The INFORUM International System

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ABSTRACT *The linked system of seven national INFORUM models is described here. The principles of the linkage are set out. Similarity in software implementation is fundamental, while diversity in the structure of the input-output tables is tolerated and variety in economic content encouraged. The flow of information on prices and imports among the models is fundamental to the linking mechanism. The structure and functional forms used in linkage is laid out in detail. An application of the system to study the mutual destruction of a protectionist trade war concludes the paper.*

1. Introduction

Many economic issues transcend national borders in their impacts. Almost by definition, a national economic model is therefore limited in its ability to handle such issues. The object of the INFORUM system of international models is to allow national models such as those described in previous papers in this issue to address questions in which the international impacts and feedbacks are significant. Seven of these national models have been linked by a mechanism that uses trade flows and prices at the individual sector level. This paper explains the principles on which the linkage works, describes the information passed among the models, sets out the forms of the equations used in the linkage system, and indicates the required data. It concludes with a short list of questions which have been studied with the system and a glance at a simulated protectionist trade war.

2. Scope and Principles of Linkage

The distinguishing feature of the INFORUM linkage system is its attention to sectoral detail. The sector linkage system is important because input-output models at their core require and yield sectoral detailed data. Therefore linkages of such models require that the steel sector of one country be linked to the steel sector of all the others.

A second important principle is that the country models need not be identical in the level of sector detail or in the base year table employed. Each national model maker is free to use the most recent table available and at a level of detail which is appropriate for that country, though sectoral linkage can present problems when the models are of widely different levels of aggregation.

Another principle of linkage is that there be a similarity of computer code but not necessarily of functional form in the models. The fastest mode of linkage is when all

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of the models are run by the same person on the same computer. The linkage of several models, each of which had a different operator's manual, would soon founder on the rocks of incorrect scenario specification, excess overhead expenses, and general confusion of the operator. The advantages of substantially similar code are obvious: if a researcher knows *one* model well, then he knows the mechanics of running the others.

The system links individual national models, not models of regional groupings of nations making up the entire world. Models for the United States, Canada, Japan, the Federal Republic of Germany, France, Italy, and Belgium were linked in the study reported in this paper. That is, each of them provides each of the others with sectoral information. Models for Austria, Mexico, and South Korea have been included in the linked system shortly before this issue goes to press. Models of the United Kingdom, Spain, and Poland are undergoing substantial developmental work at the present time.

The fact that a significant portion of world trade is not covered by trade among the nations whose models are linked means that a central trade allocation model is not necessary. Country models have individual export and import functions. Attention is paid to country trade balances; but strict accounting identities, such as "total world imports of USA-made computers equals USA computer exports" are neither possible nor necessary because of the openness of the system. Some further aspects involving the data requirements for countries or regions that are not part of the system will be discussed in the section on equation forms.

Another aspect of the linked system is its time dimension. All of the models are annual models. Each national model has its own unique base year. If a national model borrows data from other models with lags (such as lags on prices), it is the responsibility of the data-borrowing model to store that information correctly. Linkages involving models of different base years is handled quite routinely and easily as will be explained in the section on functional forms.

3. Information Flows

The essential feature of any linkage is a flow of information. Each year, each model sends out a vector of domestic prices and a vector of import demands, each of a length equal to the number of sectors in the model. Each model, in return, receives similar vectors from each of the other models. Weighting together import demands, the receiving country can produce an index of demand for its own exports. Also, the other models' prices can be weighted together to determine an average import price and a price of competing exporters. Note that the information flow is sector specific.

Exchange rates are exogenous for several reasons. The first one stems from the content of the models. An important factor in determining the exchange rate is the relationship between the nominal rate of interest and the rate of inflation at home versus abroad. At the present time, most of the models in the system do not produce interest rate forecasts. The lack of this key variable is probably sufficient to bar any attempt at exchange rate modelling. Another reason is that the empirical literature demonstrates that forecasting exchange rates is highly problematical.   As an example, a news report (*Wall Street Journal*, 1989) recently compared the results of some 34 forecasters. In projecting the yen/dollar rate for six months ahead in December 1988, all 34 had the yen too strong and the average prediction was for a rate of 121 rather than the 144 actual. The closest forecast had a prediction of 135 yen per dollar. In view of such difficulties, we currently have exchange rates exogenous to the system

and yet allow them to be altered easily to conform to different scenarios. In the practical operation of the system, exchange rates are determined in such a way that they produce sensible current-price trade balances and that a rough purchasing-power-parity ratio is maintained. Thus, the German mark is constantly rising in value against the French franc at the same time that inflation is slightly stronger in France than in West Germany.

