AN APPROACH TO METROPOLITAN EMPLOYMENT FORECASTING

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The development of techniques for subnational area forecasts has lagged behind other branches of the youthful and imperfect science of economic forecasting, and the field of metropolitan area forecasting is even more retarded than that of regional forecasting. Although there has been a considerable volume of research into metropolitan land use and planning models, the research results in the related area of income, employment and output forecasting have been very meagre. No doubt, the scarcity of metropolitan economic data has been a major factor in this lag, but the most serious bottleneck, in my view, is the failure to develop a satisfactory method of forecasting the exogenous component of urban economic change.

This note outlines an approach to this difficult task which has two main virtues at least: first, it avoids the purely demand-driven causation that characterises the more familiar crude export base and input-output methodologies; second, it places each metropolitan area in the wider framework of the national economy and stresses the role of interurban competitive success in generating urban growth. Although this model picks up, in a very crude way, some of the interdependencies and feedbacks characteristic of input-output models and also retains elements of the 'exogenous impacts-service industries' dependency found in export base theory, its main distinctive features stress the importance of agglomeration economies, supply considerations and the relative strength of locational attractors as the primary determinants of differential metropolitan growth.

This note is not concerned with the structure of the metropolitan forecasting model as a whole which is intended ultimately to move from industrial structure to occupational structure to income distribution to the housing stock. Nor is it concerned with the various submodels (population submodel, government sector submodel) that will be linked to the overall model or with the spatial allocation of forecast growth. Rather the aim here is merely to suggest an approach to forecasting the first, if crucial, block of such a model - namely a vector of industry employment. The measure of employment is selected in preference to output (value added, income) for several reasons: to facilitate application of a supply of labor constraint; to permit the use of continuous data runs as a forecasting base whereas other measures are available only for isolated years (e.g. Census periods); the model is framed in terms (e.g. reliance on an occupation-income matrix, predicting changes in the housing stock as one of the outcomes) which makes employment a more useful input into subsequent blocks of the model than output or income.

*Director, Center for Research in the Social Sciences, University of Kent at Canterbury. This paper is a small outgrowth from the work of a study group of the Economic Department at the University of Pittsburgh, which began work in 1971 on the development of a growth and forecasting model for the Pittsburgh metropolitan area and for Western Pennsylvania. The composition of the group includes Professors E. M. Hoover, D. B. Houston, A. Maeshiro, R. Riefler, S. H. Chou and G. Gruver. Although discussions with these members were valuable, they are in no way to be held responsible for any shortcomings in this paper.

Before describing the method preferred in this study, brief consideration must be given to more obvious alternatives. The three most straightforward methods of forecasting metropolitan employment exogenously are (i) industry-by-industry forecasts; (ii) export base models; and (iii) input-output models. All have major defects. Method (i) simply forecasts employment growth industry by industry, either by disaggregating national forecasts (or in a two stage disaggregation sequence, national to regional, then regional to urban) using a ratio-apportionment or shift-share adjustment technique or by extrapolating (not necessarily linearly, and sometimes making other adjustments) from past metropolitan growth rates. There are at least two serious objections to this method. First, the assumption of no interdependence between sectors is clearly invalid and can endanger the value of the predictions. Second, the methodology adopted is purely mechanical and devoid of behavioural content. Application of such procedures will tend to understate competitive shifts between metropolitan areas and to yield forecasts that are increasingly inaccurate the longer the projection period.

The deficiencies of the export base method are too well known to bear repetition. The gross instability of base-service ratios is probably the most serious practical (as opposed to theoretical) objection. The main source of instability is the assumption that all local market industries are dependent on the performance of the city's export industries, whereas it is obvious that the growth of many service industries is linked to the increase in population. Also it is useful to separate out other sources of growth such as non-local government expenditures, although on a broad interpretation this can be counted as part of exports. The other serious drawback of export base forecasts is their inability to take account of the locational attraction that highly competitive service industries may have for new firms in the sense that a broad range of good quality business services and an efficient urban government sector might help a city to obtain a disproportionate share of mobile industry.

