Chapter 8
Innovation Cycles and Urban Dynamics

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8.1 Introduction: Urban Systems are Adaptive Systems

Urban systems are adaptive systems, in the sense that they continuously renew their structure while fulfilling very different functionalities. Many examples of adaptation in city size, spacing, and their social and functional components have been given in Chapter 6 of this book. There, we defined the structure of urban systems as a rather persistent configuration of relative and relational properties differentiating cities, which, over long periods, maintains the same cities in categories of size or socio-economic specialization. The content of these categories changes in terms of the quantitative thresholds or the qualitative attributes used for defining them at each date, but they retain the same meaning in terms of the relative situation of cities in the urban systems. Hierarchical differentiation and socio-economic specialization are the major structural features shared by all city systems. On the scale of national, continental, or world urban systems, the structures result mainly from self-organization processes, even if intentional decisions made by individuals or institutions (for instance, the choice of Brussels for the seat of many European Union institutions) may sometimes influence the general configuration.

In the present chapter, we emphasize how the process of innovation is essential in shaping the structure and dynamics of urban systems. Feedback processes can be observed, through which social and technological change occurs in every town and city, while the particular features of this propagation of innovation determine functional and size differentiation among cities. In addition, the spontaneous organization of systems of cities encourages further production of innovation. There is an incentive to innovate that stems from the very structure of urban systems. Urban systems are viewed as subsets of cities involved in a multiplicity of exchanges, through different networks that use these exchanges for a variety of economic, political and social functions relating to operation, management, or control. The exchanges that take place in these networks also convey information about innovation. While most innovations induce smooth change, without any deep structural transformation and

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only slightly affect the urban hierarchy, some of them emerge in correlated bundles, which can accelerate the hierarchization process, or even lead to the emergence of new types of cities, via specialization.

Using different examples at different times in history and in different parts of the world, we demonstrate how the urban hierarchy is linked to the hierarchical and selective process of diffusion of innovation, as well as to the improvement in transportation technologies. The dynamics of competition inherent in urban systems at once activates, and, is reactivated by, the innovation process. We also discuss the vulnerability of specialized cities and the conditions for their resilience.

8.2 Innovation and Hierarchical Structure of Urban Systems

Here, we discuss the feedback between the innovation process and the hierarchical structure of urban systems. First, we analyze how this structure constrains the propagation of innovation that in most cases takes the form of a hierarchical diffusion process. Second, we recall how this diffusion process and the correlated distributed growth process in systems of cities shape their hierarchical structure. Third, we show that the asymmetries and staggered time-lapses in this process reinforce the urban hierarchy over time by introducing a hierarchical selection within urban systems.

8.2.1 Innovation Propagation in Urban Systems: Hierarchical Diffusion

We define innovation as an invention that has become socially accepted. Innovation can be of various kinds and includes new products, or new technology, as well as new social practices, which in general are more long-lasting than mere fashions. More specifically, we define an innovation cycle as a bundle of new products, new economic activities, new professions, and the accompanying new social practices that are created more or less simultaneously over a rather short period, because they rely on the same kind of technology (such as the type of energy used or a production process). Because of the correlation between the multiple features of change, these innovation cycles may have a large impact in differentiating cities in urban systems (Hall & Preston, 1988).

Spatial diffusion of innovation is the term used to refer to the process of adopting this type of grouped innovation by cities. This process is by no means passive and spatially homogeneous. On the contrary, cities (i.e. the social entities that are stakeholders that were or are investors in these urban places, such as firms, local authorities, or private individuals) are engaged in permanent competition with other cities (i.e. with stakeholders investing or living there) for the capture of as many innovations as early as they can. Indeed, there is an economic advantage attached to the early adoption of innovation because the profits are maximum, not at the very beginning of its existence (the risks of failure and the costs of testing various options are still high then) but in the early stages of diffusion, when the prices are still high (before production processes and consumption become widespread) (Pred, 1966).

Hägerstrand (1952) was the first to formalize the propagation of innovation among towns and cities as a hierarchical diffusion process: the largest cities are the first to capture the benefit of the innovation, then the innovation filters down the urban hierarchy, according to urban size, through imitative or competitive processes: the larger cities adopting first, then the medium size cities, and later the smallest towns. The early adoption in largest cities is easily explained by the high levels of information and skilled labor and the diversity and capacity of infrastructures, that are the distinctive attributes of large cities (these attributes being themselves the result of previous successful adaptation to previous cycles of innovation, i.e. the consequence of an intrinsic historical path dependency in the dynamics of urban systems). The largest cities are those that have benefited from their adaptations to many successive innovation cycles, which explain their large sizes. As a consequence, they have also developed broader diversity of activities and attained higher levels of social and organizational complexity. These characteristics explain why they have a greater probability of developing further innovation at an early stage.

8.2.2 Innovation, Distributed Growth and Hierarchical Structure

When a city adopts an innovation (or is selected as a place to produce the corresponding goods and services), there is generally a return, including profits that are generated by the new activities, as well as indirect benefits. This process was modelled a long time ago under the economic base theory (Ullman, Dacey, & Brodsky, 1971). Urban growth is greatest in the emergence stage (because of the initial advantage associated with a new production), so that at each time period, advanced cities keep pace with innovation, draw returns from it and grow, whereas non-adapting cities grow less (or not at all). Urban growth may be translated, in variable proportions, as an increase in population or general wealth, but it can also include more qualitative aspects such as changes in human capital, acquisition of knowledge, and diversification of local resources.

In Chapter 6 of this book, we described the dynamics of urban growth in a variety of urban systems. We demonstrated that, once a territory has stabilized under political control, and towns and cities have been established until they completely fill the geographical space under consideration, the systems of towns and cities, whatever their former history and corresponding morphological features, evolve according to a common process we call *distributed growth*. Over short time intervals, there is a wide variation in city growth rates, but many seemingly random fluctuations between time intervals, so that over long periods, all cities grow at the same rate on average (Pumain, 2000). In Fig. 8.1, we illustrate how this distributed growth process, which progressively adapts the system of cities to a larger size without changing its basic hierarchical structure, is linked to the qualitative changes that occur in towns and cities because of the spatial diffusion of innovations. Paulus (2004) performed multivariate analyses on the distribution of the labour force among economic activities for 354 French *aires urbaines* observed at five points in time between 1962 and 1999. The trajectories in Fig. 8.1 connect the successive positions of the same city in the plane defined by the first two factors of

