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A Guide to using the Input-Output Model of Statistics Canada

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Table of Contents

Introduction

The Input-Output **(I-O)** model uses the Canadian Input-Output **(I-O)** tables to track and quantify the economic activity generated by changes in consumption or production. The Canadian I-O tables present one of the most complete and detailed accounting framework of the Canadian economy available. As such the model has the greatest potential of all major economic models for capturing the flows of goods and services between industries and consumers at relatively detailed levels.

One of the most common uses of the I-O model is to simulate the impact of a demand shock on the economy. By *shock,* we mean any change or departure from the status quo, in this case any change in demand for goods and services. Any increase in consumption of goods and services will generate both direct and indirect economic production, the latter resulting from the purchase of inputs. Clients of the I-O Division often wish to know how much total economic activity a new industrial project will generate and which industries or regions will benefit the most. The I-O model probably provides the first best answers to those questions.

Description of the tables supporting the model

There are three types of I-O tables:

- Input table
- Output table
- Final Demand table

The Canadian Input and Output tables are rectangular. At the most detailed level, they consist of 243 industries by 679 commodities (including primary inputs, and various margins). Each cell of information in the Input table contains the dollar value of the parts, services, raw materials or labour used up in the production process of the associated industry. The Input table provides a detailed decomposition of the total production costs. The following table contains part of the Input table at the Medium (M) level. For example, the agricultural industry consumed $1,817.4 million dollars of fertilizer as an input in 1995.

The tables are available in various levels of aggregation from 243 industries by 679 commodities at the most detailed level to only 21 industries by 57 commodities at the least detailed level. Generally, an I-O model simulation will report the results at three different levels of aggregation in order to facilitate data treatment and analysis.

Simulation model

The Input-Output (I-O) model simulates the impact of a shock or a change in final demand or industry output on the economy, in particular, the business sector[1]. The model exploits the interindustrial linkages of the input and output tables to track the total production of the goods and services in order to satisfy the final demand or output shock. It indicates which domestic industries were directly responsible for meeting the demand and how much of that demand was siphoned or "leaked" off to foreign imports and other "leakages" such as inventories and government services. We refer to this first round impact as the **direct effects.**

These direct suppliers will in turn purchase goods and services from other industries as inputs. The model repeats this process of purchasing intermediate inputs until the model has identified all the indirect commodities in the full chain of the production process. We refer to the accumulation of these rounds of impact as the **indirect effects**. The direct and indirect effects combine to form the **total effects**.

The impact of a given expenditure project can be measured by the amount of Gross Domestic Product (GDP) generated by industry or for the entire domestic business sector[2]. The gross output as measured in the total effects can be misleading because it contains double-counting (in fact, some output may be counted several times). To illustrate this point think of the price of a loaf of bread. It already includes the cost of the flour. Adding the cost of the flour to the price of the loaf of bread would result in a figure that has little economic meaning. However, gross output can be useful in making comparisons at the detailed industry level, where double counting is minimized.

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1 The business sector includes all individuals and companies that produce goods and services for sale at a price intended to cover all production costs.

2 GDP at factor cost is essentially equivalent to value-added, i.e., the value added by the primary inputs (labour and capital services) to the intermediate inputs transformed in the production process. GDP at market prices includes taxes.

Examples

The potential uses of the I-O simulation model are numerous. Here are a few examples. Whenever possible, one of the best ways to use the model is compare the results of various alternative scenarios given a well defined set of criteria.

1. Short-term job creation

Due to a recession or a regional unemployment problem, government may wish to create employment through different types of public work projects or targeted subsidy programs. The I-O model indicates which industries would be affected directly and indirectly and estimates how many jobs would be created.

2. Economic significance

An analyst can use the I-O model to calculate the total value-added (GDP) generated by a shock. This figure as a percentage of national GDP allows the user to estimate the importance of the economic activity in question in relation to the overall economy. In a similar manner, we can calculate the significance of the activity by individual industry. We accomplish this by dividing the total production per industry generated by the model by the actual total production per industry.

3. Fiscal impacts

The increase in the output of a particular industry will result in higher tax revenues for the government but will also draw more government subsidies. For instance, in some industries, net tax revenues are actually negative due to the importance of subsidies. The I-O model will give a rough estimate of the fiscal impact of a new investment project or increased industrial output. This may be particularly important, especially if additional public assistance is being proposed.