4. Functional Forms

The linkage of the models is accomplished primarily through four country-specific equations: one for exports, one for imports, one for domestic prices, and one for users' prices. They will be explained in turn.

Exports depend on import demands by other countries for the commodity and the price of competing exporters. The particular *nonlinear* form of the export equation was chosen so that both the price elasticity and the marginal exports per unit growth in foreign demand would remain constant at differnt level of demand, though the marginal exports per unit of foreign demand would be affected by prices. For example, if the price elasticity is 2.0, then a 5 percent reduction in the relative price of exports should lead to a 10 percent change in exports *at any level of foreign demand*. Neither equations linear in the foreign demands and prices nor those linear in their logarithms have both of these properties simultaneously. Therefore our export equation is defined as follows:

$$e_{i,t} = (b_0 + b_1 \; \Sigma_k \; w_k m_{k,i,t}/m_{k,i,0} \,) \, (p_{i,t}/f_{i,t} \,)^{\eta}$$

where

$e_{i,t}$ 	one country's exports of input-output sector i in year t

w_k 	the fraction of those exports which went to country k in the base year of the national model

$m_{k,i,t}$ 	imports into country k for commodity i in year t

$p_{i,t}/f_{i,t}$ 	a moving average of domestic (p) and foreign (f) prices of commodity i in year t (see fuller description below).

b_0, b_1, and η are the estimated parameters specific to this commodity and country.

The foreign price, f, is a weighted exchange rate adjusted price of competing exporters. It is defined as follows:

$$f_{i,t} = \; \Sigma_k \; s_k p_{k,i,t} r_{k,t}/p_{k,i,0} r_{k,0}$$

where

$s_k =$ country k's share of world exports of commodity i in year 0 (base year of national input-output table;

$p_{k,i,t} =$ domestic price index of commodity i in country k in year t; and

$r_{k,t} =$ exchange rate (foreign currency units per unit of home currency) of country k in year t.

Thus, the foreign price used in the export equations can be interpreted as a price of competing exporters. Therefore, if the home country's currency appreciates, i.e. r falls, the prices of the foreign competition appear to fall. If that fall is not met by a commensurate fall in the domestic price, then there will be an increase in the relative price of exports.

Imports depend upon domestic demand for the commodity and the relative import to domestic price ratio. The equation form for imports is similar to that of the export equation for exactly the same reasons given for the form of the export equation. It is written as:

$$m_{i,t} = (b_0 + b_1 d_{i,t}) \, (p_{m,i,t} / p_{i,t})^{\eta}$$

where

$m_{i,t} =$ volume of imports of commodity i year t,

$d_{i,t} =$ domestic demand for commodity i in year t (domestic demand is defined as domestic production plus imports less exports),

$p_{m,i,t} =$ price of imports of commodity i year t (see fuller description below);

$p_{i,t} =$ domestic price of commodity i in year t.

b_0, b_1, and η are parameters to be estimated.

The import price, $p_{m,i,t}$, is defined as follows:

$$p_{m,i,t} = \Sigma_k \, v_k p_{k,i,t} r_{k,t} / p_{k,i,0} r_{k,0}$$

where

$v_k =$ share of imports of commodity i originating from country k in base year of national model;

$p_{k,i,t} =$ domestic price in country k of commodity i year t;

$r_{k,t} =$ exchange rate of country k in year t.