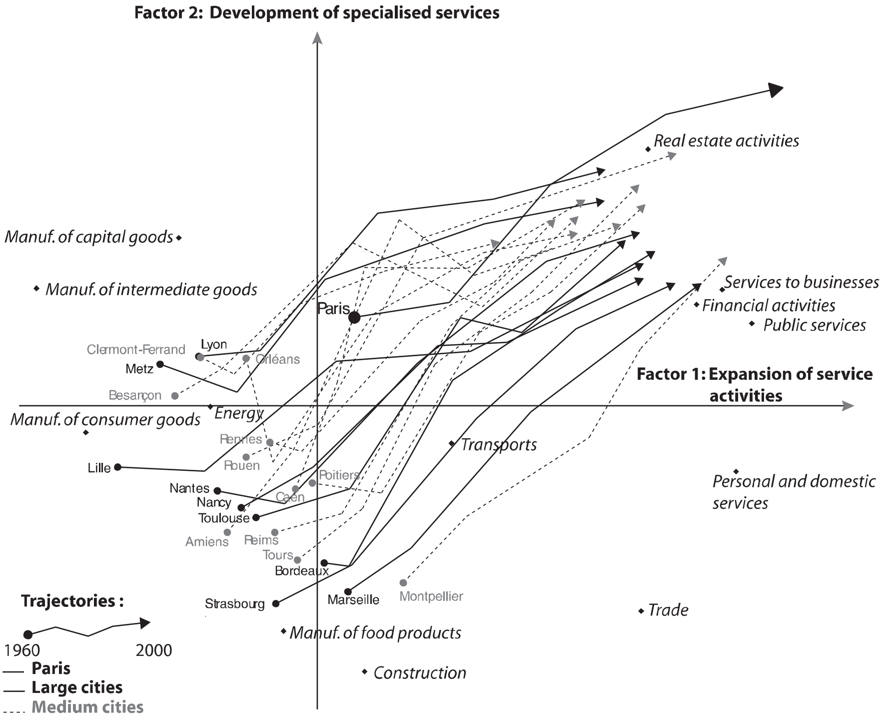

Fig. 8.1 Co-evolution of cities in socio-economic space
Source: Fabien Paulus (2004)

a principal component analysis for that period of time (for the sake of readability, only the largest cities are represented in the figure). The parallelism of the curves is striking. It shows that all cities have registered the same trends in the transformation of their socio-economic structure over that interval of fifty years, reflecting a general decrease in manufacturing activities and a transition from traditional retail and services towards more specialized business, financial, and administrative services.

Figure 8.1 thus illustrates a wide diffusion of the innovations of the time in all parts of the city system. These innovations are expressed here for economic sectors but they follow similar trends when professions or skills are considered. It is because of this general adaptation to socio-economic change that the fundamental structure of the system is maintained: as changes diffuse rapidly everywhere, the initial relative differences are not greatly modified. The diffusion of innovation not only contributes to maintaining the differentiations among cities, but it also explains why all urban systems have a highly skewed distribution of city sizes. The French statistician Gibrat (1931) was the first to demonstrate how a stochastic process of urban growth generates the hierarchical distribution of city sizes (as a lognormal distribution or "law of proportional effect"). This model has been tested many times on a number of urban systems (Robson, 1973; Pumain, 1982; Guérin-Pace, 1995; Moriconi-Ebrard, 1993; Bretagnolle, 1999; Gabaix & Ioannides, 2004) and can be accepted as a rough but rather robust first approximation of the growth distribution in urban systems. However, the most frequently observed deviations go against the hypothesis of independence of cities, since they include periods of temporal autocorrelation between growth rates and a slight trend towards positive correlation (or negative in some urban systems, especially in the US) between growth and city size. The challenge now is to find a better model for describing urban change, which includes interactions between cities, and to explore further the connection with the innovation process (Favaro, 2007).

It has also been observed in empirical studies that urban growth rates are linked with innovation cycles (Berry, 1991), involving a changing relationship with city size: at the beginning of a cycle, larger cities tend to grow faster, then growth rates tend to equalize, then small towns tend to grow faster (Robson, 1973). This last stage was even interpreted as a "counterurbanization" trend (predicting a decline or even the "end" of the largest metropolises) during the years 1970–1980, while in fact it simply marked the declining stage of the post Second World War innovation cycle (Cattan, Pumain, Rozenblat, & Saint-Julien, 1994). However, in the long run, and partly because of these time lapses and partly because of selection processes during the diffusion of innovations, the urban growth process is not purely stochastic. Some cities grow significantly faster, and others undergo relative or even absolute decay, to an extent that cannot be predicted from a homogenous stochastic model.

8.2.3 Hierarchical Selection and Reinforcement of Urban Hierarchies

The consequence of the early adoption of innovation by large cities is that they draw greater benefit from the innovation (the initial advantage), and this is translated into a persistent tendency for their growth rates to be slightly above the average of towns and cities overall. We have seen in Chapter 6 that the inequalities in city sizes increase over time, especially during periods of fast growth. This *hierarchical selection* is reinforced by the logically correlated trend of smaller towns having growth rates below the mean, either because they adopt innovation when the associated benefits are becoming much smaller or because they are never reached by the innovation. The latter is especially likely when rapid transportation modes or infrastructures are considered: it was observed for the diffusion of railways, freeways, and, more recently, high-speed trains and airports (Bretagnolle, Paulus, & Pumain, 2002). But it was also observed in the case of much older networks, using less sophisticated transportation technologies.

8.3 Innovation and Specialization: Emergence and Persistence of Urban Geodiversity

Besides the effects of hierarchical selection, a second type of asymmetry is created in urban systems by the innovation process. Sometimes, the resources for which exploitation becomes profitable are not available in every location; they give rise to *urban specialization* because the related economic activities can only develop in a few urban sites. Usually, the development of a new urban specialization gives rise to exceptionally high growth rates, as the booming cities attract migrants and profit-oriented investments. This has been the case when certain mineral resources became exploitable, such as in 19th century coalmines in the British Midlands or Belgian Wallonia, gold in California, or diamonds at Kimberley, South Africa. In this line of thinking, we should remember that several location factors that, in a deeper past, explained the emergence and success of many towns and cities are also geographical "accidents" of another kind, those influencing the layout of long distance trade routes, for instance wide valleys or topographic corridors, estuaries and bays for maritime routes, major crossroads, or contact points between different regions. Among the more recently exploited spatially concentrated resources are mountain slopes for skiing or coastlines for tourism. The places where public or private funds have been injected to create a local concentration of skill and knowledge can also be considered as nodes of possible concentration of investment and urban specialization, for instance the large universities that have generated "technopoles." The recurrence of specialization processes and their effect on cities' development explains that, over long periods, the positive correlation between city sizes, diversification of urban activities, and urban growth tends to decrease with the length of the time interval under consideration (Shearmur & Polese, 2005).

Since medieval times, less than a dozen large innovation cycles have left traces still visible today. An example in the European urban system is the existence of specialized cities (Fig. 8.2). Even if the economic cycle that gave rise to these urban specializations has been over for a long time, cities carry the marks of the momentary intensity of investments that were made at the relevant time. This is visible in their architecture and in the collective representations, what is called the "city image." Urban marketing experts use architectural and urban heritage, as well as mental connotations that are associated with the city, as a resource for developing the city's

