Conjoining an input-output model and a policy analysis model: a case study of the regional economic effects of expanding a port facility

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Abstract. A 484-sector Massachusetts static input-output (MIO) model is conjoined with the Massachusetts Economic Policy Analysis (MEPA) model which includes supply relationships, industrial location responses to changing costs, and a production function allowing substitution among inputs. This makes it possible to draw upon the distinctive features of both models. The technique is demonstrated by a study that analyzes the effect on the Massachusetts economy of the expansion of a container port facility at Boston. The approach presented here has general applicability to policy analysis and planning studies that require both the detailed regional inter-industry interactions captured by a disaggregated input-output model and the cost, price, supply, location, and demand interdependencies which are endogenous in the best regional forecasting and policy simulation models.

1 Introduction

Aggregate interindustry relationships have been incorporated in macroeconometric forecasting and policy simulation models both at the national (for example, Preston, 1972) and at regional level (for example, Conway, 1978; and Treyz et al, 1980). Interindustry relationships have also formed a basis for the selection of explanatory variables for some regional models (for example, Glickman, 1977). However, for forecasting and policy simulation it has typically been necessary either to use the aggregate input-output equations embedded in an econometric model or simply to use an econometric model to generate the final demand vector for an input-output model, as in l'Esperance et al (1977).

This choice is generally necessitated by the lack of the disaggregated time-series data that would be required to estimate a disaggregated regional econometric model. For example, the Massachusetts Economic Policy Analysis (MEPA) model requires thirteen years of quarterly observations on wages, capital costs, fuel cost, and the cost of material inputs for an industry in order to determine factor input proportions for that industry. The assembly or estimation of these data for twenty-five endogenous sectors was feasible. But a model with all, or a substantial proportion, of the 484 sectors in the Massachusetts input-output (MIO) model made endogenous would clearly require unavailable data.

The sectoral detail of a disaggregated input-output model is appealing, however, because of the accuracy such a model can provide in capturing interindustry impacts and secondary effects. The flexibility and realism of a good regional forecasting and policy simulation model make it possible to capture cost, location, and factor substitution effects which are beyond the capabilities of traditional static input-output analysis. Using the two types of models jointly produces many of the advantages of both at a reasonable cost in terms of data requirements, model complexity, and computer time.

The prospect of conjoining the two types of models was especially compelling in the study undertaken by the University of Massachusetts and Regional Science Research Institute for the Massachusetts Port Authority (Massport) to evaluate the economic effects of container-port expansion. Demand disturbance columns which could easily be adapted to Massachusetts had been developed previously at the four-digit SIC level for construction and changes in port activity as part of a study by the Regional Science Research Institute (1977) for the Port of Philadelphia. The MIO model, a Massachusetts regional version of the 1967 BEA national input–output model (BEA, 1974) had already been constructed by Cournoyer and Kindahl (1977), and the MEPA model, developed by Treyz et al (1977), was fully operational and had been repeatedly tested in other policy simulations.

Subsequent to the conjoining described here, MIO and MEPA type models have been developed for the forty-eight contiguous states by Stevens and Treyz (1981) based on BEA input–output data for 1972 provided by the US Department of Commerce (BEA, 1979).

In the remainder of this paper, the general approach to conjoining the two models is presented. Then the specific application to the container-port study is described. The results of this application are then presented and discussed.

2 General approach

2.1 *The overview*

The conjoining process can be best understood as a sequence of two steps. (In practice, the computations for these steps are intertwined; the distinction here is for expositional clarity.) The first part conjoins the two models for the special case in which the data which comprise the final demand disturbance vector refer to the same year as the benchmark year of the MIO model. The second part makes the required calculation to project into the future the effects of the demand disturbance computed in the base year.

Figure 1 is a schematic presentation of the first step. Reference in that diagram to particular equations refer to the more detailed discussion of these methods in section 2.2. The essence of the process involves creation of two artificial sets of data: the first set, the 'Z' vector, is an artificial final demand vector for the 29-sector MEPA model which will duplicate exactly the pattern of employment obtained by finding sectoral employment from the 484-sector MIO model and aggregating to the 29-sector level. The second set, the 'A' vector, is a set of adjustments which will make the wage bill generated by the MEPA model consistent with the wage bill implied by aggregation of the wage bill of the MIO model. The 'A' adjustment vector is necessary because the appropriate weights for calculating the average two-digit wage rate and the wage bill for the three-digit and four-digit sectors within a two-digit sector are functions of the disturbance vector itself, whereas the initial wage rates from the MEPA model are independent of the disturbance.