Method (iii), input-output forecasting, is easily the most sophisticated of the three demand-determined methods. Its primary advantage is that it picks up all the interindustry interdependencies (and if an interregional model is used, all the interregional feedbacks too). It is also a very flexible tool since, depending on whether static or dynamic formulations are adopted, it is capable of generating short-, medium- or long-term forecasts as required. However, the objections to the input-output approach are somewhat strong. Its data requirements are very heavy especially for a metropolitan area, since in this case there is little alternative to an industrial survey approach. Even more serious, is that it does not avoid the tricky and critical problem of forecasting changes in final demand so that some additional forecasting technique has to be grafted on to the model in order to predict the exogenous component of the forecast. Furthermore, input-output models are much more suitable for generating output than employment forecasts. Their value for the latter role depends on the constancy (or predictability) of employment-output coefficients, a dangerous reliance especially in times of, or in sectors, experiencing rapid technical change. Finally, the technical relationships inherent in input-output analysis make it difficult, if not impossible, to allow for intermetropolitan shifts in competitiveness. On the other hand, if a satisfactory method of forecasting changes in the exogenous variables is discovered and if time and data cost constraints permit, a metropolitan forecasting model may well include an input-output matrix as a suitable instrument for tracing intersectoral repercussions of the exogenous impacts.

CHARACTERISTICS OF THE MODEL

The general features of the metropolitan employment forecast model outlined here are easily summarized. First, instead of a simple classifica-

tion of metropolitan activities into 'basic' and 'service' sectors a four-fold classification is adopted: two extra-metropolitan groups of industries, export-oriented industries and government-linked industries, and two sets of local industries, people-oriented industries and industry-oriented industries. Only the last of these four sectors is dependent on the levels of activity in the other sectors of the metropolitan economy. Second, for prediction purposes the crucial export-oriented sector is sub-divided into two components: (a) industries that are well established in the metropolitan area; and (b) industries that are either new to or 'grossly under-represented' in the metropolitan economy. The most difficult part of the whole forecast is identifying and predicting change in these 'new' export-oriented industries. Forentirely new industries identification is easy, but for under-represented industries there must be a cut-off point between 'under-represented' and 'well-established'. This will vary from industry to industry according to economies of scale, the degree of specialisation in the national economy, the relative weight of transport costs in the industry in question, and other factors.¹ As for prediction, the major question is: under what conditions will industries new to the city be developed? Since the entry of new industries can never be predicted with certainty, the need is for some kind of probability model which takes into account both the relative attractiveness of the city for growth industries in general and the attractiveness of the city for particular industries. Agglomeration economies differ in type and extent from industry to industry, while certain industries are more likely to flourish in cities of a particular size or with a particular economic and social structure than in others. Also, there are sets of industries which are normally found in spatial association with each other in 'activity clusters' (e.g. because they are dependent on each other, or benefit from common agglomeration economies), and major gaps in a city's clusters may provide a clue to the most likely industries to be attracted there. All these factors may be taken into account in assigning probability weights to each industry for a particular city.

Third, there are three main exogenous impulses on metropolitan employment change in this model: forecast national employment in export-oriented industries; forecast federal and state government expenditures; and forecast metropolitan population. The last of these is only semi-exogenous, since the overall metropolitan growth model, when it is fully developed, will contain a population submodel. There are obviously feedbacks from other parts of the metropolitan economic system into population change, while certain components of population change itself have to be dealt with as lagged-endogenous variables in the sense that the past population structure is an important determinant of the present structure.

For the purposes of analysis, the metropolitan economy is assumed to consist of n industries which can be grouped into four main sectors: the set $a \rightarrow n$ represents export-oriented industries selling to non-local markets, and in the model these are divided into two subsets, $a \rightarrow i$ consisting of existing metropolitan industries ($k=1$) while the subset $j \rightarrow n$ refers to 'new' or under-represented export-oriented industries ($k=1$); the set $o \rightarrow q$, $r \rightarrow u$ and $v \rightarrow z$ stand for government-linked industries ($p=1$), people-oriented industries ($s=1$) and industry-oriented industries ($z=1$) respectively.

