THE EMPLOYMENT SECTOR OF A REGIONAL POLICY SIMULATION MODEL

George I. Treyz, Ann F. Friedlaender, and Benjamin H. Stevens*
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I. Introduction and Overview

Despite the rapid development of techniques of regional economic analysis during the past fifteen years, most regional models have continued to focus upon selected aspects of the regional economy rather than upon its totality. Economic base models and regional input-output models have concentrated upon the relationships between the output and employment in the export sectors and the local sectors; comparative cost models have concentrated upon the response of the export sectors to changes in relative regional production costs; and regional econometric models have concentrated upon the determinants of employment in the export sectors and the relationships between regional economic activity and that of the nation.

This disparate collection of partial-equilibrium models generally does not make it possible to determine the full general-equilibrium effects of a given economic change on the total regional economy. For example, although economic base/input-output models permit the estimation of the indirect and induced employment and output effects arising from a change in final demand or the level of activity in the export sector, they treat the level of activity in the export sector as exogenous and do not permit factor substitution. Similarly, although comparative cost models explicitly recognize that the location of export industries is largely determined by relative production costs, they do not consider the interrelationships among the industries within the export and local sectors or the role that factor substitution can play in regional employment levels. Finally, although regional econometric models generally use a neoclassical labor demand function, and hence explicitly consider factor substitution, they do not fully differentiate between the factor-substitution and production cost effects of a change in regional input prices. Furthermore, they do not account for the full set of linkages among the industries in the export and local sectors.

The growing need for comprehensive regional models for planning and policy analysis suggests that there would be substantial value in having models that synthesize the relevant aspects of existing regional economic theory into a single integrated construct. Such an integrated model would be useful for both forecasting and policy evaluation and should include the following features:

First, it should recognize that factor substitution is possible and that an increase in the regional price of any given factor will tend to cause substitution in favor of other factors (the factor-substitution effect);

Second, it should recognize that an increase in any input price in a region relative to that in other regions will tend to increase production costs in the region in question. The result will be a reduction in the comparative locational advantage for the affected region and a tendency toward a relative shift in employment in national-market industries away from that region to lower-cost regions (the location effect);

Third, it should be able to quantify the relative magnitudes of the factor-substitution effect and the location effect arising from any given change in regional input prices;

Fourth, it should recognize that a complex set of interrelationships exists not only between the export sector and the local sector, but also among the various industries within each sector.

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1 See, for example, Isard (1960), Tiebout (1962), Bourque et al. (1967), Miernyk (1970), and Polenske (1974).

2 See, for example, Weber (1928), Hoover (1937), Isard (1956) and Borts and Stein (1964).

3 See, for example, Friedlaender et al. (1975), Adams et al. (1976), and Gluckman (1977).
Since the employment sector forms the heart of the general-equilibrium effects, it is useful to concentrate upon it initially in developing a regional policy model. Hence this paper reports on the employment sector that fulfills the foregoing criteria within the context of a model of the Massachusetts economy.

Although the Massachusetts Economic Policy Analysis (MEPA) model is undergoing continual development, we believe that the treatment of its employment sector is sufficiently innovative and well developed to warrant its dissemination and discussion at this time. Widespread and repeated use of this model by legislative committees and executive agencies in Massachusetts indicates its value and suggests that similar models can and should be developed for other states. Ultimately a multiregional form of the model could be used for policy analysis at the federal level.

Briefly, this paper takes the following form: section II discusses the interrelationships among the industries in the export and local sectors and presents the input-output relationships in the employment equations. Section III then shows how this framework can be merged with a neoclassical employment demand function, and how the relevant regional employment coefficients in the local sector can be estimated. Section IV then considers the determinants of export employment and develops an estimating equation for these industries. Section V integrates the employment demand analysis of the previous two sections and provides a partial equilibrium analysis of the employment effects of a given change in regional factor costs. Section VI provides a brief summary and conclusions.

II. Basic Accounting and Input-Output Relationships

The basic employment accounting identity is

$$E_i = E_i^I + E_i^X$$ (1)

where $E_i$ represents total regional employment in industry $i$, and $E_i^I$ and $E_i^X$, respectively, represent employment in the local-serving and the export (national market) portions of sector $i$. Local-serving employment is estimated using a modified regional input-output model as described in this and the following sections. Export employment is determined by a structural equation developed in a later section of the paper.

Although a number of economic base models assume that local output is used only for final consumption (e.g., Bolton (1966)), it is important to recognize that local output is also used as an input into other regional industries. Furthermore, in many previous models of the economic base type, the employment in each sector has been assigned arbitrarily and exclusively to either the local or the export category, based usually on indirect evidence concerning local versus national demands (cf. Pfouts (1960)). Obviously, most industries serve both local and export markets. But methods developed for allocating each sector's employment between these two categories have been generally arbitrary and often inconsistent, in part because they have not been firmly based on theory (cf. Greytak (1969)).

