and retail space, both functions that attract daylight activity, significantly increases the number of check-ins an area receives. Somehow counterintuitively, a significant and positive coefficient is associated with industrial use. This might be driven by areas that used to be industrial (and are still coded that way) but in the last years have undergone regeneration processes that have attracted many cultural activities (e.g. the northern docks across from the Central Station), strong drivers of 'check-ins'. The model seems to offer a plausible explanation for the data and capture correctly most of the anticipated effects on the levels of Foursquare activity. In addition, it captures a good deal of the variation in the data, reaching an R^2 of slightly over 0.73, which gives us confidence in the specification and in the subsequent interpretation of the effect of diversity.

The estimated effect of diversity is 0.0152 (0.1518 × 10, due to rescaling) and the coefficient is significant at the 10 per cent level. This implies that, according to our model, a unity increase in the degree of cultural diversity present in the neighbourhood induces a boost in the number of 'check-ins' of approximately 1.5 per cent. If that is the case, the evidence from this study suggests that Foursquare users positively value cultural diversity and, everything else being equal, show a preference for diverse enclaves when they check in. If we assume that this is a good proxy to measure where activity (i.e. urban buzz) is located within the city at a given point in time, we are thus stating that cultural diversity in fact does have a positive and significant impact on urban buzz, at least for the case of Amsterdam.

The results shown so far relate to a model that does not explicitly take space into account. In that context, the observations are assumed to be independent of each other, regardless of where they are located in space. However, as we have noted in Section 3, if that is not the case and the spatial scale we are using does not completely encapsulate the values of urban buzz, we might be incurring a bias when estimating the coefficients (Anselin 1988). In order to account for these spatial effects properly, we estimate[6] the spatial lag model in equation (2) via ML. There are two details that we have to take care of before delving into the results. The first one is the nature of the spatial relationships we introduce in the model through W. The choice of one or another type of matrix has to be made ex ante and, consequently, the use of W has been criticized in the literature (e.g. Gibbons and Overman 2012). In this study, we adopt a pragmatic approach and test several different specifications to ensure that our results and conclusions are not exclusively tied to the choice of W. In particular, we tried K-nearest neighbours ($k = 6$), a distance threshold and contiguity weights based on the queen criterion (i and j are neighbours if they share at least an edge or vertex). Because the estimates are very similar and the conclusions do not change, we only report the results for the latter. In addition, we always row-standardize the matrix so the spatial lag can be interpreted as the average value of an observation in its vicinity. The second issue relates to the assumption of normality implicit in ML estimation, as reliable estimates are only to be obtained if this condition holds. The bottom of Table 1 shows the Jarque–Bera test of normality, which takes the null of a normal distribution in the OLS residuals and, if rejected, can be taken as

[6] All the computations relating to spatial methods in this paper were performed using the Python library PySAL (Rey and Anselin 2010).

a sign of a problem. We obtain 1.711, which we cannot reject, leading us to conclude that ML is an appropriate estimation method for our model. Finally, in order to reinforce our choice of a spatial lag specification, the very bottom of the table shows the results of the LM diagnostics of spatial dependence, which offer guidance on the spatial data generating process (either a lag or an error, see Anselin 1988 for more details). When using the more reliable robust version, the indication is clear towards a spatial lag process.

The spatial lag results are reported in the second column of Table 1. The general conclusions of the model point in the same direction as in the OLS case since no sign or level of significance is greatly affected. However, it can be seen that the coefficients are in the vast majority (with the exception of one significant variable) overestimated: when space is accounted for in the model, their magnitude is more limited. This is also the case with the coefficient of diversity, which is downwardly corrected from 0.15 to 0.13, but remains significant at the 10 per cent level, pointing to a significant impact of a more diverse neighbourhood on its level of buzz. The OLS upward bias is a typical result when positive spatial autocorrelation is present and highlights the importance of these methods in dealing properly with spatial effects and obtaining correct estimates. The ρ parameter, associated with the spatial lag of the dependent variable, is slightly larger than 0.4 and highly significant. This is an indication of a process of positive spatial autocorrelation whereby neighbouring observations tend to have similar values.

Table 1. Results for the aggregated volume of *check-ins*

	OLS	ML-Lag
Foursquare – Arts and entertainment	0.0285*** (0.008)	0.0158** (0.007)
Foursquare – College and university	-0.0104 (0.012)	-0.0063 (0.010)
Foursquare – Food	0.0208*** (0.006)	0.0132*** (0.005)
Foursquare – Other	0.0121*** (0.003)	0.0128*** (0.003)
Foursquare – Outdoors and recreation	0.0171** (0.008)	0.0093 (0.007)
Foursquare – Professional and other places	0.0129** (0.005)	0.0099** (0.004)
Foursquare – Travel and transport	0.0138** (0.006)	0.0134*** (0.005)
Industrial use	0.0184** (0.008)	0.0217*** (0.006)
Office use	0.0339*** (0.008)	0.0224*** (0.006)
Sports use	-0.0271 (0.030)	-0.0213 (0.024)
Retail use	0.0187 (0.032)	0.0408 (0.026)

		OLS	ML-Lag
Total venues		0.0209*** (0.006)	0.0138*** (0.005)
Total units		0.1853*** (0.036)	0.1737*** (0.030)
Diversity		0.1518* (0.080)	0.1267* (0.065)
Constant		2.1549*** (0.524)	-0.0511 (0.670)
P			0.4399***
	R^2 *Jarque–Bera*	0.735 1.711	
	LM Lag Robust LM Lag LM Error *Robust LM Error*	20.8748*** 12.0798*** 8.9422*** 0.1472	

**** Significant at 1%, ** significant at 5%, * significant at 10%, insignificant otherwise. Standard errors are shown in paretheses below the estimates.*

'Total units' and 'diversity' are rescaled to avoid multicollinearity issues by pre-multiplying them by 0.001 and 10, respectively.

The last piece of the analysis comprises an exploration of the granular temporal dimension of the Foursquare data. We set out to study how the impact of cultural diversity varies across the time of the week. For every neighbourhood, we disaggregate the number of check-ins by the time of the week and rerun different models of equation (2) using the volume of activity in each time slot as the dependent variable. The following times of day are considered: morning (5 a.m. to noon), weekday afternoon (noon to 6 p.m.), evening (6 p.m. to 10 p.m.) and night (10 p.m. to 5 a.m.). Each of these is further divided between weekday (Monday to Friday) and weekend (Saturday and Sunday), resulting in eight different times of the week. Figure 2 displays the ML estimates[7] for the coefficient of diversity for each time of the week, along with the 95 per cent confidence intervals. The effect is lowest on a weekday morning and grows over the day to reach its peak during the night of a weekday. Over the weekend, the effect decreases a little in the morning but picks up again during the evening and night. Except for the weekday mornings, they are all significant at the 5 per cent level. This pattern is very much consistent with the idea of cultural diversity valued by Foursquare users as a consumption amenity: in typical working hours, its effect is negligible, but as the use of time shifts more into leisure and entertainment, the effect becomes more relevant,

[7] Although we only present ML estimates from the spatial model, we tested several alternative specifications, including a pooled regression, a regime regression using the time of the week as the regime variable and spatial versions of these. Since all the main conclusions remain unchanged, we only show the ML models for consistency with the previous part of the analysis. Additional results are available from the authors on request. Equally, although we only show the estimates for diversity, full model results are available.

highlighting that users particularly prefer diverse neighbourhoods for the activities they engage in at the end of the day or at the weekend.

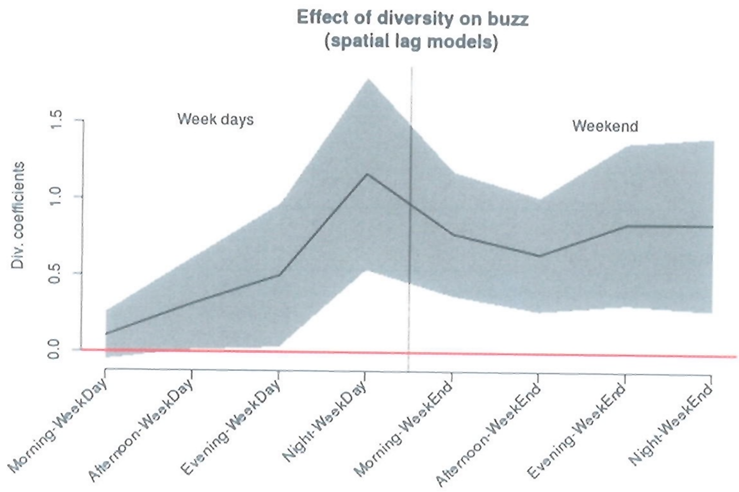

Figure 2. Coefficient estimates and 95 per cent confidence intervals

11.6 A Policy Perspective on Urban Buzz

This paper adopts a novel data set and approach to measuring urban buzz quantitatively and to studying its main determinants, with a particular focus on the effect of cultural diversity. Using data from the online location-sharing service Foursquare, we quantitatively define urban buzz as the 'check-in' volume per neighbourhood and present an empirical model for the city of Amsterdam. This includes not only a measure of cultural diversity, but also information on the availability of venues to 'check into' as well as on land use, and properly accounts for the presence of spatial autocorrelation in the buzz variable. The main results suggest a positive and significant effect of cultural diversity on the level of buzz activity that occurs in a neighbourhood. This implies that, given the same economic functions and availability to check in, a greater level of cultural diversity is associated with a larger volume of check-ins.

Urban buzz reflects the wealth-creating potential of urban areas as a result of density, connectivity and proximity advantages among the heterogeneous groups – including distinct migrant groups – that reside in modern cities. Creativity and diversity appear to be key factors in the dynamic performance conditions of such areas. What can policy do to favour such urban buzz phenomena? Urban buzz finds its genesis in urban agglomeration advantages of various kinds, and it seems plausible that policy efforts to exploit the benefits of urban territorial capital (including social, creative, entrepreneurial and innovative capital) may concentrate on the provision of conditions that favour such capital. Land use policy, educational policy and entrepreneurial stimuli may then offer promising strategic directions. Moreover, since the results presented in the previous sections point to a positive and significant effect of cultural diversity on this phenomenon, a focus from policy makers on protecting and even stimulating such characteristics of cities and neighbourhoods is an additional recommendation that derives from this study.

Especially in a European setting – where most cities house a wealth of cultural heritage that often acts as an attraction force for innovative business – due policy attention to the exploitation of historic–cultural resources as a source of economic progress would be meaningful. There is an increasing awareness in Europe that cultural heritage is not meant to craft a city in stone, but that the past can be used as an engine for economic progress, by attracting visitors, business and residents.

This study represents a first experiment to explore the usefulness of new data sources originating from the Web and how they can be employed to answer questions about the physical world. In this sense, the positive results obtained regarding the main question asked at the beginning of the paper (how does cultural diversity affect urban buzz?) should prompt more activity in the future rather than being taken as a road end. In particular, and without being exhaustive, we will conclude by suggesting three avenues that we consider especially relevant. Further research could extend the present results by looking at the components of diversity in relation to urban buzz (which particular socio-economic groups have greater participation?) and trying to disentangle the potential identification issues by including information on wages and the wage gaps between groups. An aspect that has been assumed throughout the paper but that would certainly be interesting to test empirically too is the extent to which the effect of urban buzz influences the socio-economic development of a neighbourhood. Finally, a deeper analysis of the nature of Foursquare data, aiming to delve into the intricacies and characteristics of its users as well as their socio-demographics, would also be illuminating. For all those reasons, this study should be taken as an inspiring starting point rather than as a conclusive end.

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PART D:

COMPETITIVE URBANITY

Urban competition and performance

High-performing cities

Global digital connectivity

12 A MULTI-ACTOR MULTI-CRITERIA VIEW ON GLOBAL CITIES*

Abstract

The strong worldwide urbanization trend calls for a repositioning of cities, especially large cities with a global impact. These cities tend to become economic, logistic and political powerhouses and are increasingly involved in a competition regarding their integral performance. The present paper aims to trace the extent to which and why some cities outperform others. Starting from an extensive database on many important characteristics of global cities, this paper offers a multi-criteria methodology for identifying the relative position of various important cities on the basis of distinct assessment criteria. Another novel element in this approach is the explicit consideration of the perceptions of important classes of stakeholders on the performance outcomes of the various cities involved. From a technical assessment perspective, the applied part of the paper employs the MAMCA and PROMETHEE techniques, which have proven their analytical power in various multi-criteria evaluation problems over the past years. The paper concludes with some policy perspectives and lessons.

Keywords: Urbanization, global cities, multi-criteria analysis, performance, stakeholders, MAMCA, PROMETHEE, GAIA

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12.1 Aims and Scope

In our urban century, the majority of the people on our planet will live in cities. Urban agglomerations tend to become the ultimate 'destiny' of mankind, posing unforeseen challenges for urban research and policy. In the '*New Urban World*' (see Kourtit and Nijkamp 2013), dominated by connected large cities and urban networks, our society will face serious concerns related to housing, sustainable modes of living, poverty, employment, accessibility, competitiveness and economic vitality.

Worldwide, cities are increasingly seen as engines of economic growth and sustainable development (see Nijkamp 2008). This strategic importance of modern cities – and increasingly, urban agglomerations and metropolitan areas including polynuclear or satellite areas – depends not only on location advantages (including Marshall–Arrow–Romer (MAR) spatial externalities), but also on two other types of externalities, viz. social capital externalities and connectivity externalities. The first category is described well by Jacobs (1969), who introduces the concept of an urban 'melting pot': cities house a multiplicity of people with different cultural, ethnic or language backgrounds, which may at times create tensions, but also form the seedbed conditions for innovative and creative behaviour (see e.g. Florida 2002). The second type of externality is based on economies of connectivity – either physical connectivity through for example road or airline networks or virtual connectivity through global information or Internet networks (see e.g. Taylor 2004; Tranos and Nijkamp 2013).

The changing scene of cities – from an island position to a nodal position in global networks – has brought about a series of challenges and concerns regarding cities of the future (see e.g. Blanke and Smith 1999; Hall 2004; Jacobs 2012). According to Nanetti (2012), a strategic vision of future cities calls for the following traits in urban development: territorially specific, future-oriented, problem-solving, strategically informed, operationally translated and politically committed. There is indeed a need for a strategic perspective on 'sustainable urbanism' (see Healey 2007; Farr 2008; Diappi 2012), in which urban gentrification, culture, creative land use, accessibility and ecological sustainability play a central role.

Clearly, the specific favourable facilities and social capital conditions of modern cities tend to induce more creativity and profitability. A spatial concentration of activities, involving spatial and social proximity, increases the opportunities for interaction and knowledge transfer, while the resulting spillover effects reduce the cost of obtaining and processing knowledge. In addition, knowledge workers preferably interact with each other in agglomerated environments in order to reduce the interaction costs, while they are more productive in such environments. It is, therefore, no wonder that cities are becoming the cradle of new and innovative industries. Innovative firms based on advanced services in the early stages of the product and company life cycle – when dealing with manifold uncertainty – prefer locations where new and specialized knowledge is abundantly available at low costs (see e.g. Audretsch 1998; Camagni 1991). Cities offer in this context enormously rich potential for a wide array of innovative business opportunities.

Another major megatrend in human settlement patterns is noteworthy in this context, viz. a structural rise in urbanization in the past centuries. Our world has turned into an urban world, with more than half of the world's population living in cities nowadays (see also Kourtit et al. 2012). The urbanization degree is still on a rising edge, notably in Latin America, Africa and Asia. This megatrend means not only a quantitative change in the share of inhabitants in urban areas in the national territory, but also a qualitative transformation of both a socio-economic and a political nature. Modern network cities have turned into spearheads of (supra-)regional and (supra-)national power, not only from a socio-economic perspective (business, innovativeness, jobs, wealth), but also from a geo-political ('cities as global command and control centres'; see Sassen 1991) and a technological perspective.

To meet a wide array of future challenges and opportunities, urban agglomerations and their business operations have to be smart and resilient. Therefore, over the years, modern global cities have dramatically changed the way of managing the dynamics in urban development in order to become and remain an attractive environment for various stakeholders, for example by attracting and retaining firms or tourists and recruiting talented people in a vibrant urban environment. To that end, appropriate support systems for a creative business environment need to be developed and more resources for sustainable growth need to be provided. The repositioning of modern global cities calls for a solid evidence-based benchmarking analysis.

A major question is now: which critical parameters may serve as policy handles for successful urban development? The road towards the economic growth, social inclusion and environmental sustainability of a city is not easy to follow. In recent years, the concept of a 'smart city' has gained increasing popularity and has prompted a great deal of policy attention and research interest (see e.g. Winters 2010; Caragliu et al. 2011). In a recent paper by Nam and Pardo (2011), a list of smart cities all over the world can be found, while various definitions of a smart city – and conceptual relatives of a smart city (e.g. digital city, learning city) – are also recorded and described. A main issue in analysing smart cities – or related concepts – is: what makes a city smarter than another city?

The above question has prompted much empirical research on the ranking of cities in our world, such as the Economist Intelligence Unit addressing the liveability of cities. Obvious caveats in comparing the performance of different cities are: differences in city size, the number and type of indicators used, the sample of cities chosen, the goal of the interurban comparison, etc. In the present study, we will compare the performance of various world cities based on a set of extensive and carefully collected indicators. In a relatively short time, this set of indicators – known as the GPCI (Global Power City Index), provided and updated on an annual basis by the Mori Memorial Foundation in Japan (2012) – has become a unique source of scientific research on cities worldwide (see e.g. Kourtit et al. 2012).

Our study now aims to offer an in-depth analysis of the GPCI database on 40 world cities (see Section 10.2). It offers a comparative benchmark assessment of these cities by investigating their detailed performance indicators on the basis of a recently developed multi-criteria model coined MAMCA (see Section 10.3). A novel element here is the explicit consideration of the perceptions and priorities of various distinct classes of stakeholders. The results of this experiment are presented and interpreted in Section 10.3, while Section 10.4 offers some policy perspectives and lessons.