THE MODEL (see figure 1)

The basic characteristic of the model is a distinction between existing and 'new' (including grossly under-represented) export-oriented industries with a different method used to forecast employment growth in each sub-sector. The procedure is as follows:

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Existing Export-Oriented Industry

Forecast employment in existing export-oriented industries (a , b , ... i , $i=1$), by forecasting output as a function of non-local demand and then converting to employment via use of employment-output elasticity coefficients.

$$x_{U,t+n}^i = a^i + b_{1U}^i d_{R,t+n}^i + b_{2U}^i d_{N,t+n}^i + b_{3U}^i d_{F,t+n}^i \quad 1.1$$

where x_U^i = output in industry i in the metropolitan area

d_R , d_N , d_F = regional, interregional and foreign demand for i respectively.

b_{1U}^i , b_{2U}^i , b_{3U}^i = shares coefficients estimated from past regressions, but possibly with adjustments to reflect foreseen changes in the metropolitan area's relative competitiveness.

$$\log e_{U,t+n}^i = \alpha^i \log x_{U,t+n}^i$$

where e_U^i = metropolitan employment in industry i

α^i = employment-output elasticity coefficient estimated exogenously (e.g. from past data for the metropolitan area or from national data).

'New' Export-Oriented Industry

A much more difficult task is the forecast of employment growth in industries that are new to the metropolitan area. For the purposes of this model we have confined the 'new industries' problem to the export-oriented sector, though clearly new industries also might develop in the government-linked, people-oriented and even in the industry-oriented sectors. However, in all these latter cases the entry of new industries does not have to be treated as exogenously determined, and their growth is easier to predict depending on the forecast levels and types of non-local government spending, the size and structure of the population and changes in the scale of all metropolitan industries. It would be possible, however, to broaden this component of the forecast to include all new industries not merely those in the export-oriented sector, if desired. The distinction between 'existing' and 'new' industries is difficult to draw when the latter group includes industries that may be embryonic in the metropolitan economy, but only on a small scale. This raises the problem of defining the cut-off point between established and new industries, a problem which is discussed below.

The hypothesis here is that metropolitan growth in new non-local industries will be determined by the metropolitan area's ability to compete for interregionally mobile employment in these industries. The latter is composed of two elements: (i) national employment growth in each of the industries over the forecast period, (ii) an estimate of potentially interregional model employment in each of these industries. The second of these elements takes into account the fact that in export-oriented industries locational shifts between regions may occur over time, and that these shifts may take the form of relocation of existing plants. Although some employment growth will take place in established immobile firms, and the location of many new firms will be predetermined (e.g. by the location of their founders), it is assumed that (i) plus (ii) represents as estimate of potentially mobile employment to be distributed among different areas of the national economy (and particularly among competing SMSAs) by some allocative mechanism.

How do we estimate (ii)? Clearly, this presents serious difficulties. One relevant factor must be past data on interregional mobility of firms (and employment) by industry. Also, it seems likely that the rate of interregional plant mobility will be a direct function of the national growth rate, and that adjustments should be made for expected variations in this growth rate when projecting past trends in interregional job movements. Another useful variable in this forecast may be an inertia coefficient attached to each industry. This coefficient will be determined by such factors as the capital costs of constructing a plant of minimum efficient scale, the market area of the industry (national-market industries are obviously more mobile than regional-market industries), and the existence (if any) of unique industry-specific locational determinants.

For each industry k , either new or grossly under-represented in the metropolitan area, we have the following equation measuring potential interregionally mobile employment in the national economy:

$$\Delta e_{IM(t+n)-t}^k = \Delta e_N^k(t+n)-t + \int_t^{t+n} e_M^k \quad 1.3$$

where e_{IM}^k = potential interregionally mobile employment in 'new' industry k .

e_N^k = national employment in industry k .

e_M^k = an estimate of mobile employment in existing firms in industry k .

n = forecast period.

Also

$$e_{U,t+n}^k = e_{o,U,t}^k + s_{U/N}^k \Delta e_{IM(t+n)-t}^k \quad 1.4$$

where $e_{o,U,t}^k$ = initial employment at period t in industry k in the metropolitan area.