An important feature of the model presented here is that it avoids arbitrary categorization. Furthermore, by emphasizing the internal structure of the regional economy, the model provides a method for the consistent determination of the employment engaged in production for both local intermediate use and local final consumption, as well as for export.

Since local output is used both as an input into other regional industries and as final regional demand, it follows that

$$E_i^I = \Sigma_j e_{ij}^I E_j + \Sigma_h d_{ih}^I D_h$$ (2)
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where

\[ e_{ij}^k = \text{the number of regional employees required in industry } i \text{ for each regional employee in industry } j; \]

\[ d_{ih}^k = \text{the number of regional employees required in industry } i \text{ for each regional unit of demand in sector } h; \]

\[ D_h = \text{the regional final demand in sector } h. \]

The \( e_{ij}^k \) and \( d_{ih}^k \) coefficients are obvious analogs to the familiar input-output coefficients; however, they differ in that they refer to employment rather than output and relate to employment for local use rather than total regional employment. The \( e_{ij}^k \) and \( d_{ih}^k \) coefficients are obtained by first deriving \( e_{ij} \), which is a measure of employment in industry \( i \) that would be required per unit of regional employment in industry \( j \) if all inputs were to come from within the region. It is later modified to reflect the proportion of input \( i \) that is actually purchased by industry \( j \) from within the region.

As a first step, the labor/output ratio in industry \( i \) is defined as

\[ e_i = E_i/X_i \]  

(3)

where \( X_i \) represents total output of industry \( i \) in the region and \( E_i \) is as previously defined. Following input-output terminology, \( X_{ij} \) is defined as total shipments from industry \( i \) to industry \( j \), irrespective of the geographic source of input \( i \). Thus,

\[ E_{ij} = e_i X_{ij}. \]  

(4)

Then, again from input-output, define \( a_{ij} = X_{ij}/X_i \) as the amount of output of industry \( i \) used per unit output of industry \( j \). It follows that the amount of employment in industry \( i \) used per unit of employment in industry \( j \) is

\[ e_{ij} = (e_i/e_j)a_{ij} = (E_i/X_i)(X_{ij}/X_j)(X_j/E_j). \]  

(5)

Finally, only a portion of input \( i \) will be supplied to industry \( j \) by producers of \( i \) located within the region. Therefore,

\[ e_{ij}^k = \rho_i \cdot e_{ij} \]  

(6)

where \( \rho_i \) is defined as the regional purchase coefficient for good \( i \). It represents the proportion of total regional intermediate use and final consumption of good \( i \) that is supplied by local production.

The \( d_{ih}^k \) are derived by a completely analogous procedure. If \( X_{ih} \) represents total shipments from industry \( i \) to final demand sector \( h \), then,

\[ a_{ih} = X_{ih}/D_h \]  

(7)

\[ d_{ih} = e_i a_{ih} \]  

(8)

and

\[ d_{ih}^k = \rho_i d_{ih}. \]  

(9)

III. Estimation of Local Employment Coefficients

The previous section presented the accounting identities of the internal input-output structure of the regional economy. However, the \( e_{ij}^k \) and \( d_{ih}^k \), which are the local employment coefficients in the accounting system, are not constants. Unlike traditional input-output analysis, the model presented here permits factor substitution in response to changes in relative input prices. In this section, the local employment coefficients are developed within this more general framework and their estimation is illustrated for Massachusetts.

The assumptions upon which this part of the model is based are straightforward:

1. Firms seek to maximize profits.
2. The regional and national production processes of industry \( i \) are the same and can be described by a Cobb-Douglas production function with constant returns to scale (CRS) and factor neutral technical change.
3. The marketing advantage of local production for local use is sufficiently strong and stable to assure that \( \rho_i \), the proportion of the regional use of the commodity \( i \) that is supplied from local production, will remain constant, at least over the forecast period, even if there are changes in relative regional production costs.
4. The distribution of production of national market goods and services among all regions will respond to changes in relative production costs.

While the first assumption has periodically been questioned by believers in the behavioral theory of the firm (e.g., Marris (1964)), it is a well-accepted neoclassical postulate that does not need to be defended. The second assumption is somewhat less tenable, particularly in view of the recent work of Jorgenson and others (1973),
which questions the separability postulate implied by a Cobb-Douglas or similar production function. Nevertheless, the Cobb-Douglas function has received empirical support and appears to be a reasonable form to use for this generation of the model. The assumption of uniform technology across the nation is probably not correct at the two-digit SIC level. This is, in part, because of the variation in the composition of two-digit industries among states. However, again, this assumption is necessary for this generation of the model.

