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Abstract: As urban systems are complex systems, their further evolution cannot be merely a linear projection of the most recent trends, nor can it be taken for granted that the future will replicate what happened in the past. Nor can we reliably predict the evolution of European cities by looking at those in North America. We have developed a new theory, at a conceptual level, which can not yet be entirely formalised in a mathematical way but which can be experimented with agent based simulation models. We present here the main principles of the conception of the model and the first results of its experimentation. Our ambition is first to reproduce the evolution of urban systems in different parts of the world, second to use this validated tool for exploring the future evolution of cities under a variety of hypothesis about changes in the local or global context.

Introduction

Based on historical observations, we have built a general computer model (SIMPOP2, coming after SIMPOP, see Bura et al., 1996) to help exploring the fundamental process of urban self-organisation and growth, and to derive predictions about the future of urban systems (Bretagnolle et al., 2006). In our model, we represent urban systems as subsets of cities involved in a multiplicity of exchanges, through the different networks that use them for a variety of economic, political and social functions of operation, management or control. For instance, a city supplies services to its surrounding region and produces manufactured goods which are sold to other cities in a broader network. The city innovates by creating a new function or by deciding to adopt one by imitation. The model suggests that the spontaneous appearance of new innovation, which can be a new technology (the tramway in 19th century, the automobile in 20th century) as well as a new social behaviour (the invention of tourism at the end of 19th century, its democratisation during the second half of 20th) have a particularly strong influence on how cities grow and evolve. The model will be calibrated on urban systems for different countries in the world. Results of simulation help to understand how the urban hierarchy is linked to the hierarchical diffusion of innovations, as well as to the improvement of transportation technologies, and to make scenarios configuring the future cities hierarchies and networks according to the growing impulses of globalisation as European integration.

1 The evolution of urban systems

We define urban systems as subset of cities which are submitted to the same general constraints (whatever they are, political, legal or economic and cultural, or stemming from the same limited resources) and whose evolutions are interdependent because of the many interactions that link cities together. (Geographers would call this coherent envelope a "territory"). For long historical periods, this frame which is relevant for delimiting systems of cities can be a national state (as it used to be the case for the last two centuries), but it may encompass a continent, or even the whole world in the case of certain cities. We briefly extract a few salient features of the urban dynamics, which also is an historical evolution, before explaining how we can model it.

1.1 After the urban transition

We want to develop a model which can be useful, not only for reproducing the past evolution of urban systems, but as well for helping to make predictions about them. We have to be aware then of the specific context in which this future evolution has to be conceived, as compared to the previous trends in urbanisation. The 21^{st} century opens a new stage in the history of systems of cities: the urban transition which in two hundred years completely transformed our way of inhabiting the planet, from a scattered and rather homogeneous rural settlement system into a very concentrated, hierarchical and heterogeneous urban system, is now over. What future can be expected for cities in developed countries, where there is no longer migration from rural areas or local demographic growth for sustaining the cities development? Will population and activities continue to concentrate in the largest metropolises? Are the small and medium size towns condemned to decline and disappear, as did so many villages in the past? Both trends are suggested by our accumulated knowledge about past urban dynamics, but we should think of possible reversals that may happen because of completely different processes. Among the most frequently remarked potential changes are: the demographic recession (population growth rates have been above plus 1% per year for two centuries, they have become negative in some countries); the preoccupation for environmental quality and preservation of resources may hamper the further development of large cities; new technologies for the circulation of information may change the relationships between the conception of cities, as places of work and residence.

Reversals in dynamics also could come from outside: as the urban transition is continuing in developing countries, with unprecedented urban growth rates, very large cities are becoming more and more the specificity of the urban systems in poor countries. In parallel, the globalisation of the economy and of social information is developing new networks and increasing interdependencies between cities in the world. The disequilibrium between the hierarchy of city sizes according to their population and according to their gross product or income is obviously not sustainable over very long periods of time. So if the laws of urban dynamics which we mention below are useful for validating an urban model, according to an acceptable representation of the past, they will have to be adapted and revised before using it as a predictive tool.

