined on the basis of the industries' output prices which are themselves determined by their input costs. The industries' input costs are in turn composed of two categories: intermediate input costs and primary input costs. Intermediate inputs are those inputs that are produced (or could be produced but are imported i.e. competing imports) by the industries of the business sector of the ecomomy and consumed by these same industries during the same year. Capital goods are typically consumed over a time span exceeding the current year and are therefore excluded from the set of intermediate inputs even though they are produceable commodities. Since intermediate inputs are themselves outputs of the same set of industries, their costs can be established endogeneously so that all prices ultimately rest on primary input prices. These intermediate input prices are determined on the basis of the interrelationships of the industries of the business sector of the Canadian economy.

The primary input prices refer to the prices of all commodities which are not produced by the business sector of the Canadian economy in any particular year. These include the prices of capital services, labour, non competing imports and of household and government supply of goods and services. Nevertheless, households do not supply any input to the business industries and their ouputs are not included in the set of primary inputs while governments do and their supply of goods and services are included.

The alternative models, that are presented next, are transformations of the basic model whereby additional constraints are specified on the behavior of prices. Typically, these constraints take the form of resetting exogeneously some prices which were treated endogeneously in the basic model. These prices include (alternative model 1) all or part of the industries' selling prices and (alternative model 2) all or part of the commodity prices supplied by the business sector. A third alternative model is also presented in which capital service prices are determined endogeneously through a markup on sales relationship. It may be seen as a more convenient way of determining the price of capital services than in the basic model in that the markup approach has more intuitive appeal as a concept than the level of the price of capital services.

All of the price models to be presented rest on basic accounting identities and will be explicitely derived from these identities in order to provide the reader with better insight about their meaning. Parameters in these relationships are based on the most recent input-output tables except for a subset of them which can be modified by the user. Once set, the parameters are treated as fixed during a given simulation. The parameters are the industries' market shares and their technical input-output coefficients (both primary and intermediate) and the import coefficients. The latter can be modified by the user, while the former are normally considered as fixed. The fixity of all these parameters in simulations mean that no price substitution is allowed for by the model as a result of changes in relative prices.

The impact of the price shocks are measured by comparing alternative scenarios in which some prices have been preset by the user to the base scenario in which all prices are set equal to one.

2. THE STANDARD MODEL

The price model rests on the basic input-output accounting identity which equates a given industry's total costs to its total sales. For all industries taken together, we have:

$$g_c = U_c^T i + Y_{cp}^T i + Y_{ck}^T i \qquad (2.1)$$

where the subscript c indicates that the corresponding variables are measured in current prices, the superscript T is used for the transposition of matrices and vectors and where

g_c is the vector of industries' gross output;

U_c is the matrix of intermediate inputs;

Y_{cp} is the matrix of primary inputs excluding "other operating surplus";

Y_{ck} is the other operating surplus (income of capital)

and

i is the summation vector of appropriate dimension.

For each industry, that is for each row of the previous equation, total sales are set equal to the total cost of intermediate inputs plus the total cost of all primary inputs excluding capital plus the cost of capital which is taken as being the "other operating surplus". The "net income of unincorporated business" is treated in the model as part of the other primary inputs. Current price variables are related to the constant price variables (which appears without the c subscript) by the following identities:

$$
\begin{aligned}
g_c &= \hat{p}_g\, g \\
U_c &= \hat{p}_q U \\
Y_{cp} &= Y_p \bullet P_y \\
Y_{ck} &= Y_k \bullet p_k
\end{aligned}
\qquad (2.2)
$$

where

p_g is the vector of industries' selling prices (endogenous);
p_q is the vector of commodity prices (endogenous);
P_y is the matrix of the prices of the primary inputs excluding capital (exogenous);
p_k is the price vector of capital services by industry(exogenous) and
$\hat{}$ is the symbol used to denote a diagonal matrix formed from the corresponding vector and $\bullet$ the symbol used to denote the Schurr (element by element) matrix product.