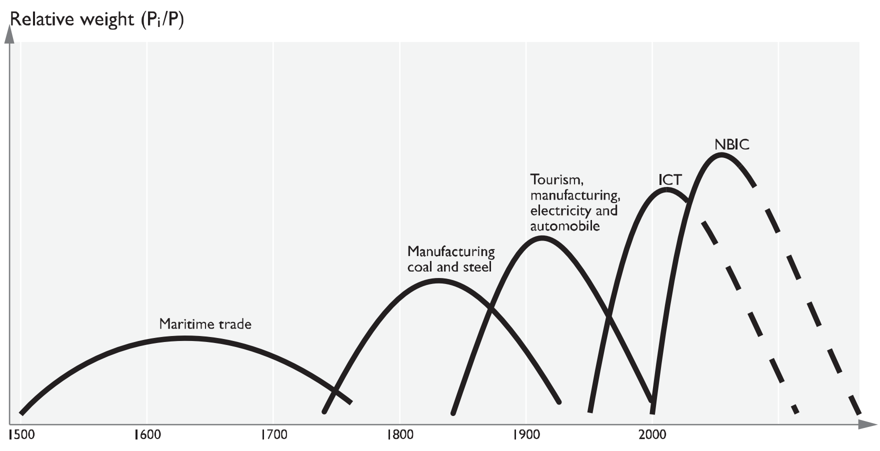

Fig. 8.2 Main innovation cycles having generated urban specialization in Europe

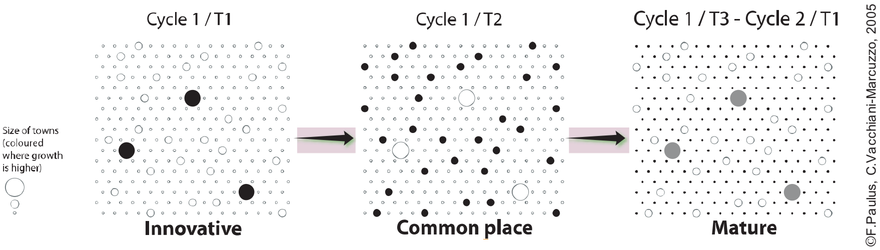

Fig. 8.3 Diffusion and substitution in the urban system

attractiveness for tourism purposes, for new types of economic investors, and for consolidating a social consensus around an urban development project (Markusen & Schrock, 2006).

Thus, urban specializations are explained partly by the unequal diffusion of some innovation cycles that are linked to spatially concentrated resources. But they may also result from the hierarchical diffusion process itself. For stakeholders, the interpretation of the hierarchical diffusion of innovation can be considered as a rational choice (in the sense of economic game theory), which is constrained by the hierarchical configuration of urban systems at a higher level. Duranton and Puga (2001) have recently explored the linkages between initial location and subsequent relocation of firms according to the industrial cycle to which they belong. Firms can only find the urban diversity that favors their learning of technologies and procedures in large cities, and they subsequently relocate to places where they can develop their activity. The costs of investment in a new product or services, which are higher in large cities (higher rents and wages), can only be borne in the first stages of innovation diffusion, when expected profits are still high; in later stages, the activity becomes profitable only in smaller towns where the costs are lower. However, this purely economic reasoning can hold only if the accompanying social potential can follow, in other words, when the required knowledge has percolated through the spatially differentiated social system from large metropolises towards smaller towns. Fujita and Hamaguchi (2001) thus explain how large cities favor innovation while relocation leads to more specialized urban places. Figure 8.3 gives a diagrammatic representation of how innovative activities corresponding to a given innovation cycle locate at first (time T1) in the largest cities, then diffuse to medium size towns (time T2), and become restricted to certain specialised small towns (time T3), while activities of another innovation cycle emerge in the largest cities.

8.4 Innovation Cycles and Scaling Properties of Urban Systems

The largest cities become larger because they were successful in adopting many successive innovations. Many of these innovations later become part of the activity of all towns and cities, since they meet needs that become commonplace (for instance, the primary and secondary education and health services in cities of the developed world today). But the functioning costs in these large urban areas are also much higher, and many activities are forced to migrate out to smaller settlements where they can sustain their economy. So at each time period, the activities belonging to a new cycle of innovation remain circumscribed for a while at that upper level of the urban hierarchy, then diffuse among other cities, then become more restricted, first escaping from the largest cities, and finally remaining concentrated in only a few small towns.

Thus at a given moment, it can be expected that the most advanced technologies concentrate in the largest cities, while current technologies are ubiquitous and outdated technologies remain only in small towns. The corresponding activities can then exhibit three different scaling parameters for a general model

$$S_{ij} = P_i{}^{\beta} \tag{8.1}$$

where the importance of economic sector j in city i (measured by employment or production) is expressed as function of the city size P_i:

Leading technologies (top of current innovation cycle): $\beta > 1$
Commonplace widespread technologies (diffusion stage): $\beta = 1$
Mature technologies (decay or substitution stage): $\beta < 1$

This model was applied to three urban systems. Our first test of the theory is based on the distribution of the labor force in 276 French urban areas (the largest "*aires urbaines*",[1] which are roughly equivalent to the American Metropolitan Standard Areas). Inevitably, the official nomenclatures used for economic activity (32 categories of the NES – *Nomenclature Economique de Synthèse*) do not always correspond exactly to historical innovation cycles: they were not designed for this purpose, even if they are revised from time to time to provide a more apt description of current economic activities (Desrosières, 1993). Because of the somewhat arbitrary aggregation of activity sectors that they give, it would be hazardous to interpret the value of scaling parameters in absolute terms. Moreover, it is obvious that the content of activities that we classify as "mature" at the level of aggregated economic sectors can be just as up-to-date, in terms of technological and managerial processes, as the diffusing or even leading activities, at the level of individual firms. What the model seeks to express is an aggregated spatio-temporal view of the whole system of cities and over very long periods.

8.4.1 Scaling and Diversity of Urban Functions

According to the theory above, the activity profile of the largest cities is expected to be more diversified than that of the smallest cities: if large cities successfully adopt

[1] There are 354 "aires urbaines." We selected the 276 largest in order to have the same number of urban units as in the case of US. The minimal size is then 17,000 inhabitants.

many innovation cycles, they will carry traces of past cycles, so that their functional profile is likely to be more diverse and more complex. In support of this, the number of employees in 20 economic sectors was collected in order to calculate a diversification index (Paulus, 2004). This diversification index D is based on Isard's specialization coefficient I, that is,

$$D = 1 - I, \tag{8.2}$$

where

$$I = \frac{1}{2}\sum \left| {}^{x_{ij}}\!/\!\left(x_{i.} - x_{.j}\right)\!/_{x_{..}} \right|, \tag{8.3}$$

and x_{ij} = employment of activity j in city i, $x_{i.}$ = total employment of city i, $x_{.j}$ = total employment in activity j, and $x_{..}$ total urban employment – I corresponds to the Euclidian distance between the economic profile of the town and the mean profile). When D is close to 1, it indicates that the city's economic profile is diversified. On the other hand, a city with a diversity index close to 0 has most of its employment concentrated in a single economic sector.

The relationship between city size and economic diversity is clearly visible from the graph in Fig. 8.4. The correlation is strong, with a coefficient of determination equal to 50%, even if variations remain. All "*aires urbaines*" larger than 200,000 inhabitants belong to the most diversified group of cities. The less diversified cities are only the small ones.

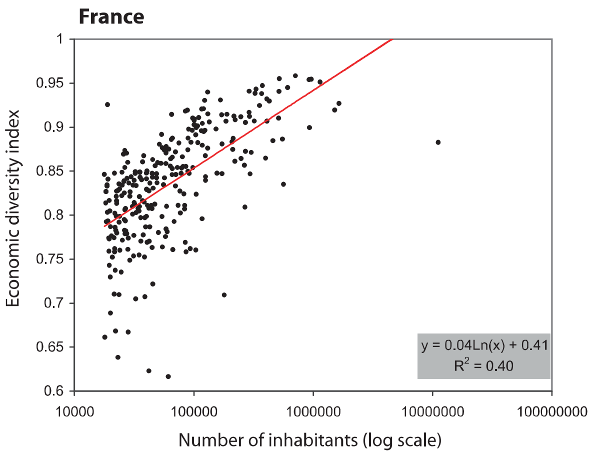

Fig. 8.4 Economic diversity and urban size. Source: INSEE – Recensement de la population, 1990

8.4.2 Scaling Parameters and Stage of Activity Sectors in the Innovation Cycle

Not only is this global indicator in agreement with our interpretation, but the same is true for the results of more detailed investigation about scaling parameters, using data on employment according to economic sector. We plotted cities according to their size (logarithm of the number of inhabitants) on the X-axis and the logarithm of the number of employees in a given economic sector on the Y-axis. To calculate the scaling exponent (β), using the least squares technique, we estimated the slope of the line that fits the set of points. This data set is provided by the last French census, in 1999.

