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Integrated Forecasting Models of Urban and Regional Systems

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1 Introduction

The evolution of urban and regional systems is not an autonomous process of nature but is the result of human decisions - of thousands, millions of decision, many small and some large, occurring over time as a broad stream of concurrent, unrelated or interrelated, individual or collective, choices.

Planners and public decision makers in charge of such systems face a difficult task: to steer a system which, on the one hand, is largely subject to external influences in the form of national policies and long-term economic cycles, and, on the other hand, is largely controlled by private decisions of firms, investors, and other individual or corporate actors. In this situation, it is of vital importance for them to know in advance which of the few and limited policy instruments at their disposal are likely to be most effective and, moreover, will have the most desirable effects.

So urban and regional scientists have tried to develop techniques for forecasting the impacts of public policies on regional development. A prerequisite for this is to understand the forces shaping it, and this means to understand the mechanisms behind the millions of private decisions made every day in the region, which cannot, or can only in an indirect way, be controlled and influenced by the public authority. In their search for understanding the behaviour of private decision makers, researchers have tried to identify groups of private actors behaving in similar, regular, and predictable ways such as travellers, shoppers, workers, households, firms, or organisations. Next, they have tried to separate the decision fields in which these actors pursue their specific activities such as travel, shopping, finding a job or a residence, establishing a business, investing, producing or shipping commodities. Such decision fields are commonly called markets: the transport market, the labour market, the retail market, the housing market, the construction market, the land market, and other less visible markets like the ones for knowledge and capital. Finally, they have constructed models of these markets: transport, retail, employment, housing, or land-use models.

Characteristically, such models focused on only one, or at most two, of the decision fields or markets at a time and thus comprised only a small section of the activities relevant for regional development. However, the markets interact and these interactions cannot be ignored without missing essential feedback information. This was the motivation for building more comprehensive, multiactivity urban and regions models that explicitly address the interconnectedness of the various urban and regional markets.

Such 'integrated' modelling approaches are the topic of this paper, and in particular, empirically oriented, spatially disaggregated, multiactivity mathematical models built for the purpose of forecasting the spatiotemporal development of urban and regional systems; where 'multiactivity' indicates that the models include more than one sector or field of human activity, such as employment, population, housing, and transport, and 'urban and regional systems' may be anything from a town to a system of regions in a nation.

The paper is *not* a comprehensive review of all existing models of this kind, but focuses on one aspect of their definition, the multiactivity or *integration* aspect. In particular an analysis is given of how in these models the economic, demographic, etc. subsystems are linked, that is, which interactions or feedbacks between them are recognised in the models and how. The discussion starts from an 'ideal' comprehensive urban-regional model encompassing many conceivable aspects of potential relevance for regional policy making. Then a few typical urban and regional models will be reviewed and compared with this comprehensive model in terms of completeness and feedback structure. Two basic approaches to linking the subsystems of integrated models are distinguished: in 'unified' models, *one* algorithm or system of equations is used to model *all* subsystems, whereas in 'composite' models specialised, and hence, different, submodels are used for each subsystem.

Unified modelling approaches are superior in terms of coherence and internal consistency, but it is frequently necessary to sacrifice essential detail with respect to subsystem specification. Composite approaches, on the other hand, have no restrictions as to how single-activity subsystems are modelled, but face the problem of consistently linking them. In the paper, typical examples of both types of models are identified and their advantages and disadvantages discussed. It is the purpose oft the paper to show that the integration of subsystems in a multiactivity modelling framework is a largely unresolved and widely neglected problem.

2 A model of integrated models

To provide a framework for the subsequent discussion, an 'ideal type' multiactivity urban-regional model is sketched out in this section[1]. Figure 1 is a compact diagrammatic representation of such a model. Each box in the diagram represents a group of variables or rather the set of equations generating them. Adjacency of boxes indicates that their contents are closely interrelated by causal (or definitional) links. The directions of links shown are the ones considered to be the most important; in fact, at this level of aggregation most links are bidirectional. The numbers in the boxes are referred to in the following discussion. The letters in circles on the edges of boxes indicate policy instruments.