8. Regional and interregional impacts

An analyst can use the Interprovincial model to determine output by industry for an individual province or for a group of provinces, as well as the interregional flow of goods and services between the provinces.

9. Technological flows

To the extent that goods and services embody new technologies, the I-O model can be adapted to trace the flow of technologies throughout the economy. This is a relatively specialized use of the model.

Putting the I-O model into perspective and some cautionary notes

Most people think of the I-O model as an economic model. In many respects, it is not. The I-O model is a complex and detailed **accounting** model of the inter-industrial structure of the Canadian economy. Contrary to macro econometric and general equilibrium models, there are no money supply, no relative prices and no inflation in the I-O model. There are no limits on input supply and thus no bottlenecks occur in the model. The lack of relative prices means that there is no economic behaviour responding to scarce or limited resources.

The model says nothing about the ability of the economy to respond to increases in production in short periods of time. As with most other economy wide models, the I-O model does not automatically capture technological spin-offs and negative externalities such as environmental pollution, or positive externalities resulting from, for example, industrial clustering[4].

Effectively dealing with the limitations of the model requires experience and judgement. The results of modest shocks are most likely trustworthy. Large shocks simulating new demand or output may strain limited resources and cause price changes with difficult to predict economic impacts. The model is static, not dynamic, and therefore calculates a new "equilibrium" without specifying the path to get there.

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4 The jargon **externalities** refer to costs or benefits that accrue outside the production process (i.e., external to the production process).

However, in spite of its limitations, the I-O model does a remarkably good job of capturing the structure of the Canadian economy, a structure that appears to be relatively stable in the medium term. The simplicity of the model can also be an advantage as the results are relatively reliable and easy to understand. Large, theoretically sophisticated macroeconomic models are sometimes difficult to fit to the data and produce ambiguous, difficult to interpret results. For these reasons, I-O modeling often provides the most cost effective means of analyzing a given economic problem.

Available models and data

At the present moment, the National 1995 and the Interprovincial 1990 I-O models are available for simulation purposes.

At various times, clients have requested the use of I-O price, energy and tax models[5]. Given their availability, arrangements can be made to use these models on request. Custom made I-O applications can be arranged.

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5 The Input Output Division no longer builds or maintains the closed version of the I-O model. In the closed version, labour incomes are respent. This is due to the difficulties in building such a model and the tendency to misuse the closed model for public policy purposes. For a further discussion, see *Statistics Canada's Input-Output Model: General Description, Critical Analysis of Partially Closed Version and Alternative Solutions*, Technical Series No. 52-E, Ottawa, Input-Output Division, June 1991, 19 p.

