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MACROECONOMIC PROBLEMS

Problems Using the Input-Output Method for Analysis and Forecasting of Economic Development

Why Are Input-Output Tables Important?[1]

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Abstract—The new input-output tables published by Rosstat for 2011–2015 are indeed an achievement worth celebrating. These tables form a comprehensive picture of the economy that show how its many parts are connected. They serve as a basis for national accounts and for envisioning possible futures for the economy.

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I shall try first to explain what input-output tables are and then why they are important. They are, however, intimately connected with national accounts. Indeed, one important reason for making an input-output table is that the process of constructing it leads to better national accounts. So we are thus led to the question of why national accounts are important. And that question leads to the question of why nations began making national accounts in the first place. And that is a tale of war and depression, a tale of an intellectual stream flowing from Russia to America and on to England and thence to the whole world.

So what is an input-output table? *In principle*, it is a rectangular table that lists down the left side every product made or used in the economy as well as, usually at the bottom, primary inputs such as labor and capital services. Across the top are listed the same products plus, on the right, "final demand" columns such as personal consumption, investment, export and government consumption. Imports appear as a negative column. In each cell of the table is entered the value of the product named in the row used in producing the product named in the column or going to the final named in the column. Conceptually, the sum of all entries in the row for any product must equal the sum of all entries in column for that product. This equality imposes an important check on the entries in the table.

Of course, no such table ever really exists. There are simply too many products. So ryazhenka gets combined with kefir and even cheese and fluid milk into a "Dairy products" row and column. Large tables run up to about 400 such "product combinations" which are called "products" for short. The Rosstat 186 products for the 2011 base year table is altogether respectable, as is the 68 products for other years.

[1] The article is published in the original.

What we have been describing is a product-to-product table. They are rarely made by statistical offices, which instead prepare what are now commonly called *supply* and *use* tables.

The *use* tables have "products" in the rows but in the columns they have "industries" defined as a collection of establishments (plants). It is common for a given "establishment" or plant to produce a number of different products. For example, an establishment may produce $3 million of bakery products, $2 million of dairy products and $2 million of meat products. It will be classified in the Bakery products industry (and column) in the *use* table; all inputs into this establishment will appear in the Bakery products column of the *use* table. The *supply* table shows what *products* each *industry* makes. The Bakery products of establishments in the Bakery industry are called *primary* products of the industry while the other products of the industry are *secondary* products.

By an intuitive, common-sense iterative process of removing from each industry the inputs needed to make its secondary products and putting them into the industries to which those products are primary – but never removing more or an input than there is – it is possible to compute a product-to-product table consistent with the supply and use tables. These tables are sometimes confusingly called "symmetric" tables because both rows and columns refer to products, but they are not at all what called symmetric matrices in mathematics.

Input-output tables and national accounts. The first important use of the supply and use tables is to anchor a nation's national accounts in its production statistics and to impose a strict discipline in making those accounts. The definition of Gross Domestic Product includes only the value of final products. When petroleum is extracted from the ground and sold to a refinery which sells gasoline to filling stations which sell it to households and to truckers, only the value of the gasoline sold to households or governments or exports counts in GDP. Without an input-output table, a statistical office making national accounts will probably just assume that some constant fraction of retail sales of gasoline goes to these final demands. There is no checking with production statistics or uses by other industries. In making and input-out table, however, a complete gasoline balance must be constructed: how much was produced and imported, how much was used in each productive industry, how much was exported, and how much sold to households and governments. Moreover, the sales to productive industries have to be consistent with what is known about the inputs and outputs of those industries. Clearly this is a much more disciplined process than just assigning a constant fraction of retail sales.

So the first result of making an input-output table is more trustworthy national accounts. Of course, that then raises the question of what national accounts are good for. Today, they are used in the popular press as indicators of how the economy is doing, but they are also the framework for economic forecasting, especially with formal, mathematical models. These uses are peaceful enough and somewhat routine.

Origins of national accounts and input-output tables. But the beginnings on national accounts were anything but routine. Here I draw on the masterful book *The Income of Nations* by Paul Studenski and on conversations I was privileged to have many years ago with Simon Kuznets and Wassily Leontief.