Domestic prices are the sum of domestic goods and services unit costs plus the sum of imported goods and services unit costs plus the unit costs of primary factors (labor, capital, indirect taxes, etc). The input-output equation is simply

$$\mathbf{p} = \mathbf{pD} + \mathbf{p_m M} + \mathbf{v}$$

where

$\mathbf{p}$ = row vector of domestic prices
$\mathbf{p_m}$ = row vector of import prices
$\mathbf{v}$ = row vector of value added per unit of real output
$\mathbf{D}$ = matrix of input-output coefficients of domestically produced goods
$\mathbf{M}$ = matrix of input-output coefficients of imports goods.

Note that $\mathbf{A} = \mathbf{D} + \mathbf{M}$, where $\mathbf{A}$ is the total coefficient matrix.

The domestic price equation given above is affected by international trade directly in two ways. The first is in the computation of the import prices and second is in the determination of the import matrix $\mathbf{M}$. If imports for a given sector increase, then the coefficients in matrix $\mathbf{M}$ increase and those in matrix $\mathbf{D}$ decrease. In this manner, the importance of the import price in the computation of all other prices in incorporated as a matter of course in the models. Indirectly domestic prices may be affected by international trade *if* the vector $\mathbf{v}$, itself, is a function of either imports, import prices, exports or the competing price of exports. In some models, notably the Japanese, Canadian, Italian, German and South Korean, the return to capital portion of $\mathbf{v}$ is a function of the competing price of exporters.

Users' prices are defined as a mixture of domestic and foreign prices with proportions being determined by the shares of domestic and imported goods in domestic consumption. They are particularly important in determining the sectoral distribution of private consumption expenditures.

5. Examples of Applications

In recent years the system has been used to produce several different long term outlooks under widely varying assumptions. The principal use of the system has been to study the effects of changes in assumptions relative to some base scenario. One of the first of these exercises concerned the effects of a return to a high U.S. dollar exchange rate (see Nyhus, 1988). Within the six months prior to this conference, the system was used to examine the effects of another oil shock and of a large but gradual rise in the real price of oil over the next ten years. Another group of scenarios altered the growth perspectives by changing the growth rates of labor productivity. A related scenario looked at the effects on the core model countries of no growth at all in the rest of the world. Yet another examined the effects of increased U.S. competitiveness; an alternative looked at enhanced European competitiveness. The USA and Canadian models were used to study the effects of the recently signed USA-Canadian Free Trade Agreement. A final scenario looked at the effects of a regional trade war. This last scenario will be discussed below.

As an example of the system in action, consider the case of a regional trade war. In this scenario economic rivalry becomes especially intense. Protectionism in the form of trade quotas and restrictions is the focus of this scenario. Three trading blocks

composed of North America (USA and Canada), Europe (Germany, France, Italy, Belgium, the Netherlands, and the United Kingdom), and Japan each impose a series of import restrictions against imports from the other blocks. The import restrictions are not applied to imports from other members of the same block or from the rest of the world. In addition, the import restrictions vary by broad commodity class, with restrictions on agricultural imports being the most severe. The table below summarizes the amount of restriction by commodity class and period. The war begins in 1990; reaches its high point from 1991 to 1993 and then is gradually ended by 1997.
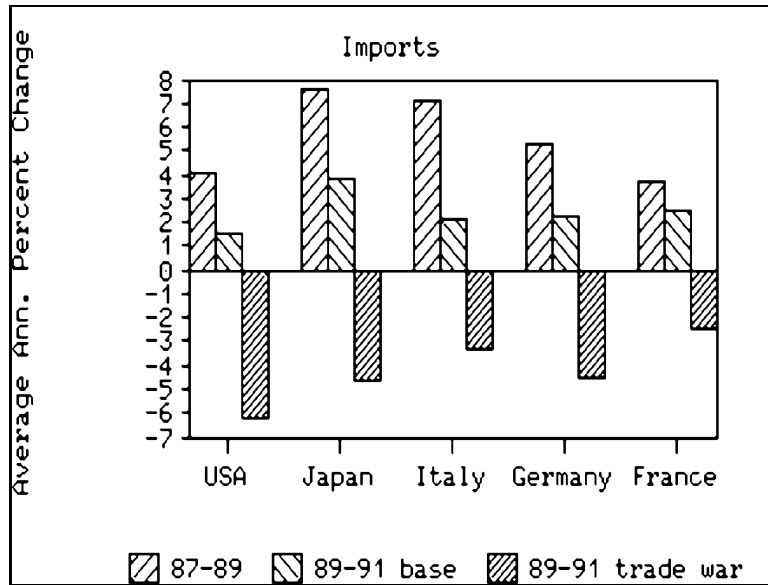
Percent Reduction of Imports