The assumption that a constant proportion of the local demand for each good or service will be fulfilled from local production may be reasonable in some cases. A region tends to have a strong comparative advantage in the supplying of local needs, though this advantage varies widely with the type and transportability of the product. Thus, for example, a large proportion of local demand for personal services can be expected to be fulfilled by each region itself; as a consequence, personal services should be a minor export or import of most regions. In any case, constancy of the regional purchase coefficients, at least over the course of a model run, is a necessary assumption if this generation of the model is to be of acceptable complexity.

Given these assumptions, it is possible to obtain quantifiable expressions for the local employment coefficients. Recall from expressions (6) and (9) that the \( e_{ij} \) and \( d_{ij} \) are obtained by multiplying the total labor usage coefficients, \( e_{ij} \) and \( d_{ij} \) (respectively given by equations (5) and (8)), by the regional purchase coefficient \( \rho_i \).

While correct as an accounting identity, there are two reasons why equation (5) is not very useful for empirical application. First, region-specific interindustry shipment data for the \( X_{ij} \) are generally not available, while regional output data are available only at five-year intervals from the Census of Manufactures. Second, even if the relevant data were available, a simple estimate of \( e_{ij} \) would not yield any information about the response of the economy to changes in regional production costs. Fortunately, it is possible to obtain an equivalent expression that not only is quantifiable, but also reflects the underlying determinants of demand for labor and inputs.

By direct substitution, it is straightforward to show that the following expression is equivalent to equation (5):

\[
e_{ij} = \kappa_i \cdot l_i \cdot \frac{E_i}{E_j} \cdot b_{ij}
\]

where

\[
\kappa_i = \text{the proportion of the output of sector } i \text{ that is delivered to sector } j \text{ as shown in the most recent national input-output flow table, that is, } \kappa_i = \frac{X_{ij}}{X_i},\text{ where the superscript } u \text{ represents national variables};
\]

\[
l_i = \text{the regional labor intensity relative to the national labor intensity for sector } i; \text{ that is, } l_i = \frac{(E_i/X_i)}{(E_u/X_u)};
\]

\[
E_i, E_j = \text{national employments in sectors } i \text{ and } j, \text{ respectively};
\]

\[
b_{ij} = \text{the regional materials/labor ratio for input } i \text{ in industry } j \text{ relative to that of the nation}; \text{ that is, } b_{ij} = \frac{(X_{ij})}{(X_{ij}/E_j)}.
\]

Data on national employment and interindustry shipments are readily available. Moreover, if the technology of every industry can be characterized by a CRS Cobb-Douglas function, then

\[
X_j = \theta_j (E_j)^{\sum_i (K_j)^{\lambda_{ij}} (F_j)^{\rho_{ij}}} \prod_{i=1}^n (X_{ij})^{\theta_{ij}}
\]

where \( \theta_j \) represents a neutral technical change factor; \( E_j, K_j \) and \( F_j \), respectively, represent the labor, capital, and energy inputs of industry \( j \); \( X_{ij} \) is as previously defined; and \( \sum_{i=1}^{s} \lambda_{ij} = 1 \), where \( s \) ranges over all factors and material inputs.

It is straightforward to derive the following cost function from this production function:

\[
C_j = (1/\theta_j)(w_j/\lambda_{ij})^{\lambda_{ij}}(c_j/\lambda_{ij})^{\lambda_{ij}}(f_j/\lambda_{ij})^{\rho_{ij}} \prod_{i=1}^n (y_{ij}/\lambda_{ij})^{\theta_{ij}}X_j
\]

where \( w_j, c_j, f_j \) and \( y_{ij} \), respectively, represent the labor, capital, energy and materials cost of industry \( j \). Since the demand function for any given factor can be obtained by differentiating the cost function with respect to its price, the demands for labor and any material inputs are respectively given by:
\[ E_j = \lambda_i, (1/\eta_j)(w_j/\lambda_i)\sum_{i=1}^n \left( y_{ij}/\lambda_i \right)^{\alpha_{ij}} X_j \]  
(13)

\[ X_{ij} = \lambda_i, (1/\eta_j)(w_j/\lambda_i)\sum_{i=1}^n \left( y_{ij}/\lambda_i \right)^{\alpha_{ij}} (f_j/\lambda_i)^{\beta_{ij}} \]  
(14)