The second step in the conjoining process makes the adjustments necessitated by the fact that the date of the final demand disturbance will typically be different from the benchmark year of the MIO model. Several adjustments (detailed in section 2.3) are required. In particular, adjustments for growth in labor productivity and for wage rates are required; it would be unwise to assume that those remained constant over time. In addition, it is also necessary to change the appropriate cost parameters in the MEPA model to reflect the direct effect of new port facilities on export and import costs.
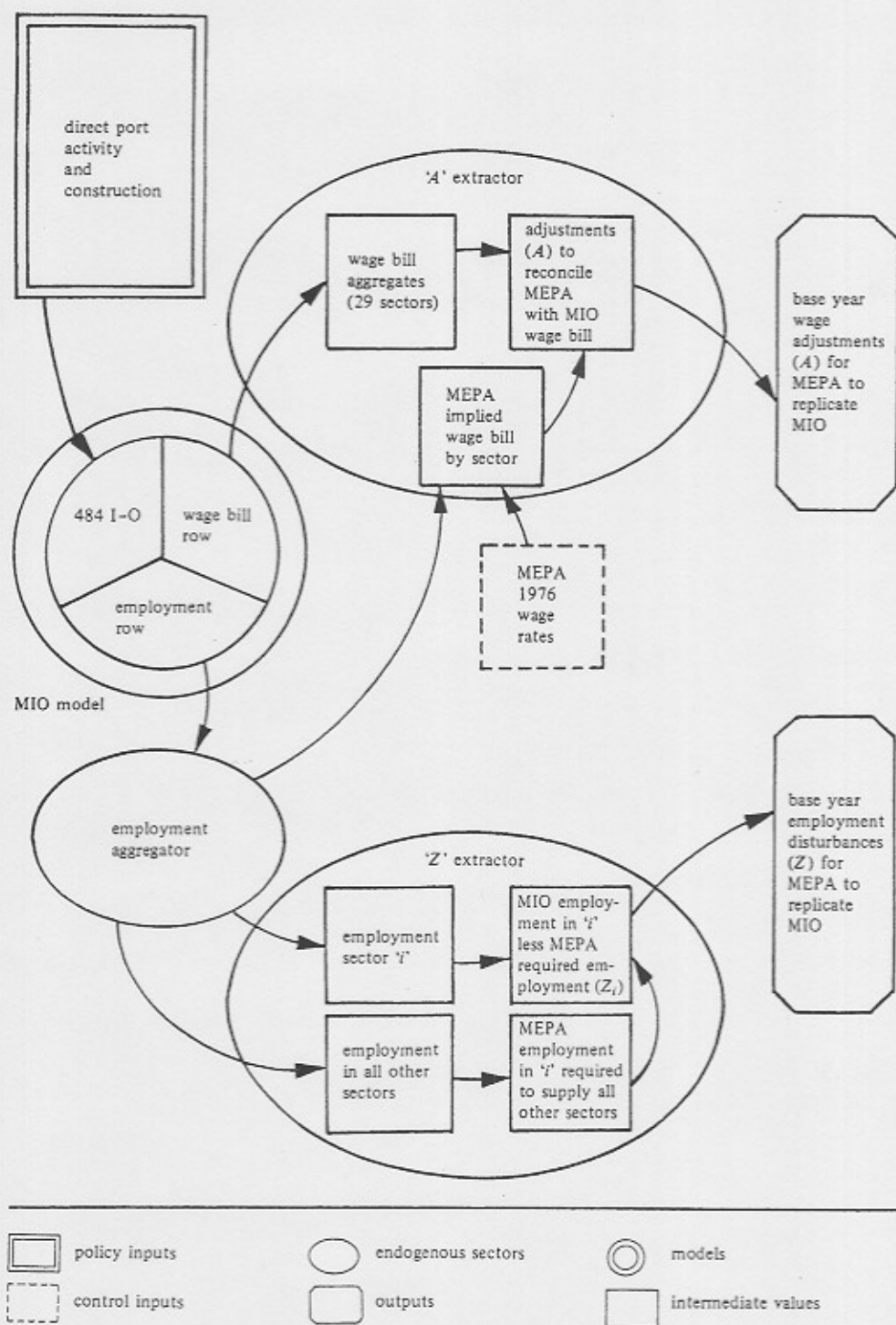
Figure 1. Procedure for conjoining the MIO and MEPA models in the base year 1976.
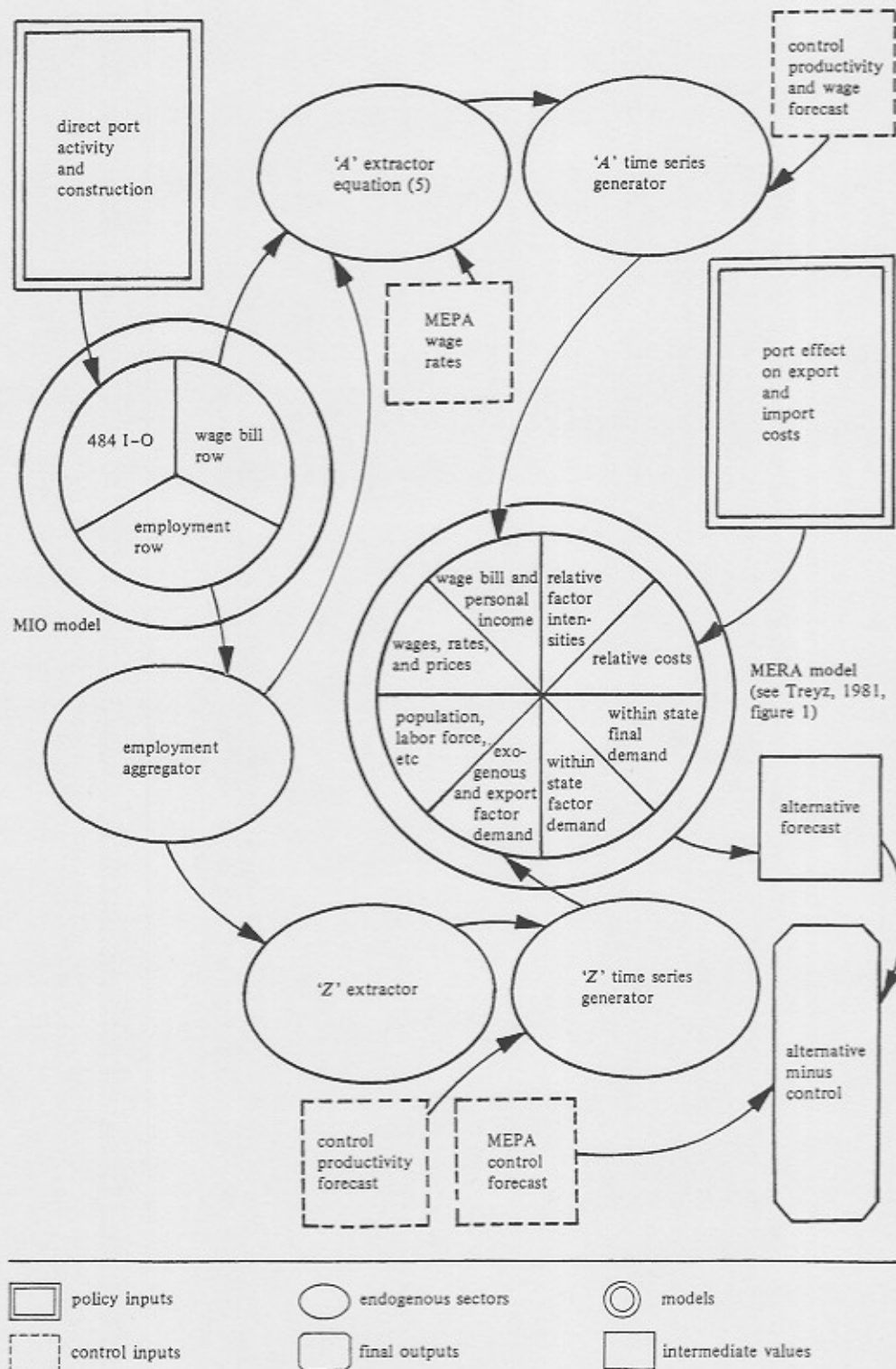
Figure 2. Conjoined models as used for a port study.