$s_{U/N}^k$ = metropolitan area's anticipated share in interregionally mobile employment in industry k .

The component $e_{o,U,t}^k$ will be very small, since the industry is more or less 'new' to the metropolitan area. The other major problem in this part of the forecast is determination of the share coefficient $s_{U/N}^k$. Crude share ratios such as urban to national population ratios are obviously inappropriate to stand as surrogates for the share coefficient for at least four reasons: (a) the objective here is to estimate the metropolitan area's competitive pull for this industry relative to other cities; there is no reason why these competitive pulls should cancel out as implied in the population share ratio; (b) since export-oriented industries sell to outside markets, metropolitan population size is scarcely a relevant influence; (c) if new industries do develop in the city in question, then unless the industry is new to all areas it must reduce the shares of other cities in the system and, consequently, there is no rationale for a stable shares assumption; (d) a crude overall share ratio of this kind does not permit the shares coefficient to vary between industries, and even if the city is successful in attracting new industries it is most unlikely to attract all of them and to the same degree.

The most satisfactory approach to determining the value of $s_{U/N}^k$ is by resorting to locational attractors such as agglomeration economies, market potential, labor market economies, public service efficiency and site availability, and a probability coefficient to reflect the likelihood of the industry being attracted to competing and intervening cities and whether or not the industry fits in well with the city's 'activity clusters'.²

Thus

$$s_{U/N}^k = \delta_U^k \cdot e_U / e_N \quad 1.5$$

e_U / e_N (the metropolitan area's share of national employment) is used as a normalising factor while δ_U^k is the adjustment coefficient. On the analysis above this is determined by

$$\delta_U^k = f[w_1 G_U / \bar{G} + w_2 L_U^k / \bar{L}^k + w_3 B_U^k / \bar{B}^k + w_4 C_U / \bar{C} + w_5 A_U^k / \bar{A}^k + w_6 V_U / \bar{V}] \quad 1.6$$

provided that $1 - e^{-\frac{k}{\rho_U}} \geq T$

where e = base of natural logarithms

ρ_U^k = probability coefficient reflecting the pull of industrial complex compatibility in the city and the attractive force of intervening opportunities in other cities for industry k .

T = a critical threshold level.³

$w_1 - w_6$ = weights where $\sum w = 1$

G = measure of public service efficiency.

L^k = measure of labor market economies which may be industry-specific

B^k = measure of availability of business services (again possibly industry-specific).

C = index of leisure and cultural facilities.

A^k = availability of sites for industrial and commercial purposes⁴; although it is not easy to make these specific to industry k it may be feasible to draw a distinction between the availability of central sites and suburban sites since some mobile sectors will need to locate centrally while others tend to locate near the fringe of metropolitan areas.

V_U = an index of income potential for the city, used to represent market potential

$\bar{G}$ = measure of relative public service efficiency in other metropolitan areas, e.g. an average for all other metropolitan areas or an index of public service efficiency in the closest competing metropolitan area (i.e. the main competing city in the same region). $\bar{L}^k$, $\bar{B}^k$, $\bar{C}$, $\bar{A}^k$, and $\bar{V}$ are also average or relative measures for other cities in the system.

Despite the difficulty of predicting the city's attractive power for mobile capital and industry, this could be a crucial component of the forecast in that this attractive power may be the primary determinant of whether or not the metropolitan growth rate rises above the average. A major problem in forecasting the entry of new industry into a metropolitan area is that chance, timing and other considerations rule out a clear determinate forecast. This explains the need for a probability coefficient to be assigned for each industry in each city. The probability coefficient will be higher the more likely that the industry fits into the city's industrial structure and the fewer the rival cities competing for it.