Table 8.1 shows scaling exponents for certain economic sectors classified according to their approximate stage in the innovation cycle. Consultancy and assistance activities, as well as financial activities (Fig. 8.5) are representative of economic sectors which became leaders during the current innovation cycle and emblematic of the "knowledge society." The β exponents are well above 1. This result confirms that these economic sectors are much better developed in the largest cities and absent or tiny in the smallest ones.

Employment levels in hotels and restaurants can be interpreted as a proxy for measuring the impact of the tourism innovation cycle. Tourism emerged at the end of the 19th century, as long distance travel became faster via railway networks. This activity spread widely during the 1960s and can now be considered as a diffusing activity. The β exponent is close to 1 and the quality of fit is very good. Just a few small towns have many more employees in hotels and restaurants than the average in the urban system. These cities remain specialized.

The manufacture of food products, as a mature industry, scales sublinearly with city size (Table 8.1). This activity was an innovation a long time ago, when it replaced domestic production. Today it remains important in small towns only, and tends to account for smaller proportions in Paris and other large cities, which have

Table 8.1 Scaling parameters and stage of economic sectors in the innovation cycle (France)

Stages in technological development innovation cycle	Economic sector	Power-law exponent (β)	(β) 95% Confidence limits	R^2
Innovative	- Consultancy and assistance activities	1.21	1.17–1.26	0.92
	- Financial activities	1.16	1.11–1.21	0.91
Common place (adapting)	- Hotels and Restaurants (tourism)	1.03	0.99–1.07	0.90
	- Health and social services	0.96	0.93–1.00	0.92
	- Education	0.98	0.96–1.01	0.96
Mature	- Manufacture of food products, beverages and tobacco	0.90	0.83–0.97	0.70

Source: INSEE, Recensement de la population, 1999, 350 aires urbaines

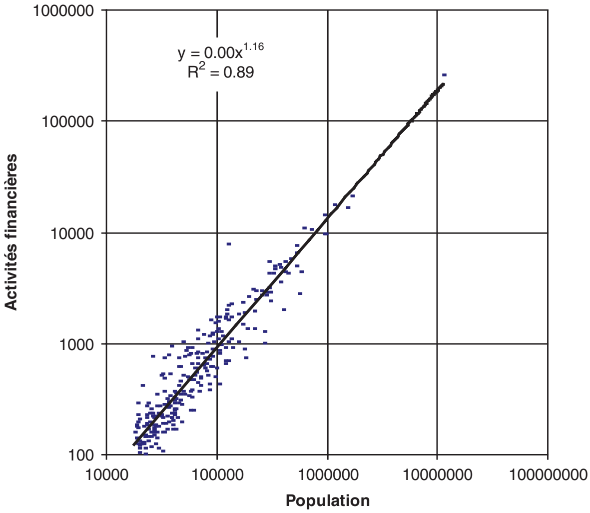

Fig. 8.5 Employment in financial activities as a function of city size (France)
Source: INSEE, Recensement de la population, 1999

been deserted by manufacturing activities since the 1960s (there can of course be other reasons, such as the proximity with places of production, for locating food production in the countryside). We could not identify any other sector scaling sub-lineraly with city size, but a much more detailed analysis of the manufacturing sector would be required: we recognize here the inadequacy of the existing nomenclature for the purpose of our study.

We compared the scaling exponents that have been calculated for the United States urban system, using, as urban units, the 276 MAs (258 MSAs and 18 CM-SAs, Porto Rico is excluded – the smallest size is 57,800 inhabitants). Employment data per sector is derived from the Census 2000, using the 20 sectors of the North American Industry Classification System (NAICS) nomenclature.[2] There is no exact match between this economic nomenclature and that used by the French statistical institute, but reasonable comparisons are possible (Table 8.2). In particular, the number of urban units and the level of disaggregating of activities are close and introduce no bias. Globally, the values of scaling exponents for similar activities are close. The economic sectors that belong to the most recent innovation cycle, including all modern business services like finance and insurance, real estate or scientific services (generally summarized as APS and FIRE), scale superlinearly in both countries with city size. The beta exponent is 1.21 for the professional,

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[2] Actually, NAICS (US nomenclature) and NES (French nomenclature) are both related to the International Standard Industrial Classification of All Economic Activities (ISIC) proposed as guidelines for national classifications by the United Nations Statistical Commission.

Table 8.2 Comparison of scaling parameters for similarly defined economic sectors in US and France

	France	United States
Professional; scientific and technical services/Conseils et assistance et Recherche et Développement	1.21	1.21
Finance and insurance/Activités financières	1.15	1.14
Wholesale trade/Commerce de gros	1.11	1.09
Administrative and support and waste management services/Services opérationnels	1.07	1.11
Accommodation and food services/Hôtels et restaurants	1.04	0.98
Construction	0.99	1.01
Retail trade/Commerce de détail, réparations	0.97	0.98
Health care and social assistance/Santé, action sociale	0.96	0.96
Manufacturing/ensemble des industries	0.92	1.0
Manufacturing/ensemble des industries sans IAA	0.95	

scientific and technical services and 1.15 for finance and insurance sector in both countries (Fig. 8.6). Common activities such as utilities, accommodation, food services or retail trade scale almost linearly with size (for instance, retail trade: 0.97 in both cases). Sublinear scaling would probably characterize some subdivisions of the manufacturing sector if details were provided for the US, as is the case using the French nomenclature of activities.

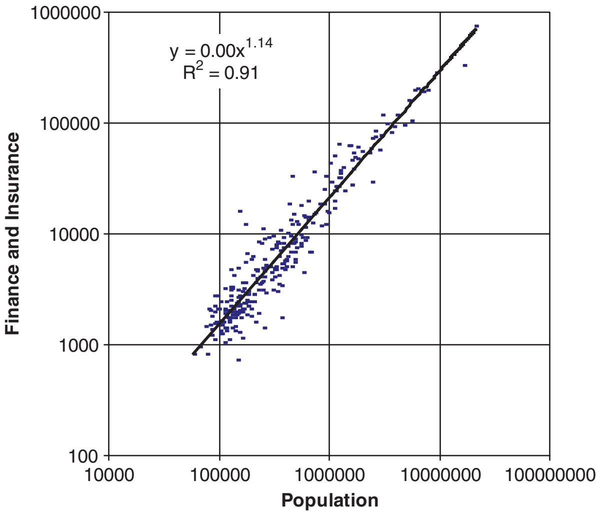


Fig. 8.6 Employment in financial activities as a function of city size (United States)
Source: US Census.

8.4.3 Scaling Parameters and Hierarchy Among Occupational Groups

We also applied the same method to occupational groups, as they are described by the French census. Following this nomenclature, it is quite easy to classify the labor force according to average skill levels. We find that the highly skilled jobs scale superlinearly with city size, whereas unskilled jobs (mainly employed workers) do scale sublinearly, and standard skills (such as teachers) are simply proportional to city size (Table 8.3).

Once again, we compared those results on French urban system with the US urban system. We used the SOC nomenclature which is quite different from the French one (PCS) as it takes more into account the hierarchy among the occupation in firms. The French one emphasizes instead the skill criterion and the homogeneity of individuals and households behaviours among social "milieux" (Desrosières, 1993). Nevertheless, we found corroborating results (Table 8.4).