In the above identities the price vector p_q is a weighted average of domestically produced commodities p_{qd} and competing imports p_m, the weights being the import shares (noted $\hat{u}$):

$$p_q = \hat{u}p_m + (I-\hat{u})p_{qd} \qquad (2.3)$$

The domestic commodity price vector p_{qd} must be interpretated as the vector of the average price at which the domestic producers are selling each commodity. Indeed, each commodity may potentially be produced by more than one industry which may sell them at a different price. The distribution of domestically produced commodities by industry is given by the market share matrix D defined as:

$$D = V\,\hat{q}^{-1} \qquad (2.4)$$

where V is the constant price matrix of the industries' (rows) output by commodities (columns) and q the constant price vector of commodity outputs. The domestically produced commodity prices are then related to the industries' selling prices p_g by:

$$p_{qd} = D^T p_g \tag{2.5}$$

That is, each commodity average price is equal to a weighted average at which the producing industries are selling their commodities, the weights being given by their market shares. As this interpretation of the relation (2.5) is novel, its is further explained in the Appendix.

Substituting the definitions (2.2) into the basic identity (2.1) yields:

$$\hat{g}p_g = U^T\hat{p}_q i + (Y_p \bullet P_y)i + \hat{Y}_k p_k \tag{2.6}$$

In (2.6), the capital input cost is entered as a regular matrix product rather as a Schurr product as is the case with the other primary inputs for there is only one such component by industry. As outlined in the Appendix, we could have replaced the intermediate input component of (2.6) by the Schurr product of U with the intermediate input price matrix P_u without changing the end results of the model as will now be derived. Multiplying (2.6) through by the inverse of $\hat{g}$ gives:

$$p_g = \hat{g}^{-1}U^T\hat{p}_q i + \hat{g}^{-1}(Y_p \bullet P_y)i + \hat{g}^{-1}\hat{Y}_k p_k \tag{2.7}$$

In some reference year t_o, we now define the parameter matrices

$$\begin{aligned} B &= U_o\hat{g}_o^{-1} \\ H_y &= Y_{po}\hat{g}_o^{-1} \\ \hat{H}_k &= \hat{Y}_{ko}\hat{g}_o^{-1} \end{aligned} \tag{2.8}$$

We further assume that the parameter matrices are invariant with respect to prices (no price substitution) and invariant through time (the same parameters apply to a simulation carried for any year t). Given these assumptions, the variables and parameters of the static price model need not be indexed through time. Substituting (2.8) into (2.7) gives:

$$p_g = B^T p_q + (H_y^T \bullet P_y^T)i + \hat{H}_x p_x \tag{2.9}$$

where we have used the rule (easily derived by inspection) that if $\hat{\lambda}$ is a diagonal matrix then for any matrices A and B, we have

$$(\hat{\lambda}A \bullet B) = \hat{\lambda}(A \bullet B)$$

In the reference year, current and constant price flows are identical so that by (2.2) all prices are equal to one (i.e. $p_g = i_g$, $p_q = i_q$ etc.) and by (2.9):

$$i_g = B^T i_q + H_y^T i_y + \hat{H}_x i_g \tag{2.10}$$

which is as expected since (2.10) simply says that all inputs coefficients sum to one. We are now in a position to describe the standard price model as the system formed by equations (2.3), (2.5) and (2.9):

$$p_q = \hat{u}p_m + (I-\hat{u})p_{qd} \tag{2.3}$$

$$p_{qd} = D^T \; p_g \tag{2.5}$$

$$p_g = B^T p_q + (H_y^T \bullet P_y^T)i + \hat{H}_x p_x \tag{2.9}$$

In the above system, the prices p_x, p_m and P_y are the exogenous prices determining the prices of industries p_g, the domestic commodity prices p_{qd} and the commodity prices p_q. The system can be solved by substituting (2.5) into (2.3) and the result into (2.9) to finally obtain for p_g:

$$p_g = [I - B^T(I - \hat{u})D^T]^{-1}[B^T\hat{u}p_m + (H_y^T \bullet P_y^T)i + \hat{H}_x p_x] \tag{2.11}$$

Once p_g has been computed, then p_{qd} may be directly computed from (2.5) and then p_q from (2.3).

3. FIXING INDUSTRIES' SELLING PRICES

It may sometimes be convenient for the user to preset exogeneously the selling price of some industries. Doing so is tantamount to considering the price of capital or labour as being determined residually in the industry's price equation (2.9). Since the latter prices may no longer be of any interest, it does not matter which is treated residually as both may be discarded from the model together with the industry's equation. The remaining equations may then be solved as in the standard model. However, from a modeling point of view, it is preferable to have only one set of equations in which we may arbitrarily fix exogeneously some industry selling prices rather than to reformulate the analytic solution for each specific case. If no industry selling prices are set exogeneously, then the model will give the same results as the standard model which then appears as a particular case of the more general model. If capital prices as residually determined in industries in which selling prices have been preset, we may rewrite equation (2.9) as