Since it is assumed that the production function does not vary across regions, similar expressions for \( E_i \) and \( X_{ij} \) can be derived. Dividing \( E_j \) by \( E_i \) and \( X_{ij} \) by \( X_{ij} \) yields

\[ E_j/E_i = \left( w_j/y_j \right)^{\alpha_{ij}} (c_j/c_i)^{\kappa_{ij}} (f_j/f_i)^{\beta_{ij}} \]  
(13a)

\[ X_{ij}/X_{ij} = \left( w_j/y_j \right)^{\alpha_{ij}} (c_j/c_i)^{\kappa_{ij}} (f_j/f_i)^{\beta_{ij}} \]  
(14a)

Solving (13a) for \( (E_j/X_j)/(E_i/X_i) \), it is easy to obtain

\[ l_i' = (E_j/X_j)/(E_i/X_i) = \left( w_j/y_j \right)^{\alpha_{ij}} \]  
(15)

Since the \( \lambda \) coefficients of a CRS Cobb-Douglas production function are given by the factor shares, \( l_i' \) can be estimated directly from observable data on factor and input prices and expenditure shares. However, because the cost function is based on cost-minimizing behavior, \( l_i' \) represents the equilibrium labor intensity of the region relative to the nation. Since adjustments do not occur instantaneously, a moving average of past \( l_i' \) is used to estimate the actual relative labor intensity, \( l_i^\ast \), for industry \( i \) in period \( t \).\(^{10}\)

Similarly, dividing equation (14a) by equation (13a) gives

\[ b_j' = (X_{ij}/E_j)/(X_{ij}/E_j) = (w_j/y_j)/(w_i/y_i). \]  
(16)

Again, since equilibrium does not occur instantaneously, a moving average of \( b_j \) is used to estimate \( b_j^\ast \), the actual ratio of materials for \( i \) to labor for \( j \) in period \( t \).\(^{11}\)

The expressions for \( l_i' \) and \( b_j \) can be substituted into equation (10) to estimate the \( e_i \). The next problem is to estimate the \( d_i \). First, note from equation (8) that \( d_i \) depends on \( a_i \). If one assumes that \( a_i = a_i^\ast \) (i.e., \( X_i/D_i = X_i^\ast/D_i^\ast \)), the development of the expression for \( d_i \) is similar to that for \( e_i \) and results in

\[ d_i = \kappa_i l_i E_i/D_i. \]  
(17)

The derivation of the regional purchase coefficients, \( p_i \), is all that remains to complete expressions (6) and (9). The \( p_i \) merely reflect the fact that a region is an open economy. Goods and services for production inputs or to serve final demand will be imported, rather than produced locally, to the extent that regional comparative costs and product transportability warrant. The regional employment coefficients must be reduced to reflect the "leakage" of purchases typical of an open economy.

Regional purchase coefficients have been developed and estimated by Stevens et al. (1975, 1978) in order to evaluate accurately regional economic effects and disaggregated local multipliers in regional input-output impact studies. In the somewhat different form used here, define

\[ p_i = (S_i)(X_i/U_i) \]  
(18)

where

\[ S_i = \text{the proportion of industry } i \text{ in the region} \]

shipped to destinations within the region;

\[ X_i = \text{regional production of commodity } i; \]  
and

\[ U_i = \text{total regional use of commodity } i \]  
as an input to production and to serve final demand.

Data for \( S_i \) are not generally available for most regions. For practical purposes, data from the Census of Transportation on the percentage of each regional output shipped less than 100 (or 200 or more for larger regions) miles seem adequate to approximate intraregional shipments.\(^{12}\)

\(^{11}\) The lag structure used for \( b_j \) is the same as that used for \( b_j^\ast \).

\(^{12}\) For "production areas," as defined by the Census, data
The logic of the ratio \( X_i / U_i \) is quite straightforward. The larger the production of a good or service in a region relative to its internal use, the more likely it is that any particular purchase of the product as an input to production or to fulfill final demand in the region will be made locally. Thus a sector that is capable of being a net exporter \( (X_i / U_i > 1) \) should normally have a high regional purchase coefficient and vice versa.\(^{13}\)

Data are not available to measure \( X_i / U_i \) directly. However, this ratio can be determined indirectly. Define the ratio of regional to national use as

\[
U_i / U_i = \Sigma_{j} \mu_{ij} (X_{ij} / X_{ij}^{*}) + \Sigma_{k} \mu_{ik} (D_{ik} / D_{ik}^{*}). \quad (19)
\]

Then it is possible to obtain \( X_{ij} / X_{ij}^{*} \) from equation (14a) and \( X_{i} / X_{i}^{*} \) from equation (15). Using these values and

\[
X_i / U_i = (X_i / X_i^{*}) / (U_i / U_i^{*}) \quad (20)
\]

as an exact expression,\(^{14}\) it is easy to obtain estimates of the regional purchase coefficients, using equation (18).