12.2 Description of the Database

Cities are engines of economic power but also nodes in global networks. They need each other, but are also each other's competitors. The combination of internal strength and external orientation determines the growth potential and economic position of cities (see Neal 2012). Cities operate on an international playing field; hence, their socio-economic performance may show considerable variation. The question is then: why do some cities outperform others? This idea formed the basis of the creation of the above-mentioned GPCI database. This database contains extensive information – in numerical form – on many world cities, which are evaluated and ranked according to their 'magnetism', e.g. their competitive power to attract creative people and business enterprises from all over the world. This open-access database is carefully validated through field visits and in-depth reports. It contains a wealth of multi-annual data on major critical indicators – and a very detailed list of sub-indicators – of the economic strength of the relevant cities contained in the database. At present, this data system has accurate information on 40 world cities ranging from New York to Istanbul and from Tokyo to Geneva. In addition, a similar database has been created for 9 Japanese cities that were not included in the overall database, for instance Sapporo, Yokohama, Nagoya and Kobe. This extensive GPCI database also offers the possibility to benchmark each individual city, in terms of strength and weakness regarding each individual performance indicator.

Thus, the GPCI aims to offer systematic and comparative information on the comprehensive economic position of major cities in the world, and it achieves this by focusing on a wide variety of functions performed by the cities under consideration. For each individual city, six main classes of functions were carefully mapped out and numerically assessed, viz. *economy*, *research and development*, *cultural interaction*, *liveability*, *environment* and *accessibility*. In addition, the importance of these indicators was carefully assessed by five distinct groups of stakeholders, viz. *managers*, *researchers*, *artists*, *visitors* and *residents*. The summary results from the 2012 GPCI rankings are contained in Figure 1.

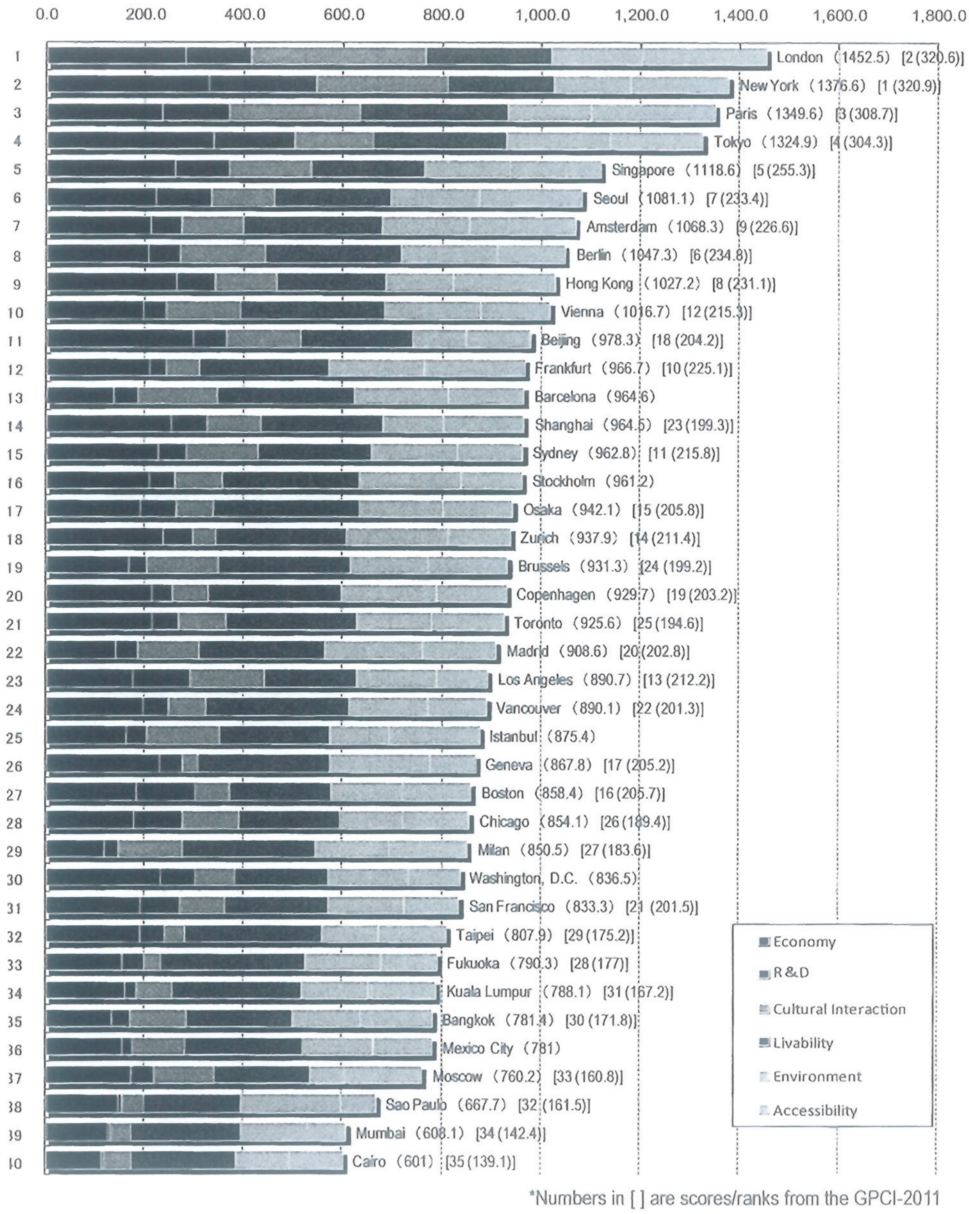

Figure 1. Comprehensive scores and rankings of 40 global cities for 6 functions

Source: Mori Memorial Foundation (2012)

12.3 Results of the MAMCA Model

Our study has tried to identify the potentially most powerful global city – measured in terms of six main criteria and a vast set of subcriteria – by applying an appropriate multi-criteria model, coined MAMCA. MAMCA is a member of the family of multi-criteria analysis methods that have gained substantial popularity over the past decades. It has also often been applied in urban and regional evaluation methods (see e.g. Nijkamp et al. 1991; Munda 2006). The MAMCA (in full, multi-actor, multi-criteria analysis) model allows us not only to perform a multi-criteria analysis on the basis of standard information on alternatives and choice criteria, but also to include preference elicitation through the explicit involvement of relevant stakeholders (Macharis 2004; Macharis et al. 2009). MAMCA is a methodology: a stepwise structured approach to analysing the opinions of these stakeholders. The data from the GPCI system are very suitable for the MAMCA approach, as they include the criteria and the underlying indicators for each actor together with the importance these actors attach to a specific criterion. Within our evaluation methodology, different multi-criteria analysis (MCA) techniques can be used. In this paper, we show the possibilities of two frequently used and related MCA methods, namely the analytical hierarchy analysis (AHP) method (or Saaty method) and the PROMETHEE method, in order to analyse the GPCI data. Both methods have found extensive application in the MCA literature.

We will first illustrate the use of MAMCA by addressing the relative performance profiles of seven rather arbitrarily chosen cities from our GPCI set. By the use of expert choice software, supporting the use of the analytical hierarchy process method developed by Saaty (1982), the data of GPCI (2012) for the cities of London, Paris, New York, Tokyo, Singapore, Amsterdam and Brussels were selected, taking into account the observed preference intensity of various classes of stakeholders regarding these cities.

The meaning of the MAMCA analysis will be clarified by means of Figure 2, in which the viewpoint for the category 'visitor' is shown. On the horizontal axis, the criteria for this class of actors are shown. The height of the bar shows the weight the class of visitors attaches to the respective criterion concerned. The left axis gives the scales of these weights. On the right axis, the scores of the cities on the criteria provided by the class of visitors can be seen. The overall ranking is also shown. This overall ranking is a weighted sum of the specific score for each of the criteria, while taking the weights into account. London, Paris and New York are clearly ranked in a top position for this actor. However, all the cities have clear positive performance outcomes, but amongst these are also elements for which they can improve their performance. The dining possibilities in Tokyo really stand out, for example, while its mobility (in particular, accessibility) leaves room for improvement. What also becomes obvious from this figure is that some criteria clearly differentiate between the cities, like dining or cultural interaction, while other criteria, like safety, are quite similar for all the cities.

Next, when we bring the points of view of all the classes of stakeholders regarding these seven cities together in a multi-actor profile (as shown in Figure 3), we can again observe some very interesting elements. In this graph, the different categories of actors are shown on the horizontal axis. If all the actors receive an equal weight, then Paris, London and New York all end up in a top position, but one can also clearly see differences in achievement. Researchers appear to prefer New York, while artists prefer Paris. Tokyo is in the middle, followed by a lower group consisting of Berlin, Singapore, Amsterdam and Brussels. Berlin, Amsterdam and Brussels appear to show the same pattern, always with the same ranking, but Singapore is clearly very attractive for conducting business, but clearly much less attractive to the class of artists.

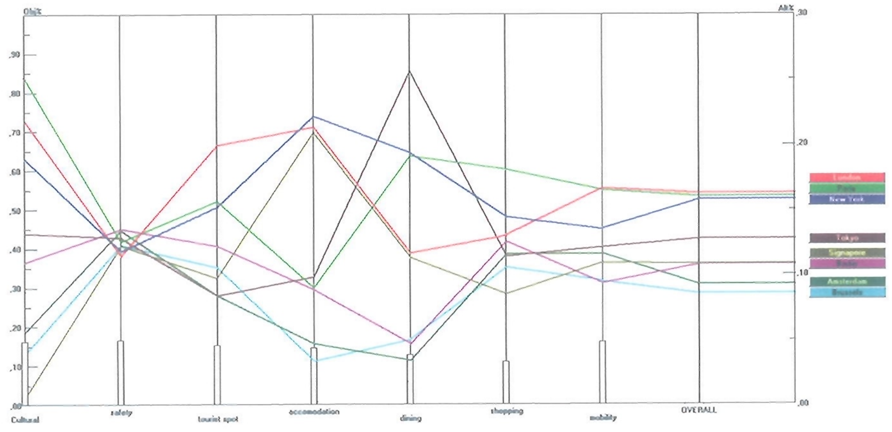

Figure 2. MAMCA results for seven world cities from the perspective of the class of 'visitors'

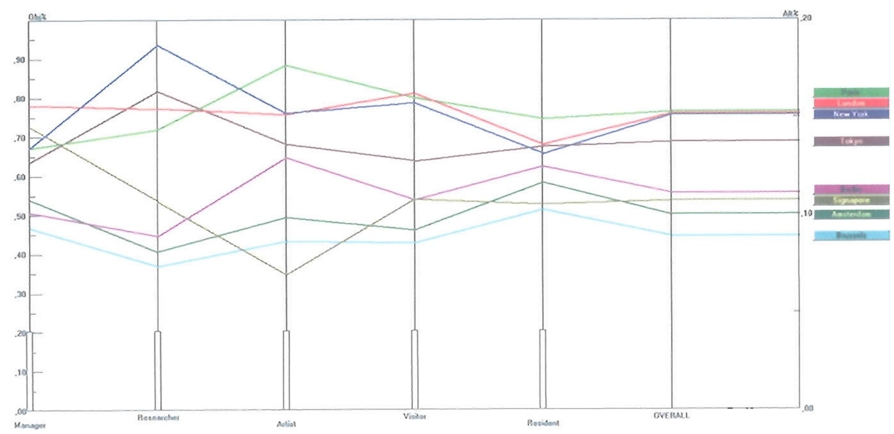

Figure 3. MAMCA results for seven world cities from the perspective of all the classes of stakeholders

The advantage of the MAMCA model is that it has the potential to offer the strength–weakness profiles of various choice alternatives, seen from the perspective of both different judgement criteria and different groups of stakeholders. Clearly, if the number of choice options is very large (in our case, 40 cities), it becomes somewhat cumbersome to present all the outcomes in one graph. However, any specific subset of interesting choice alternatives can of course be taken and mapped out in the respective graphs. In the remaining part of this section, we will offer the results from various other interesting combinations of cities in order to illustrate the power of the MAMCA approach.

It goes without saying that several sensitivity analyses are also possible with the MAMCA model, for instance by adding all the cities from the GPCI database or by zooming in on size classes, continents, specific stakeholders or specific criteria. If we make a selection of the top-ten most efficient cities from the GPCI database – with a selection made on the basis of a recently undertaken DEA analysis – for details, see Kourtit et al. (2012) – the multi-actor analysis shows that for each class of actors New York and Tokyo are really on top of and far above the others (see Figure 4). For the remaining eight cities, we see that they exhibit different profiles. For example, Hong Kong appears to have a very high ranking for managers, but a lower one for artists.

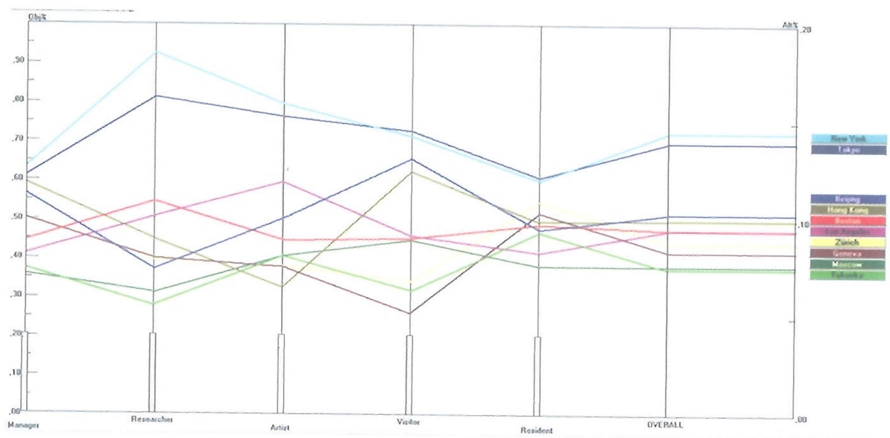

Figure 4. MAMCA results for the top-ten world cities from the GPCI database, from the perspective of all the classes of stakeholders

It may also be added that for the class of top-ten GPCI cities the strength–weakness profile for a given class of stakeholders, for example the class of visitors, can again be mapped out, so that a more detailed view of the positive and negative aspects of a city for that specific actor can be provided (see Figure 5). This figure also shows which criteria might really be differentiators. The more the scores are dispersed, the more this criterion differentiates among distinct judgement criteria, for example high-class accommodation; on the other hand, mobility (including accessibility), a criterion that receives a large weight from the class of visitors, appears to discriminate less between the different cities considered here. Furthermore, safety is certainly a criterion for which the cities that score highly on most of the other criteria do not perform so well.

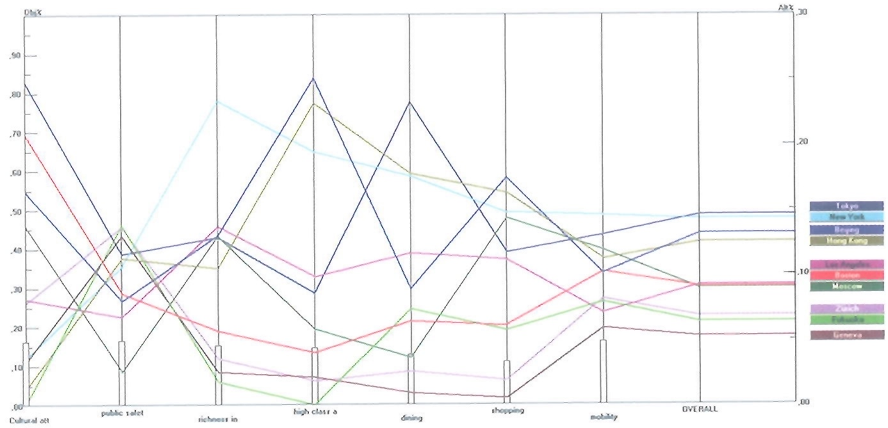

Figure 5. MAMCA results for the top-ten world cities from the perspective of the class of 'visitors'

For the ten lowest-scoring cities – in terms of efficient performance – in the DEA analysis executed by Kourtit et al. (2012), a similar analysis is executed next, in which Paris essentially acts as a benchmark for the others. We present here (see Figure 6) only the overall results, seen from the perspective of all the classes of stakeholders. This figure is similar in contents to the above-presented Figure 4. It appears that Paris clearly stands out in this class of lower-ranked cities. Clearly, although it is not an efficient city, it has several advantages for different actors.

The clearly differentiating nature of the MAMCA model results can be shown by focusing our attention, for example, on the class of 'artists'. In this respect, Paris takes the clear lead in its importance as a cultural and artistic centre, far above all the other cities in this subset of GPCI cities (see Figure 7).

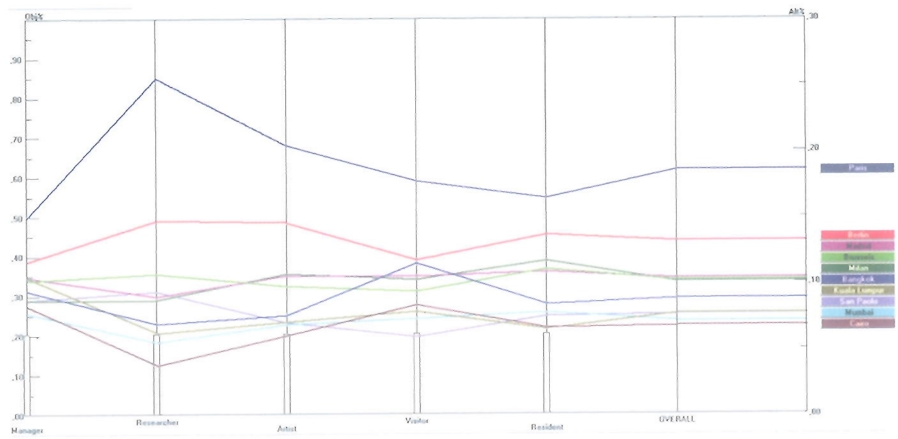

Figure 6. MAMCA results for the bottom-ten world cities – in terms of efficiency – from the perspective of all the classes of stakeholders (with Paris as a benchmark)

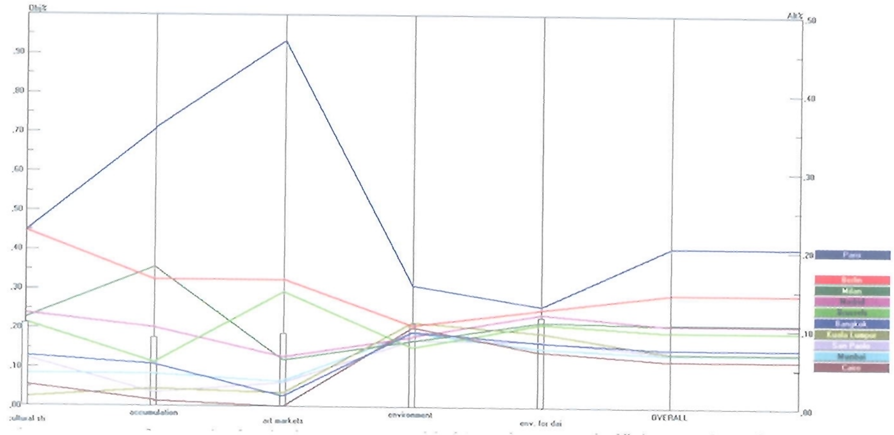

Figure 7. MAMCA results for the bottom-ten world cities – in terms of efficiency – from the perspective of the class of 'artists' (with Paris as a benchmark)

The MAMCA model clearly offers a broad perspective on the factors determining the perceived performance of world cities. An often-heard complaint regarding the use of multi-criteria analysis (MCA) for evaluating choice alternatives is that the results may be sensitive to the MCA method chosen. To clarify the scope of such a multi-criteria method, we therefore use another MCA method, the so-called PROMETHEE approach (for details see Brans and Mareschal 1994) and its extension towards group decisions (see for details Macharis et al. 1998). This method – and in particular the so-called GAIA variant – is able to link the total performance evaluation of relevant alternatives to the various classes of stakeholders. In using the PROMETHEE software called D-Sight, different analysis methods can be used. We will present here the results of a specific technique, the GAIA method. The GAIA (geometrical analysis for interactive aid) plane is a two-dimensional visual representation of a decision problem in which the alternatives and their contribution to the various criteria are simultaneously displayed. In a multi-actor setting, GAIA will show the points of view of the different actors in the plane. Additionally, a decision stick can be used to investigate further the sensitivity of the results as a function of weight changes (see Brans and Mareschal 1994).