$$p_g = (I - \hat{d})[B^T p_q + (H_y^T \bullet P_y^T)i + \hat{H}_k p_k] + \hat{d}\bar{p}_g \qquad (3.1)$$

where $\bar{p}_g$ is a vector of exogeneously set industries' selling prices and where d is a vector of binary variables taking a value of 0 for endogeneously determined industries' selling prices and 1 when the price is set exogeneously. The system of equations formed by (2.3), (2.5) and (3.1) may then be solved which for p_g gives:

$$p_g = [I - (I-\hat{d})B^T(I-\hat{U})D^T]^{-1}\{(I-\hat{d})[B^T\hat{U}p_m+(H_y^T \bullet P_y^T)i + \hat{H}_k p_k] + \hat{d}p_g\} \qquad (3.2)$$

The corresponding solution for p_k is given by:

$$p_k = (I-\hat{d})\bar{p}_k + \hat{d}[\hat{H}_k^{-1}(p - B^T p_q - (H_y^T \bullet P_y^T)i] \qquad (3.3)$$

where $\bar{p}_k$ is the vector of preset capital prices.

4. FIXING COMMODITY PRICES

Through its intervention, the government may decide to regulate the price of certain commodities. The price at which these commodities sell is then disconnected from cost considerations. Import prices, however, are considered to be given by international market conditions over which the government has no control. Hence, only domestic commodity prices are considered to be subject to control and can be fixed exogeneously in the price model.

The logic to fix prices of domestic commodities outside the model is similar to the one applied in the previous section: one defines dummy (binary) variables δ which are introduced in the domestic commodity prices equation (2.5):

$$p_{qd} = (I - \hat{\delta})D^T c_g + \hat{\delta}\bar{p}_{qd} \tag{4.1}$$

Equation (4.1) states that domestic commodity prices are either determined by costs (δ=0) or exogeneously (δ=1). In addition to the introduction of the dummy variables in the commodity price equation, we also have replaced the industries' selling prices p_g by their average production cost c_g. The reason for that substitution is that industries' selling prices will themselves be partly determined by the exogeneously determined commodity prices as, by definition, they are a weighted average of the latter given by:

$$p_g \equiv Cp_{qd} \tag{4.2}$$

where C is the industries' product mix matrix defined by

$$C \equiv \hat{g}^{-1}V$$

Therefore, industries selling prices need not be equal to average production costs when some commodity prices are fixed exogeneously. The industries' selling price equation is thus replaced by the following average cost equation:

$$c_g = B^T p_q + (H_y^T \bullet P_y^T)i + \hat{H}_x p_x \tag{4.3}$$

The system formed by equations (2.3), (4.1) and (4.3) is a complete system which can be solved for p_{qd}, p_q and c_g.
The solution for c_g is given by:

$$c_g = [I - B^T(I-\hat{u})(I-\hat{\delta})D^T]^{-1}[B^T\hat{u}p_m + B^T(I-\hat{u})\hat{d}p_{qd} + (H_y^T \bullet P_y^T)i + \hat{H}_x p_x] \tag{4.4}$$

Once c_g is known, the value of p_{qd} can be determined directly from (4.1) and then p_q from (2.3). But we still have to find the solution for p_g. This solution is given by identity (4.2) which solves for:

$$p_g = C(I-\hat{\delta})D^T c_g + C\hat{\delta} p_{qd} \qquad (4.5)$$

Equation (4.5) simply says that industries' selling prices are either determined by production costs as before or, when commodity prices are set exogeneously, by the weighted average of these commodity prices.

5. THE MARKUP ON SALES MODEL

The last alternative model to be presented is the one in which the user decides to fix the (gross) profit margin on sales τ rather than the price of capital as in the standard model. In this model, the price of capital is thus endogeneous and determined on the basis of profit margin on sales τ defined by:

$$\tau = \hat{g}_c^{-1} Y_{ck} \qquad (5.1)$$

That is, the profit margin is given by the capital income (other operating surplus) divided by total sales. But from (2.2) we have:

$$Y_{ck} = \hat{Y}_k p_k$$

Substituting into (5.1) yields:

$$\tau = \hat{g}_c^{-1} \hat{Y}_k p_k$$

$$= \hat{g}_c^{-1} \hat{g} \hat{H}_k p_k$$

$$= \hat{p}_g^{-1} \hat{H}_k p_k \qquad (5.2)$$

Solving (5.2) for p_k gives:

$$p_k = \hat{H}_k^{-1} \hat{\tau} p_g \qquad (5.3)$$

Substituting (5.3) in the industries' selling price equation (2.9) and using (2.3) gives

$$p_g = B^T \hat{u} p_m + (H_y^T \bullet P_y^T) i + [B^T (I-\hat{u}) D^T + \hat{\tau}] p_g \qquad (5.4)$$