Commodity	1990	1991	1993	1997
Agriculture	10	70	70	0
Mining	0	0	0	0
Nondurables	5	40	40	0
Machinery	5	40	40	0
Transportation Equip.	20	60	60	0
Other Durables	5	30	30	0

According to the table, for example, the U.S. imposes restrictions on Japanese and European motor vehicles such that imports from those countries are reduced 20% in 1990, 60% in 1991, 60% in 1992, 60% in 1993, 45% in 1994, and so on.

The import restrictions work in the following manner. The restrictions on imports from opposing blocks increase demands for domestically produced goods to replace the imports. Next, restrictions imposed by opposing block countries reduce exports and thus reduce domestic production and employment. The reductions in output and employment lead to reductions in income, which lead to overall losses in output.
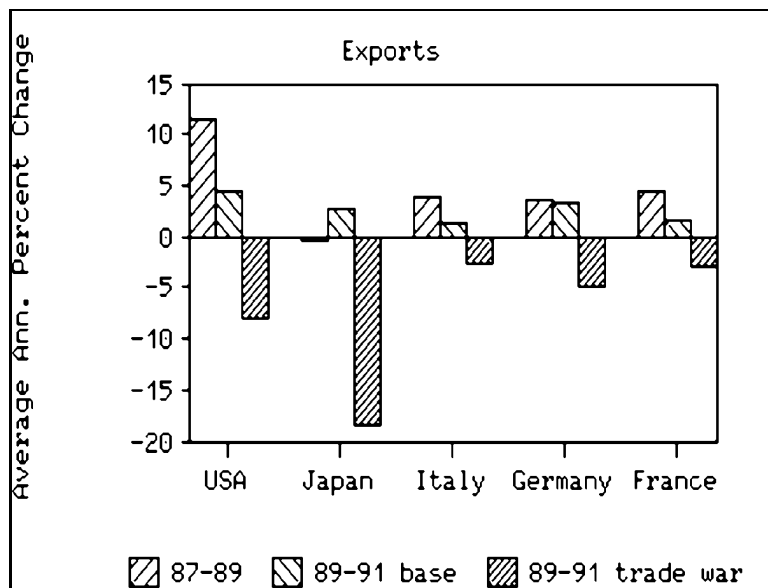
In each of the following figures, three bars are shown for each country. Each bar shows an annual average percentage growth rate for a certain period. The first bar shows the rate for 1987-89; the second, the growth rate for 1989-91 under a base-line scenario; the third, the growth rate for 1989-91 under the trade war scenario outlined above. For our illustration, we will only consider the initial effects arising in the first two years of the war.

Imports are sharply reduced in all of the countries under the trade war scenario. The final reductions are largest for Japan, smallest for France. The import reductions *directly* resulting from the restrictions are, however, greater for the USA than for Japan. Japan's *overall* reduction is greater because the overall negative effect of the trade war is far greater on Japan than on the other countries. The proportion of imports coming from opposing blocks is higher in the USA than in the other countries. The direct impacts are smaller for Italy, Germany, and France because a smaller share of their imports come from the USA, Canada, or Japan. Japan's direct impacts are also small because Japanese imports are heavily concentrated in raw materials, which are not -- with the notable exception of agricultural products -- directly impacted.

The trade restrictions are particularly grievous to Japan. Japanese exports are highly concentrated in the protected goods, and a large share of Japanese exports go to North America and Europe. The loss of export markets results in decline in Japan's share in the overall economy. As one can see from the adjacent graph, the European countries are proportionally much less affected by the trade war. The USA more closely resembles Europe than Japan because its links to the Canadian market are assumed to be unaffected.