Figure 2 draws together all of the strands outlined above. It shows in schematic form the relation of the MIO and MEPA models to the various adjustments discussed in sections 2.2 and 2.3, and shows the path of flow of data inputs to the conjoining process through the various procedures, culminating in the output of 'alternative minus control' forecast—the estimate of the effect of the policy proposal on the Massachusetts economy.

2.2 Base year conjoining

The first step in linking the MIO and MEPA models is the conversion of the output impacts from the processing sectors of the three-digit and four-digit SIC MIO model into employment impacts for the one-digit and two-digit SIC MEPA model. This is done by converting the outputs from the MIO model into employment and then aggregating from the 484 three-digit and four-digit SIC employment categories into 29 one-digit and two-digit SIC categories. Thus

$$E_k^I = e_k^I X_k^I , \qquad \text{for all } k , \tag{1}$$

where

E_k is the employment in MIO sector k;
e_k is the employment per dollar output of k;
X_k is the 'disturbed' output of sector k which includes the direct and indirect effects of the exogenous change (disturbance) in final demand, as determined from an input-output calculation; and
I   as a superscript refers to the MIO model.

Then,

$$E_i^M = \sum_{k \in i} E_k^I , \qquad \text{for all } i, k , \tag{2}$$

where

M   as a superscript refers to the MEPA model; and
i, k are the MEPA and MIO sectors, respectively. (Note that each sector k is assumed to be a subset of a single sector i, without exception.)

The next step is to extract the part of the MEPA model which corresponds to the processing sectors of the MIO model. This is used to obtain the values which will enable the MEPA model to capture, in aggregate form, the employment interactions which take place at the 484-sector level. The basic part of the employment equations of the MEPA model for the processing sector is represented as follows:

$$E_i^M = \sum_{j, j \neq i} [\kappa_{ij} h_i (E_i^u / E_j^u) b_{ij} r_i E_j^M] + Z_i , \tag{3}$$

where

κ_{ij} is the proportion of the output of sector i that is delivered to sector j as shown in the most recent national input-output table;
h_i is the labor intensity in the region relative to the nation for sector i;
E_i^u is the national employment in industry i (in general, the superscript u denotes a national variable which corresponds to a previously defined regional variable);
b_{ij} is a thirteen-year moving average of the relative regional cost of commodity i multiplied by the relative regional wage in industry j;
r_i is the regional purchase coefficient for commodity i (this is the proportion of local use that is supplied locally); and
Z_i is an added disturbance or policy-directed change in employment.

This equation is explained in detail and its derivation is given in Treyz et al (1980). Suffice it to say here that this equation automatically updates the I-O coefficients to those used in a control national forecast and allows for factor substitution in production based on relative input costs.

In order to determine the Z_i which would generate the appropriate E_i^M using the fixed input–output processing sector of the MEPA model, the following equation must be solved for all i:

$$Z_i = E_i^M - \sum_{j,\, j \neq i} [\kappa_{ij} h_i^{76}(E_i^{u76}/E_j^{u76})b_{ij}r_i E_j^M] \,, \tag{4}$$

where

76   as a superscript refers to 1976 values; and

Z_i is the disturbances required in the MEPA model equations to generate the same direct plus indirect employment effects as those in the MIO model when the MEPA model processing sector is extracted and used with fixed coefficients.

In addition to the Z_i values found from the above, the difference between the change in total wages implied by the 484-sector impact result and the change implied at the more aggregate MEPA level must also be found. This can be done by calculating the total change in the wage bills implied by the two models and applying the difference between them as an adjustment to personal income (and hence the generation of consumption demands) in the MEPA model. Thus

$$A_i = \sum_{k \in i} (E_k^{I76}W_k^{I76}) - E_i^{M76}W_i^{M76} \,, \tag{5}$$

where

A_i is the adjustment to personal income for sector i in the MEPA model; and

W_i is the wage level in sector i for 1976 in the MIO and MEPA models as specified by the superscripts.

When the Z_i and A_i values are calculated and used in the MEPA model, it will simulate the 1976 results which would have been obtained if it had actually incorporated the 484-sector MIO structure.

2.3 Dynamic conjoining

In order to generate the appropriate Z values for future time periods, two additional steps are required. In the presentation that follows, time subscripts 't' will be added to the variables where required for clarity.

First, the appropriate E_{it}^M values in equation (2) must be calculated by adjusting the e_{kt}^I of equation (1) for appropriate changes in productivity. This is accomplished by dividing equation (2) by an index of output per man-hour in each industry (G_t) set equal to 1.00 in 1976 and increasing over time, based on national data and forecasts for that industry. Second, A_{it} in equation (5) must be modified for productivity growth and for changes in wage rates. This is accomplished by dividing by G_t and multiplying by an index of average Massachusetts wages having a value of 1.00 in 1976 and increasing according to the MEPA control forecast.