1.2 Two laws of urban dynamics

In every urban system there are very large differences in city sizes, of several orders of magnitude, as measured by the total population they concentrate, their surface, or their economic gross product. Statistics are most often given for population figures. The number of cities is in inverse geometrical proportion of their number of inhabitants, as summarized by Zipf in his famous “rank size rule” (1941). This hierarchical differentiation within system of cities is an emergent property which characterizes the organisation of urban systems. This emergent property which is observed at the macro level of systems of cities is produced by the multiple interactions which occur between individual towns and cities. The fact that a town or a city maintains over time its size within a given proportion of the other cities’ size, that the spacing between cities is more or less regular and that over long time periods there is a rather consistent persistency of the hierarchical order, cannot be inferred from the nature and function of one single city. One has to search for processes which are able to explain this emerging property at the macro level of the urban system according to the *rules of interactions* occurring at the meso level of individual cities.

This has been interpreted in many models by simulating the competitive growth process, which represents both the dynamics of each town and the resulting statistical aggregate under the form of the distribution of city sizes. For instance Gibrat's model has been tested in many empirical studies (Robson, 1973, Pumain, 1982, Guérin-Pace, 1993). However, the demonstration in these models is statistical and non spatial. Interactions between cities are neglected in these stochastic statistical models. We have formalised the complex dynamics of spatial interactions which are resulting in the growth process, including reversal of influence over time according to the definition of neighbouring places by a simple modular model (Page et al., 2001). The relations between cities mass and spacing, and their evolution over time, have been studied by Anne Bretagnolle (1999) who demonstrated how urban interactions are regulating the relative size of the elements within an urban system, according to the speed and intensity of spatial interactions. The hierarchisation is produced from the bottom by the short-circuiting of smaller intermediary centres linked with the process of space- time convergence, and from the top by the various processes of hierarchical diffusion of the innovations in the urban system (Bretagnolle et al., 2000 and 2002).

A link is established then with the second main structural property of urban systems, which is their qualitative socio-economic diversity, as expressed in typologies of the functional specialisation of towns and cities, which lasts without major changes in general for several decades. This slow dynamics of relative change in the interurban division of labour is produced through small deviations in a general process of diffusion of socio-economic changes, which is a much more rapid dynamics. According to that very incremental process of interactive adjustments, all cities are transforming in more or less the same direction and intensity in the phase space of activities, as illustrated for French cities during the period 1962-90 by Fabien Paulus (2004). Such a result introduces a way for generalising central place theory in the broader framework of an evolutionary theory of urban systems (Pumain, 2000). Urban hierarchy and functional diversity are emerging properties stemming from a co-evolution process of towns and cities, which are co-operating and competing for the access to socio-economic innovations, by trying to capture better relative positions in spatial and social networks. One method for testing the hypothesis of this theory is to translate them as rules of interaction between towns and cities in a simulation model.

2 The SIMPOP model

A first version of SIMPOP model was designed in collaboration with the research group of J; Ferber (1995). The ambition of this first prototype was limited to the simulation of a few theoretical principles (Bura et al., 1996). The model had a limited number of cities (less than 400) and was roughly calibrated on the urban pattern of Southern France. The simulations allowed to demonstrate that one could reproduce the historical emergence on an urban hierarchy (over a period of two thousand years) from a set of rural villages, only when interactions could occur between them (through a market and a competition for the acquisition of urban functions) and if new urban functions (i.e. innovations) were added more or less continuously during the process. The second version of this model, called SIMPOP2, that we present here, is adapted for a larger number of agents (about five thousands of towns and cities in Europe). It also includes a better representation of the competitive interaction between cities within the model, through the introduction of two new agents which make explicit the role of the functions of innovation and governance within the dynamics of the urban system. This is a way to complete the theory of urban systems within the framework of complex systems theory, by substantiating the urban growth process in social terms.

2.1 Cities as collective agents

SIMPOP differs from most models of multi-agents systems (MAS) in two aspects. First, it is a model of interactions between urban entities, i.e. geographical objects that are defined at an aggregate level, whereas many models using MAS for simulating social interaction consider as agents the individual persons. The "behaviour" of our aggregated agents is certainly not reducible to the behaviour of individual persons, for instance as in models of cognitive economy. However, while observing empirically the evolution of cities over long periods of time, we were able to collect a number of regularities that can be summarised in stylised facts attesting of a relative autonomy, a persisting identity, and a consistent set of rules of transformation, which are enough for defining at this level a collective agent. In the first version of SIMPOP cities were simply reactive agents, using information they got on other cities by exchanging information with them, whereas in SIMPOP2 we introduced rules allowing cities to develop strategies for the acquisition of innovation, under the form of a new agent called "urban governance". This capacity becomes interesting when different scenarios of urban policies are introduced in the simulations.