The GAIA method plots the different cities in a two-dimensional space by using a principal component analysis. Each axis represents the point of view of each of the actors concerned, while the decision axis (the red axis) shows the cities that overall achieve the highest score. For the sake of illustration, in the next graph, a comparison is made between the EU cities (the yellow ones) and the non-EU cities (the purple ones) within the top-ten cities of the GPCI database (see Figure 8).

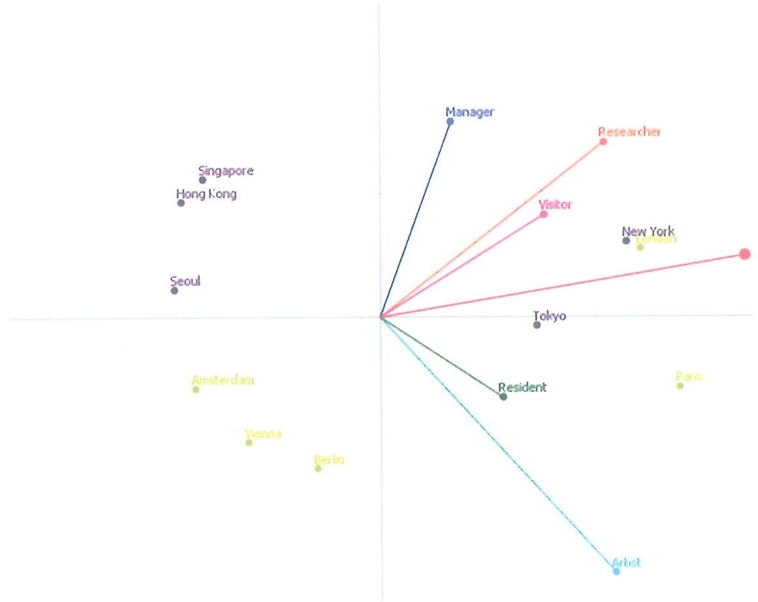

Figure 8. GAIA plane with topological positions for the selected EU and non-EU top-ten cities

It is interesting to see that the actor axes in Figure 8 are pointing to the right, meaning that the perception of stakeholders regarding the performance of the cities is not completely opposite. The points of view appear to deviate most between artists and managers. The decision axis is pointing in the direction of New York, London and Tokyo. Most of the European cities are situated at the lower level, showing that these are interesting places to stay as residents or artists.

Clearly, such types of analysis can be carried out for different cities and perspectives in our database. A similar analysis can, for instance, be performed with a distinction between mega-cities and non-megacities, OECD countries and non-OECD countries, and so forth. All such experiments allow us to identify the contribution of each of these points of view to the overall score.

Such ranking analyses can be undertaken for various subsets, such as the top-ten cities in our database, discussed above (see Figure 9). Then, it emerges that Paris, London, New York and Tokyo are clearly ranked at the top. The contribution of each of the actors is equally divided. Singapore has quite a unique profile. It scores very well for managers, but not as well for artists. In this graph, it is clear that the points of view of visitors and researchers are very close to each other. If we look at the scores on the criteria of these two actors, we see indeed that there is quite a high correlation between them.

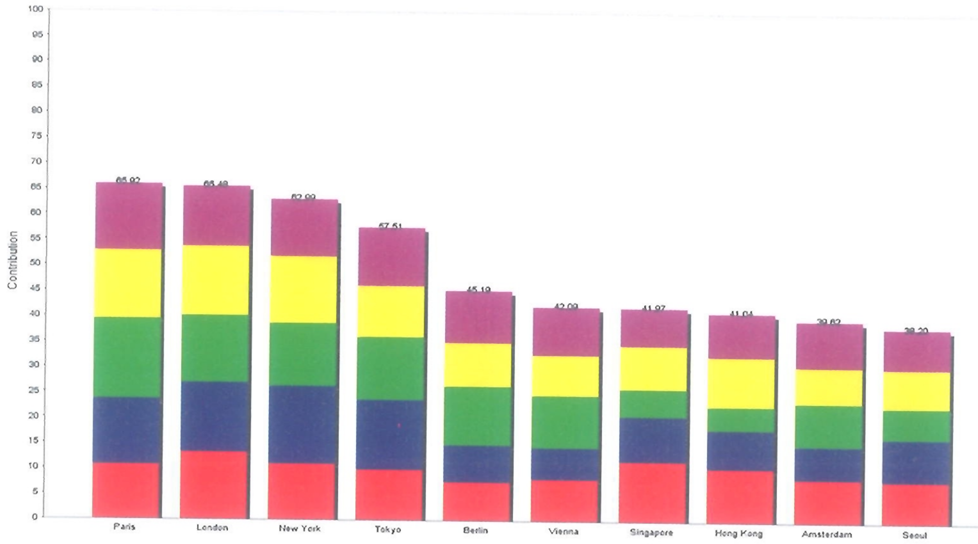

Figure 9. Overall ranks of the top-ten cities on the basis of the GAIA method

In addition to achieving a ranking of cities based on a combined multi-stakeholder–multi-criteria approach, it is also possible to identify the closeness between clusters of cities through an appropriate cluster algorithm based on an A versus B analysis. In Figure 10, the two classes of actors 'visitors' (A) and 'researchers' (B) are compared with each other. The higher the correlation between the two criteria, the more the cities are located near the diagonal line. We see that for these two classes of actors, the correlation is not particularly high, meaning that these actors have quite differentiated and independent objectives/criteria.

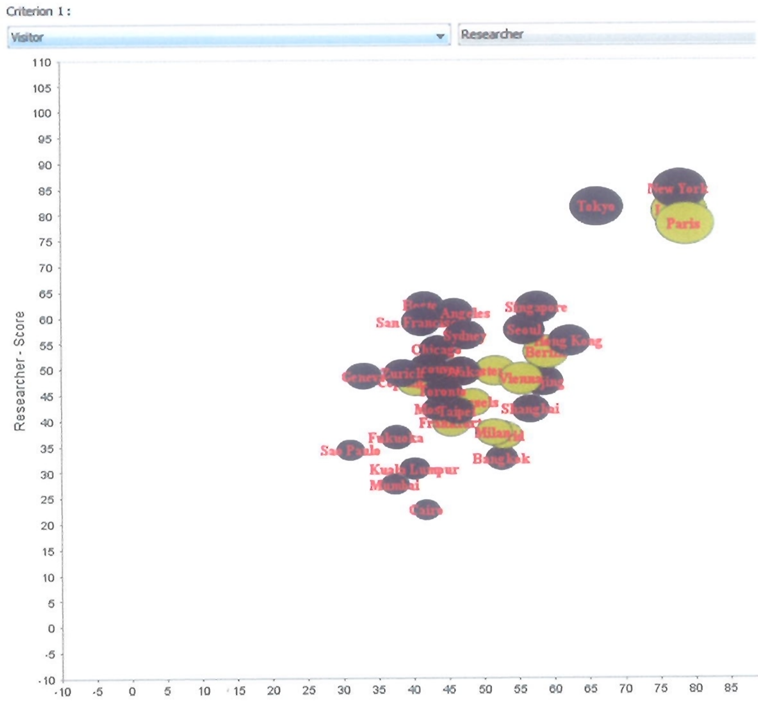

Figure 10. A (visitor) versus B (researcher) analysis with all te cities (green: EU countries, purple: non-EU countries)

Comparisons of individual criteria between actors are also possible. An obvious but illustrative example in our modelling approach is a combined analysis of two attraction factors, viz. the concentration of artists (a social network criterion for artists) and the cultural attractiveness of a city (an attractiveness criterion for visitors). Figure 11 shows that this correlation is indeed very high, as the cities are located near the diagonal. This kind of analysis can indicate the most prominent and interesting interactions between the criteria at hand. Thus, if a city is addressing one of them, this will also indirectly lead to an interesting increase in the scores of another related actor.

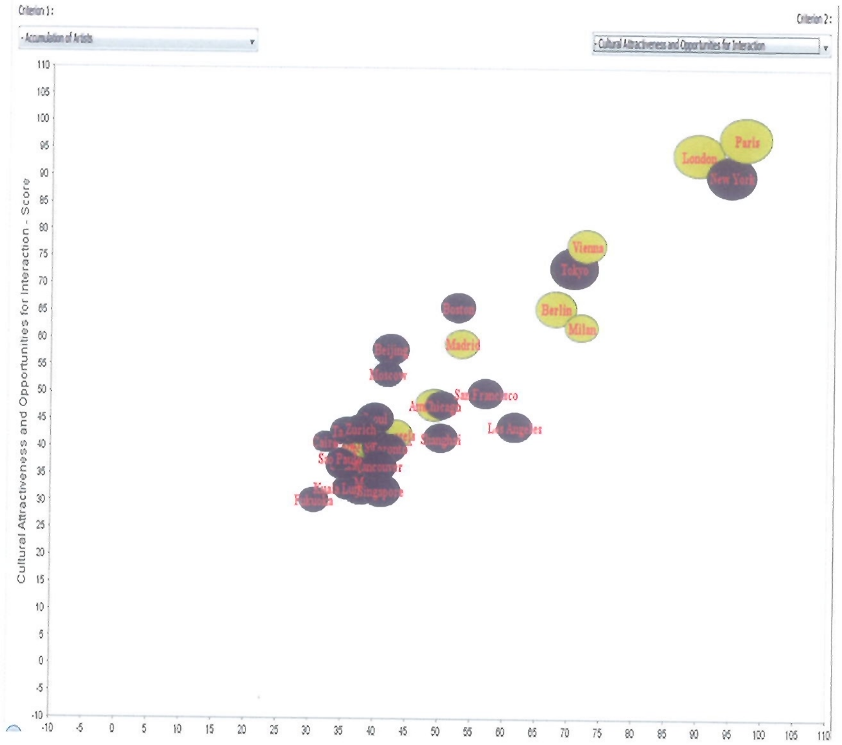

Figure 11. A (concentration of artists) versus B (cultural attractiveness) analysis of all the cities

If we compare the PROMETHEE method with the AHP method for a MAMCA application to the GPCI data, we may conclude that they are quite complementary. In Figure 12, we show the analysis for the same seven randomly selected cities as considered above for AHP. The GAIA plane appears to show better the points of view of the different actors and how the cities can be clustered according to these points of view. For example, New York, London, Tokyo and Paris are situated on the positive side of the plane (in the direction of the decision stick). Paris scores higher for residents and artists, while New York and London score higher for researchers and managers. Also, for the cities that have a lower score, important findings can be extracted from these visual presentations. For example, Singapore scores well for managers, but less well for artists, a conclusion that we have also drawn from the AHP analysis.

12.4 Policy Lessons

The above analysis has brought to light important findings on the relative position of major cities in our world. Apparently, if we look at the rankings of all cities for each individual main indicator, there is no unambiguous winner in all the dimensions. In multi-objective programming terms, there is no single super-efficient solution in the set of alternatives (see Rietveld 1980).

However, there are several cities that score higher on all the indicators than others. These cities may be called *dominant* cities, as they outperform all the others. Clearly, the results may change if different groups of stakeholders attach different priorities (weights) to the various main indicators.

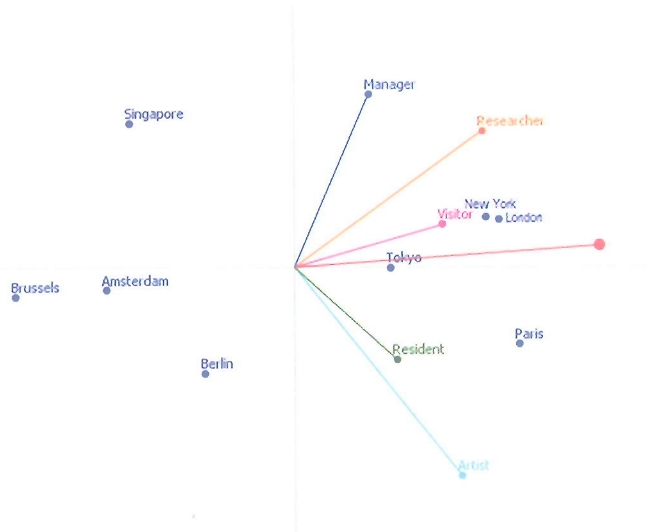

Figure 12. GAIA plane for seven world cities, as compared with Figures 2 and 3

Cities can apparently create new urban histories, through a concerted effort to address simultaneously the main strategic indicators that are decisive for the global performance of an urban agglomeration. The benchmarking information from our analysis may prompt urban policy action. The above results, however, also call for some caution. Cities are self-organizing organisms that are not entirely makeable. There are issues such as social cohesion, ethnic conflicts, ageing, international migration, natural disasters, human health conditions and urban governance systems that are difficult to incorporate into a numerical indicator system, even though such factors may be decisive for the future fate of a city.

In addition, it is also noteworthy that an indicator list – extensive as it may be – will never be entirely complete and entirely fit for purpose. For example, the GPCI list is under-represented in terms of the key indicators related to local housing markets, labour markets and quality of the educational system. A globally successful city can only sustain a high profile if it is at the same time a 'social polis' with access to many urban amenities by its citizens.

It should be added that there is another element that is difficult to handle, but nevertheless critical for urban competitiveness, viz. the state of urban technology, e.g. in terms of the access to and use of advanced technologies, such as biotechnology, nanotechnology, information technology, etc. Technological capital seems nowadays to be a *sine qua non* for modern cities. Clearly, technological capital is not 'manna from heaven', but can be created by dedicated human and policy efforts, for instance through education and research, in the spirit of the endogenous growth theory (see e.g. Komninos 2002). However, technological capital creation often does not lie in the hands of local policy institutions, but more in the hands of multinational business firms. A seedbed policy for attracting modern technology towards an urban agglomeration is then a key parameter for a city to achieve an internationally competitive position.

Our results are fascinating and intriguing. A long-range dedicated urban development policy does matter. The points of view of the actors allow us to look at the performance of cities from different angles. The MAMCA analysis also allows to see the dependencies between the different underlying criteria and the criteria that really make the difference. This allows cities to choose which criteria to work on and by doing so how to increase their attractiveness.

Finally, it should be noted that, next to positive forms of policy for the '*New Urban World*', effective policies coping with the negative externalities or shadow sides of cities are also needed, for instance regarding ethnic segregation, crime, pollution, etc. (see Healey 2007). After all, the city is, by definition, a dynamic and vulnerable spatial entity that needs to take care of its multiplicity of constituents.

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13 EXCEPTIONAL PLACES: THE RAT RACE BETWEEN WORLD CITIES*

Abstract

This paper aims to provide a new methodological and empirical contribution to the rising literature on the relative performance and benchmarking of large cities in a competitive world. On the basis of a recent detailed database on many achievement criteria of 35 major cities in the world, it seeks to arrive at a relative performance ranking of these cities by using Data Envelopment Analysis (DEA). A novel element is the use of a new type of 'Super-Efficiency DEA' to identify unambiguously the high performers ('Exceptional Places') in the group of world cities investigated. This new productivity-based approach is complemented with two new directions in DEA research, viz. a Distance Friction Method and a Context. Dependent method.

Keywords: Benchmarking, Major cities, Data Envelopment Analysis (DEA), Super-Efficiency DEA Exceptional places, Productivity-based approach, Distance friction method, Context-dependent method Performance analysis, Urban competitiveness, Global power city index (GPCI), Attractive urban milieu and climate, Sustainability, Competitive advantage, Growth development

* Kourtit, K. Nijkamp. P., and Suzuki, S. (2013). Exceptional Places: The Rat Race Between World Cities. Computers, *Environment and Urban Systems*, 38, 67-77.

13.1 Exceptional Cities

The structural and worldwide urbanization trend has prompted the emergence of metropolitan areas of an unprecedented scale. Especially in the current globalization age, such areas act as international power stations, with a rich pluriformity of centripetal and centrifugal economic, political and technological forces. Such world cities have a strong global control and command impact, not only because of their sheer size, but more so because of their innovative and creative potential (Glaeser & Kerr, 2009; Sassen, 1991; Shefer & Frenkel, 1998). In this context, the local R&D, knowledge and learning base also plays an important role (Acs, FitzRoy, & Smith, 2002; Kourtit, Nijkamp, & Stough, 2011; van Geenhuizen, & Nijkamp, 2011).

World cities are increasingly also involved in fierce competition on global product and service markets, and consequently these metropolitan areas have to create favorable conditions for economic agents, such as: a healthy entrepreneurial climate; a specialized basis of industrial clusters; a diversified economic structure; an ecologically sustainable urban environment; a high quality research and educational infrastructure; a balanced population structure with sufficient skills; international accessibility through majors hubs etc. (see also Cheshire & Magrini, 2009). World cities are essentially involved in a permanent global battle that is concerned with the maximum development and exploitation of agglomeration externalities in international spatial networks.