In addition to these modifications, two refinements are required. These involve both construction and cargo-handling, the two sectors most heavily affected by the proposed new container-port facility in Boston.

The wages both for the facility construction workers and for longshorepersons are projected to be substantially higher than the average for their corresponding sectors in the MIO model. This means that the employment estimated for these sectors from a given level of sector output will be too high and the wage rates W_k^{I76} will be too low. Appropriate adjustments were made to equations (1) and (5).

An adjustment for construction investment is also necessary. This adjustment is required because the MEPA model automatically generates the construction necessary to provide the capital facilities associated with increased employment in any sector. This endogenous construction tends to duplicate the exogenously determined construction of the container port. The double-counting of construction effects which this would entail is eliminated through the neutralization of the endogenous MEPA investment equation with respect to transportation facilities.

3 Effects of expanding container-port facilities

The effects of expanding container-port facilities at Boston beyond those required for normal growth are presented in table 1. Here the assumption is made that the new facilities would capture some cargos that would otherwise be shipped via New York or other East Coast ports. However, the short-run effects include only effects associated with the construction and increased port activity. Cargo capture, and thus cost reduction, is assumed to take effect only after the three-year construction period because the port, in the short run, will be just barely able to meet normal shipment demands until the new facilities become fully operational.

New container port facilities, in the long term, are assumed to reduce container shipment costs by 10% for additional cargo shipped through the port relative to the average cost of shipping Massachusetts cargos via other East Coast ports. This saving was translated into a percent change in the total costs of doing business in Massachusetts for industries dependent on waterborne container shipments, either to obtain their inputs or to sell their outputs. Given that transportation costs are a minor portion of total costs and that container shipment costs are usually a minor portion of total transportation costs, these savings in total costs are generally of the order of 10^{-3} or 10^{-4}%. Nevertheless, they are sufficient to generate a modest amount of additional employment in industries which would expand in Massachusetts as a result of the improvement, however slight, in the comparative locational advantages of the state.

Several features of the figures reported in table 1 are worth noting. In the short-term construction period the average number of direct construction employees per ten million dollars investment is only 44, compared to the total employment increase of 165. This apparently large indirect multiplier effect can be attributed in part to the construction demands for port equipment (the increase in durable manufacturing

Table 1. Effects on the Massachusetts economy of expanding Massport container-port facilities beyond the level necessary to meet normal growth [Values per $10 000 000 investment unit. Source: Stevens et al (1979).]

	Short-term effects due to construction and port activity	Long-term effects		
		from cost reductions	from port activity	total
Wage and salary employment [a]:				
(a) manufacturing				
durable	18	8	−12	−4
nondurable	1	7	−5	2
total	19	15	−17	−2
(b) nonmanufacturing				
construction	44	1	8	9
transportation and utilities	27	1	88	89
trade and services	75	18	58	76
total	146	20	154	174
Total of (a) and (b)	165	35	137	172
Massachusetts population [a]	68	13	54	67
Number of unemployed [a]	−72	−15	−57	−72
Personal income [b]	4·30	0·8	6·3	7·1
Disposable income [b]	3·60	0·7	5·2	5·9
State government revenue minus expenses [b]	0·39	0·1	0·6	0·7
Wage index [c]	0·003	0+	0·003	0·003
Relative business costs [c]	0·002	0−	0·002	0·002

[a] In numbers of persons. [b] In $ million. [c] In percentages.

employment is almost entirely in the nonelectrical equipment industry) and to increased employment in transportation, especially longshorepersons. In addition, the high wages of construction workers and longshorepersons and the fact that the increased employment, in general, tightens labor markets so that overall wage levels rise, lead to a substantial increase in personal income and, hence, in consumer demands. Furthermore the impacts of the higher wages (and overall business costs) on locational advantage occur gradually over a five-year period; therefore, their dampening effect is not fully felt in the first three-year period.

It is clear from the short-term analysis that the conjoining of the two models yields measurable benefits. In particular, the indirect links of port construction to equipment manufacture and increased transportation employment would have been underestimated by the aggregate input–output structure of the MEPA model.