Cities main attributes are their size, which is measured in two ways, first by the population it concentrates at a give date, second by the wealth it has accumulated. City size is one of the most important properties of an urban entity, because it represents the result of all its past evolution. This size is also represented in a more qualitative way by the diversity of functions that a city fulfils. We define an urban function as a set of coordinated activities which are differentiating the role a city is playing within a system of cities. Urban functions may be of a political nature (as national and regional capitals), they can be services for the population (we call them central functions, including four hierarchical levels, as in central place theory), they also can be more specialised production functions, as those which were created by the main cycles of economic and technological innovation. We recognize in the model for Europe four main cycles which generated strong urban specialisations, mainly the development of large harbours for long distance maritime trade between 16th and 18th century, the industrial revolution of 19th century creating and developing so many industrial towns, the second industrial revolution at the turn of 20th century, the emergence of technopoles in the second half of 20th century, which can be reinforced by the contemporary arrival of converging technologies. But other economic specialisations, however marked, are more difficult to date and link to a specific cycle, as the specialisation in finance which is developing and concentrating in a few large financial centres according to a very progressive process since 16th century. The tourism functions have two distinct periods of emergence, the first one in the second half of 19th century, the second one in the second half of 20th,

The second aspect which makes our agents differ from other MAS models is that our agents are immobile, as they represent places in geographical space. However, one has to insist on the social character of the geographical space where interactions between cities are taking place. Cities which are connected by rapid trains, airlines and modern communication networks do not evolve in the same geographical space than cities which were interacting only through reduced and delayed information exchanges at the time where trips used only human walk or horses. To give an idea of the importance of this historical process, one has to figure out that since two centuries the average speed of circulation between European cities has been multiplied by 40, while urban population was multiplied only by a factor 7 and income by a factor 14. The interactions are much affected by the technical innovations in the communication systems and the increasing level of urban resources. Both modify the relative situation of elementary cities in the networks of their relational space. To translate this is our model, we have defined for each urban function a specific spatial range which represents the maximum possible distance for their interactions, and this range is evolving through time. For instance, a city operating central functions had a maximal average range of 20 km (equivalent of one day trip) before the 19th century, while this maximal range reaches 200 km today.

2.2 Two temporal scales for interactions

The objective of our model is to reproduce emerging properties of the systems of cities through simulating interactions between individual cities. In this process, we distinguish two types of interaction processes, which differ according to their degree of autonomy relatively to the modeller (they are more or less endogenous to the system) and to their typical time scale.

The first type of interaction corresponds to the main hypothesis of self-organisation in complex systems, according to which the emerging properties at the upper level are produced through interactions at a lower level. We simulate then the emergence and maintenance of an urban hierarchy through a distributed growth process of the population of cities, which is depending itself on the economic exchanges they have. At any step of the simulation, each city has a supply of goods and services which is produced by each urban function it fulfils. The quantity produced depends on the labour force which is dedicated in the city to this activity, and on a productivity which is specific to each function at that time. This available supply is offered on the market of other cities which have a demand for this product and are accessible in a given spatial range (or a network of potential customers). The production is distributed among them after a few iterations. The balance of all exchanges is computed, and the result will affect the city wealth (accumulation or reduction), the city population (growth rate with a positive or negative random factor), and the repartition of its labour force (the share of dedicated population can be reduced if the sector has unsold production, or increased if there is an unsatisfied demand). Then it is this process of exchanges on a market place which can introduce a more or less rapid differential growth among cities, according to their unequal success on the market. A city is more or less successful in selling its specialised production to the other cities (the success depending mainly on the competitive situation of cities which mutually define their local environment in a given neighbourhood, but also on various local factors as the anteriority of the exchange network, the already established city’s influence in the networks, the city size and other functions influencing its maximum range for developing exchange networks, and some unpredictable other facts represented by a random correction applied to the growth). This process of market exchanges is driving the urban dynamics at a local level and is occurring on many short time intervals, it is defined at a short time scale in the model. By transforming in a progressive way the economic profile of cities (changes in the share of labour force dedicated to each function), this process also conveys the many incremental changes which characterize the continuous adaptation of cities to diffusing innovations.