Government-Linked Industry

Employment in government-linked sectors such as non-local administration, defence contractors and space-related manufacturing and research establishments can be treated as a function of federal and state government expenditures. The local government sector, on the other hand, can be regarded as if dependent on the overall performance of the metropolitan economy and is therefore placed in the industry-oriented sector. Forecasting future federal and state government expenditures in a metropolitan area is not an easy task, and is subject to many uncertainties and unforeseen turns of events. This will have to be determined by a separate submodel for the government sector, and from the viewpoint of this paper we assume that these expenditures are determined exogenously. Thus,

$$x_{U,t+n}^p = f(FX_{U,t+n} + SX_{U,t+n}) \quad 1.7$$

where x^p = output of government-linked industry

FX_U = federal government expenditures in metropolitan area

SX_U = state government expenditures in U

The allocation of total government-linked output x_U^p among each individual industry p depends upon the nature and types of non-local government expenditures. Since the exogenously determined forecast of federal and state government expenditures will be built up from detailed breakdowns by departments and types of expenditures, the sectoral allocation procedure should not be too difficult. Once individual industry outputs have been obtained, conversion to employment can be made via use of an equation similar to 1.2:

$$\log e_{U,t+n}^p = \alpha^p \log x_{U,t+n}^p \quad 1.8$$

People-Oriented Industry

Many local industries in the metropolitan economy are far more dependent on the size, structure and composition of the metropolitan population than on export industries. These industries include local government, primary and secondary education, health and welfare, retail distribution, residential construction, local passenger transport services and personal services. It becomes essential, therefore, in a metropolitan forecasting model to predict the future size and composition of the population. Hence a separate population sub-model becomes a necessity. This submodel needs to predict the effects of natural increase but must also, especially in a metropolitan context, contain a migration forecasting model as a crucial element. The determinants of gross and net migration for a metropolitan area are very complex, and there are many feedbacks from other parts of the metropolitan forecasting model. For instance, there will be a feedback from the export-

oriented sector into the population block (not illustrated in Figure 1 and from later components of the model (e.g. from housing stock characteristics, employment and unemployment, changes in income distribution). The structure of the population/migration submodel will not be treated here. Assuming that we have as an input the forecast size, age composition and structure of the metropolitan population, then we can estimate employment in each people-oriented industry as a function of the size and age composition of the population.⁵ The justification for forecasting employment directly as a function of population is that productivity changes tend to be much slower in the people-oriented sector and, in any event, measures of output are ambiguous for services. Thus, for each people-oriented industry s , we have an equation

$$e_{U_{t+n}}^s = a^s + b_1^s P_{U_{t+n}} + b_2^s \phi_{P_{U_{t+n}}} \quad 1.9$$

where P_U = metropolitan population

$\phi_{P_{U_{t+n}}}$ = a measure of the age composition of metropolitan population

Industry-Oriented Sector

The industries in this sector are the closest parallel within this model to the dependent service industries found in an export base forecast in the sense that the chief independent variables affecting their performance are the levels of activity in other industries in the metropolitan economy, particularly but not exclusively in the export-oriented sector. Industry-oriented industries include business services (such as advertising, computing services, accountants, legal services), haulage, non-residential construction, raw materials production and intermediate goods industries selling to local markets.⁶ It is clear, however, that the dependent mix of industry-oriented industries will vary according to whether export-oriented, government-linked or people-oriented activities are being considered. It is also probable that the mix of dependent activities will vary between the long established export-oriented sector and the 'new' export-oriented sector. Thus, if an export-base employment relation is to be used, then this must be a disaggregated base-service relationship of the type suggested by Weiss and Gooding (5). Ideally, the degree of disaggregation obtained from an input-output model would be more appropriate, but given the data collection problems for metropolitan input-output tables multiple regression equations of the following type are probably sufficient

$$e_{U_{t+n}}^z = a^z + b_1^z \sum_i e_{U_{t+n}}^i + b_2^z \sum_k e_{U_{t+n}}^k + b_3^z \sum_p e_{U_{t+n}}^p + b_4^z \sum_s e_{U_{t+n}}^s \quad 1.10$$

The independent variables are, of course, the forecasts obtained from procedures (1) to (4) above, while the constant term a^z and the regression coefficients $b_1^z - b_4^z$ will be obtained via fitting past data. Thus, this method of estimating industry-oriented employment allows for variation in impact between different sectors of the metropolitan economy (e.g. $b_1^z \neq b_2^z$) and for differential impacts of each independent sector on each separate industry-oriented activity (e.g., $b_1^z \neq b_1^y$).