2.1 Model subsystems

It is immediately obvious the model in Figure 1 is a tow-level system. The top half represents a 'regional' model in a 'national' framework', the lower half an 'urban' model. These designations are only labels indicating the spatial nesting of the two levels: the 'urban' level may equally well comprise a number of communities, and the 'national' framework may also be a state or a province and any larger spatial entity for which aggregate economic and demographic forecasts exist. The 'urban' level is always subdivided into geographical subunits called zones. The 'regional' level is normally multiregional, but may also consist of only one region with the remainder of the 'national' system being the 'rest of the world'. Furthermore, it is possible to conceive of the model as having only one spatial level. In that case, either the 'urban' level is left out entirely, or the 'regional' level is substituted by exogenous trajectories of total employment and population of the urban region.

[1] The idea of using a fictitious model as a frame of reference was borrowed from Bolton (1980a).

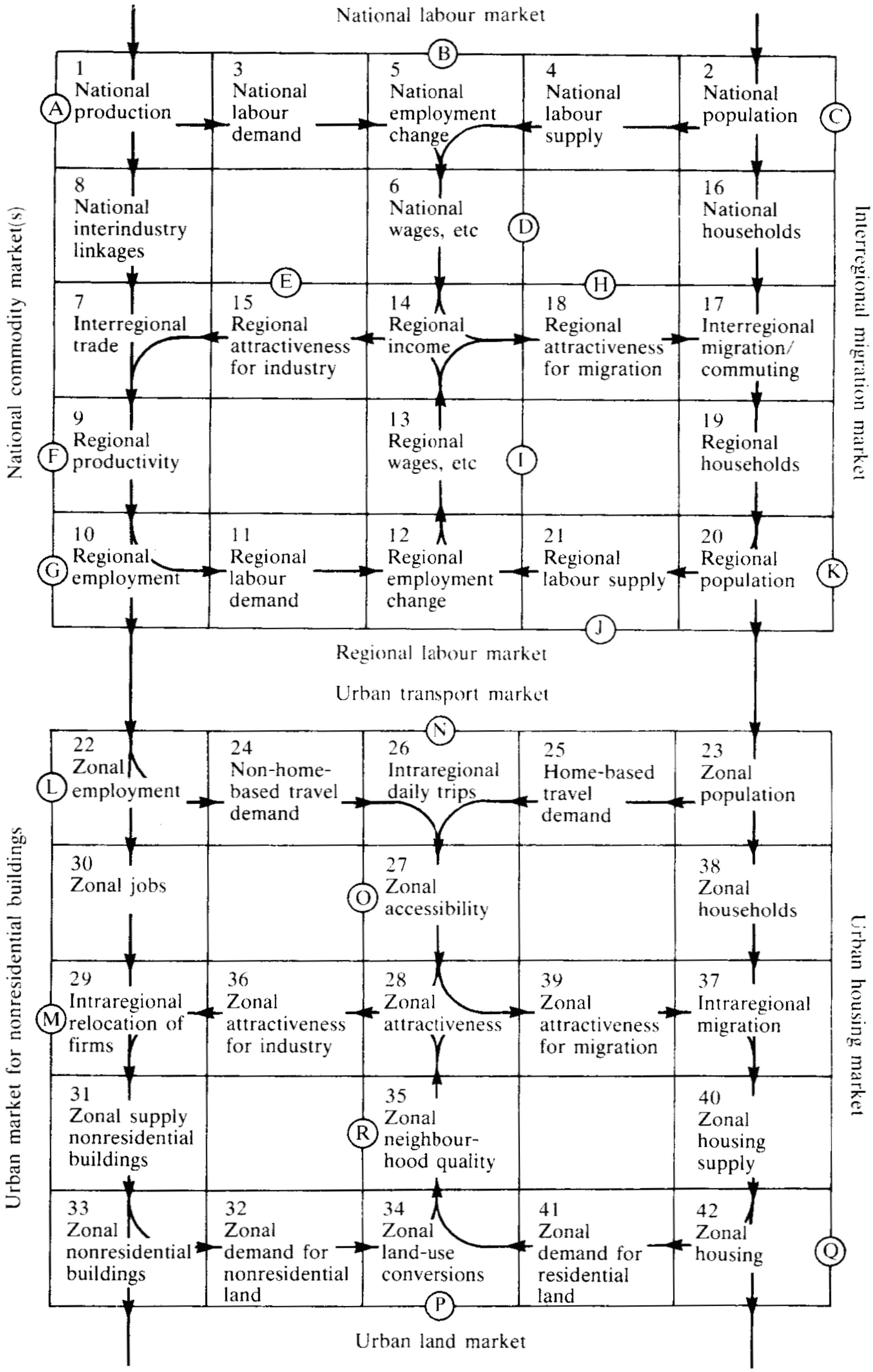

Figure 11. A model of integrated models.

A second observation that can be made is that the model is organised by markets. Eight markets can be distinguished:

- the national labour market,
- the national commodity market,
- the national (interregional) migration market[2],
- the regional labour market,
- the urban transport market,
- the urban market for nonresidential buildings,
- the urban housing market,
- the urban land market.

Each of these markets is placed between two corner boxes of the model diagrams representing major stock variables of the urban-regional system: on the left-hand side, they refer to the production or employment sphere:

- national production,
- regional employment,
- zonal employment,
- zonal nonresidential building,

whereas on the right-hand side they refer to the population or household sphere:

- national population,
- regional population,
- zonal population,
- zonal housing.

Each market itself is represented by three boxes: the two outer boxes next to the corner boxes spell out the relevant demand and/or supply variables, and the box in the centre of each market contains the transactions occurring in each of them:

- employment change, national,
- interregional trade flows,
- interregional migration,
- employment change, regional,
- intraregional daily trips,
- intraregional relocation of firms,