In order to capture other features of the urban evolution, we have defined another process of interaction between cities which occurs at a longer time scale. The more dramatic qualitative transformation of cities through the adoption of innovation by acquiring new urban functions is activated each time new types of functions emerge in the system of cities. This process is defined exogenously, as it would be very difficult to simulate inside the same model the emergence of new technologies which give rise to completely different economic and spatial behaviour, at a given historical time. We have to define “from outside”, what is the nature of the new urban function, as well as the parameters which govern its dynamics for all towns and cities: what will be its level of productivity and demand, and how they evolve, which portion of labour force the function will involve, what is the range for selling its production, under which spatial rules (see below, section 2.3). Of course the adoption of such innovation by cities is a slower process than the ordinary trade which they will generate. The adoption of a new function also is a competitive process between cities, which can decide to acquire it, according to their governance strategy, or receive it according to their ability to manage the function. This ability is defined in a set of rules, either according to criteria based on the previous evolution of cities, as their size or wealth, which give them different capacity to innovate, of on some specific resources which were not used until then (as coal mines, or tourism amenities), or to other selective criteria. This large scale temporal process is linked to the short time one since many selection criteria for the adoption of innovation include attributes which were generated by the past evolution of cities in their daily trade. In turn, the acquisition of a new function modifies the relative power of a city in its trade networks with other cities.

In our model, we have moreover differentiated the spatial nature of interaction according to the type of urban functions under consideration.

2.3 Three types of spatial interaction

The urban functions we have selected are not only classified according to the period of their emergence as innovation, but also according to the type of spatial interactions that they generate between cities. The *central functions* are generating exchanges which follow a rule of proximity: cities which receive information about the supply of a production as well as cities which inform about their demand are located at a maximum distance. This type of market operates then under a spatial rule which can be formalised by a gravity model. The *administrative functions* are developing their interactions inside the borders of a given territory (for instance a region or a state), since those functions are providing resources by levying taxes on the production of all cities which are located in the administrative subdivision of the city where this function is attributed. The *network functions* are defining their subset of cities providers or customers according to other rules: they can build networks including cities that are located at much longer distance and without exploring the demand of all their neighbouring cities before. Of course the spatial range for building these large networks varies according to historical time.

2.4 Multilevel feedback loops

Urban dynamics is not only made of a two level process of interactions and emergence, which would generate the properties of a system of cities from the exchanges occurring between cities. There are also important processes which are linking the organisation levels of urban systems in a different, non hierarchical way. We can give as an example for individuals or firms the fact that they can develop, from their city of residence, linkages with cities belonging to a different national or continental system, forming networks at very contrasted and multiple spatial ranges, which can be totally determinant for their own dynamics, independently of the general processes we have identified here. In our model however, we think important for the validity of simulations to consider as relevant, for the dynamics of urban system, a level of intervention which cannot be allocated to the city level or to the level of the system of cities, but which is “above” or “outside” them, although partly embedded within them. Let us call “meta” level the social institutions which generate this set of parameters or rules, which can be decisive for driving the urban evolution but cannot be considered as emanating from cities or even from the system they form. Examples of such interfering processes are the large demographic or economic trends, or types of policies which have consequences on the spatial organisation of societies.

Most of these exogenous trends or events are figured in our model through parameters or rules. However, we have managed to introduce within the model itself two of these multi-level interactions, because they create interesting feedback loops for the urban dynamics.