We can display a synthetic view of the strong relationship between professions and city size by using factor analysis. The input tables are fairly simple: for France, it includes eight entries for urban size and five columns for occupational groups; correspondingly eight and seven for US. The less detailed classifications for professional groups are used here and for both cases. On both plots (Fig. 8.7 parts A and B), the distribution of occupations underlines the transition from small towns to the largest cities (Paris alone in the French case). The society of small towns has a concentration of many workers, whom we can consider as unskilled in terms of current technological development. Medium size towns concentrate relatively more skilled employees, such as technicians, clerks and salesmen. The largest cities, especially Paris and MAs from 5 to 10 million inhabitants in the US, house a larger proportion of highly skilled people (executives and professionals). This cross-sectional view corresponds to the historical process of emergence of more skilled activities that

Table 8.3 Scaling parameters and hierarchy of skill among occupational groups in French urban areas

Stages in technological development innovation cycle	Occupational group	Power-law exponent (β)	(β) 95% Confidence limits	R^2
Highly skilled	- Civil servant executives	1.21	1.15–1.26	0.84
	- Management and business executives	1.15	1.11–1.18	0.86
Skilled	- Technicians	1.06	1.03–1.13	0.86
	- Teachers	0.95	0.93–0.97	0.96
Unskilled	- Skilled workers	0.87	0.82–0.92	0.74
	- Unskilled workers	0.80	0.75–0.86	0.70

Source: INSEE, Recensement de la population, 1999

Table 8.4 Scaling parameters of main US occupational groups

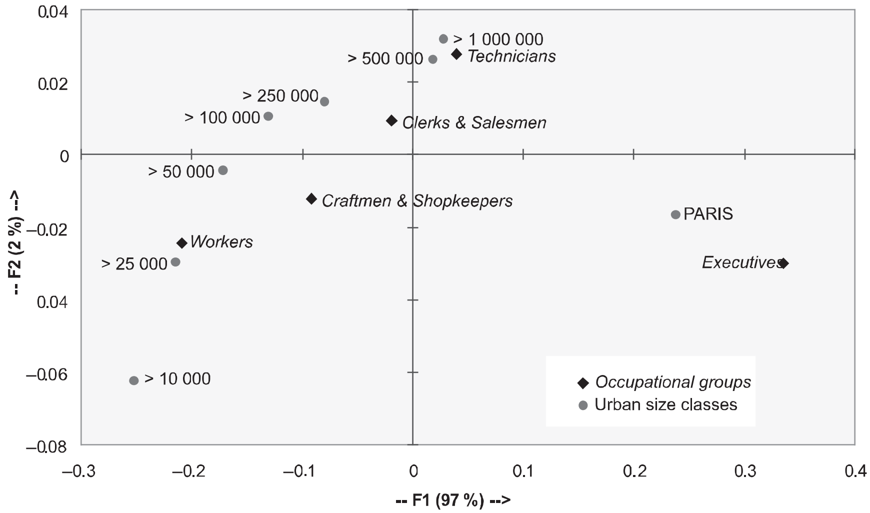
Main US occupational groups	Power-law exponent (β)	(β) 95% Confidence limits	R^2
Management, business and financial	1.11	1.09–1.14	0.97
Professional A (1)	1.16	1.12–1.20	0.92
Professional B (2)	0.96	0.94–0.98	0.97
Service (3)	0.97	0.96–0.98	0.99
Sales	1.01	1.00–1.02	0.99
Office and Administrative	1.04	1.02–1.06	0.98
Working-class (4)	0.96	0.94–0.98	0.97

(1) Computer and mathematical – Architecture and engineering – Life; physical; and social sciences – Legal – Arts; design; entertainment; sports; and media; (2) Community and social services – Education; training; and library – Healthcare practitioners and technical; (3) Healthcare support – Protective service – Food preparation and serving – Building and grounds cleaning and maintenance – Personal care and service; (4) Construction and extraction – Installation; maintenance; and repair – Production – Transportation and material moving.
Source: US Census, 2000.

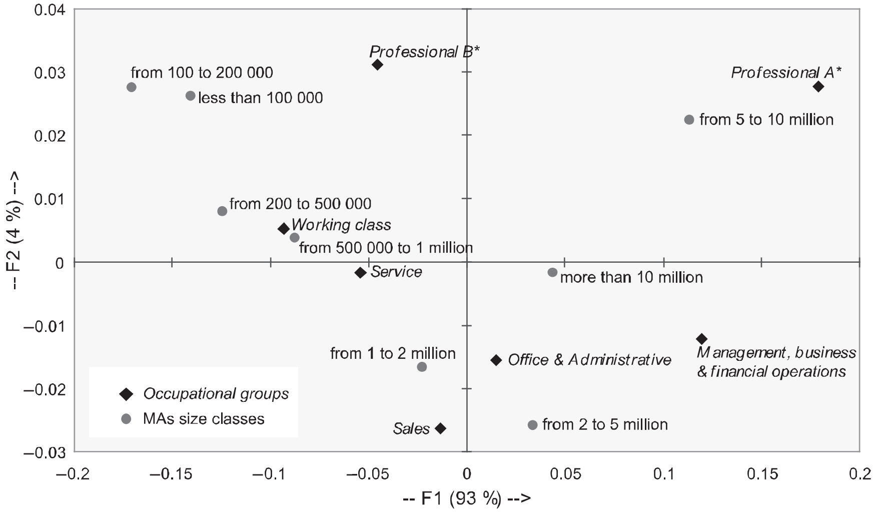
develop first in the largest cities. It represents in a synthetic way the evolutionary process of divergence of human capital levels across cities (Glaeser & Berry, 2005). Unlike the economic nomenclature where types of products change over time almost every couple of decades, more or less mirroring innovation cycles, the nomenclature of professions evolves at a slower pace. It approximates the hierarchy of social status, which in modern societies is linked to the level of skill, even if only loosely. The actual content of skill may change rapidly, while the identification of the corresponding social categories remains almost the same. That is why, unlike economic sectors, the aggregate categories corresponding to the highest skill (executives, intellectual professions), which contribute intensely to innovation, are not likely to diffuse through all cities over time, but remain concentrated in the largest. But if we envisaged professions in a more detailed way, we might find that for instance the highly skilled mechanic who constructed automobiles one by one in the very center of Paris at the beginning of the 20th century corresponds today to a worker in a decentralized plant in a much smaller town. Of course, the equivalence is not easy to establish, and the evolution is not so simple.

8.4.4 A Further Test: Evolution of Scaling Exponents Through Time

Another test of the theory consists in observing how the scaling parameters evolve over time. It can be expected that the now leading technologies can still increase their parameter value, while the activities of older cycles should have decreasing values. Using our historical database on employment per economic sector in French urban areas from 1962 to 1999 (Paulus, 2004), we explored the evolution of the scaling parameters (Fig. 8.8).



A: France; Source: INSEE, Recensement de la population, 1999.



* *Professional A : Computer and Mathematical ; Architecture and Engineering ; Life, Physical and Social Sciences ; Legal ; Arts, Design, Entairtainment, Sports, and Media.*
Professional B : Community and Social Services ; Education, Training and Library ; Healthcare Practioners and Technical.

B: US; Source: US Census 2000.