- intraregional migration,
- zonal land-use conversions.

Feedbacks between the various markets are represented by the boxes in the centre of each model diagram; they take the form of signals in terms of attractiveness indicators, the most prominent being on the regional-national level regional income, and on the urban level zonal attractiveness including accessibility.

Like any abstraction, the diagram has many weaknesses. An important one is that prices do not appear explicitly, but have to be associated with the demand and supply variables implicitly. Another deficiency is that the transport system is not shown at all at the regional-national level and only implicitly at the urban level. The same applies to land supply, that is, the existing land-use

[2] Interregional migration is not normally understood to be a market, but in fact has all the essential properties of one with potential migrants representing demand and regions representing supply and competing for skilled tax-paying in-migrants.

pattern, at the urban level. More serious may be that, at the regional-national level, policy-relevant subsystems, such as the capital market, investment and credits, are not represented in explicit terms. At the urban level, important policy fields like nontransport infrastructure and environmental policy are not represented directly. Nevertheless, within these limitations, the diagram may serve as a fairly comprehensive representation of on urban-regional system as seen from the point of view of an urban-regional policymaker.

2.2 Causal links

Now the most important causal links and feedbacks within this model of a model will be outlined briefly using the numbering system in Figure 1.

National production by industrial sector (1) and national population (2) by age and/or sex cohorts (preferably also by nationality, occupational skill, and other classifications) may be endogenously forecast, but more frequently will be taken from national projections prepared by or for the national government; therefore it will not be of concern here how these projections are generated. Given sectoral productivity forecasts (3) and assumptions about the future labour force participation (4), changes in national employment or unemployment rates (5) can be derived, and these together with assumptions about union-industry relations may give rise to forecasts of wages, unemployment benefits, savings, and spending at the national level (6) - but all this, too, may be endogenous to the model.