The first one is a feedback connecting innovation and urban growth. The general demographic and economic growth, which corresponds to the social development of a given historical period, is translated in our model by a parameter, which is an observed mean value for growth rates at each time period. This reference parameter, which is defined exogenously, as coming from this “meta level” or organisation of the society, is then modulated through a variety of rules for differentiating the ability of cities to participate to this development. The simulations demonstrate however to what extent innovation is necessary for cities continuing to develop. It is the continuous emergence of new functions which allows for maintaining the emerging properties of the system of cities. If no new function is introduced in the system, then it will degenerate in the sense that its hierarchical properties are progressively lost. So the meta level which represents the collective knowledge of a society at a given period, including a set of possible urban functions, is giving impulse to the growth and differentiation inside the system of cities. But in reality, there is also a feedback effect from the system of cities towards this meta level of collective knowledge: through their general behaviour of competition, the system of cities gives an impulse to the creation of new innovation and to the emergence of new functions. As we said before, it is still too difficult to include this creative process in a model, because we cannot predict the qualitative and quantitative aspects which characterize each innovation, but we already have introduced in our model a partial impact of the dynamics of the systems of cities on its general growth. Actually, if we introduce in the model the historically observed growth rates from the meta-level, we obtain too large quantities. We have to reduce the values of these parameters, because the model itself generates a share of the urban growth through the interactions between cities.

Another example of interaction between multiple levels is the connection between urban functions and innovation cycles. As there are attempts for connecting Kondratief cycles with the proper dynamics of economic activity, we can suggest but not demonstrate yet that there is a linkage between the periodical emergence of new urban functions and the competitive feature of urban evolution, in a context of widening spatial ranges of their activities. In a modest way, we develop and include in our model a theory which links the cyclic aspect of innovation, as translated into the definition of new urban specialisations, and the scaling properties of systems of cities (Pumain et al., 2006). Innovative activities tend to concentrate in a first step within the largest cities, where costs are higher but which concentrate the highest skills and the potential social adepts of the novelty. Once the activity is banalised, it diffuses among cities of smaller sizes and at the end of its production cycle (when other products substitute to it) the activity remains concentrated only in smallest towns, where the costs are lower. The age of activities belong to this “meta level” we have identified for summarising processes which are “above” or “outside” the level of the system of cities itself, but it is probable that the processes of competition for the invention and attraction of new functions, and the imitation of cities having already adopted them (that are part of the intrinsic “behaviour” of cities), as well as the resulting skewed distribution of concentration of many amenities in the system of cities, could be responsible for the emergence of two time scales in the diffusion process of activities inside the system of cities: a short term rapid diffusion process generates rapid and not discriminating adjustments of all cities to the general innovation, whereas cycles involving more successful but also more discriminant long waves of urban specialisation are perhaps generated by the systemic amplification of the local and temporal fluctuations of the former general diffusion process.

3 Results of simulations

The conception of the model required two years of regular meetings between computer scientists and geographers, and one year more was necessary for implementation and diverse experimentations[1]. The SIMPOP2 model architecture was realised on a SWARM platform by Benoît Glisse (computer science) and calibrated by Anne Bretagnolle (geographer and historian) according to stylised facts extracted from the data base on European urbanisation at the UMR Géographie-cités. This data base represents in harmonised definition and delimitation the evolution of the population inside coherent urban geographical entities (i.e. urban agglomerations) at 13 dates between year 1300 and 2000, including data from various sources (among which Bairoch et al., 1985 and Moriconi 1994). We underline below a few results about the relevance of our model to represent urban dynamics and to derive predictions for the future.

3.1 Calibration and key parameters

The calibrating exercise was not an easy one. In order to avoid reproducing too many idiographic details from the European urban geography, we decided to start the calibration on a theoretical map of Europe, where towns and cities are located on a regular grid (at the edges of equilateral triangles). The initial situation included the number of cities whose size was above the 5 000 inhabitants threshold in 1300 (all of them characterised by a level 1 in central functions), and among them the number of cities which already had attained a second level of central functions or had acquired administrative functions, or were concerned by long distance trade. The location of these types of cities was chosen at random (but their relative location follows the rules which are defined for each function), as well as their size which was taken randomly from a lognormal distribution whose mean and standard deviation was comparable to the observed distribution of the time. Starting from this situation, a number of parameters were chosen, in order to reproduce the trajectory of the whole system of cities until year 2000. Some values were taken according to observations, other were estimated. We distinguish among parameters those which are considered as exogenous variables (they belong to the meta level), those which are intrinsic to the system of cities (their values are first defined exogenously but can be then endogenously revised through the dynamics of the system). The key parameters are those which were most helpful for calibrating the evolution. More than three hundreds simulations were necessary to eliminate bugs in the program, to improve the theoretical conception of the model, and to adjust the simulated evolution to the observed total urban population, the rank-size distribution of cities and the evolution of the number of cities in each size group (figure 1 and table 1) with an acceptable level of error (globally inferior to 5%).