In the middle of World War I, Russia was not doing well on the front. The czar or his advisors realized that not all resources could be put directly into the military or there would be nothing to eat. A commission was appointed to answer two questions: What would it take to win the war and could that much be devoted to the war without the collapse of the economy? The commission, appointed by Nicholas II reported to Lenin and the conclusions of the report may well have influenced him to conclude the treaty of Brest-Litovsk. The commission's report seems to have been made public at some point and was read by the young Kuznets with great excitement. I have never seen the report and would read it with great interest. It seems to have laid out the basic ideas of national accounting and made some rough calculations for Russia. In any event, Kuznets found his way to America, enrolled in Columbia University, and got a job at the National Bureau of Economic Research – which is, despite its name, a private institution in New York City. By 1929, he was working on his doctoral dissertation, an effort to make economic accounts for the United States following the ideas laid out in the report of the czar's commission.

With the stock market crash of 1929, the American economy went into a tailspin. It was clear that unemployment was soaring, but there were no statistics on unemployment. It was clear that Gross Domestic Product – a term that had not yet been invented – was plummeting, but no one knew by how much. Someone at the Commerce Department in Washington called the National Bureau of Economic Research in New York and asked if anyone there had any idea what the magnitude of the depression was. "Yes," was the answer, "there's a young Russian here working on that very question." Soon Kuznets was in Washington making the first national accounts for the United States. They appeared in the late 1930's, and "Gross National Product" entered the language.

It was not long before the world was plunged into World War II. Churchill in England was facing the same question faced by Nicholas II: How much resources could by put into the military without causing the collapse of the economy. He posed the question to Keynes, who replied, "There is a young Royal Air Force officer by the name of Richard Stone who can give you an answer." Stone was put to work on the question. He was, of course, well aware of the work of Kuznets. He soon had an answer for Churchill, but continued to work on national accounts. After the war, he was asked by the United Nations to lay out a system of national accounts. His response became the basis of the Standard National Accounts, now used by most countries. (The USA uses a different layout of the accounts which is, in my view, easier to understand.) Stone's system also included input-output tables, and in the 1950's he was active in building a forecasting model, known as Rocket, using these tables.

The first input-output tables were made by Wassily W. Leontief in the 1930s for the United States. A child prodigy, he had graduated from Leningrad University in 1924 at the age of 19, not without having been incarcerated for pasting up posters supporting academic independence. His work had already caught the attention of professors at the University of Berlin, and he had an offer of scholarship for graduate work there. But getting out of Russia did not seem possible. Then he noticed a lump on his left jawbone. The surgeon who removed it declared it a deadly sarcoma from which he would soon die. He asked for and was given the tumor in a bottle and the surgeon's diagnosis. With these he persuaded the authorities to let him out since he would be only trouble and expense to them. In Germany, the tumor was re-examined and found – benign. After several years in Germany, he went to China as an advisor on railroads, and in 1931 came to the United States to work at the National Bureau of Economic Research. His work soon led to an offer of an assistant professorship from Harvard. He replied in a letter that he would accept if he was given a part-time research assistant to make what we would now call an input-output table. At the time, the term did not exist, so the letter explained the idea. The reply said that the entire Harvard economics faculty had studied his request and was unanimously of the opinion that it was quite impossible to make such a table and that, were it made, it would have no conceivable use. Nevertheless, because of his other fine work, the request for a research assistant would be granted with the hope that the assistant's time would be spent on a more promising subject.

It wasn't. In 1941, *The Structure of the American Economy 1919–1929* was published. When later that year America was plunged into World War II, economists were quick to realize the value of these tables as more detailed guidance of the economy was needed in gearing up for wartime production. Making of the tables was taken over by the government, initially by the Bureau of Labor Statistics and later by the Commerce Department. Richard Stone, as already mentioned, knew of Leontief's work and included input-output tables as an integral part of his system of national accounts, now adopted world wide.

Thus, what is now routine originated in wars and economic crisis with an intellectual history winding through revolutionary Russia to depression America and on to wartime England and postwar development worldwide.

I also want to mention that Kuznets spoke to me of the inspiration that the work of Werner Sombart had been for him. Leontief's doctoral dissertation was written with Sombart.