Again, solving the last equation for p_g gives:

$$p_g = [I - B^T (I-\hat{u}) D^T - \tau]^{-1} [B^T \hat{u} p_m + HT^y \bullet P_y^T) i] \qquad (5.5)$$

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APPENDIX

Generalization of the Price Equations

The price relationship (2.5) over which are based the price equations of the standard model and its alternatives can be derived from accounting identities under the assumption of unicity of the domestic commodity prices. Indeed, if each commodity which is produced by many industries is sold at the same price by all producers, then the market share matrix D is invariant with respect to prices and we have

$$g_c = D_c q_c = D\ q_c \tag{A1}$$

It follows immediately from the definition of the current price variables that:

$$\hat{g} p_g = D\hat{q} p_{qd} \tag{A2}$$

But we know from basic definitions that

$$g = Vi = D\hat{q}i = Dq \tag{A3}$$

Substituting (A3) into (A2) gives:

$$\hat{p}_g Dq = D\hat{q} p_{qd} = D\hat{p}_{qd} q \tag{A4}$$

Since the latter relationship is true for all non negative vector q, then we have

$$\hat{p}_g D = D\hat{p}_{qd} \tag{A5}$$

Inspection shows that the latter relationship may imply that all prices are equal in the economy if there are sufficiently many non zero cells in the market share matrix D[1]. This is a very unpleasant outcome of the price unicity assumption. Otherwise, summing over both members of (A5) yields equation (2.5). Fortunately, the price unicity assumption is not necessary to obtain (2.5), provided that we interpret the price vector p_{qd} as the average price at which domestic producers are selling the commodities. Let us indeed consider the price matrix P corresponding to the make matrix V such that:

$$V_c = V \bullet P \tag{A6}$$

According to (A6), two industries can sell the same commodity at a different price. The Schurr product in (A6) above may be rewritten as a usual matrix product

$$V_c = \tilde{V}\,\hat{P} \qquad (A7)$$

where the matrix $\tilde{V}$ is formed from the matrix V as follows

$$\tilde{V} = \begin{bmatrix} v_1^T, 0, \ldots, 0 \\ 0, v_2^T, \ldots, 0 \\ \\ 0, \ldots, v_m^T \end{bmatrix} \qquad (A8)$$

and

$$\hat{P} = \begin{bmatrix} \hat{p}_1 \\ \hat{p}_2 \\ \\ \hat{p}_m \end{bmatrix} \qquad (A9)$$

where v_i^T is the output vector of industry i and $\hat{p}_i$, the diagonal matrix of the corresponding prices. Since the value of current price outputs satisfies the relation

$$\hat{p}_{qd}q = V_c^T i = \hat{P}^T\tilde{V}^T = \hat{V}^T\hat{P}^T i = \hat{V}^T\tilde{p} \qquad (A10)$$

where $\tilde{p}$ is the price vector formed from $\hat{P}$ of all outputs of all industries. Premultiplying (A10) by $\hat{q}^{-1}$, we have

$$p_{qd} = \hat{q}^{-1}\,\hat{V}^T\tilde{p} \qquad (A11)$$

The prices of p_{qd} are thus indeed given by the total value of outputs divided by the corresponding quantities and therefore constitute averages. By definition, the current price market share matrix (which is no more invariant with respect to prices), D_c is such that

$$V_c i = D_c\hat{p}_{qd}q \qquad (A12)$$

But

$$V_c i = \hat{g}p_g \qquad (A13)$$

and since

$$g = Dq \qquad (A14)$$

we finally get, combining the last three relations:

$$\hat{p}_g Dq = D_c\hat{p}_{qd}q \qquad (A15)$$

This relationship is valid for all non negative output vector q such that dividing through, we have

$$\hat{p}_g D = D_c\hat{p}_{qd} \qquad (A16)$$

Summing on both sides of this equation and noting that market shares sum to one leads to equation (2.5) of the text.

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