Fig. 8.7 City size classes and occupational groups (Multivariate analysis)

On the upper graph in Fig. 8.8 are represented the sectors which have an increasing or stable β exponent from 1960 to 2000. They are the three economic sectors which are involved in the current innovation cycle: a good example is research and development, where the β exponent was about 0.9 in 1962 and rose progressively to 1.2 in 1968 and 1.84 in 1999. It may seem surprising that the β exponent is

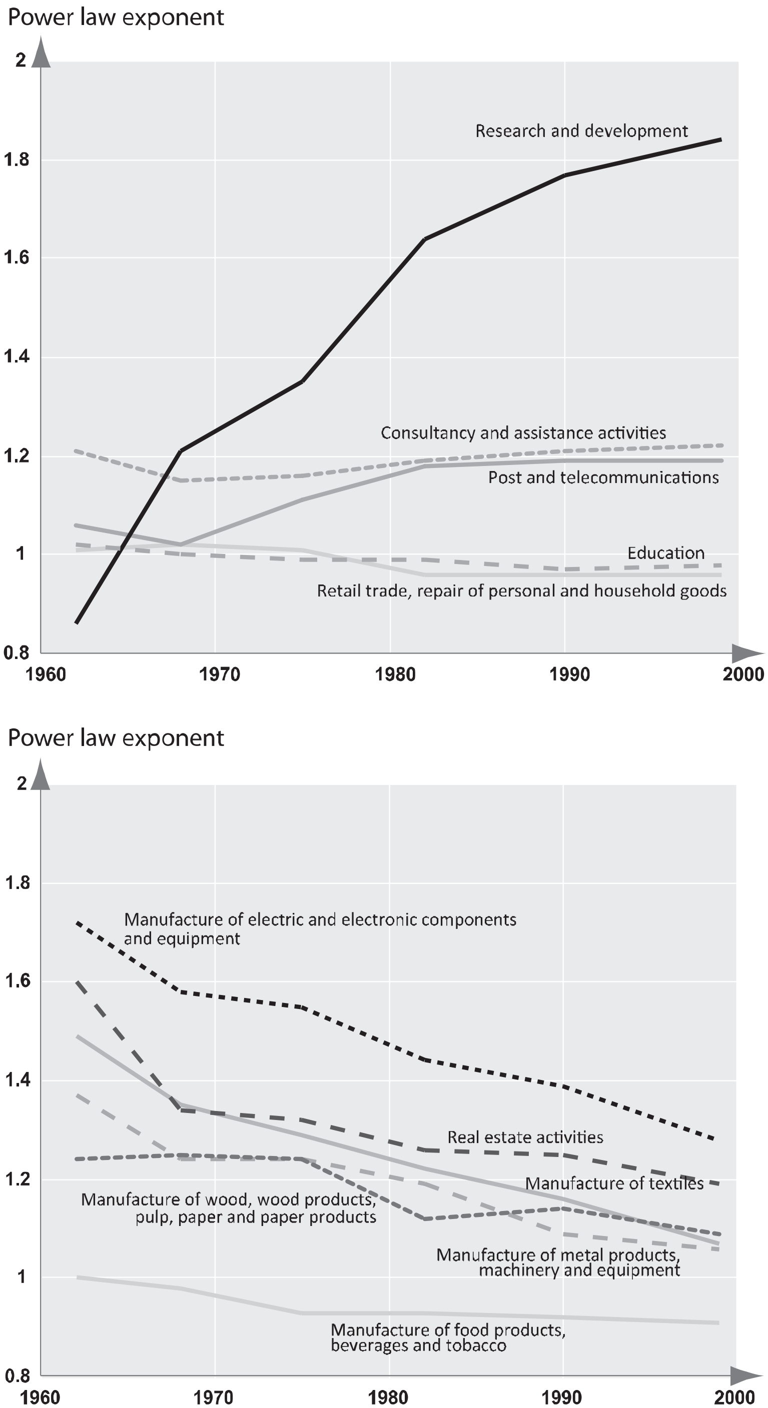


Fig. 8.8 Evolution of scaling parameters (France)
Source: INSEE, Recensement de la populations, 1999

less than 1 at the beginning, at a time when this sector began to acquire a crucial role in the production system. This can be understood if we keep in mind that, at this time, the total number of employees in this sector was very small and 90% of cities had no employees at all in this economic sector. In this context, some small towns hosting a research center could have as many researchers as larger cities, Paris being an exception. But rapidly, as this research activity became prominent in the economy, with a high rate of employment growth, the largest cities assumed a leading position. In the same context of the growing importance of the society of communication, we also notice that post and telecommunications scale at 1 in 1968 and at 1.2 in 1999. Consultancy and technical assistance activities are more stable, with a β exponent always above 1. On the same graph, education and retail trade exhibit β exponents which are very close to 1 at each date. This can be explained by their fairly stabilized function at this stage of development (although the function has frequently been renewed in its qualitative content), even if it is tempting to interpret their spatially ubiquitous distribution in a static functional perspective, as expressing the satisfaction of basic universal and elementary needs of resident populations. Such activities would probably scale non linearly in countries with a lower level of development or in earlier historical periods.

The lower graph in Fig. 8.8 represents the decreasing values of β exponents for certain economic sectors over time. Most of these sectors are manufacturing industries. This decrease can be understood as a process of hierarchical diffusion of the technological development of these industries, leading towards a higher relative concentration in the lower part of the urban hierarchy. Nevertheless, it should be noted that all these activities retain β exponents above 1. Manufacturing industries are not all mature. Diversity within these manufacturing industries is wide, with some plants that are on the forefront of the technology and some others that belong to an older stage. For example, while numbers of employees in the textile industry are falling, the value of the β exponent is also decreasing but remains above 1 (in 1962, it was equal to 1.5 and at the end of the century, its value is 1.1).

We see here the difficulty in considering that economic activities or urban functions directly reflect different stages in innovation cycles. Economic data provided by the statistical offices are not well suited to pinpointing innovations. Nomenclatures of economic activity sectors are constructed to identify products, and are periodically revised in order to categorize new, innovative productions. But this process of categorization is not systematic: some new sectors have been identified, while old sectors may remain under the same name in the nomenclature with completely new content. A good example would be the automobile industry: at first the small innovative workshops where automobiles were invented did not appear in the nomenclature under any other name than “mechanics.” Later, the category “automobile industry” was invented. Today, the category still exists, but the content of the activity has changed, involving robots and all sorts of technological improvements. Nowadays, its content covers both innovation in the production process and a long standing invention in the field of transportation technology. This can explain the poor quality of fit and the fact that the value of the β exponent remains close to 1 after having decreased.

The above point helps to decide between two alternative interpretations of the urban scaling laws. The first is longitudinal, and it considers that the model represents the relationships between the size of a typical town or city and parts of its activities at different stages in its development. The second interpretation of the model is transversal, considering it to represent the distribution of different activities among cities of different sizes at a given period. The first interpretation does not consider the diversity in functional specialization among cities, but interprets the differences in the scaling parameters as reflecting the ability of different activity sectors to adopt a spatial organization that optimizes the trade-off between the advantages and the costs of location in a city of a given size. The second interpretation acknowledges the functional diversity of the system of cities and the progressive substitution of activities at the different levels of the urban hierarchy over time. Our last result showing the evolution of the scaling parameters of certain economic sectors over time seems to support this interpretative framework. This would also remain consistent if we enlarge our observation of urban system to extend beyond national boundaries, including international division of labor and delocalization of activities with lower technological levels and fewer requirements for the skill of labor force towards countries where the production costs are lower. (But in these countries, the multinational firms, which represent an "innovation" there, locate according to the hierarchical diffusion process that we mentioned above, see for instance Vacchiani-Marcuzzo, 2005).