We next ask, following the top-down convention, how growth or decline of industrial sectors as predicted at the national level will affect individual regions. Here the prediction of interregional trade flows (7) by an interregional input-output framework based on nationally derived interindustry linkage coefficients (8) may be one of several possible ways of answering this question, and this will, with appropriate productivity forecasts for the region of interest (9), yield sectoral employment forecasts for the region (10).

Regional employment (10) and the resulting demand for labour (11) will affect the employment-unemployment balance on the regional labour market (12) and hence regional wages, unemployment benefits, savings, end expenditures (13). These make up the most important factor of regional attractiveness - regional income (14) - and, together with other less tangible locational factors, establish the comparative attractiveness of the region for industry (15), in particular for nonbasic industries subsisting on the income generated in the region.

On the population side, a transformation of national populations (2) into households (16), the relevant economic agents, seems necessary. Households are the decision units for interregional, that is long-distance, migration (17), which is still largely employment-oriented and hence a function of income differences between the regions (18). In-migrant households plus stayer households make up the future households of the region (19), but, in addition, households change in age, income, size, etc. over time, that is, they have to undergo an 'ageing' process. The same applies to regional population (20): it changes through migration as well as through births, ageing, and deaths, and, of course, all changes of households and population need to be consistent in the model. Last, regional population (20) determines the labour supply in the region (21) and thus the employment level (12), income composition (13), total regional income (14), and the attractiveness of the region for industry (15) as well as for further migration (18).

At the urban level of the model, again total employment and total population on the next higher spatial level are the points of departure. Zonal employment (22) and zonal population (23) give rise to non-home-based (24) and home-based (25) travel demand which, subject to the existing transport supply, result in the pattern of daily intraregional freight and person trips (26). This trip pattern reflects the spatial structure of the urban system and gives rise to accessibility indicators (27) which constitute an essential part of the attractiveness of the zones in the region (28).

Future zonal employment by industry (22) is a function of total regional employment by industry (10), but also of intraregional relocation decisions of firms (29). For firms, employment must be converted to jobs (30) for which workplaces of different size and locational requirements must be provided. These represent the demand for offices, factory buildings, shops or warehouses in the urban market for nonresidential buildings; the supply may consist of new or vacant buildings (31). New industrial and commercial buildings consume land (32) and are added to the existing stock (33), which in addition undergoes processes of degradation, rehabilitation, or displacement. Changes in land use (34) affect the neighbourhood quality of a zone (35), which represents, besides accessibility (27), the other important component of the attractiveness of a zone (28). Zonal attractiveness for industry (36) is an input to relocation decisions of firms (29) and as such may lead to clustering or separation effects between groups of industries.

Future zonal population (23) is the combined outcome of demographic change and migration. Migration can be divided into intraregional migration (37) and in-migration to and out-migration from the region as predicted at the regional-national level (17). Both kinds of migration again require the transformation of population into households (38). The main determinants of intraregional, that is, short-distance, migration are changes in size and income of households during their life cycle, zonal attractiveness for migration (39),and housing supply (40). Housing supply may be new housing, in which case it has to compete on the land market with other, more profitable, land uses (41), but in large part consists of existing stock vacated by other households (42). As in the case of nonresidential buildings, the housing stock continuously changes in composition through degradation, rehabilitation or displacement.

2.3 Policy instruments

Policy instruments at the national level comprise the traditional instruments of national economic policy, such as taxes, regulations, credits, subsidies, and government consumption (A), unemployment benefits (B), and special transfers, that is, housing allowances, to certain groups of the population (C), but may also include, for instance, interventions into union-industry negotiations through wages or work-time controls (D). Region-specific policies addressing the economy include public infrastructure investments for increasing the attractiveness of the region for industry (E), technology and innovation programmes (F), or direct subsidies to certain industries in the region (G). Other regional policies may address the population of the region either through monetary incentives for in- or out-migration (H), local taxes (I), training programmes for unemployed workers (J), or direct transfer payments given to specific parts of the population in the region (K).