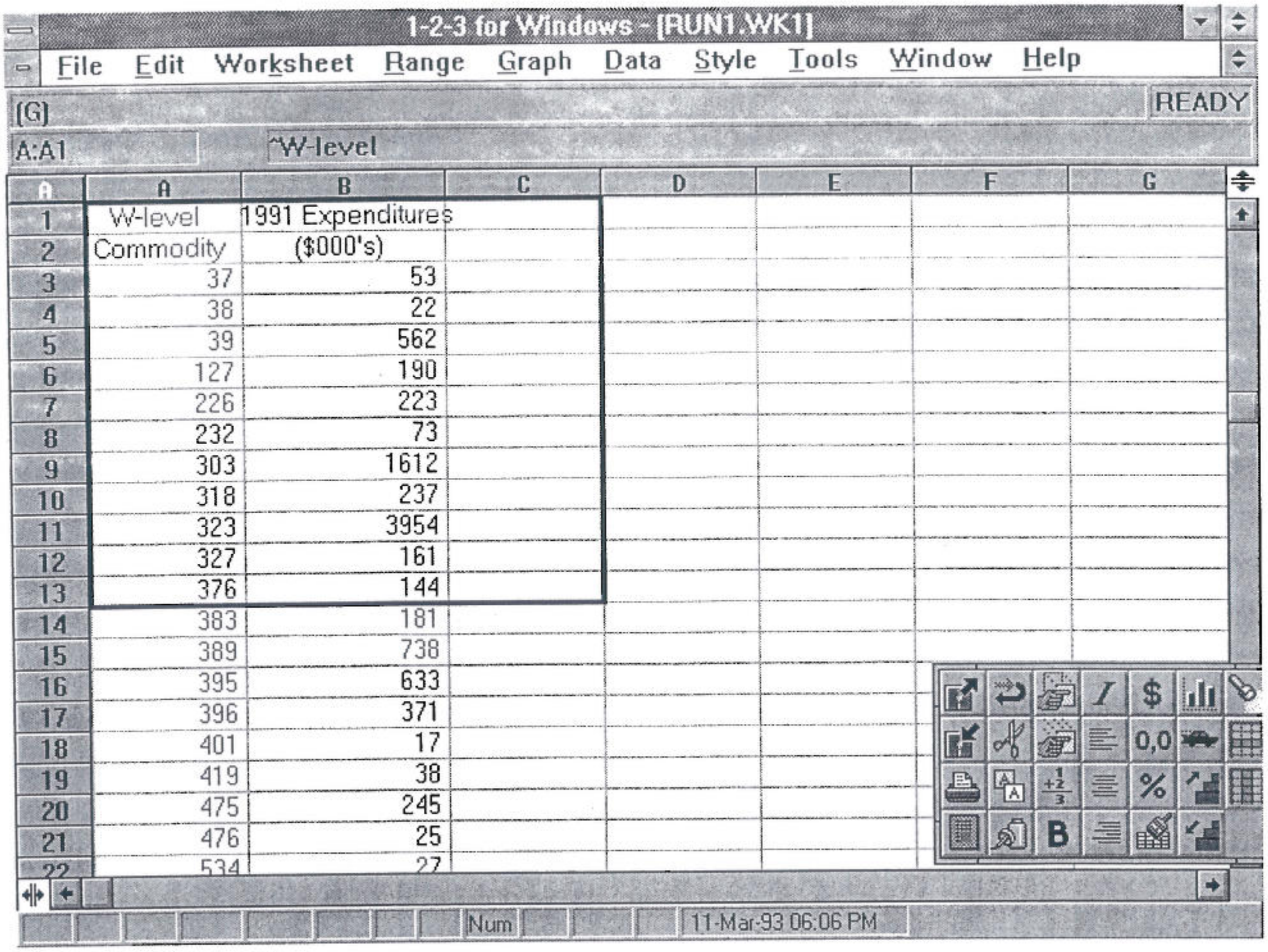
How to prepare a simulation

Simulations should be done according to scenarios that group like activities. For example, one simulation may involve the construction and start-up costs of establishing a new industrial plant. The second simulation may involve the operating costs of running the plant.

The client should first decide whether to shock the model with final demand expenditures or industry output. The best way for the client to maintain the greatest degree of control over the simulation is to prepare a vector column of expenditures or output by I-O commodities at the W-level (Worksheet level) which lists 679 I-O commodities. Input-Output commodity classifications are listed in Table XIV, *The Input-Output Structure of the Canadian Economy 1993-1995 issue,* Catalogue 15-201XPB, Ottawa, 97 p.

The client prepares two vector columns of I-O commodity codes and dollar amounts (values by commodities) in the appropriate row. For a simulation involving shocks on a small number of commodities, the data can simply be mailed or faxed in and we will enter it manually. For larger numbers of commodities, say more than 10, in order to expedite the execution and delivery of the simulation, the data should be supplied on a EXCEL template that the I-O division will supply. The simulation shock data can then be sent by E-Mail to I-O Division. This speeds up the process and eliminates the possibility of operator error which could occur when entering the data.

On the following page is a sample of how a spreadsheet containing data for an I-O simulation with the national model might appear. For an I-O simulation with the interprovincial model, each separate targeted province and/or territory should have its own column.



	A	B
1	W-level	1991 Expenditures
2	Commodity	($000's)
3	37	53
4	38	22
5	39	562
6	127	190
7	226	223
8	232	73
9	303	1612
10	318	237
11	323	3954
12	327	161
13	376	144
14	383	181
15	389	738
16	395	633
17	396	371
18	401	17
19	419	38
20	475	245
21	476	25
22	534	27

- Do you wish to modify the leakage coefficients? For example, if you are sure that final demand will be satisfied by domestic producers only, direct import coefficients can be set to zero. If the shock is meant to simulate industrial output, then we will set the direct leakage coefficients to zero.