At first sight, our theory may appear counter-intuitive, since urban activities which scale sublinearly with city size should, as is the case among biological species for metabolic rates and size of organisms, illustrate a state of better efficiency or adaptation: they have found a mode of organization that provides scale economies. This may be true for some specific urban services such as water or energy supply. To maintain a static interpretation of this type, it must be concluded that innovative activities waste resources, since they are more abundant in the largest places. In the early stages of emergence of a new market system, many resources, both human and material, are not used in an efficient way. Nor do they need to be, given the possibility of monopoly profits. Efficiency is gained over time. Thus we prefer to support our evolutionary view, even if seemingly more complicated, rather than the more general static explanation, which cannot explain in a satisfying way all the empirical evidence we have found. Of course, more empirical testing is required to consolidate our hypothesis.

8.4.5 Innovation in Emerging Countries: The Example of South Africa

Another illustration of the generality of the theory can be provided by exploring countries that are totally different in their economic structure. South Africa is an interesting example because, as an emergent country, its economy is somehow "between" industrialized and developing worlds. There is a huge volume of literature on new patterns of international trade and division of labour between developed and developing countries, which we will not detail here. Our hypothesis is that, even if the temporality of innovation cycles is different (and probably delayed) when compared to developed countries, any economic "innovation" would adapt to the existing structure of the system of cities and diffuse downwards through the urban hierarchy of city sizes. Of course, testing this hypothesis is not easy because the existing databases do not include in their nomenclatures typologies that would be directly relevant for our theory, in terms of duration of economic cycles.

Nevertheless, Vacchiani-Marcuzzo (2005) analysed the repartition of economic sectors in South African urban agglomerations and built a database that includes 90 urban agglomerations defined according to our criteria of consistent geographical entities (morphological and functional, see Chapter 6). The South African nomenclature of economic activities for the year 2001 is aggregated in ten sectors, which cannot be perfectly compared with those used for French and American cities. Moreover, we know that the informal sector, which is not taken into account in the official nomenclature, represents a non-negligible part of the total employment (one third at least).

Despite these differences in conception, which also reveal qualitative differences in the economic structure of the country, the results of scaling measurements are interesting (Fig. 8.9). They clearly differentiate a very dynamic sector, regrouping

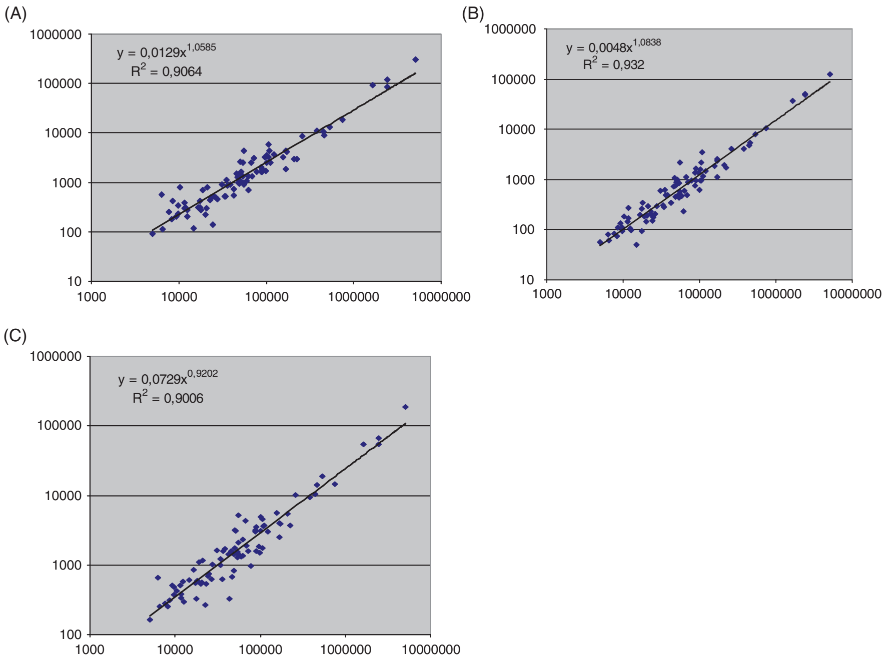


Fig. 8.9 Employment in economic sectors and city size in South Africa. **A**: Leading economic sectors – Finance, Insurance, Real Estate (FIRE); $\beta = 1.06$; 95% CL: 0.98–1.13; $R^2 = 91\%$; **B**: Leading economic sectors – Transportation; $\beta = 1.08$; 95% CL: 1.02–1.15; $R^2 = 93\%$; **C**: Mature economic sectors – Domestic services; $\beta = 0.92$; 95% CL: 0.86–0.98; $R^2 = 90\%$. Source: Data base CIS-CVM/Census of Population 2001 and Data base CVM

activities of finance, insurance and real estate (FIRE), that scales supralinearly with city size ($\beta = 1.06$), and another one, the domestic services, which scales sublinearly ($\beta = 0.92$) and represents a more obsolete part of the economy. Whereas the FIRE sector reveals that the largest South African cities participate in the economic globalization, the domestic services express a form of social organization that was diffused broadly over all the South African territory, since it corresponds to a very old type of division of labour that was effective in this country. The first process clearly selects the upper level of the urban hierarchy, while smaller towns can still be chosen as locations for very specific economic sectors such as mining industries, which in the past contributed in a very significant way to the creation of the Northern part of the South African urban system. However, the transportation sector represents a specific case: it scales supralinearly with city size with the highest slope ($\beta = 1.08$). This result may appear surprising compared to other countries such as France or USA where this sector is part of mature activities, but on the contrary, in South Africa it reveals the effects of emerging new transport networks and still booming logistic activities.

8.5 Conclusion: Innovation and Sustainability of Urban Development

We shall discuss the relationship between innovation and sustainability of urban systems in more detail in Chapter 12. We want to recall here that innovation is an essential driving force in urban dynamics. Knowledge and information, reflexivity, and the ability to learn and invent provide the impetus for urban development. The crucial role that cities have played in generating innovations – intellectual and material, cultural and political, institutional and organizational – is well documented (e.g. Bairoch, 1988; Braudel, 1992; Hall. 1998; Landes, 1999). The role of cities as centers for the integration of human capital and as incubators of invention was rediscovered by the "new" economic growth theory, which posits that knowledge spillovers among individuals and firms are the necessary underpinnings of growth (Romer, 1986; Lucas, 1988). As Glaeser (1994) points out, the idea that growth hinges on the flow and exchange of ideas naturally leads to recognition of the social and economic role of urban centres in furthering intellectual cross-fertilization. Moreover the creation and repositioning of knowledge in cities increases their attractive pull for educated, highly skilled, entrepreneurial and creative individuals who, by locating in urban centers, contribute in turn to the generation of further knowledge spillovers (Feldman & Florida, 1994; Florida, 2002; Glaeser & Saiz, 2003; Bouinot, 2004). This seemingly spontaneous process, whereby knowledge produces growth and growth attracts knowledge, as the driving force enabling urban centers to sustain their development through unfolding innovation, actually is the result of their adaptive organization. As stressed by David Lane, it is the organization of cities, that provide scaffolding structures where *knowledge* can be generated, developed, stored and accessed, and economic organizations – firms and networks of firms, as well as development agencies etc. – that carry out economic activities – production, exchange, finance and so on – which generate growth. The conceptual definition of a city is a center of organizational activities, and this fundamental functionality is generally undervalued by the advocacy of "agglomeration economies."