***Input-output tables and vision*[2].** The largest selling publication of the United States government is the biennial *Occupational Outlook Handbook* prepared by the Bureau of Labor Statistics. There is a copy in the hands of the occupational counselor in virtually every high school (grades 9–12) in the USA. The projections of occupations by type are derived by summing across industries of projections of occupation by type by industry. Consistency of the projections of employment by occupation in the various industries is achieved by relating it to the output of the various industries in an input-output table projected ten years ahead. Thus, every year millions of youngsters use an input-output table, though few if any of them know it. Unfortunately, little information is available about how this matrix of the future is made.

In the discussions leading up to the ratification of the North American Free Trade Associations (NAFTA) a prominent role was played by the projections of two linked input-output based models. The US model was built in the US and the Mexican model in Mexico but with the same software so linking the models and running them together was relatively easy. The models quantified the gains to both sides of the agreement and seemingly played some role in winning ratification of the treaty over the loud objections of certain special interests.

One of the most interesting economic policy proposals of recent years has been the carbon tax, basically a tax on CO2 emissions into the atmosphere. The tax would be applied to the industry doing the emissions, but figuring out how it would affect the prices of consumer goods, exports, and government purchases requires the use of input-output tables.

An always important use of input-output tables is drawing up detailed, consistent pictures of how the economy can develop in the future. These are created by computer-based models of the economy. I prefer those that go year-by-year into the future so that investment in each industry can be related to growth in that industry. These include the Inforum family of models such as the one built by the Institute of Economic Forecasting of the Russian Academy of Science, which will, by the way, be revised to use the new tables. The consistency of the forecasts of the various industries is assured by the relations of the input-output tables in the model. There is no need to "control" such models with a macromodel; indeed, doing so only distorts the results.

In my experience, forecasters working for producers in individual industries find the forecasts of a model with several hundred sectors marvelously detailed for other industries and hopelessly aggregated for their own industry. Thus, for example, a client in the paper industry needed forecasts of about forty types of paper: newsprint, coated newsprint, book printing paper of various grades, computer printer paper, card stock, wrapping paper, paper sacks, cardboard, paper for making corrugated box board, and so on. With a lot of help from the client and the paper industry association we related the sales of each of these types of paper to use by various industries and were able to produce forecasts year-by-year over a ten year horizon for each of these types of paper. A similar study was done for a client in the plastics industry. A study for machine tools was similar except that the sales depended on the capital investment by the various industries. Thus it was essential that the input-output forecasting model go year-by-year with capital investment in each industry calculated by equations that used the course of output in the investing industry.

One of the currently interesting challenges is forecasting an industry that atpresent barely exists. Some years ago it was discovered that the CFCs (chlorofluorocarbons) used in aerosols and refrigerants were the root cause of the hole in the ozone layer that was a great health hazard. The CFCs were replaced by HFCs (hydrofluorocarbons) which did not disturb the ozone layer. But later they were discovered to be terrible for global warming. The 2016 Kigali amendment to the Montreal Protocol which had led to the replacement of the CFCs calls for the gradual replacement of HFCs by HFOs (hydrofluoroolefins) which neither damage the ozone nor cause global warming. Thus, there is now a new HFO industry, and potential industry par-

[2] This section benefited greatly from a conversation with Douglas S. Meade.

ticipants are turning to input-output models for help in forecasting.

Forecasting of imports is not particularly difficult; they depend on the outputs of the industries that use them or on consumption expenditures, investment, or government spending, all things already in a model. Forecasting exports, on the other hand is always both important and difficult. They depend on what is happening in other countries. So the idea naturally arises to build models of a number of countries and forecast the exports of each country from the imports of all the others. The idea is simple enough, but actually doing it is a bit more complicated, especially when the individual country models are multisectoral – that is, based on input-output tables – and the sectoring plans of these tables are all different. Complicated though it is, such a linking of a number of models has been accomplished, first by the Inforum group at the University of Maryland and now in a project in Florence, Italy with participants from the Istituto Regionale Programmazione Economica Toscana (IRPET) and from the University of Florence. Models contributed to the project include those for Russia, the USA, China, Japan, Poland, Italy and other European countries.

Countries very dependent on the export of petroleum, natural gas and their derivatives are, with good reason, concerned to diversify their industry. These input-output based, internationally-linked systems of models provide a comprehensive, consistent picture of the future world economy against which to design a diversity strategy.