The foregoing methods were used to estimate the regional purchase coefficients for twenty-one manufacturing and five non-manufacturing sectors in Massachusetts. Table 1 presents the results of these estimations along with a few of the key variables which were used in the calculation of the employment coefficients and which reflect the structure of the regional economy. A full table of the relevant employment coefficients and their determining variables will be available to interested readers upon request.

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for the \( S_i \) are available. But generally, none of these areas will correspond adequately to the region under study. Disclosure problems in the transportation data, as well as the fact that the minimum shipment distance published for states is 100 miles while the "radius" of a state like Massachusetts is only 50 miles, means that a number of estimation procedures have to be used in practice. This also applies, of course, to shipments of "non-commodities," such as services, for which no data exist.

\(^{15}\) Even for levels of \( X_i / U_i \) greater than 1, however, \( \phi_i \) may be less than 1 if \( S_i \) is small enough. The latter case suggests an industry whose product is simultaneously exported and imported. This is a reasonable possibility, especially since at the 2-digit level each sector reflects an aggregation of a number of diverse products.

\(^{14}\) In order for this equality to hold exactly, it must be assumed that either the nation has zero net exports in each sector \( (X_i^{*} = U_i^{*}) \) or the proportion of each sector's output that goes to foreign sales is the same for the region as for the nation.

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IV. Export Employment

Once local employment, \( E_j \), is estimated, the amount of export employment can be obtained ex post from the identity given in equation (1). For purposes of forecasting and policy evaluation, however, it is desirable to relate export employment to relative production costs. Given this structural relationship, the total employment is the sum of local employment, estimated via equation (2) ft., and export employment, which is estimated as follows.

Assume that the share of national output of any given industry \( i \) that is produced by the region for export to other regions responds to relative production costs. Thus,

\[
X_i / X_i^{*} = \gamma_i P_i + \nu_i \quad (21)
\]

where

\( P_i \) represents production costs in the region relative to the nation;
\( \gamma_i \) and \( \epsilon \) are coefficients to be estimated; and
\( \nu_i \) represents an additive error term.

Since production is subject to constant returns to scale, local and export inputs can be allocated proportionately to local and export outputs.\(^{15}\) Thus, using the definition of \( l_i \):

\[
X_i / X_i^{*} = (E_i / E_i^{*})(1/l_i). \quad (22)
\]

Substituting equation (22) into equation (21) then yields

\[
E_i / (E_i^{*} l_i) = \gamma_i P_i + \nu_i. \quad (23)
\]

Since it is important to explain the number of export employees in all industries, it would be desirable to avoid pooling in the estimation of equation (23). However, the attempt to estimate sector-specific elasticities for Massachusetts was unsuccessful because the sample period was too short. Thus, pooling had to be employed. However, simple pooling would have given equal weights to large and small industries; therefore,

\(^{15}\) If production is divided into outputs for local use and for export, and inputs are allocated accordingly, one can write

\[
X_i = E_i^{*} K_i F_i \quad (24)
\]

where the superscript * denotes production for export. Deriving the cost function from this expression and dividing the resulting demand function for \( E_i^{*} \) by the national labor demand equation yields equation (22).
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TABLE I.—SELECTED EMPLOYMENT SECTOR PARAMETERS

<table>
<thead>
<tr>
<th>Region</th>
<th>Proportion of Employment Dependent on Exports*</th>
<th>Proportion of the 7th Sector’s Costs Attributable to Labor</th>
<th>Proportion of Output Going to Consumption and Government Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Regional Purchase Coefficient $p_i$</td>
<td>$\lambda_{l_1}$</td>
<td>$\lambda_{k_1}$</td>
</tr>
<tr>
<td>Manufacturing Durables</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ordinance (19)</td>
<td>.63</td>
<td>.87</td>
<td>.40</td>
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<tr>
<td>Lumber (24)</td>
<td>.09</td>
<td>.62</td>
<td>.48</td>
</tr>
<tr>
<td>Furniture (25)</td>
<td>.25</td>
<td>.68</td>
<td>.45</td>
</tr>
<tr>
<td>Stone, Clay, etc. (32)</td>
<td>.41</td>
<td>.49</td>
<td>.48</td>
</tr>
<tr>
<td>Primary Metals (33)</td>
<td>.17</td>
<td>.62</td>
<td>.42</td>
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<tr>
<td>Fabricated Metals (34)</td>
<td>.28</td>
<td>.75</td>
<td>.31</td>
</tr>
<tr>
<td>Non-Electrical Machines (35)</td>
<td>.33</td>
<td>.83</td>
<td>.32</td>
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<tr>
<td>Electrical Equipment</td>
<td>.14</td>
<td>.92</td>
<td>.41</td>
</tr>
<tr>
<td>Transport Equipment (non M.V.) (370)</td>
<td>.03</td>
<td>.95</td>
<td>.33</td>
</tr>
<tr>
<td>Motor V. &amp; Parts (371)</td>
<td>.01</td>
<td>.96</td>
<td>.30</td>
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<tr>
<td>Instruments (38)</td>
<td>.28</td>
<td>.91</td>
<td>.41</td>
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Non-Durables