Conclusion

The I-O model exploits the simple but detailed accounting relationships furnished by the I-O tables to measure the economic activity generated by a change in consumer or government expenditures, investment or industry output. The national and interprovincial versions of the I-O model provide more industry and commodity detail than any other comparable economic model, and because of this, are often used in conjunction with other economic models. Simulation results also show the effect on GDP by industry and its components such as labour income, taxes and subsidies.

The I-O model is essentially a resource allocation model which responds to shocks through quantity adjustments. It does not incorporate market behaviour — there are no relative prices — but still manages to provide a surprisingly useful and reliable portrait of the anatomy of production relationships in the economy.

Mathematical appendix

To illustrate the I-O model, we first look at a simple text book model with a minimum of detail, then we look at the equation that summarizes the Canadian I-O model[6].

In a text book industry by industry Leontieff input-output model, one attempts to calculate the $n \times 1$ gross output vector g for n I-O industries, that would satisfy the final demand vector f and the indirect industrial demand Ag in the following equilibrium equation

$$g = Ag + f, \tag{1}$$

where the $n \times n$ technical coefficient matrix A contains coefficients a_{ij} which represent the quantity of *i* th good needed to produce one unit of the *j* th good. The solution to the equation (1) is

$$g = (I - A)^{-1} f, \tag{2}$$

where I is the identity matrix. We refer to the matrix $(I - A)^{-1}$ as the *multiplier* or *impact matrix.* It shows the direct and indirect output requirements to meet the final demand f. Embodied in the impact matrix is the iterative process of an infinite number of successive demands for intermediate goods and services

$$\begin{aligned} g &= f + Af + A(Af) + A^3 f + \ldots + A^k f + \ldots \\ &= (I + A + A^2 + A^3 + \ldots + A^k + \ldots) f. \end{aligned} \tag{3}$$

As k tends to infinity, $A^k f$ tends to zero. For practical purposes, $A^k f \cong 0$ after 12 to 14 iterations. In the first round of production, f represents the direct output requirements to meet final demand f. In the second round of production, Af furnishes the goods and services necessary as inputs in the production of f, and so on until the term $A^k f$ converges to zero. The Canadian I-O model by comparison is more complex. The

8 See Alpha C. CHIANG, *Fundamental methods of mathematical economics,* 3rd edition, New York, McGraw-Hill Book Company, 1984, 788 p.

technology is rectangular, e.g., over 600 commodities by 243 industries, and we subtract leakages such as imports. Generally, we use the Canadian open I-O model to calculate the total output by industry necessary to respond to a given expenditure or investment. The output is determined by an equation similar to[7]

$$g = [I - D(I - \hat{\mu} - \hat{\alpha} - \hat{\beta})B]^{-1} D\,(I - \hat{\mu} - \hat{\alpha} - \hat{\beta})f, \qquad (4)$$

where $g =$ vector of values of industry gross output;

$D =$ domestic market share matrix, which is calculated by dividing each element in a column of the output matrix by the total of the column (total commodity output);

$\hat{\mu} =$ the import coefficients (the hat ^ designates a diagonal matrix where the off diagonal values are all zeros), which represent the propensity to import;

$\hat{\alpha} =$ the government production leakage coefficients;

$\hat{\beta} =$ the withdrawal from inventories leakage coefficients; and

$B =$ the industry technology which is calculated by dividing each element in the columns of the input matrix by the total of the corresponding column (total industry inputs). Note that primary inputs are absent in the B matrix.

The matrix $[I - D(I - \hat{\mu} - \hat{\alpha} - \hat{\beta})B]^{-1} D$ is known as the impact or inverse matrix and is conceptually similar to the $(I - A)^{-1}$ matrix given in the previous example. In this specific case, it is the impact matrix of the final demand expenditure shock f on gross output by industry g.

Industry GDP components matrix Y are calculated by multiplying the matrix of primary input coefficients H times the gross output by industry g: $Y = Hg$.

For more detailed explanations, consult the documents listed under **References**.

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9 Equation (4) is a much simplified version of the equation that is presently used in the national model.

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