At the urban level, the repertoire of policy instruments to influence the economic development of the urban region is limited. Direct subsidies (L) or relocation assistance (M) given to individual firms may attract some employment or prevent the loss of some, but will not in general fundamentally change the competitive position of the region. More policy options are available to improve the residential quality of the region. Upgraded public transport services (N) or new road construction (O) may increase the accessibility of workplaces and services, land-use controls (P) and neighbourhood improvement schemes or new public facilities (R) may increase the attractiveness of residential areas, and public housing programmes (Q) may contribute to reducing imbalances in the housing market.

3 Existing integrated models

It would be unreasonable to postulate that any real model should contain all the subsystems, causal links and policies listed in the preceding section. However, every one of them has been considered important by at least some modellers and might therefore be a candidate for inclusion in an 'integrated' urban-regional model, if the word is to have any meaning at all. Hence it seems worthwhile to take a look at a few existing multiactivity urban and regional models to see which of the subsystems and interrelationships are treated in most of them and how. However, no complete review of all existing such models will be attempted here. Such reviews have been undertaken by Bolton and Chinitz (1980) for US multiregional models and by Issaev et al. (1982) in the course of an extensive survey on multiregional models at the International Institute for Applied Systems Analysis (IIASA). As far as regional models are concerned, the following passages draw on these sources. The observations on urban models are based in part on an earlier analysis (Wegener, 1982a).

3.1 Comprehensiveness

The most striking observation to be made is that to date there exist no urban and regional models that come anywhere near what has been described as an 'integrated' model in the preceding section.

Bolton and Chinitz (1980) looked at six operational multiregional models developed in the United States of America and found that none of them covered even the major components of the economic subsystem. For instance, production and consumption were both endogenised in only four of the six models. Of the forty-nine multiregional 'economic' models studied in the IIASA survey, only ten contained a 'complete' representation of the economic system such that production, employment, investment and prices or wages were endogenous (Rietveld, 1982), and in eighteen models either production or employment were not represented at all. Population was endogenous in only twenty-five of the forty-nine models, but in only four of these was population broken down into age-sex cohorts, a prerequisite for the application of biometric forecasting techniques. Only seventeen of the models predicted interregional migration flows, and only nine took account of interregional commuting. Not surprisingly, in most models the representation of the labour market was rather crude, with regional unemployment being determined endogenously in only twenty-one of the forty-nine models.

At the urban level, the situation is not much different. It is ironic that there was a, now historical, debate about 'large-scale' urban models (Lee, 1973), because in fact there never have been, and there are not today, any really comprehensive urban models. This can be demonstrated by looking at a sample of twenty-two multiactivity urban models[3].

Of these twenty-two models, only very few come close to covering all four urban subsystems represented in the lower half of Figure 1. Most models remain within the nested employment-population relationship introduced by the Lowry (1964) model, usually with a few extensions into other subsystems. Following the example of the Lowry model, all twenty-two models include a residential-location submodel; indeed it is the only subsystem present in all models. The next most

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[3] The twenty-two urban models were in chronological order: Lowry (1964); Garin (1966); EMPIRIC (Hill, 1965); NBER (Kain et al., 1976); Berechman (1976); Boyce (1977); Los (1978); TRANSLOC (Lundqvist, 1978); ARC (Geraldes et al., 1978); ITLUP (Putman, 1980; 1983); TOPAZ (Brotchie et al., 1980); LILT (Mackett, 1980); Toronto (Said and Hutchinson, 1980); Turin (Bertuglia et al., 1980); MRRM (Oguri, 1980); SILUS (Mehta and Dajani, 1981); Brussels (Allen et al., 1981); Choukroun and Harris (1981); Anas (1981; 1982); Beaumont et al. (1981); Dortmund (Wegener, 1982b); Merseyside (Madden and Batey, 1983; 1986); Tokyo (Nakamura et al., 1983).

frequent activity modelled is retail and/or household=serving employment, which is endogenous in seventeen of the twenty-two models. That is somewhat surprising as these sectors make up only a relatively small fraction of total employment, but may be explained by the fact that well-known model types exist for modelling retail and household-serving employment. Models for locating nonservice employment are contained in only twelve models, which means that in the remaining models the location of basic employment has to be provided exogenously, as virtually all residential location submodels in the sample rely in some way on the work-to-home spatial relationship.