<table>
<thead>
<tr>
<th>Region</th>
<th>Proportion of Employment Dependent on Exports*</th>
<th>Proportion of the 7th Sector’s Costs Attributable to Labor</th>
<th>Proportion of Output Going to Consumption and Government Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Regional Purchase Coefficient $p_i$</td>
<td>$\lambda_{l_1}$</td>
<td>$\lambda_{k_1}$</td>
</tr>
<tr>
<td>Food (20)</td>
<td>.36</td>
<td>.37</td>
<td>.22</td>
</tr>
<tr>
<td>Textiles</td>
<td>.31</td>
<td>.62</td>
<td>.38</td>
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<tr>
<td>Apparel (23)</td>
<td>.36</td>
<td>.70</td>
<td>.38</td>
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<td>Paper (26)</td>
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<td>.42</td>
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<td>Printing</td>
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<td>.55</td>
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<tr>
<td>Chemicals (28)</td>
<td>.19</td>
<td>.65</td>
<td>.29</td>
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<td>Rubber (30)</td>
<td>.55</td>
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<td>Leather (31)</td>
<td>.68</td>
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<td>.57</td>
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<tr>
<td>Other Durables (39)</td>
<td>.56</td>
<td>.72</td>
<td>.48</td>
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Non-Manufacturing

<table>
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<th>Region</th>
<th>Proportion of Employment Dependent on Exports*</th>
<th>Proportion of the 7th Sector’s Costs Attributable to Labor</th>
<th>Proportion of Output Going to Consumption and Government Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Regional Purchase Coefficient $p_i$</td>
<td>$\lambda_{l_1}$</td>
<td>$\lambda_{k_1}$</td>
</tr>
<tr>
<td>Contract Const. (C)</td>
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<td>.05</td>
</tr>
<tr>
<td>Transport &amp; Utilities (R)</td>
<td>.74</td>
<td>.42</td>
<td>.29</td>
</tr>
<tr>
<td>Wholesale &amp; Retail Trade (T)</td>
<td>1.00</td>
<td>.05</td>
<td>.63</td>
</tr>
<tr>
<td>Finance, Insurance &amp; Real Estate (FIR)</td>
<td>1.00</td>
<td>.07</td>
<td>.35</td>
</tr>
<tr>
<td>Services &amp; Misc. (SV&amp;M)</td>
<td>1.00</td>
<td>.20</td>
<td>.49</td>
</tr>
</tbody>
</table>

*Estimated as $E_i = E_i^* E_i$, where $E_i^*$ is estimated according to equation (2).

Both sides of equation (22) were multiplied by the mean values of the products of $E_i^*$ and $I^*$ over the sample period to act as a scaling factor. The equation to be estimated is then:

$$ (E_i^*/E_i^* I^*) \cdot E_i^* I_i = \beta_i P_i + u_i $$ (23a)

where $\beta_i = \gamma_i E_i^* I_i$ and $u_i = u_i E_i^* I_i$.

The variable $P_i$ represents the average cost of producing $X_i$ for the region relative to the average production costs in the nation. From the cost function given in equation (12) above, it is straightforward to obtain

$$ P_i = (C_i/X_i)/(C_i^*/X_i^*) = (w_i/w_i^*)^{E_i^*} $$

$$ (c_i/c_i^*)^{E_i^*} (f_i/f_i^*)^{E_i^*} \prod_{j=1}^n (y_j/y_j^*)^{E_i^*} $$(24)

where all variables have been previously defined. However, equilibrium does not occur instantaneously. Therefore, lags in adjustment have to be taken into account. For this reason, $P_i$ is defined as

$$ P_i = \sum_{h=1}^T (1/\tau) P_{i-h} $$ (24a)
where $\tau$ is an estimated parameter representing the average length of time required to return to a locational equilibrium.