An interesting question is now how global players and local experts view the potential and performance of these cities. In recent years, various attempts have been made to develop a classification or ranking of world cities based on their actual performance or their perceived success (see e.g. Arribas-Bel, Nijkamp, & Scholten, 2011; Grosveld, 2002; Kourtit, Nijkamp, & Arribas, in press-a; Suzuki, Nijkamp, & Rietveld, 2011; Taylor et al., 2009). Especially the seminal work of Taylor and associates has gained world-wide recognition. A main challenge in empirical research is the development of a consistent, quantitative data base that is appropriate for a comparative, strategic benchmark analysis.

One of the most detailed databases on world cities can be found in a recent study on the 'Global Power City Index' (GPCI) undertaken by the Institute for Urban Strategies and The Mori Memorial Foundation (2010). A thorough analysis of various world cities, 35 in total, was made in this study report, including not only the megacities of New York, London, Paris, Tokyo or Beijing but also cities from emerging economies such as Sao Paulo, Mumbai, Kuala Lumpur or Cairo. The GPCI database contains six major clusters of relevant information on these cities. We employ this database for a benchmark analysis of these cities and, therefore, it is discussed in slightly greater detail in the next section.

The basic proposition of the present paper is that a pure ranking of world cities on the basis of their weighted achievement scores does not tell us very much about their economic efficiency, which in the long run will be decisive for their prosperity and sustainability.

Therefore, our study aims to provide a more critical analysis of the performance data on these 35 metropolitan areas by using Data Envelopment Analysis (DEA) to position these cities on the basis of their relative performance, i.e. by relating their output to their input. This ratio is much more informative about the actual economic profile of the city concerned. In this study, we also make a new contribution to DEA analysis: namely, 'Super-Efficiency DEA', combined with a 'Distance Friction Minimization' model by introducing a new method for calculating and identifying super-efficient actors (in our case, cities). This methodology will be explained in Section 13.3–13.5. Then, Sections 13.6–13.8, respectively, present and interpret the various empirical findings for the database described above. Finally, the paper concludes with some suggestions for follow-up research and policy action.

13.2 Description of the World Cities Database

For a systematic comparison of cities' performance analysis and their urban competitiveness, our empirical approach is based on a unique data set, the 'Global Power City Index' (GPCI), produced by the Institute for Urban Strategies, under the aegis of the Mori Memorial Foundation (2010) in Tokyo for the year 2010.

The GPCI index is used, as a strategic tool, to evaluate and rank the comprehensive power determinants of 35 major cities worldwide, in terms of the strengths and weaknesses of their performance in: creating wealth; enhancing social development; attracting investments; providing an open and attractive urban 'milieu' or climate; offering access to social capital and networks; encouraging integrated sustainability; and harnessing both human and technological resources in productivity and competitiveness at local and global scales. In other words, the aim of these world cities is to maximize urban XXQ (the highest possible urban quality) which may strengthen their foundations for securing socioeconomic development and competitive advantage in a global playing field (Nijkamp, 2008).

The comprehensive performance scores and rankings of these global cities in the GPCI-data set are based on six main categories, namely: "Economy", "Research & Development", "Cultural Interaction", "Liveability", "Ecology & Natural Environment", and "Accessibility". Each of these main indicators was subdivided into relevant and measurable sub-indicators, so that finally a consistent and tested database on 69 sub-indicators for 35 world cities was created. Thus, we have a complete, extensive and quantitative database for a great variety of relevant urban (sub-) indicators for all world cities under consideration.

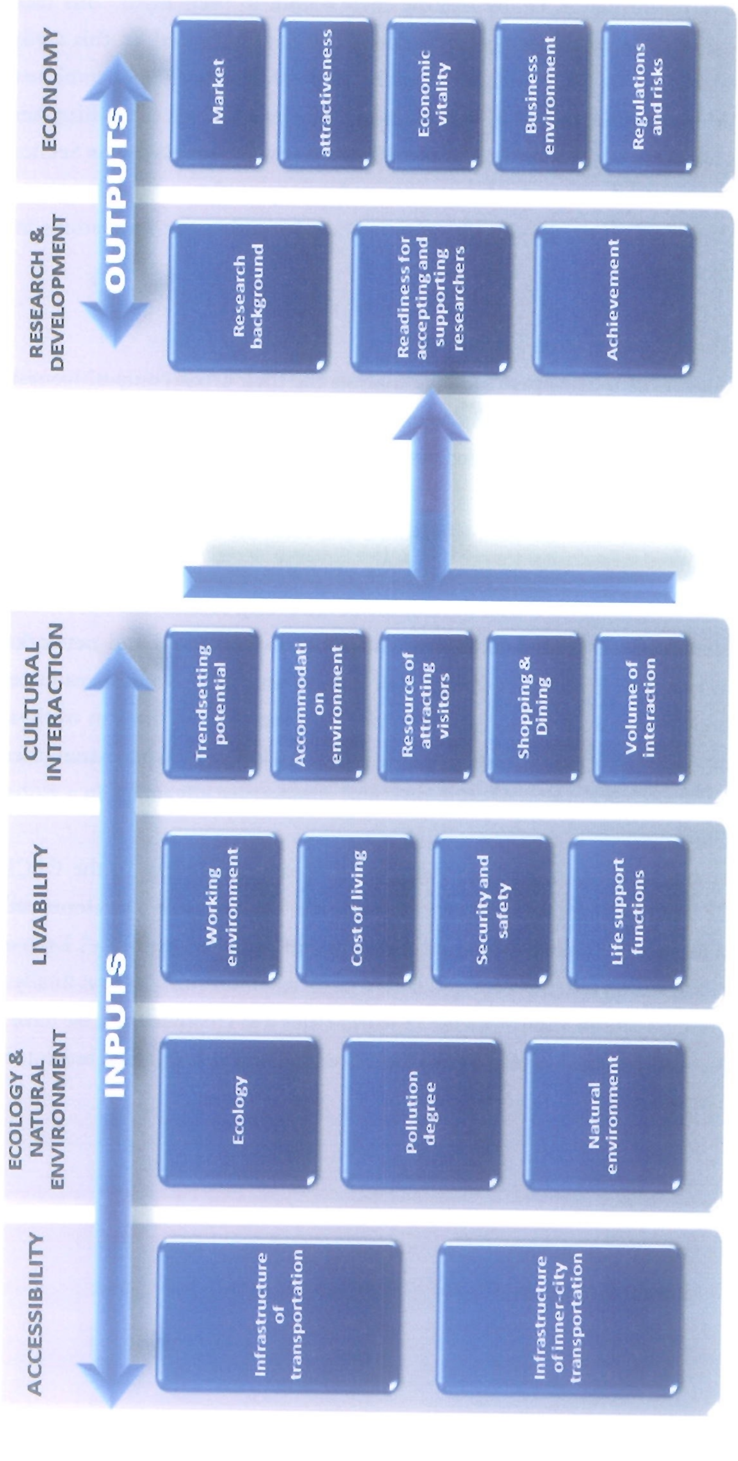

Figure 1. An overview of the main categories of performance indicators used in GPCI-2010.

Next, a set of five worldwide types of actors was identified: managers, researchers, artists, visitors, and residents. These people were asked to score the importance of each of these indicators, so that a weighted average importance score for each city could be calculated. All details can be found in the above-mentioned GPCI-2010 report. See Annex A in this paper for more details of the ranking results of these cities as presented in the above mentioned study (more details can also be found in Kourtit, Arribas, & Nijkamp, in press-b). Figure 1 provides a concise analytical presentation of the main categories of performance indicators derived fromthe GPCI report.

The GPCI-2010 database was collected systematically for all relevant cities in the sample. It was also carefully checked by both local experts and independent scientists, so that its reliability may be judged as satisfactory. Cleary, the sample of 35 world cities may be extended in the future, but for our analytical purposes it meets our demands. This operational framework of empirical information is used in our DEA analysis in order to explore and represent in a comparative sense the Super-Efficiency performance of these global cities in terms of urban input (or resource) and output indicators and outputs regarding their economic achievement.

13.3 Data Envelopment Analysis (DEA): New Roads

13.3.1 The CCR model

In this section, we will outline the various steps of our DEA experiment, starting from a standard DEA tool and proceeded towards a Super-Efficient DEA, while using two additional techniques, viz. a Distance Friction Minimization (DFM) and a (Stepwise) Context-Dependent (CD) method. The standard Charnes et al. (1978) model (abbreviated hereafter as the CCR-input or CCR-I model) for a given Decision-Making Unit DMU_j $(j=1,\ldots,J)$ to be evaluated in any trial o (where o ranges over 1, 2 ..., J) may be represented as the following fractional programming (FP_o) problem:

$$
\begin{aligned}
(FP_o) \quad & \max_{v,u} \quad \theta = \frac{\sum_s u_s y_{so}}{\sum_m v_m x_{mo}} \\
\text{s.t.} \quad & \frac{\sum_s u_s y_{sj}}{\sum_m v_m x_{mj}} \le 1 \quad (j = 1, \cdots, J) \qquad (1) \\
& v_m \ge 0, \ u_s \ge 0,
\end{aligned}
$$

where θ represents an objective variable function (efficiency score); x_{mj} is the volume of input m $(m=1,\ldots, M)$ for DMU j $(j=1,\ldots,J)$; y_{sj} is the output s $(s=1,\ldots,S)$ of DMU j; and v_m and u_s are the weights given to input m and output s, respectively. Model (1) is usually called an input-oriented CCR model, while its reciprocal (i.e. an interchange of the numerator and denominator in objective function (1), with a specification as a minimization problem under an appropriate adjustment of the constraints) is usually known as an output-oriented CCR model. Model (1) is obviously a fractional programming model, which may be solved stepwise by first assigning an arbitrary value to the denominator in (1), and then maximizing the numerator. But it is preferable to transform (1) into a linear programming model, as the CCR model (1) can be shown to have the following equivalent linear programming (LP_o) specification for any DMU $_j$:

$$
\begin{aligned}
(LP_o) \qquad & \max_{v,u} \quad \theta = \sum_s u_s y_{so} \\
\text{s.t.} \qquad & \sum_m v_m x_{mo} = 1 \\
& -\sum_m v_m x_{mj} + \sum_s u_s y_{sj} \le 0 \\
& v_m \ge 0\,, \;\; u_s \ge 0\,.
\end{aligned}
\tag{2}
$$

The dual problem of (2), DLP_o, can be expressed by means of a real variable θ, using the following vector notation:

$$
\begin{aligned}
(DLP_o) \qquad & \min_{\theta,\lambda} \quad \theta \\
\text{s.t.} \qquad & \theta x_o - X\lambda \ge 0 \\
& Y\lambda \ge y_o \\
& \lambda \ge 0\,,
\end{aligned}
\tag{3}
$$

where the transposed (T) presentation $\lambda = (\lambda_1, \;\; \cdots \;\; \lambda_J)^T$ is a non-negative vector (corresponding to the presence of slacks for each DMU), X an ($M\times J$) input matrix, and Y an ($S\times J$) input matrix. We can now define the input excesses $s^- \in R^m$ and the output shortfalls $s^+ \in R^s$, and identify them as 'slack' vectors as follows:

$$s^- = \theta x_o - X\lambda\,; \tag{4}$$

$$s^+ = Y\lambda - y_o\,. \tag{5}$$

These equations indicate that the efficiency of (x_o, y_o) for DMU$_o$ can be improved if the input values are reduced radically by the ratio θ^*, and the input excesses s^{-*} are eliminated (see Figure 2). The original DEA models presented in the literature have thus far only focused on a uniform input reduction or a uniform output increase in the efficiency-improvement projections, as shown in Figure 2 (θ^*=OC'/OC).

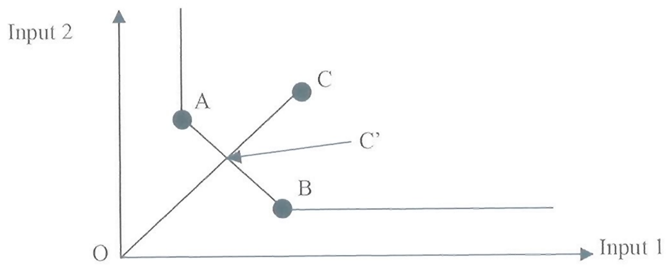

Figure 2. Illustration of original DEA projection in input space

We also observe that the maximum efficiency score to be achieved by efficient DMUs based on the CCR model is 1. In practice, this often means that the CCR model usually computes more than one high-ranking DMU. And that prompts the question whether out of the group of high-ranking DMUs the highest-ranking (super-efficient) DMU can be identified. This will be discussed in subsection 13.4.

13.4 The Super-Efficiency Model

The unsatisfactory identification of efficient firms in a standard DEA model – where all efficient firms get the score 1 – has led to focused research to discriminate between efficient DMUs, in order to arrive at a ranking – or even numerical rating – of these efficient firms, without affecting the results for the non-efficiency. In particular, Andersen and Petersen (1993) developed a radial Super-Efficiency model, while later on Tone (2002, 2003) designed a *slacks-based measure* (SBM) of super-efficiency in DEA. In general, a Super-Efficiency model aims to identify the relative importance of each individual efficient firm, by designing and measuring a score for its 'degree of influence' if this efficient firm is omitted from the efficiency frontier (or production possibility set). If this elimination really matters (i.e. if the distance from this DMU to the remaining efficiency frontier is large), and thus the firm concerned has a high degree of influence, and outperforms the other DMUs, it gets a high score (and is thus super-efficient). Thus, for each individual firm a new distance result is obtained, which leads to a new ranking – even a rating – of all original efficient firms.

The main problem in Super-Efficiency DEA is how to define the distance between an efficient DMU and the production possibility set that emerges after the elimination of one single efficient DMU. In the literature, the SBM (see Tone, 2002, 2003) has been advocated. And this method will also be applied in our empirical investigation.[1]

[1] In the meantime, the above mentioned literature has also mentioned some more refinements of the SMB approach, such as the Super-SBM-I-C (the super-efficiency SBM method with DEA input-orientation under constant returns to scale), the Super-SBM-I-V (under variable returns to scale), the Super SBM-O-CC (with output orientation under constant returns to scale), the super-SBM-O-V (under variable returns to scale), and even the Super-SBM-GRS (under general returns to scale) .

Anderson and Petersen (1993) have developed the Super-Efficiency model to arrive at a ranking of all efficient DMUs. The efficiency scores from a super-efficiency model are thus obtained by eliminating the data on the DMU_o to be evaluated from the solution set. For the input model, this can then result in values which may be regarded – according to the DMU_o – as a state of super-efficiency. These values are then used to rank the DMUs and, consequently, efficient DMUs may then obtain an efficiency score above 1.000. The super-efficiency model may be suitable to find for our comparative data base on big cities in the world the set of highest performing smart cities. These can be ranked in descending order and are coined 'Exceptional World Cities' or 'Exceptional Places'.

The super-efficiency model based on a CCR-I model can now be written as follows:

$$\begin{aligned} &\min_{\theta,\lambda,s^-,s^+} \quad \theta - es^- - es^+ \\ \text{s.t.} \quad &\theta x_o = \sum_{j=1,\neq o}^{J} \lambda_j x_j + s^- \\ &y_o = \sum_{j=1,\neq o}^{J} \lambda_j y_j - s^+ \\ &\lambda_j, s^-, s^+ \geq 0 \end{aligned} \tag{6}$$

where e is a unit vector (1,...,1), representing a utility factor for all elements. This model will be used in our search for 'Exceptional Places' from which an ambiguous ranking will emerge.

13.5 A New Super-Efficiency DEA Based on a Distance Friction Minimization (DFM)

13.5.1 Outline of the Distance Friction Minimization (DFM) approach

As mentioned, the efficiency improvement solution in the original CCR-input model requires that the input values are reduced radially by a uniform ratio θ^*(θ^*=OD'/OD in Figure 2). The (v^*, u^*) values obtained as an optimal solution for formula (1) result in a set of optimal weights for DMU_o; (v^*, u^*) is the set of most favourable weights for DMU_o, in the sense of maximizing the ratio scale. v_m^* is the optimal weight for the input item m, and its magnitude expresses how much in relative terms the item is contributing to efficiency. Similarly, u_s^* does the same for the output item s. These values show not only which items contribute to the performance of DMU_o, but also to what extent they do so. In other words, it is possible to calculate the distance frictions (or alternatively, the potential increases) in improvement projections. Suzuki et al. (2010) used the optimal weights u_s^* and v_m^* from (1) as the basis for the efficiency improvement projection model. A visual presentation of this approach is given in Figures 3 and 4.

In this approach, a generalized distance friction is employed to assist a DMU to improve its efficiency by a movement towards the efficiency frontier surface. The direction of efficiency improvement depends, of course, on the input/output data characteristics of the DMU. It seems appropriate to define the projection functions for the minimization of distance friction by using a Euclidean distance in weighted spaces. This forms the key of the DFM (Distance Friction Minimization) model. Thus, the DFM approach can generate a new contribution to efficiency enhancement problems in decision analysis by employing a weighted Euclidean projection function, and, at the same time, it may address both input reduction and output increase. We will not provide a detailed description of the various steps involved, but details can be found in Suzuki et al. (2010).

By means of this DFM model, it is possible to present a new efficiency-improvement solution based on the standard CCR projection. This means an increase in new options for efficiency-improvement solutions in DEA. The main advantage of the DFM model is that it yields an outcome on the efficient frontier that is as close as possible to the DMU's input and output profile (see Figure 5).