Three key parameters had to be simultaneously adjusted for reproducing the observed evolution of urban population and the reinforcement of urban hierarchy over time (table 2). Each of these parameters take the same value for all cities at a given time of the simulation, they are used for modulating the growth rates of individual cities which depends on their trade with other cities. The share of exogenous growth represents the proportion of the value of the meta variable "average urban population growth" which can be injected in the model for producing the desired growth of city sizes. The market return on urban growth defines the

[1] The conception was supported by two research programmes of the European Commission, TIGRESS (for EUROSIM) and ISCOM (for SIMPOP2). Other participants included Cécile Buxeda, Jean-Marc Favaro, Hélène Mathian, Fabien Paulus, Lena Sanders, and Céline Vacchiani-Marcuzzo.

supplementary growth rate which is produced in a city by a successful balance of its exchanges. The attraction of labour force represents how the city labour force involved in a particular urban function will react to a positive or negative balance of trade.

Figure 1

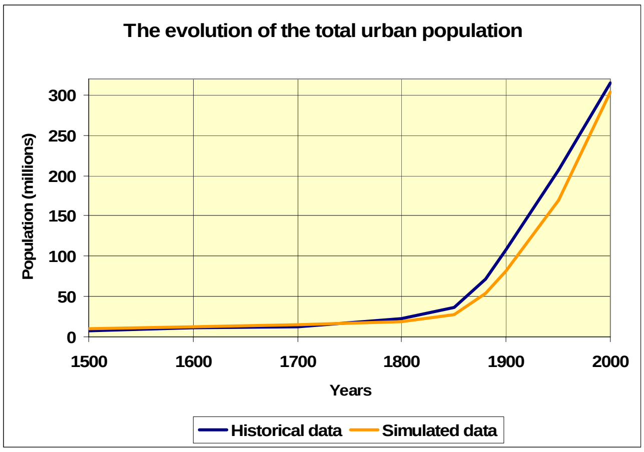

Table 1 : Number of cities observed and simulated aggregated in size groups at three dates

Number of inhabitants	1500		1800		2000	
	Observed	Simulated	Observed	Simulated.	Observed	Simulated.
> 1 million	0	0	0	0	42	45
500- 1000	0	0	3	0	42	50
100-500	4	6	15	20	398	226
50-100	17	16	35	53	541	367
25-50	37	73	83	80	1013	697
10-25	135	230	473	406	3024	3582

Table 2 Main parameters of the SIMPOP2 model

Level of definition	Main parameters
Meta variables	Average urban population growth Average economic growth
System variables (Europe)	Maximum number of cities at each date Type, date of emergence, evolving productivity, demand and spatial range of urban functions Maximum number of cities per function
Key parameters (adjusted for calibration)	Share of exogenous growth Market return on urban growth Attraction of labour force per function

3.2 Endogenous and exogenous growth

One interesting result of the simulations is that the urban dynamics which is embedded in the model through the interactions between cities generates a non negligible part of urban growth. Three stages in the value of this parameter were distinguished for arriving at a better calibration of the urban systems evolution. In the pre-industrial stage, the estimated value is 1/2. This means that the model itself generates one half of the urban growth. During the industrial stage, the value is ¾. This means that the model needs a more vigorous external hint for reproducing the fantastic urban growth rates of this period. After 1950, the model enters in a post-industrial age and the value of the parameter stabilised around 2/3. A complementary interpretation of this evolution could help to discuss the ability of the model to represent the urban dynamics over such a long time period: before the 19th century, urban growth was very low and all historians insist on the very low frequency of long distance exchanges and the scarcity of interurban network relationships. Although our model takes this into account by allocating to almost all urban functions very low ranges, it gives perhaps too many opportunities to cities for growing through trade, compared to what has existed at that time. Conversely, the industrial "revolution" deserves really its name in changing dramatically the regime of interurban interactions, and this can explain why a larger share of observed urban growth has to be injected in the model. In a more stable configuration where growth trends are considerably reduced as it is the case for Europe since 1950, the intrinsic dynamics of the system is generating a broader share, up to one third of urban growth.