The parameters were actually estimated by fitting the non-linear equation:

$$
\left( \frac{E_{it}^{*}}{E_{it}^{*} - l_{it}} \right) \left( \frac{E_{it}^{*} - l_{it}}{E_{it}^{*} - l_{it}} \right) = d \tilde{\beta}_{i} \left( \sum_{k=1}^{n} (1/\hat{r}_{ik}) P_{i}^{*} - \hat{r}_{ik} \right) \epsilon + u_{it}
$$

(23b)

where $i$ ranges over all industries and $d_{i}$ is a dummy variable which takes the value of one for $i = 2, 3', \ldots, n$ for each of the sectors in turn and zero otherwise. The program performed a systematic search over the relevant values for $\beta_{i}, \tau$ and $\epsilon$ to minimize the sum of the squared error of $u_{it}$.

The data used were eighty-seven quarterly observations for twenty-three employment sectors for Massachusetts and for the United States from the first quarter of 1954 through the third quarter of 1975. However, the labor intensity calculation required 52 quarters of data; therefore, only 35 quarters remained for estimation. The estimated elasticity of response value ($\epsilon$) was -4.28 and the length of location response ($\hat{r}$) was 5 years (20 quarters). These two values were statistically significant at the 1% level.

The reduction in squared error for $u_{it}$ for 805 observations was from 0.01015 when $\epsilon = 0$ to 0.00828 when $\epsilon = -4.28$. This reduction yielded a significant $F$-statistic at the 1% level even after compensating for an average $\rho$ of 0.9 (see Johnston (1960), p. 178). The $\beta$ values were all statistically significant. In order to estimate a goodness of fit for total employment, simulated export employment for each industry was combined with local employment for that industry and then all sectors were aggregated to obtain a simulated total employment value. This resulting sample period simulated value had a correlation coefficient of 0.92 with the actual values (squared $r = 0.84$). The root mean squared error was 0.019 compared with the average employment value of 1.950.

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V. The Direct Effects of Cost Changes

Equation (10) indicates that local employment depends on relative labor intensities and relative output prices, while equation (23) indicates that export employment depends on relative production costs and relative labor intensities. Thus by differentiating the employment equation with respect to relative production costs, relative labor intensity, and the relative price level of output, it is straightforward to obtain the following expression for the percentage change in employment in the $i^{th}$ sector:

$$
\frac{\hat{E}_{i}}{\sigma_{i}^{\epsilon} \hat{P}_{i} + \hat{l}_{i}} - (1 - \sigma_{i}^{\epsilon})(1 - D_{i}) \hat{Y}_{i}
$$

(25)

where

$\sigma_{i}^{\epsilon}$ = the export share;

$\epsilon$ = the elasticity of location response to regional costs;

$\hat{P}_{i}$ = the percentage change in relative regional costs;

$\hat{l}_{i}$ = the percentage change in relative regional labor intensity;

$D_{i}$ = the percentage of local output going to final demand; and

$\hat{Y}_{i}$ = the percentage change in the regional price of commodity $i$.

Each term in the above expression lends itself to intuitive interpretation. The first term ($\sigma_{i}^{\epsilon} \hat{P}_{i}$) represents the location response and shows that employment will change in proportion to the product of the export share, the elasticity of the location response, and the percentage change in regional production costs in reaction to the latter. The second term ($\hat{l}_{i}$) represents the labor substitution term and gives the employment effect of a change in labor intensity. The third term ($(1 - \sigma_{i}^{\epsilon})(1 - D_{i}) \hat{Y}_{i}$) represents the intermediate input substitution term and indicates that employment will change as local intermediate users substitute other inputs for intermediate inputs that have increased in price.

If one ignores the feedback effects of changes in capital and labor costs in industry $i$ and in intermediate input costs, it is possible to express $\hat{P}_{i}, \hat{l}_{i}$ and $\hat{Y}_{i}$ as functions of the percentage change for the individual employment sectors are available on request.

---

19 Obtained by substituting equations (2), (6), (9), (10), (16), (17) and (23) into equation (11).
in capital costs ($\dot{c}_i$) and labor costs ($\dot{w}_i$). The following expression relates the percentage change in employment to the percentage change in capital and labor costs, holding other input prices constant:

$$
\dot{E}_i = \sigma_f \epsilon \lambda \dot{c}_i + (\lambda - 1) \dot{w}_i - \rho_i(1 - \sigma) (1 - D_i) \lambda \dot{c}_i + \rho_i(1 - \sigma_f) (1 - D_i) \lambda \dot{c}_i.
$$

(26)

It is easy to see that the direct partial equilibrium effect of any increase in labor cost will be to decrease regional employment, because all the terms involving $\dot{w}_i$ are negative. These terms show the negative location effect ($\epsilon < 0$), the negative factor substitution effect ($\lambda - 1 < 1$) and the negative intermediate input substitution effect. However, when capital costs are increased, the labor substitution effect is positive. Therefore, an increase in capital costs in a region will decrease employment only if

$$
|\sigma_f \epsilon - \rho_i(1 - \sigma_f)(1 - D_i)| > 1.
$$

(27)

This means that if the elasticity of location and intermediate input substitution is greater than unity in absolute value, the employment-increasing effects of increasing capital costs will be offset by reductions in regional production.