The losses because of the trade are enormous for *all* countries. Each of the countries enters into a recession. In this example, we have limited the war to one between particular blocks, but the overall negative situation could tempt some to impose restrictions on developing countries as well. Such actions would only exacerbate an already bad situation. The policy implications are clear. Imposing significant trade restrictions results in significant losses in domestic output and employment and ought to be avoided; there would be very, very few winners and many, many losers if such a trade war did develop. As we go on to show industry results, we will see that many industries which one might assume to benefit with import restrictions would not because of overall losses in national income.
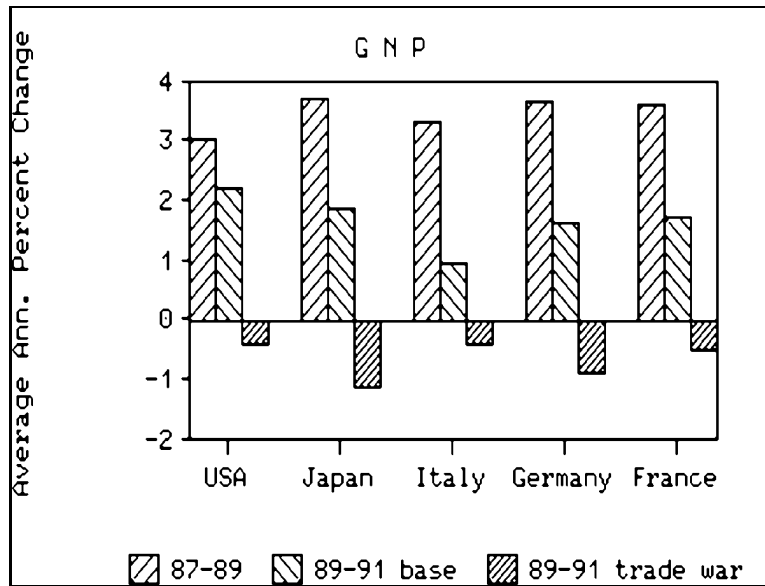
Agriculture would seem to be a prime example of a domestic industry which might benefit under restrictions. Yet, even here the benefits are small with the exception of Japan. The USA, with by far the largest agricultural industry, clearly suffers. Indeed, when one sums up the gains and losses for all the countries, the results are a net loss. The gains for Japanese farmers are clearly outweighed by the losses of American farmers. Indeed, though not shown here, the gains to Japanese farmers are also outweighed by the losses to Japanese consumers in the form of higher prices. France, the largest agricultural producer in Europe, is also a net loser.
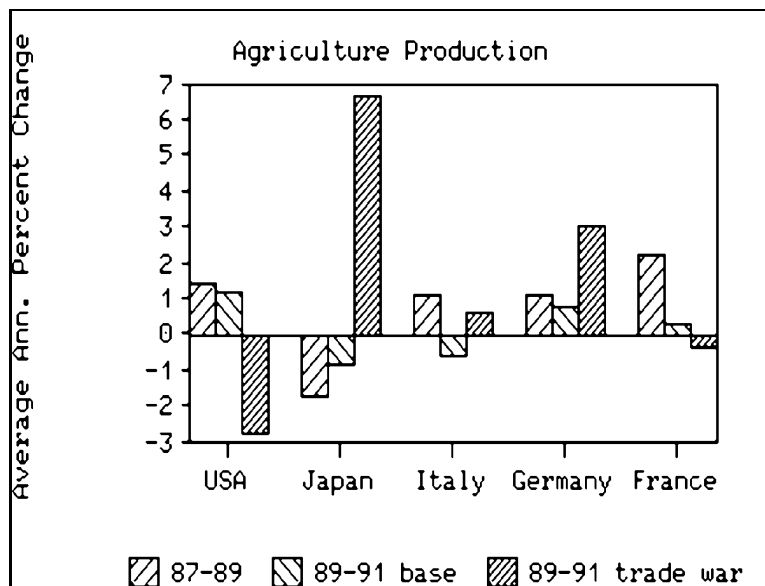
The motor vehicle industry, the most protected manufacturing industry in the trade war scenario, is not immune to the pervasive negative effects in the results. The Japanese industry is, of course, devastated by restrictions imposed in North America and in Europe. It is striking that the restrictions do not, in fact, save the American industry