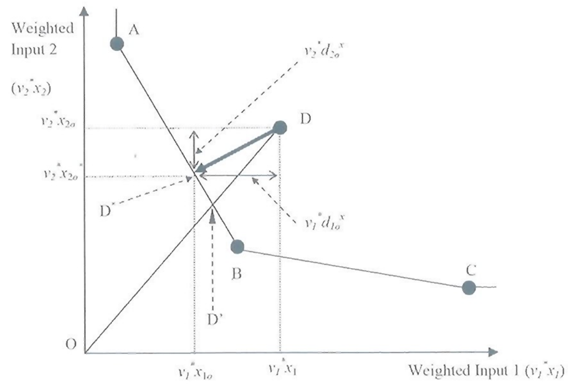

Figure 3. Illustration of the DFM approach (Input- $v_i^* x_i$ space)

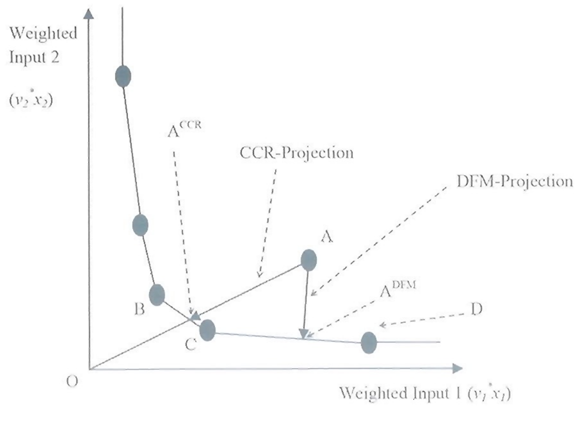

Figure 4. Illustration of the DFM approach (Output - ur*yr space)

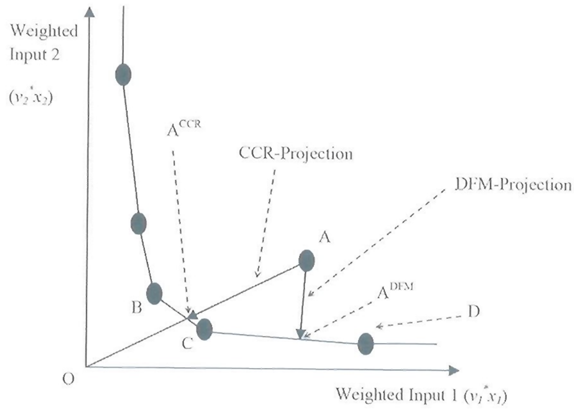

Figure 5. Degree of improvement of the DFM and the CCR projection in weighted input space

13.5.2 A proposal for a Super-Efficiency DFM model

We now design a Super-Efficiency DFM model that is integrated with a Super-Efficiency DEA model.

In a normal DFM model, the (v^*, u^*) values obtained as an optimal solution for formula (1) result in a set of optimal weights for DMU_o. Our new Super-Efficiency DFM model (hereafter SE-DFM) is now based on the idea that these optimal values result from the application of the Super-Efficiency model. The advantage of the SE-DFM model is that it yields an unambiguous and measurable outcome in a ranking of efficient DMUs, i.e. this new integrated model can be suitable to find the highest performing DMUs, while retaining all the advantages of the DFM model.

13.6 A Stepwise SE-DFM Model in DEA

13.6.1 Outline of a Context-Dependent model

The Context-Dependent (hereafter CD) model can generate efficient frontiers in successive stages (levels), and can yield a stepwise level-by-level improvement projection (for details, see Seiford and Zhu, 2003). A concise formulation of the CD model follows now.

Let $J^l = \{DMU_j, j = 1, \cdots, J\}$ be the set of all J DMUs. We interactively define $J^{l+1} = J^l - E^l$, where $E^l = \{DMU_k \in J^l | \theta^*(l,k)\} = 1$ and $\theta^*(l,k)$ is the optimal value by using formula (1) (see Figure 6). When $l = 1$, the model becomes the original CCR model, while the DMUs in set E1 define the first-level efficient frontier. When $l = 2$, it gives the second-level efficient frontier after the exclusion of the first-level efficient DMUs, and so on. In this manner, we identify several levels of efficient frontiers. We call El the lth-level efficient frontier. The following algorithm accomplishes the identification of these efficient frontiers.

Step 1: Set $l = 1$. Evaluate the entire set of DMUs, J1. We then obtain the first-level efficient DMUs for set E1 (the first-level efficient frontier).

Step 2: Exclude the efficient DMUs from future DEA runs, i.e. $J^{l+1} = J^{l} - E^{l}$ (If $J^{l+1} = \phi$, then stop.)

Step 3: Evaluate the new subset of "inefficient" DMUs. We then obtain a new set of efficient DMUs E^{l+1} (the new efficient frontier).

Step 4: Let $l = l + 1$. Go to step 2.

Stopping rule: $J^{l+1} = \phi$, the algorithm is terminated.

A visual presentation of the CD model is given in Figure 6.

13.6.2 An operational Stepwise SE-DFM Model

Any efficiency-improving projection model which includes the standard CCR projection supplemented with the SE-DFM projection is always directed towards achieving "full efficiency". This strict condition may not always be easy to achieve in reality. Therefore, in this section we will integrate the CD model with the SE-DFM approach; this will be called the "Stepwise SE-DFM" model. It can yield a stepwise efficiency-improving projection that depends on l-level efficient frontiers (l-level DFM projection), as shown in Figure 7.

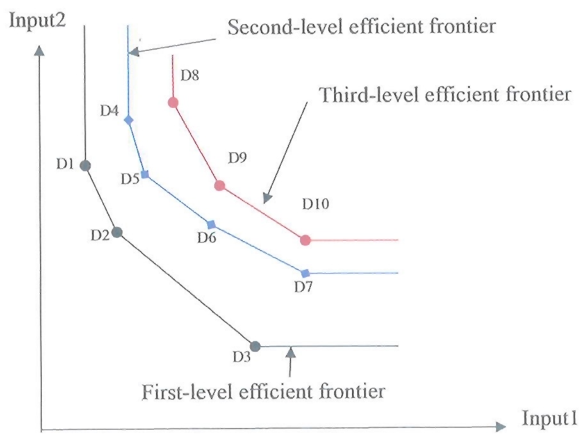

Figure 6. Illustration of the CD model

For example, a second-level DFM projection for DMU10 (D10) aims to position DMU10 on a second-level efficient frontier. In addition, a first-level DFM projection is just equal to an SE-DFM projection. We observe here that the second-level DFM projection is easier to achieve than a first-level DFM projection. A Stepwise SE-DFM model can yield a more practical and realistic efficiency improving projection than a CCR projection or a SE-DFM projection.

The advantage of the Stepwise SE-DFM model is that it also yields an outcome on a *l*-level efficient frontier that is as close as possible to the DMU's input and output profile, which means that the Stepwise SE-DFM projection can compute more effective solutions than the CD projection model (see Figure 7). This set of new DEA applications will now be applied to the GPCI database on world cities described in Section 13.2.

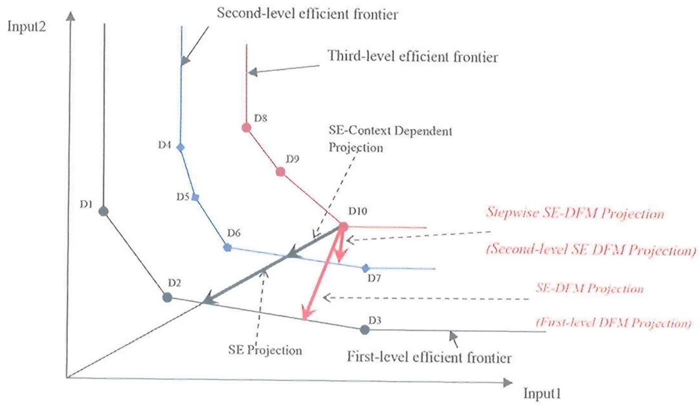

Figure 7. Illustration of the Stepwise DFM model

13.7 In Search of Exceptional World Cities

In our empirical application we will use the GPCI-2010 database-2010. But rather than seeking to achieve a ranking of cities based on a comprehensive set of indicators, we aim to look at the efficiency (or productivity) of these cities, by investigating more carefully the ratio between multi-attribute outputs and multi-attribute inputs. To that end, DEA is an appropriate tool. In our application, we will first apply the CCR model and the Super-Efficiency model in our search for exceptional world cities based on a Super-Efficiency DEA. In addition, we will apply the CD model based on the Super-Efficiency concept; in this way, the cities in our sample can be categorized according to efficiency levels based on successive levels of efficient frontiers.

13.7.1 Efficiency scores for Super-Efficiency and CCR-I

The efficiency evaluation results for the 35 world cities based on the CCR model and the Super-Efficiency model using 4 inputs ("Cultural Interaction", "Liveability", "Ecology & Natural Environment", "Accessibility") and 2 outputs ("Economy", "Research & Development") are given in Figure 8. The standard CCR model assigns an equal efficiency to 9 world cities, viz. New York, Boston, Genève, Moscow, Beijing, Hong Kong, Tokyo, Los Angeles and Fukuoka, so that it is not possible to discriminate among these cities. However, by applying a super-efficient DEA model a clear difference in performance of these 9 cities can be observed (see Figure 8).

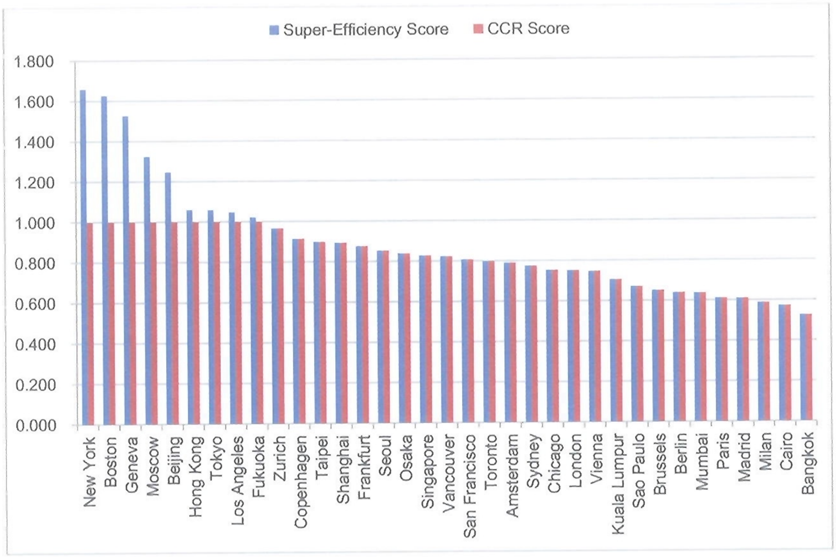

Figure 8. Efficiency score based on the CCR model and the Super-Efficiency model

In Figure 8, the rankings of the Super-Efficiency values for 9 of the 35 world cities (i.e. New York, 1.659; Boston, 1.628; Geneva, 1.527; Moscow, 1.325; Beijing, 1.248; Hong Kong, 1.060; Tokyo, 1.059; Los Angeles, 1.048; and Fukuoka, 1.022) were identified on the basis of their high Super-Efficiency score. It is noteworthy that in our analysis "New York" is the 'Exceptional World City' based on the Super-Efficiency model. This is an unambiguous result that originates from the advantages of the design of the Super- Efficiency model.

It should be added that these results differ quite considerably from those achieved in the original GPCI-2010 report (see Annex). The reason is that our productivity-based analysis allows non-megacities (such as Boston or Geneva) to achieve a favorable efficiency outcome, in which size and agglomeration effects are combined with smart management of the urban area concerned.

Nevertheless, metropolitan areas like New York or Tokyo have managed to maintain their high ranking in our efficiency analysis. Clearly, there are economies of scale for world cities, but some medium-sized world cities appear to perform exceptionally well.

13.7.2 *Efficiency scores and categorization based on CD-Super-Efficiency*

The detailed efficiency evaluation results for the 35 world cities based on the CD-Super-Efficiency model with the six performance categories E1-E6 are given in Figure 9.

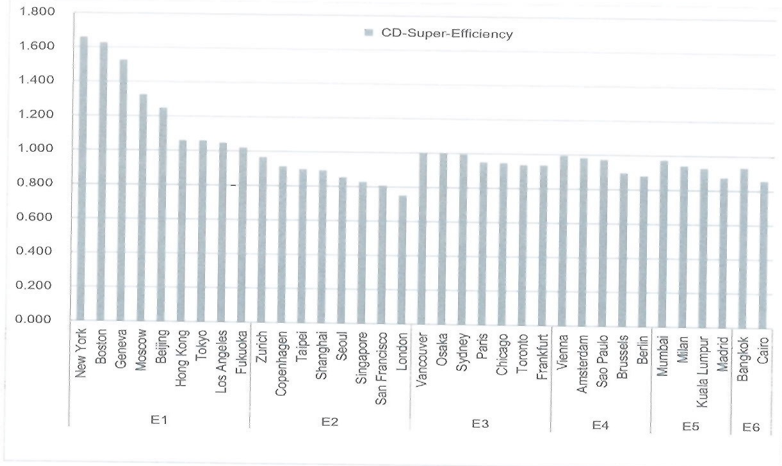

Figure 9. Efficiency scores and categorizations based on CD-Super-Efficiency

In Figure 9, the DMUs in set E1 (New York, Boston, Geneva, Moscow, Beijing, Hong Kong, Tokyo, Los Angeles, and Fukuoka) represent the cities with the highest efficiency (these cities correspond to D1, D2 and D3 in Figure 6, which define the first-level efficient frontier group). These nine are identified on the basis of the super-efficient DMU concept.

The eight DMUs in set E2 (Zurich, Copenhagen, Taipei, Shanghai, Seoul, Singapore, San Francisco, and London) are the second-tier efficient cities (these cities correspond to D4, D5, D6 and D7 in Figure 6, which define the second-level efficient frontier group), after the exclusion of the first-level efficient cities. The seven DMUs in set E3 (Vancouver, Osaka, Sydney, Paris, Chicago, Toronto, and Frankfurt) relate to the third-level efficient cities, after the exclusion of the second-level efficient cities. Next, the five DMUs in set E4 (Vienna, Amsterdam, Sao Paulo, Brussels, and Berlin) are fourth-level efficient cities, while the DMUs in set E5 (Mumbai, Milan, Kuala Lumpur, and Madrid) and the DMUs in set E6 (Bangkok and Cairo) represent the fifth-level and sixth-level efficient frontier, respectively.

On the basis of these more differentiated performance categories, we will compute in a quantitative sense an efficiency improvement projection for the nearest upper-level efficient frontier for inefficient cities in the next section.

13.8 Efficiency Improvement Projection for Inefficient Cities

13.8.1 Direct efficiency-improving projection based on SE and SE-DFM models

The direct efficiency improvement projection results based on the SE and the SE-DFM model for inefficient cities are presented in Tables 1a and 1b.

Table 1a. Direct efficiency improvement projection of the SE and SE-DFM model

DMU	Score	SE model Score(θ**)		SE-DFM model Score(θ**)	
I/O	Data	Difference	%	Difference $d_{io}^{x^*}-s^{-**}$ $d_{ro}^{y^*}+s^{+**}$	%
London	0.752	1.000		1.000	
(I)Cultural Exchange	60.6	-18.5	-30.6%	0.0	0.0%
(I)Livability	44.3	-11.0	-24.8%	0.0	0.0%
(I)Environment	57.8	-14.3	-24.8%	-13.0	-22.5%
(I)Accessibility	56.0	-15.8	-28.2%	0.0	0.0%
(O)Economy	50.5	0.0	0.0%	7.2	14.2%
(O)R&D	44.1	15.4	34.9%	0.0	0.0%
Paris	0.612	1.000		1.000	
(I)Cultural Exchange	51.3	-20.2	-39.4%	0.0	0.0%
(I)Livability	55.6	-23.9	-42.9%	0.0	0.0%
(I)Environment	56.2	-21.8	-38.8%	-18.5	-32.9%
(I)Accessibility	57.9	-22.4	-38.8%	0.0	0.0%
(O)Economy	42.9	0.0	0.0%	12.5	29.1%
(O)R&D	40.3	0.0	0.0%	0.0	0.0%
Singapore	0.829	1.000		1.000	
(I)Cultural Exchange	31.0	-5.3	-17.1%	0.0	0.0%
(I)Livability	38.6	-6.6	-17.1%	-6.3	-16.3%
(I)Environment	59.0	-10.1	-17.1%	0.0	0.0%
(I)Accessibility	42.1	-7.2	-17.1%	0.0	0.0%
(O)Economy	43.0	0.0	0.0%	4.0	9.4%
(O)R&D	29.7	3.5	12.0%	0.0	0.0%
Berlin	0.639	1.000		1.000	
(I)Cultural Exchange	28.2	-14.3	-50.7%	0.0	0.0%
(I)Livability	48.7	-17.6	-36.1%	0.0	0.0%
(I)Environment	66.8	-24.5	-36.7%	0.0	0.0%
(I)Accessibility	32.6	-11.8	-36.1%	-11.0	-33.9%
(O)Economy	33.8	0.0	0.0%	7.8	23.0%
(O)R&D	22.7	0.0	0.0%	0.0	0.0%
Amsterdam	0.791	1.000		1.000	
(I)Cultural Exchange	17.9	-3.7	-20.9%	0.0	0.0%
(I)Livability	48.2	-10.1	-20.9%	-9.2	-19.0%
(I)Environment	65.3	-13.7	-20.9%	0.0	0.0%
(I)Accessibility	41.0	-10.8	-26.4%	0.0	0.0%
(O)Economy	40.1	0.0	0.0%	4.7	11.7%
(O)R&D	18.5	3.1	17.0%	0.0	0.0%
Seoul	0.854	1.000		1.000	
(I)Cultural Exchange	20.9	-3.0	-14.6%	0.0	0.0%
(I)Livability	38.8	-5.7	-14.6%	-4.5	-11.6%
(I)Environment	55.8	-10.9	-19.5%	0.0	0.0%
(I)Accessibility	36.1	-6.8	-19.0%	0.0	0.0%
(O)Economy	36.4	0.0	0.0%	3.8	10.5%
(O)R&D	40.2	0.0	0.0%	0.0	0.0%
Sydney	0.776	1.000		1.000	
(I)Cultural Exchange	23.2	-7.9	-34.0%	0.0	0.0%
(I)Livability	45.2	-10.1	-22.4%	0.0	0.0%
(I)Environment	60.4	-14.1	-23.4%	0.0	0.0%
(I)Accessibility	29.7	-6.7	-22.4%	-5.8	-19.6%
(O)Economy	37.8	0.0	0.0%	5.0	13.1%
(O)R&D	22.2	0.0	0.0%	0.0	0.0%