3.3 Early emergence of a new function

The model revealed the importance of another fact, which we wanted to ignore in a first stage, because it could be considered as an idiographic or local feature in urban dynamics. But we were wrong and we think now that it should be included in the model. This fact is reflecting the specific position of a few cities at the head of urban hierarchies, even in very remote historical times. During the calibration efforts, it was impossible to generate the relative observed size of the largest European cities, namely London, Paris and Napoli between 1500 and 1850, and London and Paris at all dates and still in 2000. Their actual size remained somehow inaccessible to the model, once all other city sizes are adjusted. This residual would be anecdotical if reflecting the isolated case of a particular city only. But as it concerns cities which have properties in common, namely that of owning a sphere influence which overpass the limits of the European system of cities, we have decided that it was necessary to implement a new urban function in our list. This function can be called "global control" or "system gateway" because it reflects the ability of these cities to establish many connections with other cities outside of the system to which they belong, with a relatively dominant role. This specific function, which always existed in historical time and is today attributed to the so-called "global cities" (Sassen, 1991), is responsible for urban accumulation and developments which are not commensurable with what other cities of the national or continental urban system under consideration experimented at the same time periods.

3.4 Reproduction of historical events

Once the model is calibrated according to the major historical trends, it becomes possible to use the parameters for reproducing more precisely historical fluctuations in the general evolution. This has been done successfully for simulating the incidence of historical events as the Black Pleague in the middle of 14th century (which divided urban populations by a factor two in some countries), or the pre-industrial recession which induced migrations back to small towns at the beginning of 19th century. The first event has its origin outside from the European system (but possibly linked to the opening of long distance trade roads with Asia) whereas the second one is explained mainly by extended wars (and possibly a saturation of pre-industrial urbanisation according to P. Bairoch) in Europe. Keeping the general evolution calibrated, it was possible to reproduce these two fluctuations by changing momentarily the values of two parameters: the market return on urban growth was put to zero, and the demand and share of labour force related to new functions were much lowered. Figures 2 and 3 comparing observed and simulated evolutions show how such “accidents”, of course generated from outside by an intervention of the modeller, can be however reproduced by a slight change in parameters values without modifying the general dynamics of the model.

This proves the ability of the model to simulate a variety of scenarios in a reliable way, according to exogenous events or predictable trends in the meta variables of urban systems. SIMPOP2 seems as it as a reliable and useful experimentation tool, either for comparing different urban systems or for exploring their future evolution.

3.5 Further experimentations

Our experimentations with the model will follow two directions. We will compare the results of simulation obtained for Europe with calibrations made on other urban systems in different parts of the world: old urban systems of developing countries as India (including the external shock of colonial times), more recent urban systems in developed countries like United States of America, or in developing ones as South Africa. The data bases are already collected and adapted versions of the SIMPOP2 model are implemented. We will proceed by anticipating which parameters values have to be changed and testing these hypotheses during the calibration procedure. The challenge is to develop a relevant knowledge about which significant dynamical differences should be considered for simulating these urban systems which had so different historical trajectories.

While using the model as a simulating tool for prediction, we shall carefully explore the possible changes in context which have to be considered. We shall derive most probable trends by comparing observed past dynamics and the predictable changes in constraints and contexts which are of major influence on the system. Structural markers of different systems histories (as stage in the urban transition process, type of past governance and external shocks) have to be confronted to predicted trends in demographic and economic growth, as well as trendy changes in communication systems for socio-spatial interaction. The introduction of these structural features and changing trends in simulation model like SIMPOP can help to explore the possible futures of urban systems. For instance, we used an adapted version of SIMPOP2, called EUROSIM, for making predictions about the transformation of the juxtaposed national urban hierarchies in Europe in a single integrated European urban system, taking into account different scenarios as border effects, as well as the relative position of different countries and different city sizes within the integration process (Sanders et al., 2006).

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