Perhaps the most starling result of the analysis is that only a minority of seven models take the ageing of the population and/or the formation of households into account, and only three models explicitly model migration. However, the increase or decrease of population and changes of households in times of income and size during their life cycle largely determine the volume and composition of the demand for housing in the region. So it is not surprising that only nine models of the sample have an endogenous housing-supply submodel. To have no such submodel means either to assume that housing is perfectly elastic to demand changes or to specify the housing supply exogenously. if the number of vacancies in the housing stock is low, specification of the housing supply may eliminate the need for a residential model altogether. If, however, a housing supply model is present, a kind of land-use accounting framework seems to be necessary, as scarcity of vacant buildable land is one of the major forces behind the spatial deconcentration of contemporary urban regions. Yet there are three models in the sample, which have a housing-supply model, but no land-use submodel. A similar critique may be applicable to the ten models which contain an employment location submodel without taking the supply of industrial or commercial land into account. Only four models explicitly model nonresidential buildings, although these may in certain parts of to an urban region by far outnu8mber residential buildings.

If we recall that this category of urban models was originally described as land-use transportation models, the treatment of the transport subsystem in most of them is disappointing. Seven of the twenty-two models have no endogenous transport submodel at ll (some of them use fixed travel times or cots as input); of the remaining fifteen models only eight distinguish more than one mode. However, in ten models, congestion in the transport system is endogenous, which seems to be a misdirection of effort if the rest of the model is rather crude. In only two models is car ownership – one of the most important driving forces of spatial development – endogenously determined as a function of household income.

The last observation points to a common weakness of the majority of urban models: their general lack of economic variables and relationships, namely of prices and elasticities. Housing prices and rents are endogenous in only eight models, land prices in seven models, and rents for industrial or commercial buildings in only one. In line with this obvious lack of interest in the economic side of urban development, in most models, household incomes, if present at all, are exogenous. Only four models contain a representation of the regional labour market, of labour force participation, and of their combined effect on unemployment and household incomes.

3.2 Feedback structure

Even if there exist no really integrated urban and regiuonal models to date, many efforts have been made to link individual subsystems of the urban-regional system, and this has been an area of important theoretical and technical advances. Some of them are summarised below.

One line of development started from the original spatial interaction model as formulated by Wilson (1967) in the framework of entropy maximisation. Used as a transport model, the spatial interaction model predicts transport flows between origins and destinations. Used as a location model as in the

Lowry model, it predicts an equilibrium combination of flows and locations. The latter application has been the starting point for a number of generalisations and extensions aimed at consistently linking two or more subsystems of the urban-regional system by embedding it into a nonlinear constrained optimisation framework. The general idea is to formulate the relationship between the two subsystems as constraints of one process on the other and the solve the spatial interaction model under these constraints. Examples of this kind of integration effort are models linking transport and location (Boyce, 1977; Los, 1978) or models inking two or more urban activities (Brotchie, 1978; Coelho and Williams, 1978; Sharpe and Karlqvist, 1980; Leonard, 1981).

A second important stream of integration approaches is connected to input-output analysis. Starting from Garin's (1966) matrix formulation of the Lowry model, there have been various efforts to develop Lowry-like allocation models in a linear input-output format (for example, Broadbent, 1973; Macgill, 1977; Batty, 1983). Of the operational models of this kind, the multiactivity disaggregated input-output model by Echenique (Geraldes et al, 1978) and the spatially disaggregated versions of the activity-commodity framework proposed by Madden and Batey (1986) seem to be the most interesting. Other recent approaches in this spirit are the multiregional model of Schinnar (1976) and Gordon and Ledent (1980).