DMU	Score	SE model Score(θ**)		SE-DFM model Score(θ**)	
I/O	Data	Difference	%	Difference $d_{io}^{x^*}-s^{-**}$ $d_{ro}^{y^*}+s^{+**}$	%
Vienna	0.747	1.000		1.000	
(I)Cultural Exchange	24.9	-11.7	-47.2%	0.0	0.0%
(I)Livability	47.5	-12.0	-25.3%	0.0	0.0%
(I)Environment	64.3	-18.9	-29.3%	0.0	0.0%
(I)Accessibility	28.7	-7.3	-25.3%	-6.7	-23.1%
(O)Economy	36.7	0.0	0.0%	5.5	14.9%
(O)R&D	15.6	0.0	0.0%	0.0	0.0%
Zurich	0.967	1.000		1.000	
(I)Cultural Exchange	8.0	-0.3	-3.3%	0.0	0.0%
(I)Livability	45.7	-1.5	-3.3%	-0.9	-1.9%
(I)Environment	71.4	-5.5	-7.7%	-4.3	-6.1%
(I)Accessibility	29.6	-6.3	-21.3%	-5.6	-18.8%
(O)Economy	41.3	0.0	0.0%	0.7	1.8%
(O)R&D	19.2	0.0	0.0%	0.0	0.0%
Frankfurt	0.876	1.000		1.000	
(I)Cultural Exchange	10.5	-1.3	-12.4%	0.0	0.0%
(I)Livability	45.2	-5.6	-12.4%	-4.5	-9.9%
(I)Environment	66.5	-8.2	-12.4%	0.0	0.0%
(I)Accessibility	38.5	-14.3	-37.3%	0.0	0.0%
(O)Economy	38.5	0.0	0.0%	2.5	6.6%
(O)R&D	13.8	4.5	32.8%	0.0	0.0%
Madrid	0.610	1.000		1.000	
(I)Cultural Exchange	21.4	-8.4	-39.0%	0.0	0.0%
(I)Livability	48.6	-18.9	-39.0%	-20.3	-41.7%
(I)Environment	60.6	-23.6	-39.0%	0.0	0.0%
(I)Accessibility	35.4	-13.8	-39.0%	0.0	0.0%
(O)Economy	32.1	0.0	0.0%	7.8	24.2%
(O)R&D	10.9	2.8	25.8%	0.0	0.0%
Vancouver	0.825	1.000		1.000	
(I)Cultural Exchange	12.4	-2.2	-17.5%	0.0	0.0%
(I)Livability	60.7	-25.8	-42.6%	-22.4	-36.9%
(I)Environment	56.4	-9.9	-17.5%	-10.1	-17.9%
(I)Accessibility	25.9	-4.5	-17.5%	0.0	0.0%
(O)Economy	34.6	0.0	0.0%	3.7	10.8%
(O)R&D	17.8	0.0	0.0%	0.0	0.0%
Copenhagen	0.914	1.000		1.000	
(I)Cultural Exchange	11.2	-1.0	-8.6%	0.0	0.0%
(I)Livability	46.7	-4.0	-8.6%	-3.1	-6.7%
(I)Environment	62.7	-5.4	-8.6%	0.0	0.0%
(I)Accessibility	31.3	-3.4	-11.0%	-3.2	-10.2%
(O)Economy	41.1	0.0	0.0%	1.8	4.5%
(O)R&D	13.5	6.0	44.3%	7.4	54.8%
Osaka	0.839	1.000		1.000	
(I)Cultural Exchange	12.9	-2.1	-16.1%	0.0	0.0%
(I)Livability	51.6	-16.9	-32.7%	-13.5	-26.1%
(I)Environment	52.8	-8.5	-16.1%	-9.4	-17.8%
(I)Accessibility	30.5	-4.9	-16.1%	0.0	0.0%
(O)Economy	34.0	0.0	0.0%	3.8	11.2%
(O)R&D	24.1	0.0	0.0%	0.0	0.0%

Legend: I = Input ; O = Output

Table 1b. Direct efficiency improvement projection of the SE and SE-DFM model

		SE model		SE-DFM model	
DMU	Score	Score(θ**)		Score(θ**)	
I/O	Data	Difference	%	Difference $d_{io}^{x*}-s^{-**}$ $d_{ro}^{y*}+s^{+**}$	%
Brussels	0.652	1.000		1.000	
(I)Cultural Exchange	21.4	-7.4	-34.8%	0.0	0.0%
(I)Livability	46.9	-16.3	-34.8%	-17.8	-37.8%
(I)Environment	52.7	-18.3	-34.8%	0.0	0.0%
(I)Accessibility	34.4	-12.0	-34.8%	0.0	0.0%
(O)Economy	32.8	0.0	0.0%	7.0	21.4%
(O)R&D	14.7	0.0	0.0%	0.0	0.0%
San Francisco	0.809	1.000		1.000	
(I)Cultural Exchange	16.3	-3.1	-19.2%	0.0	0.0%
(I)Livability	40.0	-7.7	-19.2%	-8.2	-20.6%
(I)Environment	54.8	-10.5	-19.2%	0.0	0.0%
(I)Accessibility	29.3	-5.6	-19.3%	0.0	0.0%
(O)Economy	33.9	0.0	0.0%	4.1	12.1%
(O)R&D	28.1	0.0	0.0%	0.0	0.0%
Toronto	0.798	1.000		1.000	
(I)Cultural Exchange	16.9	-3.4	-20.2%	0.0	0.0%
(I)Livability	46.4	-12.1	-26.0%	-8.3	-17.8%
(I)Environment	52.2	-10.6	-20.2%	-12.8	-24.5%
(I)Accessibility	30.8	-6.2	-20.2%	0.0	0.0%
(O)Economy	35.8	0.0	0.0%	4.6	12.7%
(O)R&D	20.1	0.0	0.0%	0.0	0.0%
Chicago	0.754	1.000		1.000	
(I)Cultural Exchange	20.8	-5.1	-24.6%	-1.4	-6.5%
(I)Livability	36.9	-9.1	-24.6%	-9.1	-24.8%
(I)Environment	46.0	-11.3	-24.6%	0.0	0.0%
(I)Accessibility	32.8	-8.7	-26.5%	0.0	0.0%
(O)Economy	31.5	0.0	0.0%	5.1	16.3%
(O)R&D	28.9	0.0	0.0%	0.0	0.0%
Shanghai	0.894	1.000		1.000	
(I)Cultural Exchange	23.9	-2.5	-10.6%	-2.2	-9.3%
(I)Livability	46.4	-9.1	-19.6%	-6.2	-13.3%
(I)Environment	40.8	-4.3	-10.6%	-2.2	-5.4%
(I)Accessibility	31.6	-3.4	-10.6%	0.0	0.0%
(O)Economy	42.3	0.0	0.0%	2.4	5.6%
(O)R&D	11.5	2.5	21.7%	4.6	40.0%
Milan	0.588	1.000		1.000	
(I)Cultural Exchange	20.2	-8.3	-41.2%	-4.8	-24.0%
(I)Livability	49.4	-23.8	-48.2%	-16.4	-33.2%
(I)Environment	46.9	-19.3	-41.2%	-19.6	-41.7%
(I)Accessibility	30.8	-12.7	-41.2%	0.0	0.0%
(O)Economy	27.5	0.0	0.0%	7.1	25.9%
(O)R&D	9.5	0.2	2.1%	7.0	73.4%

		SE model		SE-DFM model	
DMU	Score	Score(θ**)		Score(θ**)	
I/O	Data	Difference	%	Difference $d_{io}^{x*}-s^{-**}$ $d_{ro}^{y*}+s^{+**}$	%
Taipei	0.899	1.000		1.000	
(I)Cultural Exchange	7.3	-0.7	-10.1%	0.0	0.0%
(I)Livability	45.4	-12.6	-27.7%	-10.7	-23.5%
(I)Environment	48.5	-4.9	-10.1%	-3.9	-8.1%
(I)Accessibility	28.4	-7.7	-27.0%	-5.9	-20.7%
(O)Economy	30.2	0.0	0.0%	2.0	6.6%
(O)R&D	16.7	0.0	0.0%	0.0	0.0%
Kuala Lumpur	0.706	1.000		1.000	
(I)Cultural Exchange	14.0	-4.1	-29.4%	0.0	0.0%
(I)Livability	38.7	-11.4	-29.4%	-10.9	-28.1%
(I)Environment	54.2	-15.9	-29.4%	0.0	0.0%
(I)Accessibility	30.5	-9.5	-31.2%	0.0	0.0%
(O)Economy	28.7	0.0	0.0%	4.9	17.2%
(O)R&D	4.4	11.0	250.6%	0.0	0.0%
Bangkok	0.527	1.000		1.000	
(I)Cultural Exchange	22.6	-10.7	-47.3%	0.0	0.0%
(I)Livability	39.4	-18.6	-47.3%	-20.5	-52.0%
(I)Environment	47.5	-22.5	-47.3%	0.0	0.0%
(I)Accessibility	29.1	-13.8	-47.3%	0.0	0.0%
(O)Economy	24.0	0.0	0.0%	7.4	31.0%
(O)R&D	6.9	5.7	82.1%	0.0	0.0%
Sao Paulo	0.671	1.000		1.000	
(I)Cultural Exchange	9.9	-7.1	-71.5%	-6.5	-65.8%
(I)Livability	40.2	-13.3	-33.0%	-7.9	-19.8%
(I)Environment	63.0	-23.0	-36.4%	-15.1	-23.9%
(I)Accessibility	18.8	-6.2	-32.9%	-3.7	-19.7%
(O)Economy	24.0	0.0	0.0%	4.7	19.7%
(O)R&D	3.0	6.7	224.4%	8.6	288.4%
Mumbai	0.637	1.000		1.000	
(I)Cultural Exchange	9.4	-5.9	-63.3%	0.0	0.0%
(I)Livability	42.7	-20.2	-47.2%	0.0	0.0%
(I)Environment	51.1	-18.5	-36.3%	0.0	0.0%
(I)Accessibility	17.4	-6.3	-36.3%	-5.1	-29.3%
(O)Economy	20.7	0.0	0.0%	4.6	22.2%
(O)R&D	3.9	4.1	104.0%	0.0	0.0%
Cairo	0.573	1.000		1.000	
(I)Cultural Exchange	11.9	-5.1	-42.7%	0.0	0.0%
(I)Livability	33.0	-14.1	-42.7%	-14.4	-43.7%
(I)Environment	42.5	-18.1	-42.7%	0.0	0.0%
(I)Accessibility	29.3	-14.3	-48.6%	0.0	0.0%
(O)Economy	19.6	0.0	0.0%	5.3	27.1%
(O)R&D	1.3	9.2	721.5%	0.0	0.0%

Legend: I = Input ; O = Output

We will now offer a concise interpretation of the results presented in these tables. We will take Amsterdam as an illustrative example. From Table 1a, the SE projection shows that, for instance, Amsterdam – in order to achieve a super-efficiency state – should reduce its input volumes Cultural Exchange, Liveability, and Environment by 20.9 per cent, and Accessibility by 26.4 per cent in order to become efficient. On the other hand, the SE-DFM projection results show that a reduction in the Liveability of 19.0 per cent and an increase in the Economy of 11.7 per cent is required to become efficient. It should be added that in a deterministic DEA model these findings are numerically correct, but that in policy practice such accurate adjustments will hardly be achieved. Nevertheless, this information is indicative for the direction and intensity of necessary policy handles in a city to become efficient.

For the sake of illustration, a comparison of the projection results of Amsterdam is presented in Figure 10. This result clearly shows that a different – and more efficient and effective – solution is available than the SE projection to reach the efficiency frontier.

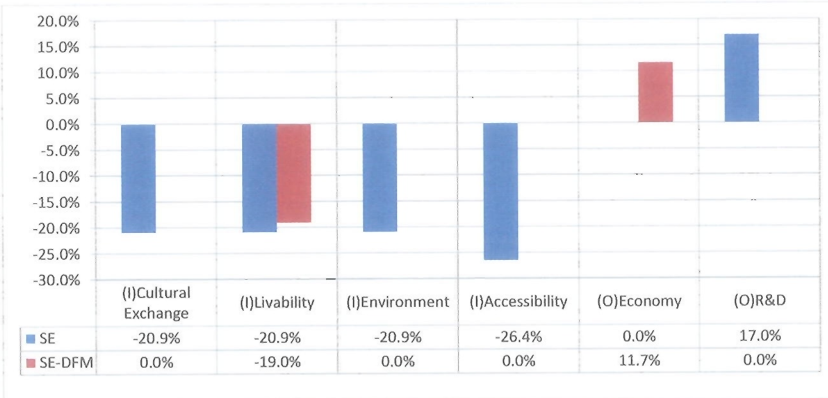

Figure 10. Projection results of Amsterdam, based on SE and SE-DFM

13.9 Stepwise Efficiency-Improving Projection Based on SE and SE-DFM Models

The stepwise efficiency-improvement projection results based on the SE and SE-DFM model for inefficient cities are presented in Tables 2a and 2b.

In Tables 2a and 2b, it appears that the ratios of change in the Stepwise SE-DFM projection are smaller than those in the Stepwise SE projection, as might be expected. In Tables 2a and 2b, this particularly applies to Sao Paulo, Brussels, Mumbai, and Kuala Lumpur, which are non-slack type DMUs (i.e. s^{-**} and s^{+**} are zero). Apart from the practicality of such a solution, the models show clearly that a different – and perhaps more efficient – solution is available than the Stepwise SE projection to reach the efficiency frontier.

The more advanced Stepwise SE-DFM model is able to present a more realistic efficiency-improvement result, which we can compare with the results of Tables 1b and b. For instance, the SE-DFM results in Table 1b show that Mumbai should reduce its accessibility indicator by 29.3 per cent, and increase the Economy by 22.2 per cent in order to become entirely efficient. On the other hand, the Stepwise SE-DFM results in Table 2b show that a reduction in Accessibility of 3.1 per cent, and an increase in the Economy of 1.3 per cent are required to become efficient (this means that Mumbai can attain the E4 level efficient frontier moving up from the E5 level). It should be noted that also in this case the same proviso on the interpretation holds, as indicated above.

Table 2a. Stepwise efficiency-improvement projections based on SE and DFM

	DMU	Score	Stepwise SE		Stepwise SE-DFM	
			Score(θ**)		Score(θ**)	
	I/O	Data	Difference	%	Difference $d_{io}x^*-s^{-**}$ $d_{ro}y^*+s^{+**}$	%
E3	Vancouver	0.999	1.000		1.000	
	(I)Cultural Exchange	12.4	-2.6	-20.5%	-2.6	-25.9%
	(I)Livability	60.7	-22.0	-36.2%	-22.0	-56.7%
	(I)Environment	56.4	-0.1	-0.1%	0.0	0.0%
	(I)Accessibility	25.9	0.0	-0.1%	0.0	-0.1%
	(O)Economy	34.6	0.0	0.0%	0.0	0.1%
	(O)R&D	17.8	0.0	0.0%	0.0	0.0%
	Osaka	0.998	1.000		1.000	
	(I)Cultural Exchange	12.9	0.0	-0.3%	0.0	0.0%
	(I)Livability	51.6	-10.0	-19.3%	-9.8	-23.6%
	(I)Environment	52.8	-0.1	-0.3%	-0.1	-0.2%
	(I)Accessibility	30.5	-0.1	-0.3%	0.0	0.0%
	(O)Economy	34.0	0.0	0.0%	0.1	0.2%
	(O)R&D	24.1	0.0	0.0%	0.0	0.0%
	Sydney	0.995	1.000		1.000	
	(I)Cultural Exchange	23.2	-9.8	-42.3%	0.0	0.0%
	(I)Livability	45.2	-2.3	-5.0%	0.0	0.0%
	(I)Environment	60.4	-0.3	-0.5%	0.0	0.0%
	(I)Accessibility	29.7	-0.1	-0.5%	-8.1	-27.6%
	(O)Economy	37.8	0.0	0.0%	0.1	0.3%
	(O)R&D	22.2	0.0	0.0%	3.4	15.3%
	Paris	0.951	1.000		1.000	
	(I)Cultural Exchange	51.3	-2.5	-4.9%	0.0	0.0%
	(I)Livability	55.6	-15.5	-27.8%	-14.4	-35.9%
	(I)Environment	56.2	-2.8	-4.9%	-1.5	-2.9%
	(I)Accessibility	57.9	-9.5	-16.5%	-7.8	-16.0%
	(O)Economy	42.9	1.4	3.4%	2.9	6.6%
	(O)R&D	40.3	0.0	0.0%	1.0	2.5%
	Chicago	0.948	1.000		1.000	
	(I)Cultural Exchange	20.8	-1.1	-5.2%	0.0	0.0%
	(I)Livability	36.9	-3.6	-9.7%	-2.2	-6.5%
	(I)Environment	46.0	-2.4	-5.2%	-1.4	-3.3%
	(I)Accessibility	32.8	-2.8	-8.5%	-1.8	-5.9%
	(O)Economy	31.5	0.0	0.0%	1.4	4.3%
	(O)R&D	28.9	0.0	0.0%	0.0	0.0%
	Toronto	0.938	1.000		1.000	
	(I)Cultural Exchange	16.9	-1.1	-6.2%	0.0	0.0%
	(I)Livability	46.4	-7.0	-15.1%	-3.5	-9.0%
	(I)Environment	52.2	-3.2	-6.2%	-3.0	-6.2%
	(I)Accessibility	30.8	-1.9	-6.2%	0.0	0.0%
	(O)Economy	35.8	0.0	0.0%	1.4	4.0%
	(O)R&D	20.1	0.0	0.0%	0.0	0.0%
	Frankfurt	0.937	1.000		1.000	
	(I)Cultural Exchange	10.5	-0.7	-6.3%	0.0	0.0%
	(I)Livability	45.2	-2.8	-6.3%	-2.2	-5.3%
	(I)Environment	66.5	-4.2	-6.3%	0.0	0.0%
	(I)Accessibility	38.5	-10.5	-27.2%	-8.7	-30.9%
	(O)Economy	38.5	0.0	0.0%	1.2	3.2%
	(O)R&D	13.8	3.4	24.7%	5.7	33.4%