In the long-term analysis, of course, the MIO model would not have been capable of measuring the wage and/or cargo cost-saving effects on industrial location. The long-term effects of higher wage levels also require some additional explanation, however. Higher wages are maintained since migration, even in the long term, is less than sufficient to fill the additional jobs generated. This means that labor markets in Massachusetts continue to be tighter than they otherwise would have been. These higher wages lead to the loss of some manufacturing employment because a high percentage of most Massachusetts manufacturing output is sold in other states. Production and employment can expand in those other states where relative costs are more favorable.

The long-term total effect of increased port activity per ten million dollars of investment is an additional net employment increase of 137. This is generated by 88 jobs directly involved in the transportation sector and associated indirect job losses and gains in other sectors. Apparently the high wage rates of longshorepersons support sufficient indirect spending, and the shipping industry demands sufficient on-shore inputs to account for the relatively high employment multiplier of $1 \cdot 6$. This multiplier is high even when compared with the long-term employment multiplier of $1 \cdot 4$ obtained in a MEPA simulation which concentrated increased employment in the defense industries (Treyz and Pitkin, 1977). The substantial increases in personal income and 'state revenue minus expenditures' results not only from the high wages of new employees and new employment, but also from the higher wage rate paid to all employees.

The effects in the 'cost savings' column result, as already noted, from the influence of decreased container cargo shipping costs on the costs of doing business in Massachusetts. This is a direct saving for export industries because it reduces delivered costs, which are the sum of production and transport costs. The reduction, for industries producing container cargos, ranges from $0 \cdot 00002\%$ for SIC 30 (rubber and plastics) to $0 \cdot 00286\%$ for SIC 39 (miscellaneous manufactures) per 100000 tons of container cargo produced. The actual percentage savings thus depend on the projected flows of the container exports by each industry. But in any case, the savings must, by any standard, be judged to be extremely small.

Cost savings on imports affect producers only indirectly for two reasons. First, a substantial proportion of imported container cargo consists of consumer goods rather than inputs to production. These goods are, of course, competitive with local production and therefore should tend to have a negative effect on Massachusetts employment in the industries producing the same goods. However, the form of the MEPA model being used at the time this study was done did not permit the capture of these competitive effects.

Second, reduced transportation costs on those container cargos that do consist of production inputs reduce their delivered costs in Massachusetts. This, in turn, reduced

the 'materials' cost as specified in the MEPA model, thereby causing substitution of materials for other factors of production. Both the reduced cost of the materials and their substitution in production reduce the costs of doing business in Massachusetts in proportion to the percentage of the total production costs accounted for by purchases of these materials.

Again the savings are extremely small, ranging from 0·00004% in the delivered cost of apparel to 0·03689% in the delivered cost of miscellaneous manufactures per 100000 tons of imported container cargo. The translation of these savings into actual business cost savings will, of course, depend upon the input—output structure of the economy, the regional purchase coefficients, the relative costs of other factors, and the like. The effects of import savings also will vary from year to year with changing cargo flows and changing relative costs, as forecast by the MEPA model.

Given the foregoing, it is not surprising that the net long-term effects of cost savings are very small. This is indicated by the fact that relative business costs in the cost reduction column 1 are changed by an amount too small to be printed by the computer program as it was set up when these simulations were run. It is also indicated by the fact that only 15 additional manufacturing jobs, and a total additional employment of only 35 can be ascribed to this cause. This extra employment does cause a miniscule rise in the wage index which, by the substitution effect and the effect on business costs, slightly reduces the positive effect on employment from the business cost reductions ascribed to lower input and shipment cost.

4 Summary and conclusions

By conjoining the MEPA and MIO models it was possible to perform a policy simulation that used both detailed interindustry relationships and well specified econometric structural equations. In the port study simulation above, it is clear that the calculated MIO disaggregate intermediate demand for inputs influenced the results in a way that would not have been captured by a simple MEPA simulation; it is also obvious that relationships in the MEPA model such as location based on relative costs, endogenous wage determination and a flexible production function, had a significant effect on the final quantitative result. Although the results of the Massachusetts study indicate only modest employment gains per ten million dollars of investment in port facility construction, they do show that substantial gains in wages, in personal income, and in state government revenues could be expected. These latter gains represent a net state income increase of seven cents per year for each dollar of investment. This is over and above the Massport revenues required to pay interest and principal on the port construction bonds.

The technique described here can have wide applicability in policy impact studies where the accuracy of a detailed input—output model is desired, but long-term forecasting of effects is also necessary. The method capitalizes on the strengths, while circumventing some of the weaknesses, of both types of models.

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