Overall Employment Projects

The final stage in the metropolitan employment projection is merely the aggregation of employment estimates for each of the main sectors in the urban economy (i.e., existing export-oriented, 'new' export-oriented, govern-

ment-linked, people-oriented and industry-oriented employment), the end products of operations (1) to (5) respectively. Thus, as shown in Figure 1):

$$e_{U_{t+n}} = \Sigma e_{U_{t+n}}^i + \Sigma e_{U_{t+n}}^j + \Sigma e_{U_{t+n}}^k + \Sigma e_{U_{t+n}}^p + \Sigma e_{U_{t+n}}^s + \Sigma e_{U_{t+n}}^z \quad 1.11$$

Whether this overall employment is feasible or not depends upon the question of supply of labor (and possibly other) constraints. Although supply factors (e.g. availability of sites, presence of necessary business services and social amenities) have been included among the locational attractors, the metropolitan employment forecast itself is nevertheless a demand for labor forecast. In certain circumstances, the forecast could be abortive because of constraints on the supply of labor. The safety value of in-migration makes this constraint much less effective at the metropolitan level than, say, for the national economy, but despite this labor shortages may slow down metropolitan growth (e.g. by having unfavorable feedbacks on the efficiency of locational attractors). The general problem of constraints on metropolitan forecasts is discussed in a little more detail below.

A first question is the classification of metropolitan industries into the export-oriented, industry-oriented, people-oriented and government-linked sectors. For many industries ad hoc allocation is reasonable enough. Defence establishments in the government-linked sector, primary education and retail distribution in the people-oriented sector, specialist business services (if provided for local firms) in the industry-oriented sector, tourism in the export-oriented sector, examples of this kind are easily allocated. But what about the steel firm that sells to outside markets and to local industries, the precision instruments establishment that sells to the federal government and to private customers, the specialist hospital that caters for patients drawn from the rest of the nation as well as the city's own residents, the intermediate inputs supplier that produces for industries both within and outside the city or the management consultancy agency with local, national and international clients? Misallocation will distort the forecasts, especially if the industry-oriented sector is badly defined since this is solely dependent on other metropolitan industries. The local sales of export-oriented firms, however, present no serious difficulty since these can easily be included in d_R . In cases where an industry's output is clearly split between two or more sectors, its employment may be allocated between the sectors concerned. In some cases, a sufficiently precise allocation may require a small-scale industrial survey.

A more intractable classification problem is the separation of established export-oriented industries from 'under-represented' ones, and identification of the broader set of interregionally mobile industries from which potential new industries in the metropolitan area will be drawn. There are several complementary approaches to help identify mobile industries. Even mobile export-oriented industries are not usually located in all cities, and in cases where they are highly localised in one or two cities they are unlikely to spread even if there are no obvious bars to mobility. In other cases, however, high coefficients of localisation reflect the fact that the industries concerned are immobile. Primary industries and resource-oriented manufacturing industries are obvious examples, though not very relevant ones since they are usually located outside cities. A more serious example from the viewpoint of this model is the case of industries which have a high degree of immobility because they are subject to marked economies of scale and/or high capital costs of constructing new plant. In such industries the probability of new plants being established in a particular metropolitan area within a given

forecast period is very low, unless there are very strong locational advantages in the area's favor and sufficient expansion in national demand over the forecast period to justify the setting up of new plants. The most mobile industries are sectors with several of the following characteristics: a growing demand for the industry's products; a large market area⁷ (industries selling to national markets are much more interregionally mobile than those selling to regional markets); few economies of scale; little or no reliance on heavy non-ubiquitous raw materials or intermediate inputs; limited fixed capital costs; premises that are flexible in use (hence commercial and financial sectors using office buildings are among the most mobile industries, though they often have specific location requirements that limit their range of locations to sizable cities). In addition, the economic and social characteristics of cities provide locational advantages that attract particular types of industries, such as market-oriented industries or industries needing the agglomeration economies that cities offer (e.g. communication economies, high ratios of technical or executive manpower). It is possible that the size of the metropolitan area of the study may be a relevant criterion for identifying potentially mobile industries if information is available on the relationship between industry specialisation and city size. However, this is probably much more useful for identifying export-oriented service sectors than manufacturing industries, movements of which are much more difficult to predict.