	DMU	Score	Stepwise SE		Stepwise SE-DFM	
			Score(θ**)		Score(θ**)	
	I/O	Data	Difference	%	Difference $d_{io}x^*-s^{-**}$ $d_{ro}y^*+s^{+**}$	%
E4	Vienna	0.994	1.000		1.000	
	(I)Cultural Exchange	24.9	-3.8	-15.4%	-3.8	-18.2%
	(I)Livability	47.5	-0.3	-0.6%	0.0	0.0%
	(I)Environment	64.3	-5.5	-8.6%	-5.3	-9.1%
	(I)Accessibility	28.7	-0.2	-0.6%	-0.1	-0.3%
	(O)Economy	36.7	0.0	0.0%	0.1	0.3%
	(O)R&D	15.6	5.6	35.9%	5.6	26.6%
	Amsterdam	0.983	1.000		1.000	
	(I)Cultural Exchange	17.9	-0.3	-1.7%	0.0	0.0%
	(I)Livability	48.2	-0.8	-1.7%	0.0	0.0%
	(I)Environment	65.3	-1.1	-1.7%	-1.1	-1.7%
	(I)Accessibility	41.0	-0.7	-1.8%	-0.9	-2.2%
	(O)Economy	40.1	0.0	0.0%	0.3	0.9%
	(O)R&D	18.5	5.3	28.5%	5.4	22.8%
	Sao Paulo	0.974	1.000		1.000	
	(I)Cultural Exchange	9.9	-0.3	-2.7%	0.0	0.0%
	(I)Livability	40.2	-1.1	-2.7%	0.0	0.0%
	(I)Environment	63.0	-24.0	-38.1%	0.0	0.0%
	(I)Accessibility	18.8	-0.5	-2.7%	-0.5	-2.8%
	(O)Economy	24.0	0.0	0.0%	0.3	1.3%
	(O)R&D	3.0	9.6	322.3%	0.0	0.0%
	Brussels	0.898	1.000		1.000	
	(I)Cultural Exchange	21.4	-2.2	-10.3%	0.0	0.0%
	(I)Livability	46.9	-4.8	-10.2%	0.0	0.0%
	(I)Environment	52.7	-5.4	-10.2%	-4.4	-9.4%
	(I)Accessibility	34.4	-3.5	-10.2%	0.0	0.0%
	(O)Economy	32.8	0.0	0.0%	1.8	5.4%
	(O)R&D	14.7	6.5	44.4%	0.0	0.0%
	Berlin	0.882	1.000		1.000	
	(I)Cultural Exchange	28.2	-7.0	-24.8%	-6.7	-31.5%
	(I)Livability	48.7	-8.5	-17.4%	-8.7	-21.6%
	(I)Environment	66.8	-14.0	-20.9%	-15.0	-28.3%
	(I)Accessibility	32.6	-3.9	-11.8%	-2.1	-7.1%
	(O)Economy	33.8	0.0	0.0%	0.0	0.0%
	(O)R&D	22.7	0.0	0.0%	2.3	10.3%

Table 2b. Stepwise efficiency-improvement projections based on SE and DFM

	DMU	Score	Stepwise SE Score(θ**)		Stepwise SE-DFM Score(θ**)	
	I/O	Data	Difference	%	Difference $d_{io}^{x*}-s^{-**}$ $d_{ro}^{y*}+s^{+**}$	%
E5	Mumbai	0.973	1.000		1.000	
	(I)Cultural Exchange	9.4	-0.2	-2.7%	0.0	0.0%
	(I)Livability	42.7	-10.2	-23.9%	0.0	0.0%
	(I)Environment	51.1	-1.4	-2.7%	0.0	0.0%
	(I)Accessibility	17.4	-0.5	-2.7%	-0.5	-3.1%
	(O)Economy	20.7	0.0	0.0%	0.3	1.3%
	(O)R&D	3.9	0.2	4.2%	0.0	0.0%
	Madrid	0.875	1.000		1.000	
	(I)Cultural Exchange	21.4	-2.7	-12.5%	0.0	0.0%
	(I)Livability	48.6	-6.5	-13.5%	-0.8	-1.8%
	(I)Environment	60.6	-7.6	-12.5%	-5.4	-10.3%
	(I)Accessibility	35.4	-4.4	-12.5%	0.0	0.0%
	(O)Economy	32.1	0.0	0.0%	2.1	6.7%
	(O)R&D	10.9	3.4	31.4%	4.5	31.3%
	Milan	0.942	1.000		1.000	
	(I)Cultural Exchange	20.2	-2.3	-11.3%	-1.7	-9.7%
	(I)Livability	49.4	-10.1	-20.4%	-8.9	-22.6%
	(I)Environment	46.9	-2.7	-5.8%	-1.4	-3.2%
	(I)Accessibility	30.8	-1.9	-6.3%	-1.1	-3.7%
	(O)Economy	27.5	0.0	0.0%	0.8	3.0%
	(O)R&D	9.5	2.8	29.5%	3.2	25.8%
	Kuala Lumpur	0.930	1.000		1.000	
	(I)Cultural Exchange	14.0	-1.0	-7.0%	0.0	0.0%
	(I)Livability	38.7	-2.7	-7.0%	0.0	0.0%
	(I)Environment	54.2	-4.3	-8.0%	0.0	0.0%
	(I)Accessibility	30.5	-2.1	-7.0%	-2.3	-8.1%
	(O)Economy	28.7	0.0	0.0%	1.0	3.6%
	(O)R&D	4.4	7.8	177.8%	0.0	0.0%
E6	Bangkok	0.933	1.000		1.000	
	(I)Cultural Exchange	22.6	-7.5	-33.1%	-6.9	-45.3%
	(I)Livability	39.4	-2.6	-6.7%	0.0	0.0%
	(I)Environment	47.5	-3.2	-6.7%	-2.6	-5.8%
	(I)Accessibility	29.1	-2.8	-9.6%	-1.8	-6.9%
	(O)Economy	24.0	0.0	0.0%	0.9	3.7%
	(O)R&D	6.9	0.0	0.0%	0.0	0.0%
	Cairo	0.859	1.000		1.000	
	(I)Cultural Exchange	11.9	-1.7	-14.1%	0.0	0.0%
	(I)Livability	33.0	-5.3	-16.0%	-1.5	-5.5%
	(I)Environment	42.5	-6.0	-14.1%	-3.9	-10.7%
	(I)Accessibility	29.3	-8.4	-28.5%	-6.6	-31.3%
	(O)Economy	19.6	0.0	0.0%	1.5	7.6%
	(O)R&D	1.3	2.3	178.6%	3.3	91.9%

13.9 Policy Lessons and Suggestions

Our DEA analysis has aimed to shed new light on the rankings of world cities. Most comparative studies are based on an aggregate (weighted or unweighted) average of a set of background factors that have been translated into operational indicators. The approach adopted in the present study has focused attention much more on the efficiency and productivity of large cities, using a comparative data set. These research presented in the present study has offered interesting insights into the benchmark position of world cities, based on an extensive data set. Our findings reveal striking differences compared with standard ranking and benchmarking procedures. In particular, the new methods to arrive at unambiguous DEA ranking results provide promising findings.

The Stepwise SE-DFM model provides the policy maker with practical and transparent solutions that are available in the SE-DFM projection to reach the nearest upper-level efficiency frontier. These results offer a meaningful contribution to decision support and planning for the efficiency improvement of strategic urban policy. And therefore, this Stepwise SE-DFM model may become a policy vehicle that may have great added value for operational decision making and planning in cities. Clearly, cities have the possibility to increase their potential. This improvement potential differs for each city, but our results offer operational guidelines on a case-by-case city basis.

In this paper we have in particular presented a new methodology, the SE-DFM and Stepwise SE-DFM model, which integrates a Super-Efficiency model, a DFM model and a CD model. The new method minimizes the distance friction for each input and output separately. As a result, the combined reductions in inputs and increases in outputs that are necessary to reach an efficiency frontier are smaller than in the standard model. Furthermore, the new model could be adapted to reflect realistic conditions in an efficiency-improvement projection. In addition, the stepwise projection allows DMUs to include various levels of ambition regarding the ultimate performance in their strategic judgment. Clearly, our deterministic DEA modeling results have to be interpreted with some caution, as the level of precision implied by our findings is in practical situations not achievable. Nevertheless, our results offer an indication of the level of intensity and the direction of policy efforts that are needed to upgrade the efficiency profile of world cities. In conclusion, our Stepwise SE-DFM model is able to present a more realistic efficiency-improvement urban policy strategy, and may thus provide a significant support contribution to decision making and planning for the efficiency improvement of the relevant agents involved.

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14 DIGITAL URBAN NETWORK CONNECTIVITY: GLOBAL AND CHINESE INTERNET PATTERNS*

Abstract

The majority of cities in our world are not only connected through conventional physical infrastructure, but increasingly through modern digital infrastructure. This paper aims to test whether digital connectivity leads to other linkage patterns among world cities than traditional infrastructure. Using a generalized spatial interaction models, this paper shows that geography (and distance) still matters for the extensive set of world cities analysed in the present study. With a view to the rapidly rising urbanization in many regions of our world, our attention is next focused on the emerging large cities in China in order to test the relevance of distance frictions – next to a broad set of other important explanatory variables – to digital connectivity in this country. Various interesting results are found regarding the digital connectivity within the Chinese urban system, while here geography also appears to play an important role.

Keywords: Digital networks, Internet, connectivity, world cities, death of distance, centrality, small-world networks, clustering, gravity model

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14.1 Prelude

Cities have over the past centuries become the cradle of political power and economic progress. Their position has become increasingly strong throughout the course of history. A highlight in the history of urban systems in our world was formed by the year 2007. This year represented an important milestone in the long record of urbanization: for the first time in human history, the city took over the 'power' from its hinterland, since as of that year more than 50 per cent of the world's population was registered as living in urban areas. The twenty-first century is nowadays even called by some people 'the urban century' (UN 2010). Surprisingly – and in contrast to this recent development – only a few centuries ago less than 20 per cent of the population on our earth lived in cities. This structural urban development is still continuing, with urbanization rates exceeding 70 per cent in various European countries and elsewhere (for details see e.g. Mega 2010). Although there are also signs of shrinking cities nowadays, these are rather an exception. Mulligan and Crampton (2005) find that city size evolution is tied to the overall national population size, although the growth rate of any city depends on a complex myriad of private and public forces (e.g. amenities, social capital, industrial diversity and connectivity).

It is also noteworthy that cities are becoming nodal points in complex, multilayered and often global networks. Traditionally, such nodal points were production and consumption centres that were connected by means of physical infrastructures through which material flows of people and goods could be transported. Infrastructure essentially acted as the backbone of an interconnected economy, with a fractal representation at various geographical scale levels (see e.g. Batty and Longley 1994).

The views on the position of global, international and connected (or network) cities have changed significantly over the years. Cities increasingly act in a system of connected networks that serve as strategic alliances for the development of our world (for an extensive urban network analysis see Neal 2012). From this perspective, urban agglomerations are not necessarily a source of problems, but offer a strategic economic platform for creative solutions and new opportunities on a worldwide scale. Thanks to the seminal work of Jane Jacobs (1961), we know that social capital (e.g. in the form of bonding and networking) and human capital (e.g. in the form of creative entrepreneurship or self-employment) are essential for smart and booming urban economies (see Nijkamp and Kourtit 2012).

In addition to the strategic reprofiling of urban areas into integrated network cities, we also observe a gradual new transformation of urban agglomerations into (regional, national or even global) spatial-economic network constellations. Worldwide, urban areas are becoming centripetal and centrifugal nodes in complex multilayered networks (Taylor 2001; Taylor et al. 2002; Taylor 2004), in which regional and national borders play a less prominent role. This new development may turn into an urban network revolution in the history of human settlements. This may lead to the emergence of hierarchical networks or interconnected global networks of urban agglomerations. Such city networks will definitely become a source of creative and strategic research and policy action regarding the future of metropolitan areas.

It is thus plausible that cities in our age are likely to turn into complex connected networks ('network cities in city networks') and will accommodate a rising share of the socio-economic activities of a nation as a result of proximity and density externalities. These spatial urban constellations have been studied in the urban science literature from a variety of different analytical perspectives (see Nijkamp 2008 for a review). Urban agglomerations and networks will become the cornerstones of global interaction and evolution.

In parallel with a rapid rise in urbanization rates, another megatrend has emerged, viz. the transition to a 'digital economy', thanks to the introduction and large-scale penetration of information and communication technologies (ICT) in all the sectors of the economy. This phenomenon has induced an intense debate on the spatial consequences of these modern technologies, which has led to various metaphors such as 'tele-cities' or 'electronic cottages'. For a critical review, see, *inter alia*, Cohen et al. (2002) and Cohen and Nijkamp (2006). In a more challenging way, the above-mentioned debate can be summarized under the heading of the validity of the 'death of distance' hypothesis (see Cairncross 2001). Despite the fuss related to this hypothesis, it has also been increasingly questioned (see Wang et al. 2003). A test of this hypothesis calls for solid empirical research (see also Gorman and Malecki 2002).

The debate on the impacts of ICT on cities already has a respectable history. It follows – from a social–functional perspective – the Castells (1996) thesis on the 'space of flows', while it also has strong roots in the regional economic analysis of ICT impacts (see e.g. Cohen et al. 2002). ICT, just like ordinary infrastructure, provides the necessary spatial framework for the development and existence of urban systems at various levels. A limited number of studies regarding the impact of traditional and digital infrastructure in emerging economies – in particular China – can also be recorded. We refer here to Démurger (2001), who offers an impact assessment of (general) infrastructure and regional growth in China, to Ding and Haynes (2006), who study the leapfrogging implications of ICT in China, and to Ding et al. (2008), who research the relation between telecommunications infrastructure and income convergence. Advanced infrastructure appears to be critical in all cases. An under-investigated issue, however, is the question of how cities and urban networks are related to digital spatial connectivity. This will be the main research challenge in this paper. The central methodological task is to investigate whether in a spatial interaction model, in which the spatial interaction refers to the digital infrastructural capacity (e.g. the digital links that form the Internet), the standard gravity model still holds. The main aim of our study is now to test whether the empirical connectivity pattern reflected in the Internet infrastructural capacity leads to a statistically significant model based on standard gravitational forces in relation to a spatial interaction model. The second aim of our study is to analyse whether the digital connectivity in urban systems in rapidly emerging economies – in particular in China – can also be appropriately mapped out by a spatial interaction representation of Internet linkages. Also, when necessary, comparisons with other world regions (e.g. Europe) are also made. In summary, the purpose of our article is to explore the symbiotic relation between urban systems and digital infrastructural networks, both worldwide and within China.

China, as an important player in both Asia and worldwide, is an interesting case because of its rapid economic and technological growth. Many Asian countries – including China – have in the past decade exhibited surprisingly high economic growth. At the same time, many of these countries have shown very high urbanization rates, to the extent that many large to very large cities can be found in Asia nowadays. The unprecedented rise in megacities in Asia is partly caused by their indigenous growth mechanisms and partly by their high-quality connectivity. A recent study by the UN (2010) demonstrated that of the world's largest cities (30 in total), 17 such megacities are located in Asia. Urban agglomeration externalities are apparently so powerful in this region that an unprecedentedly strong urbanization megatrend is emerging (see also Kusakabe 2012; Morichi and Raj Acharya 2013).

China has witnessed not only formidable economic growth in the past decades, but also a surprising rise in the urbanization degree, with many new megacities. For that reason, the infrastructure policy is of paramount importance in this country. However, physical connectivity is not sufficient; digital connectivity in an information society driven by digital infrastructure is equally important. Therefore, a closer analysis of the geographical structure and intensity of the usage of digital technologies in China (in particular, the Internet) is a challenging research task. In our empirical study, we will address in particular the digital connectivity among major urban agglomerations in China, including not only the big megacities such as Shanghai or Beijing, but also many lower-ranked – but often still multi-million – cities.

Methodologically, apart from econometrics to understand the impact of gravitational forces on the evolution of the digital infrastructure, concepts and techniques from the network analysis field are utilized. The latter has become a very advanced research area, starting from Euler's well-known Köningsburg bridge system to small-world or scale-free networks. In the recent geography and regional science literature, considerable attention has been paid to spatial linkage analysis and spatial interaction models, in which the interwovenness of cities has also been studied extensively (including the hierarchical organization of cities, e.g. in the context of central place theory or Zipf's law). With the introduction of digital technology, new types of connected networks have emerged, often of a hub-and-spokes nature, with various degrees of user intensity on different edges. A common characteristic of some these networks is their spatial reflection. The methodological novelty of this paper is the utilization of network analysis with econometrics to understand whether the gradually emerging global network connectivity pattern is also replicated at the level of an upcoming economic region such as Asia, and in particular whether such a pattern appears in a rapidly emerging country like China.

The present paper is organized as follows. After this introductory section, Section 14.2 will concisely describe the database for the models to be used, while Section 14.3 will be devoted to a modelling experiment on digital connectivity among world cities. China is a rising player in a global Internet connectivity system, and therefore, in Section 14.4, our study will zoom in on the Chinese urban network, in comparison with Europe and the USA. An explanatory causal econometric model for digital connectivity in China – and its results – will be presented in Section 14.5, while Section 14.6 will offer concluding remarks.

14.2 Data for Digital Connectivity

The main database used for this paper has been derived from the DIMES project. This is 'a distributed scientific research project, aimed to study the structure and topology of the Internet' (DIMES 2010). It is based on 3–6 million traceroute[1] measurements made daily by a global network of more than 10,000 agents, who are participating in this research project voluntarily (see Carmi et al. 2007; for a description of the DIMES project, see also Shavitt and Shir 2005). One of the outcomes of the DIMES project is an extensive database with geo-located IP (Internet protocol) links discovered by the DIMES volunteers. It contains all the IP links between any two cities discovered by the agents. Although overlapping connections between any two regions are included in the database, there is no information on the bandwidth of these links. However, this is still an infrastructural measure, as the IP links represent physical (overlapping) data links between cities, which follow the IP protocol.[2]

Some important notes should be made at this outset. Firstly, the DIMES project only includes IP links that have been captured by its agents and thus only a small fraction of the total Internet. By sending data packets from the agents' locations to known destinations, DIMES researchers record the different IP links used by its agents, completing the largest available data set for geo-coded IP links.

Secondly, there is a common limitation faced by any study focusing on the Internet from a spatial perspective: the Internet has been built as a logical network and its links are defined in topological and not in geographic terms. Therefore, the architecture of Internet destinations (IP addresses) has little to do with geographical locations (Dodge and Zook 2009). To geo-locate the above system, the DIMES project geo-codes the different IP addresses using IP registration tables. A potential accuracy issue needs to be highlighted here. It is not uncommon that IP addresses are owned by expert firms, which lease these IP addresses to content providers (Dodge and Zook 2009). This might result in a possible mismatch between the physical locations of IP addresses and the content location. However, this does not create any bias here, as the focus of this paper is on the physical infrastructure of the Internet.

Different subsets of this global DIMES data set are used for this paper. For the analysis in Section 14.3, which focuses on digital connectivity and world cities, the IP links among a sample of 34 world cities are utilized for the year 2010. This analysis is limited to a cross-section of these 34 cities for 1 year because of the scarce data on world city characteristics. More details of these data are provided in the next section. After the global analysis of linkages between cities worldwide, in Sections 14.4 and 14.5, the analysis turns to the Chinese urban system, which includes IP links

[1] Traceroutes are specific programs that map the route that a data packet follows through different nodes in order to reach its final destination (Dodge and Zook 2009).