Motor Vehicles - Output

Average Ann. Percent Change

87-89   89-91 base   89-91 trade war
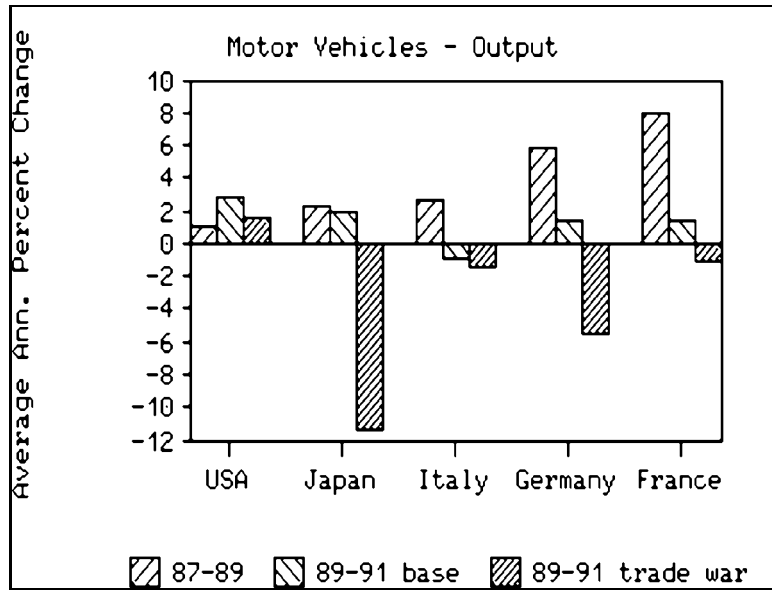
from the overpowering negative effects of the war. Within Europe, the Italian and French industries face relatively minor losses while the German industry endures a more significant loss. The lesson is clear: in trying to protect many industries at once, policy makers may make many (or all?) of them worse off. The logical consistency inherent within the modeling framework makes this result all the more powerful. The point cannot, I believe, be over emphasized.

As a final industrial example, consider the Apparel industry. Here the Europeans are the big losers while the USA and Japan endure smaller loses. Note, however, that the revival of the American industry in the base scenario is still severely blunted, and the sluggishness of the Japanese industry is intensified by a trade war. The size of the loss in Europe

Apparel - Output

Average Ann. Percent Change

87-89   89-91 base   89-91 trade war
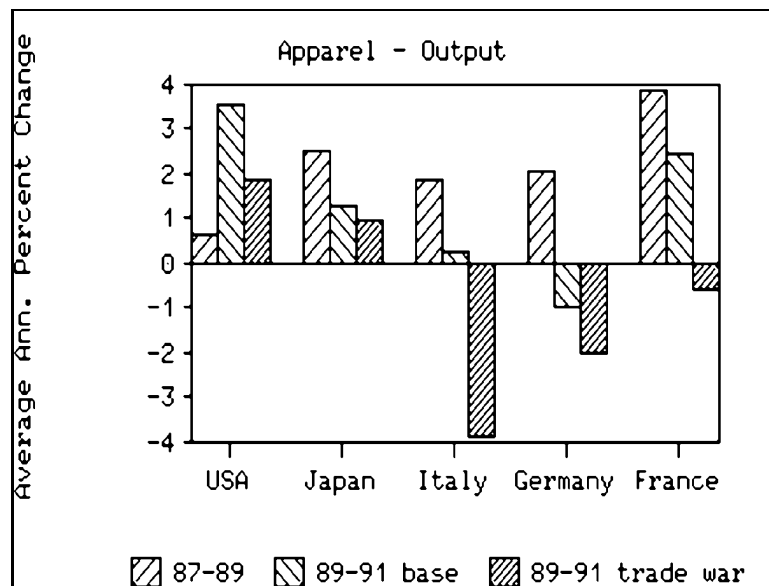
is directly associated with what is popularly perceived as the relative strength of that industry. Namely, the Italian and French apparel industries, which are export oriented, fare much worse than does their staid German counterpart.

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