How do we draw the line between under-represented industries and established ones? The most helpful approach would be to compare the location quotient in each industry for the city with that in other cities of similar size, though the appropriate cut-off point cannot be determined *a priori* without examining the distribution. Because of this, there is an element of subjectivity in drawing the boundary line. However, since employment in existing industries is forecast by reference to changes in foreign, national and regional demand, if low representation of an industry is associated with irregular vagaries in demand in each of these markets then employment in such an industry can be forecast only by assigning it to the 'new' export-oriented sector. The most troublesome aspect of this part of the problem, however, is not the designation of the under-represented industries but determining whether or not an industry completely new to the city will enter the area's economic structure within the forecast period. In the model this depends on the value of the probability coefficient $\rho_{U,K}^k$. Accordingly, some threshold level must be chosen (i.e. the critical threshold level T) so that if $\rho_{U,K}^k$ falls below the value needed to satisfy the condition $(1 - e^{-\rho_{U,K}^k} > T)$ we set $\delta_U = 0$, and predict no employment in that industry in the metropolitan area over this particular forecast period. Whereas it is reasonable to assume that this condition will be satisfied for under-represented industries, for many industries that have never been located in the metropolitan area the value of $\rho_{U,K}^k$ will be too low. Also, the value of T is not necessarily constant over time and space. It cannot be determined *a priori* but will be influenced by many factors; for instance, it will vary inversely with the national growth rate but directly with the age of the metropolitan area.

Some other practical problems, though almost as important, can only be discussed briefly. One of these, already touched upon in the paper, is the identification and measurement of locational attractors and agglomeration economies. Those selected for the model described in the text are merely examples chosen on a *priori* or casually empirical grounds, and detailed research might suggest others that are more important and/or more easily measured. Also, the key locational attractors could vary considerably from one industry to another. The length of the forecast period is another tricky practical problem. It will be determined partly by the objective of the forecast, partly by the structure and characteristics of the model. In general terms, the ultimate concern of most metropolitan forecasting models will be as an aid to more effective urban planning, and this could dictate a forecast period of anything between five and twenty years. The employment forecast-

ing model described here, however, has a structure which makes it unsuitable for forecasts much longer than the minimum of this range.

A practical consideration with much wider implications than the scope of this paper is the relevance of the spatial dimension to metropolitan forecasting models. Such models cannot afford to neglect the spatial distribution of changes in economic activities, at least if their results are to be useful for planning purposes. Whether this should be dealt with via spatial disaggregation of forecasts in each forecasting block or by sequential models for forecasting growth first and then spatial allocation is a question of choice, though the method selected will largely be determined by the structure of the model. One obvious problem is that the appropriate degree of spatial disaggregation may vary from one forecasting phase to the next (e.g., for industry forecasts a central city, inner suburbs, and outer suburbs breakdown may be adequate whereas household forecasts disaggregating household by income, occupation, race and social class may need to be spatially distributed at the small neighborhood level). For the purposes of this paper which deals with one small segment of a comprehensive metropolitan forecasting model the question of spatial allocation has been ignored. However, introducing space raises the related issues of how to define the boundaries of the study area for the forecast. In the United States context, it is probably necessary to use SMSA (Standard Metropolitan Statistical Area) boundaries to facilitate the collection and use of available data. The choice of SMSA, however, has a reasonable economic justification since metropolitan forecasts should, given the strength of decentralisation trends, refer to broadly defined metropolitan areas. In cases where SMSA boundaries differ substantially from FEA (Functional Economic Area⁸) boundaries, it may be more useful, if data availability permits, to adopt the latter especially if the employment forecast is a central feature of the model as a whole.