The two processes of diffusion of innovation and specialization have consequences on the dynamics of systems of cities. The activities that can diffuse widely through the system tend to reinforce the relative weight of the large cities, because of the growth advantage and attractivity characterizing the earlier stages of innovation, whereas the activities that focus on a few specialized towns because of some specific location factors, after boosting the development of these towns, sometimes with spectacular growth rates, then tend to hamper their further development by weakening their ability to adapt. Regarding that, predictions could be made about the threatened future of some highly specialized and valued cities, as the tourism centers of our consumption economy, which may encounter future difficulties, although in a lapse of time difficult to predict now.

The many contemporary studies on so-called "metropolization" rediscover a process that has been constitutive of the dynamics of systems of cities (Pred, 1977; Pumain, 1982) at a time when the globalization trends and the general conversion to the "information society" are generating a new broad cycle of innovations. There is an obvious relationship between the maximum possible city size of a metropolis in a given country and the population size of that country. Even if it has not yet been tested because of a lack of relevant data, the same scaling effect exists for the global urban product. Therefore, one must consider the impact of changes in the world economy at the level of nation-states when predicting the future trajectories of large cities.

The question of sustainability of urban development holds for large cities as well as for specialized ones. Watching the past, again in order to think about the future, we can illustrate how the relative weight of a city in the urban system is related to its participation, successful or not, in successive waves of innovation. On Fig. 8.10, the relative size of one city in the system at time t (on X axis) is compared to its relative size at time t + 1 (y axis). Examples were chosen for their clear connection between a city relative growth and an innovation: the trajectory of Marseilles is a growing influence linked with the development of colonial trade, then a recession followed by a recent recovery; Rouen is in continuous relative decline for the past two centuries, because of its closeness to Paris and the decline of the textile industry and harbour activities; the whole cycle of growth and decline of the motor industry explains by itself the trajectories of Detroit, and, later, Port Elizabeth, as they are both examples of extreme specialization; Durban has a more complex trajectory including, first, a prosperity stage with colonial trade (in particular, mining products from Johannesburg were exported through Durban), followed by a recession, then a recent new development of harbour activities; Dallas has been driven upward by the oil industry, whose cycle is not yet finished.

It is probable that these different evolutions will continue, within the contemporary context of globalization, no longer at the scale of national systems, but in global urban networks. The colonial period already introduced durable asymmetries

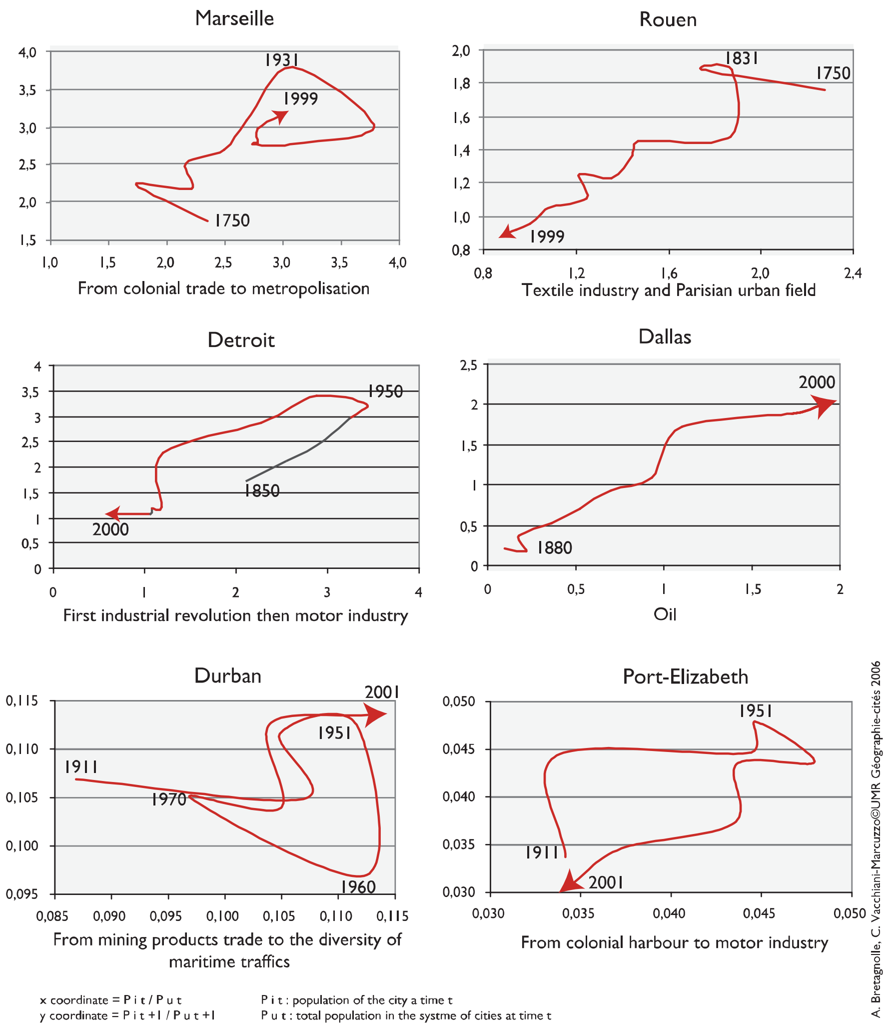


Fig. 8.10 A few examples of diverging trajectories of cities over time

in urban growth and perturbed the organization of urban systems in colonized countries. The foreign investments and the redistribution of economic activities that characterize the globalization of economies will reproduce or reinforce some of these effects. The dynamics of systems of cities will henceforth have to be analyzed at that scale.

A last important methodological and theoretical remark is about our interpretation of scaling laws in the field of urban geography. We insist that it is not a matter of disciplinary shyness or backwardness if we are reluctant to consider that there would theoretically exist something like an “average ideal city” and that “on average different cities are scaled up versions of each other” where “major adaptations must occur to reset growth under superlinear scaling to manageable levels" as assumed in Chapter 7. If we resist this "monocity" interpretation of urban scaling laws, it is not because "social sciences emphasize the richness and differentiation of human social expression" as presented in Chapter 7. Our scientific approach is not idiographic but is nomothetic, as well as the physical or biological ones. And according to our view, to be scientifically understood in their development, *cities have to be conceptually represented as elements of a differentiated system of cities*. Cities are not living only on their own resources, but from the valorization of information about distant resources that are more and more located in other cities, enhancing the social and economic power of networks. This is demonstrated by the fact that whatever their cultural, political, economic or historical context *there always are simultaneously in any given territory of the world* towns and cities of different sizes that are also functionally differentiated. Moving investment as well as social value from one city to the next is an essential part of the urban dynamics. That is why our interpretation integrates the hierarchical and functional differentiation of cities within systems of cities as a fundamental part of the explanation of urban scaling laws.

Moreover, we think that the conclusion of Chapter 7 that "it is perhaps this necessity for the city as the engine of human social development that makes man by nature a political animal" has to be reversed. It is because human beings are social animals who developed politics in increasingly large organizations that cities were invented, and that is why they remain the evolutionary expression of the political order of societies. No doubt this discussion between theoreticians of complex systems will continue well beyond the ISCOM project where it was especially fruitful. Arbitration may be provided by a closer observation of cities' past and future evolutions, using the best quality data as well as the more sophisticated methodologies of complex systems sciences.

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