The above approaches have in common that they are 'all of one kind', that is, one type of equation, or one algorithm, is used to represent the whole system modelled. Hence for these and similar models the term 'unified' multiactivity models has become common.

In strong contrast to the modelling philosophy aimed at a unification of formerly heterogeneous modelling approaches, another modelling strategy has been followed by many modellers working in the field of empirical model application. This strategy postulates that each subsystem should be modelled with the most appropriate, that is, most specific, model type available, and, as most subsystems have a different structure, the resulting model types are different. Models constructed along the lines of this modelling strategy will here be called 'composite' models.

A well-known urban model of the 'composite' type is the urban simulation model developed at the National Bureau of Economic Research (Kain et al, 1976). This model contains a considerable number of submodels such as demographic, job-change, household-formation, new construction, housing market, and rent-formation submodels, and each of them is modelled in an entirely eclectic fashion using whatever available theory or modelling technique appeared to be best suited for its specific purpose. So the model contains, besides various econometric submodels, a probabilistic microsimulation part, a choice part employing logit demand functions, and a programming submodel for determining the spatial allocation of housing demand to housing supply. Further 'composite' urban models are, among others, the ITLUP (Integrated Transportation and Land Use Package) model (Putman, 1980; 1983), the Toronto model (Said and Hutchinson, 1980), the LILT (Leeds Integrated Land-use Transport Model) model (Mackett, 1980), the Dortmund model (Wegener, 1982b). and the Tokyo model (Nakamura et al, 1983). Of the regional models, perhaps the best known 'composite' model is MIMUS, the Multiuniversity Integrated Multiregional Model of the US (Lakshmanan, 1982), a cooperation between five US universities directed at linking a national economic model with an investment submodel, a labour-market submodel, an industrial complex submodel, a population submodel, and a transportation submodel in a common modelling framework.

Composite modelling approaches have the great advantage of much more flexibility in the choice of variables, relationships, and modelling techniques. However, they have to solve the additional problem of consistently exchanging information between the submodels. Typically, the submodels contain systems of simultaneous equations, for example, optimisation procedures, within their boundaries, which are designed to be executed only once during a simulation period. However, each of these submodels is connected with at least one other submodel, mostly by a two-way link. This is particularly true for the transport submodel, which is bidirectionally connected with most other submodels. Moreover, several submodels operate on the same model variables at different times during the simulation period. One example is a household formation model which changes the composition of households in a zone, but so, in a different way, does a residential location or a housing-market submodel. Land use is another example, since all other activities need land and in fact compete for it where it is scarce.

So the decision of the model builder about the sequence in which to process the submodels of a multiactivity model may be crucial. To decide that submodel A is to precede submodel B means that A has priority access to scarce resources, for example, land, but will know what is going on in B only in the next simulation period. Conversely, B may get less from the scarce resources, but can utilise the results of A immediately. By his or her decision on submodel sequence, the model builder in fact decides on the implicit lag structure of the model. Such problems do not arise in 'unified' modelling approaches which in the way they are defined guarantee consistency in all their parts at all times. However. this advantage has to be paid for by the rigidity and uniformity of the structure which may be suited for many, but not for all, phenomena relevant to urban and regional policy-making. Besides that, some of the most exciting recent theoretical and technical innovations in urban and regional model building, connected, for instance, with dynamics, bifurcation, the simulation of microbehaviour, or the theory of search, have so far occurred outside the unification paradigm, and it still remains to be seen how much of this innovative potential can be amalgamated into the unified methodology. Moreover, unified models are, by definition, monolithic and hence tend to be large, and this is in conflict with the practical requirement of having small transparent modules that have clearly defined interfaces, can be developed and tested independently, and later be assembled to more complex hierarchical model structures.