One advantage claimed for the metropolitan employment forecasting model described here is that it is not purely demand-determined. The competitiveness of a city in the struggle to attract mobile industries depends to a considerable extent on its long-run supply position, such as the availability of industrial and commercial sites and the relative strength of other locational attractors. However, the role of short-run supply constraints is not adequately taken into account, since it has been implicitly assumed that the demands for labor predicted by the model are unconstrained. In implementing the full model it will be necessary to subject the labor demand forecasts to the supply of labor constraint that is one of the outcomes of the population sub-model. This is difficult because the supply of labor constraint is fairly elastic due to possible increases in the labor participation rate and, more important, to variations in net migration. Complications increase because of interaction between the demand for labor and changes in potential supply via in-migration, an interaction that can only be satisfactorily analysed within the framework of a simultaneous equation model. However, even without this, it may be possible to apply a labor supply constraint (if appropriate) as there is probably a maximum absorption rate for each city, placing an upper limit on the in-migration of labor.

Another important constraint, especially in the longer run, is the supply of land. This is to some extent taken care of in the model since site availability has been included as a location attraction variable. However, the aggregate supply of urban land is not fixed since in the long run the metropolitan area may extend spatially by absorbing peripheral land. On the other hand, the spatial extension process is itself very discontinuous. The consequence is that the value of the site availability variable may need readjusting both within and between forecasting periods. In the short run, the rate of construction constraint may be much more effective. This means that the comprehensive forecasting model, especially for a rapidly growing metropolitan area, must contain a sub-model for the construction sector. Another possible constraint is what may be described as the planning con-

straint. Since the powers of urban planners include the capacity to prevent particular development projects, the forecast must assume the planners are willing to accept the implications of achieving the forecast by allowing the predicted developments to take place. There is no reason why this should present a problem in most cases, since planners in rapidly growing areas are likely to hold value judgments conducive to growth while those in metropolitan areas with distress symptoms will usually be under pressure to co-operate with making provision for new industry.

Finally, a rather obvious constraint on metropolitan employment growth in this model is the constraint of the national growth rate itself, since growth in export-oriented industries is directly dependent on national growth to a substantial degree while growth in government-linked industry is indirectly dependent to the extent that federal (and possibly state) expenditures are growth-related. However, since the metropolitan employment forecasts are derived from predictions about national employment, the national growth rate is less a constraint than an intrinsic element of the model. Nevertheless, a crucial question is: what happens if the predicted national changes in employment are not achieved? Can we scale down the metropolitan forecasts in line with the extent of the actual deviation of national employment from the forecast level? The answer is probably no, since the assumption of linear relationships does not necessarily hold when an expected increase in national employment is drastically reduced. Indeed, if the national growth rate falls significantly below expectations a likely outcome is a more limited volume of mobile employment and fewer new industries in the economic structures of individual cities. Thus, a failure to attain the national employment forecast will probably be associated with a narrower geographical spread in the spatial distribution of new jobs. This suggests that in situations where it is difficult to predict national growth and a range rather than a unique forecast is decided upon a more appropriate method of forecasting the redistribution of industries into other cities is via a (non-linear) diffusion model. A diffusion theory of employment distribution would have a more explicit spatial content than the more traditional economic model of employment forecasting described in this paper. However, diffusion models are much more useful for forecasting change in the spatial economic system as a whole than in the individual metropolis.

FOOTNOTES

¹The problem of fixing the cut-off point in order to separate 'new' from existing export-oriented industries is discussed in a little more detail later in this paper.

²These refer to complexes of industries that have a high degree of spatial association. For further details, see [1].

³There is some kinship between this approach and Garnick's concept of a locational threshold[2]: 'the locational threshold can be thought of as a point at which the probability of a given region obtaining (or already having) an industry has reached a pre-determined value'.

⁴There is some evidence available in the volume of vacant urban land, though of course some of this land would be used for residential and amenity purposes. For a recent study, see [3].

⁵It would be possible, if required, to take account of other aspects of the population structure such as sex and marital status. These are ignored in the text.

⁶There is some parallel between the notion of an industry-oriented sector as suggested here and Czamanski's concept of complementary industries[4].

⁷A Leontief commodity hierarchy is, therefore, a relevant instrument for identifying potentially mobile industries. In a Leontief hierarchy industries are ranked according to the size of the market area over which their products are sold.

⁸For a definition of and rationale for the FEA, see [6].

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