Since taxes are the main policy instruments that affect wage and capital costs, it is useful to calculate how changes in various tax rates affect capital or wage costs in Massachusetts. The factor cost effects of arbitrary tax rate changes are given in table 2. These figures indicate that rather modest changes in tax rates can have a substantial impact upon regional factor cost differentials.

Using tables 1 and 2 and equation (26), the reader can calculate the direct employment effect of each tax change shown in table 2. For example, the partial equilibrium percentage increases in employment that would result from eliminating the 9.5% corporate profits tax in Massachusetts would be 2.5% in the electrical machinery sector and 0.2% in the service and miscellaneous sector.

VI. Summary and Conclusions

The direct and partial-equilibrium tax effects on employment described above are merely a demonstration of the use of equation (25). A general equilibrium analysis of direct and indirect effects requires a complete simultaneous model of the regional economy such as the MEPA model for Massachusetts. This model incorporates the relationships developed above, plus the additional equations necessary to determine the interdependent effects of a factor cost change on employment, wages, income, population, labor force participation, consumption, personal taxes, local government expenditures, and other relevant variables.

The need for a regional dimension to national stabilization policies is obvious. Unfortunately, regional input-output models contain such rigidities that they have limited usefulness for policy analysis. At the same time, most regional econometric models have been based on ad hoc regression equations and thus may be unsatisfactory as elements in a national system of simultaneous regional models. The employment equations presented here represent a consistent theoretical structure based on an explicit set of assumptions and could be applied to any region. Such applications would be interesting, not only as a way to examine regional differences in re-

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**Table 2.—The Impact of Tax Changes on Massachusetts Factor Costs Relative to U.S. Factor Costs**

<table>
<thead>
<tr>
<th>Tax</th>
<th>Tax Rate Change</th>
<th>Affected Factor Cost</th>
<th>% Change in Factor Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>State Corporate Profits Tax</td>
<td>9.5% to 0.0%</td>
<td>Capital</td>
<td>-5.5</td>
</tr>
<tr>
<td>State Corporate Profits Tax</td>
<td>9.5% to 8.5%</td>
<td>Capital</td>
<td>-0.6</td>
</tr>
<tr>
<td>State Equipment &amp; Inventory Tax</td>
<td>0.23% to 0.0%</td>
<td>Capital</td>
<td>-0.8</td>
</tr>
<tr>
<td>Local Property Tax</td>
<td>3.5% to 0.0%</td>
<td>Capital</td>
<td>-5.9</td>
</tr>
<tr>
<td>State Manufacturing Equipment Tax</td>
<td></td>
<td>Capital</td>
<td>1.3</td>
</tr>
<tr>
<td>Investment Tax Credit</td>
<td>3.0% to 0.0%</td>
<td>Capital</td>
<td>+0.2</td>
</tr>
<tr>
<td>Federal Profits Tax</td>
<td>48.0% to 0.0%</td>
<td>Capital</td>
<td>+0.0</td>
</tr>
<tr>
<td>Federal Investment Tax Credit</td>
<td>9.9% to 0.0%</td>
<td>Capital</td>
<td>+0.2</td>
</tr>
<tr>
<td>Unemployment Insurance Tax</td>
<td>1.7% to 0.0%</td>
<td>Labor</td>
<td>-1.7</td>
</tr>
</tbody>
</table>

* Except for those sectors exempted from the corporate profits tax.
response to regional and national policy changes, but also as a step toward an interactive system of regional structural models that could be used in the formulation and implementation of national economic policy.

It is important to reiterate that the employment equations presented here are still under development. It should gradually become possible to relax some of the strong assumptions that have had to be made. Work is progressing on several fronts: alternative production functions are being tried; attempts are being made to make the regional purchase coefficients endogenous functions of relative regional prices; differences in the elasticity of locational response among various sectors, and for the same sector in various regions, are being estimated; and the effects of transportation costs on the relative regional prices of inputs and on the comparative locational advantage of export producers are being explicitly modeled. Despite these efforts, many of the assumptions employed here will have to remain in force until better original data series become available.

Nevertheless, the paper demonstrates that a model can be developed and implemented which comes much closer both to meeting the requirements of general equilibrium analysis and to reflecting the best of existing regional economic and location theories than most of the regional models currently in use. It is hoped that further model development will benefit from the comments and criticisms that may be elicited by publication of this paper at an interim stage of model construction.

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A REGIONAL POLICY SIMULATION MODEL