3.3 Policy analysis

Since according to their authors virtually all urban and regional models studied were eventually designed for policy analysis, it is fair to ask what kinds of policies can in fact be investigated using them. Obviously, to forecast the impacts of a policy with a model, the model has to include Integrated forecasting models that policy among its input variables; however, it may also be sufficient if the policy can in a plausible way be transformed into a model variable which is not normally a policy variable (Bolton, 1980b). In contrast, arbitrary manipulations of input variables not related to realistic policies merely represent sensitivity tests of the model.

With this distinction one finds that amazingly few policy instruments currently being applied or discussed by urban or regional policymakers are actually represented in existing urban and regional models. Admittedly the analysis is limited because it is based only on the applications named by the authors of the model; undoubtedly, many modellers would claim that more policies could be handled by their models. Nevertheless, the evidence is unequivocal: the majority of existing models are more geared to forecasting than to policy analysis.

Of the forty-nine regional models included in the IIASA survey, twenty-two models explicitly contain some representation of national economic policy in the form of taxes, regulations, credits, subsidies, or levels of government spending. These policies have in common that they affect the level and composition of national production and employment and therefore may be associated with policy type (A) in figure 1. Other kinds of national policies are included in only a small number of models: four models predict the impacts of transfers to population (C), three those of wage controls or work-time legislation (D), and only two look into the effects of unemployment benefits or social security (B). On the regional level, public infrastructure investments (E) stand out as the most frequent type of policy, being represented in fifteen models. Other region-specific policies are very infrequent in the sample: only three models explicitly treat direct subsidies to industry in the region (G) or transfers to the regional population (K), whereas the impacts of technology or innovation programmes (F), monetary incentives for migration (H), local taxes (I), or labour training programmes (J) are not represented in any model. For seventeen out of the forty-nine regional models of the IIASA survey no specific policies are indicated for evaluation.

In a similar fashion the urban models also are biassed towards a small subset of the spectrum of potential policies. Of the twenty-two urban models analysed by the author, eighteen include some sort of zonal land-use control, either explicitly (where land use is modelled) or in the form of constraints on activity location (P). Second in frequency are transport policies: in fifteen models, transport supply can be manipulated in terms of time, capacity, or cost (O); of course, changes of public transport levels of service or fares can be investigated only in the eight models where public transport is present (N). Neighbourhood improvement schemes or new public facilities (R) can be entered into only three models, and only five models respond to public housing programmes (Q). Direct subsidies to new or relocating firms (L, M) are accepted by only one model, whereas one other model predicts the effects of subsidies or taxes on the regional level (G, I). other models show the effects of changes in the national legislation on taxes, social security or other transfers, or on land prices or rent controls (A, B, C), but none of these policies is represented in more than one model.

Many other manipulations of model inputs reported in the literature, such as variations in the regional growth rate or redistributions of certain segments of employment or population in the region, although they may be useful as scenarios, represent sensitivity tests rather than policy alternatives, as these changes are not at the disposal of local, regional, or national policymakers.

4 Conclusions

No straightforward consequences can be drawn out of the observations made in this paper. It has been shown that there exists little agreement between what it might be important to know about an urban or regional system from the point of view of a policymaker and what is actually treated in most existing models. Even models that claim to be integrated models lack either essential submodels or essential causal links between them, or both. It follows that the integration of subsystems in multiactivity urban and regional models is still a largely unresolved and widely neglected problem.

Moreover, it has been shown that there exist in parallel two conflicting modelling philosophies with respect to the building of integrated models, one directed towards unification and the other towards specialisation of model structures. Both strategies have their advantages and disadvantages, and it is impossible to make a judgment at this time as to which of the two will be more successful. However, the dominant impression derived from the analysis is that the task of building integrated urban-regional models has been too large in the past to be successfully tackled by a single researcher or research group. If integrated models of urban and regional systems are a worthwhile goal, more effective forms of cooperation between specialised research groups working at different places seem to be a necessary condition for further progress.

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