[2] These links function at level 3 of the OSI model. As noted elsewhere (Tranos 2013), the first three layers of the OSI model represent physical infrastructural capital, while the four highest layers reflect 'infratechnologies' (Tassey 1992, 2008).

only between Chinese cities. This analysis follows panel specifications and includes the period 2007–2011.

In a nutshell, the DIMES data set is, at least to the best of our knowledge, the richest available geographical data source regarding the Internet infrastructure. Despite the above limitations, the scattered locations of the agents and the size of the DIMES experiment secure the robustness of this data set, especially considering the general lack of geographic data on the Internet infrastructure.

14.3 Digital Connectivity and Global Cities: A High-Level Analysis

Before focusing on the main object of our analysis, viz. the digital infrastructure of the Chinese urban system, the global nature of our data set is utilized in order to provide an overall, global context for urban digital connectivity. As discussed in the previous section, ICT and the Internet support the globalization process and global cities are increasingly reliant upon the digital infrastructure. Nonetheless, there are hardly any studies at a global level linking the global city characteristics with the digital infrastructure. The only exception at this scale is the work of Choi et al. (2006), who investigate the network structure of the Internet backbone networks among the most well-connected world cities.[3] In order to fill this gap and provide a broader understanding of the relation between world cities and the underlying first layer of the space of flows, this section employs simple spatial interaction models (SIMs) to investigate the pull factors attracting such digital infrastructures in global cities. The conceptual model of this analysis is formulated in the following generalized version of an SIM, according to which the number of IP installed links between *i* and *j* (IP_{ij}) is affected by the characteristics of *i* (X_i) and *j* (X_j) as well as by bilateral characteristics between *i* and *j* (X_{ij}).

$$IP_{ij} = f(X_i, X_j, X_{ij}) \qquad (1)$$

The main limitation for such an endeavour is data availability, as hardly any homogeneous urban data are available at a global, cross-country level. In order to overcome this difficulty, a unique data set depicting the urban characteristics of 34 world cities, produced by the Institute for Urban Strategies (2010), is utilized here. This Global Power City Index (GPCI) offers a balanced picture of the socio-economic performance and power of 34 world cities[4] from the perspective of attracting talent, business and investment to cities, complemented with information on the perceptions of various classes of stakeholders. Based on 69 individual indicators compiled from secondary sources as well as from interviews with stakeholders, two sets of indicators were produced for the year 2010[5]: city *function* indicators, which include a normalized score on variables focusing on urban

[3] For a US-centric study on similar issues see the work of Malecki (e.g. 2002) and the work of Tranos for a pan-European perspective (e.g. 2011; Tranos and Gillespie 2009).
[4] Mumbai was also included in the GPCI, but it is excluded from our analysis as no IP data were available from the DIMES project. The rest of the cities included in the GPCI are presented in Table 3.
[5] For a detailed review of the GPCI index see the Institute for Urban Studies (2010).

accessibility, the economy and the environment; and city *actor* indicators, including variables on how managers, researchers, artists and residents perceive and score the performance of the city. Apart from the variables derived from the actor and function data, the impact of variables related to the spatial organization of the world cities sample is also tested here. Firstly, the physical distance between cities is expected to have a negative impact on the pair-level IP connectivity. As discussed elsewhere (Tranos and Nijkamp 2013), physical distance (*distance*) maintains its importance even in the frame of the digital infrastructure. Similarly, the spatial continuity (*continuity*) between the countries that host the cities included in the analysis is expected to have a positive impact on digital connectivity. Moreover, we employ variables from the world trade literature (Mayer and Zignago 2005) and we expect variables such as common language (*language*) and past colonial (*colonial*) ties to affect the digital connectivity (Tranos and Gillespie 2011).

In order to utilize these variables, model (1) is expanded in the following log-log form:

$$\ln(IP_{ij}) = a_0 lnk + a_1 \ln(X_i * X_j) + b_1 \ln\left(distance_{ij}\right) + b_2 relational_{ij} + \varepsilon_{ij} \quad (2)$$

X_i and X_j are the variables reflecting the city-level attributes discussed above. Because the dependent variable reflects the infrastructural capacity and not the flows, there is no directionality involved and therefore instead of estimating the effect of *i* and *j* separately, their combined impact is estimated using the product of X_i and X_j. Since the city-level attributes are only available for the year 2010, equation (2) is estimated cross-sectionally using the ordinary least square (OLS) method. Table 1 presents the results of the actor variables and Table 3 the results of the function variables.

Table 1. World city IP connectivity and actor-based city characteristics

Dep. Var. IP (ln)	(1)	(2)	(3)	(4)	(5)
distance(ln)	-0.322	-0.349	-0.430	-0.410	-0.522
	(0.087)***	(0.087)***	(0.091)***	(0.092)***	(0.102)***
manager	0.271	0.020	0.274	0.321	0.266
	(0.117)**	(0.170)	(0.194)	(0.196)	(0.200)
researcher		0.197	0.317	0.237	0.178
		(0.098)**	(0.107)***	(0.119)**	(0.120)
resident			-0.561	-0.660	-0.597
			(0.216)**	(0.225)***	(0.228)***
artist				0.190	0.253
				(0.124)	(0.135)*
continuity					-1.002
					(0.402)**
language					0.276
					(0.292)
colonial					-0.202
					(0.359)

Dep. Var. IP (ln)	(1)	(2)	(3)	(4)	(5)
constant	0.205	1.433	5.763	5.062	5.788
	(1.808)	(1.895)	(2.505)**	(2.538)**	(2.566)**
R^2	0.09	0.11	0.14	0.15	0.18
N	194	194	194	194	194

** p < 0.1; ** p < 0.05; *** p < 0.01; standard error in parentheses*

The first observation is the consistent negative effect of distance on the formation of the digital infrastructure at a global level. Put simply, the closer two world cities are in our sample, the more digital infrastructure is installed between them. This distance decay effect remains significant and its magnitude increases even after the inclusion of other bilateral variables, including spatial continuity. The researcher variable has a positive effect that appears to be significant throughout most of the specifications. This is not surprising either, as the digital infrastructure was always related to knowledge-intensive urban environments (Malecki 2002). In addition, the managerial effect is visible here, although it is not always significant. Indeed, the higher the (product of two cities') score on managerial issues is, the higher the connectivity between these two cities is. However, this effect ceases to be significant when more explanatory variables are introduced into the model. Moreover, a significant and consistent negative effect is detected for the (product of the) score of cities on residential issues. This effect can be interpreted as a city-size effect: the higher the size of a city and consequently the diseconomies of scale (a low score on residential issues), the higher the digital connectivity the city shares with other cities. On the contrary, creativity appears to be a significant positive factor for attracting digital infrastructure. The (product of the) score of two cities according to artists is a positive predictor of the digital connectivity between these two cities. Regarding the other bilateral variables, only spatial continuity seems to have a significant impact. However, this is negative and may reflect a minimum threshold level for distance.

Table 3 presents the estimation of (2) using the function variables. Again, interesting results can be derived regarding the distribution of the digital infrastructure among our sample of world cities. Firstly, spatial configuration appears to be important even at this scale, as apart from the distance decay effect that is present here too, accessibility has a significant positive effect: the more accessible two cities are (in other words, the higher the product of the accessibility of two connected cities is), the more digital infrastructure will be installed between them. On the contrary, although the variable reflecting the score on the urban economy is positive, its effect is of low significance. This is in accordance with previous research highlighting that such infrastructure is mostly attracted by knowledge-economy-related indicators instead of mere market size (Tranos and Gillespie 2009). Next, the environment variable appears to confirm the above comments on the effect of the *resident* variable. The city size effect, as reflected in diseconomies of scale and related low urban environmental quality, is a digital connectivity factor. Regarding the bilateral variables, the same effect as in Table 1 is observed here.

Table 2. World city IP connectivity and function-based city characteristics

Dep. Var. IP (ln)	(1)	(2)	(3)	(4)	(5)
d_ln	-0.329	-0.275	-0.291	-0.335	-0.481
	(0.088)***	(0.088)***	(0.088)***	(0.089)***	(0.102)***
accessibility		0.294	0.216	0.235	0.253
		(0.098)***	(0.110)*	(0.110)**	(0.116)**
economy			0.142	0.155	0.109
			(0.094)	(0.093)*	(0.097)
environment				-0.184	-0.184
				(0.082)**	(0.082)**
continuity					-1.093
					(0.385)***
language					0.324
					(0.280)
colonial					-0.066
					(0.350)
constant	4.061	-0.121	-0.870	2.052	3.633
	(0.705)***	(1.561)	(1.633)	(2.071)	(2.155)*
R^2	0.07	0.11	0.12	0.14	0.18
N	194	194	194	194	194

* *p < 0.1; ** p < 0.05; *** p < 0.01; standard error in parentheses*

In total, the above analysis has revealed many interesting patterns at the global level of the world city network. The digital infrastructure is clearly affected by spatial configuration – even at this scale. Thus, it can be argued that a digital system such as the Internet is also ruled by strong spatial forces. In addition, other factors related to the knowledge economy and city size appear to play important roles in the geography of this system. The next step in our analysis provides the link between the global digital network and the Chinese urban system.

14.4 The Chinese Digital Urban Network

Moving now from the global level of analysis to China, the first task is to understand the position of Chinese cities in this global system of world cities and then to understand the structure of the Chinese interurban network of the digital infrastructure. In order to do so, concepts and methods from the complex network analysis (CNA) field and the *science of networks* (Barabási 2002; Buchanan 2002; Watts 2003, 2004) are utilized. This is a new analytical field that focuses on large-scale real-world networks and their universal, structural and statistical properties (Newman 2003). CNA is a tool that enables us to explore the connectivity patterns in the topological configuration of the Chinese digital infrastructure. The latter is an essential step in order to move on to the next part of our analysis, in which the structure of the urban network in China is modelled.

Table 3 presents three different centralities for the sample of 34 world cities. Firstly, degree centrality represents the accumulated IP links for each city for each year.[6] This is a digital *infrastructural* capital measure, in which Beijing shows up as the third most connected city in our world city sample for 2010. Shanghai, the other Chinese city in our sample, is placed in the fifteenth position. Although this is an important measure reflecting the accumulated IP connectivity, degree centrality does not provide any insights into the functionality of these cities in the overall network. Following the work of Neal (2011), two more centrality indicators will now be introduced: recursive centrality (*RC*) and recursive power (*RP*). The distinctive point of these indicators is the acknowledgement of the degree centrality of the cities that are connected with the city of interest and are calculated as follows:

$$RC_i = \sum_j IP_{ij} x DC_j \quad (3)$$

$$RP_i = \sum_j \frac{IP_{ij}}{DC_j} \quad (4)$$

DC_j is the degree centrality of city *j*, which shares an IP link with city *i*, and IP_{ij} is the number of IP links between *i* and *j*. These metrics are useful in understanding the city functionalities in such a global system, as high recursive centrality is related to hub urban roles, while high recursive power reflects gateway roles (see the discussion in Neal 2011). Thus, Beijing's high performance in both metrics indicates the Chinese capital's importance in the global digital network as Beijing performs both hub and gateway roles. However, this is not the case for Shanghai, whose functionality is lower than the expected one according to the accumulated IP infrastructure, as is reflected in the degree centrality.

[6] This is a 'weighted' degree centrality measure in the sense that if two regions *i* and *j* are connected by multiple links, all of these links will be added in the degree centrality of *i* and *j*. If it had been a 'binary' centrality measure, then the multiplicity of the links between *i* and *j* would have been neglected.

Table 3. World cities' centralities and power in 2010

	Degree centrality		Recursive centrality		Recursive power	
Cities	score	*rank*	score	*rank*	score	*rank*
London	100.00	*1*	100.00	*1*	95.39	2
Seoul	94.22	*2*	20.57	*6*	25.36	*13*
Beijing	75.77	*3*	36.70	*3*	48.63	*6*
New York	47.19	*4*	66.52	*2*	21.84	*16*
Frankfurt	46.64	*5*	34.71	*4*	31.61	*10*
Tokyo	41.95	*6*	11.23	*13*	29.95	*12*
Amsterdam	33.72	*7*	14.80	*10*	76.68	*3*
Madrid	29.67	*8*	9.96	*14*	100.00	*1*
Moscow	26.83	*9*	12.64	*12*	54.97	*5*
Toronto	22.28	*10*	14.27	*11*	22.13	*14*
Paris	21.95	*11*	22.56	*5*	33.32	*9*
Singapore	19.57	*12*	6.74	*16*	6.37	*23*
Chicago	17.73	*13*	18.68	*7*	13.88	*18*
Los Angeles	13.91	*14*	17.36	*8*	6.33	*24*
Shanghai	13.23	*15*	2.92	*21*	7.87	*22*
Sydney	13.05	*16*	0.57	*26*	42.22	*7*
San Francisco	12.10	*17*	15.77	*9*	9.28	*21*
Vienna	11.10	*18*	0.60	*25*	38.25	*8*
Milan	11.07	*19*	7.84	*15*	30.38	*11*
Taipei	9.53	*20*	4.45	*19*	9.58	*20*
Zurich	5.93	*21*	0.44	*27*	21.89	15
Osaka	5.56	*22*	1.18	*24*	2.88	*29*
Cairo	5.32	*23*	0.42	*28*	4.98	*25*
Brussels	5.28	*24*	2.62	*22*	72.07	*4*
Sao Paulo	4.69	*25*	0.40	*29*	2.54	*30*
Kuala Lumpur	4.57	*26*	0.16	*33*	10.87	*19*
Bangkok	4.44	*27*	2.61	*23*	15.72	*17*
Vancouver	3.94	*28*	5.42	*17*	0.55	*32*
Boston	3.11	*29*	3.80	*20*	3.25	*28*
Copenhagen	2.94	*30*	4.67	*18*	3.77	*27*
Berlin	2.78	*31*	0.28	*31*	4.27	*26*
Geneva	1.70	*32*	0.18	*32*	2.05	*31*
Fukuoka	1.22	*33*	0.31	*30*	0.49	*33*
Hong Kong	0.02	*34*	0.05	*34*	0.00	*34*

Note: centrality measures are normalized with a maximum value = 100

After highlighting Beijing's role as the main anchor point of the Chinese IP network with the global one, our focus will turn next to the Chinese intra-urban digital network. Table 4 presents some basic network statistics for the Chinese digital infrastructure for the period 2007–2011. The size of the network during the first two years of the study period is less than 30 per cent of the network size during the last three years. Although this might reflect, to some extent, the Internet growth in China, much of this is mostly related to the data collection process and the increase in the number of DIMES project agents. Nonetheless, a change in the topology of the network can be observed. The first statistic under study is again degree centrality.[7] The large difference between the average and maximum values reflects the existence of some very well-connected nodes, which perform hub roles in the network. Regarding the change over time, while the average weighted degree centrality among the connected cities increased almost four times during the study period, the maximum degree centrality increased more than twenty times. This is the first indication of the existence of a *cumulative causation* process, according to which the higher the degree of a node is, the higher the probability of a new link to be attached to this node is. This *rich get richer* phenomenon results in a high level of inequality in terms of connectivity among the Chinese cities, which increases over time according to the Gini coefficient of the degree centrality. In the network literature (Barabasi 2003), this cumulative process is identified as preferential attachment (Batty 2012) and will be further analysed below.

Table 4. Network statistics for China's IP network

Net. Statistics	2007	2008	2009	2010	2011
Nodes	219	224	781	780	784
Links	420	432	1557	1606	1638
Av. degree centrality	56.555	90.951	144.095	257.805	249.704
Max. degree centrality	2830	4671	32660	57889	59490
Density	0.017	0.017	0.005	0.005	0.005
Av. network distance	2.515	2.71	2.944	2.884	2.825
RN av. network distance	4.078	4.082	4.801	4.821	4.818
Clustering coefficient	0.462	0.351	0.364	0.393	0.408
RN clustering coefficient	0.012	0.011	0.006	0.004	0.004
Gini coefficient	83.77	89.06	93.4	93.71	93.83

Note: RN is a random network with the same number of nodes and links

[7] Just as before, this is a weighted degree centrality measure.

The outcome of the uneven distribution of the IP links among the Chinese cities is an *efficient* digital network. Indeed, despite the very low density of the CP, which decreases over time, the average network distance is exceptionally short. In the CNA framework, distance does not refer to the Euclidean distance, but to the number of nodes that separate any two nodes.[8] For the case of the Chinese digital infrastructure, any two cities are separated on average by two intermediate nodes, resulting in a network distance of less than 3. The latter is an indication of efficiency, as it reflects the ability of the network to transfer data flows with minimal routing.

The above qualities and efficiency of the network can be attributed to the *small-world* (SW) characteristics of the CP. The latter refers to a widely used network model, the main characteristic of which is the existence of highly connected cliques,[9] which gain global connectivity via a few links that span the entire network, linking distant clusters (Watts and Strogatz 1998). This theoretical network model became popular because of its many real-world applications. The digital infrastructure in China resembles SW networks because of the short average distance – shorter than those observed in same-size random networks (RNs)[10] – and the high clustering coefficient[11] – higher than those discovered in same-size RNs.

Apart from the latter, an essential element of the SW networks is the distribution of nodes' degree centrality, which distinguishes this network type from another well-established network model known as *scale-free* (SF). SF networks share the above characteristics with SW networks, but the degree distribution of their nodes follows a power law, contrary to the exponential functions that distinguish SW networks. The different distributions reflect the difference between these two types of networks in terms of the nodes' heterogeneity: while the power law degree distribution of the SF networks reflects the existence of very few super-connected hubs and a vast majority of less-connected vertices (Barabási and Albert 1999), the exponential degree distribution of SW networks resembles highly connected cliques and less heterogeneous nodes. Following Newman (2005), the estimation of the degree distribution curve is based on the *cumulative degree function* (CDF) derived from an inverse rank-plot graph. The CDFs for the period 2007–2011 are presented in Figure 1.

[8] Because there are usually numerous different ways to connect any two given nodes (known as *walks*), research commonly focuses on the shortest path, known as distance (Nooy et al. 2005).

[9] A clique is a 'sub-set of a network in which the actors are more closely and intensely tied to one another than they are to other members of the network' (Hanneman and Riddle 2005).

[10] RNs were introduced by two Hungarian mathematicians, Paul Erdös and Alfréd Rényi, and refer to large-scale networks with no obvious structure (Erdös and Rényi 1959). The distribution of vertices degrees follows a Poisson distribution, which means that the majority of the vertices on the network have the same number of links and they are found nearby the average degree <k>; vertices that deviate from this are rare.

[11] The clustering coefficient C_i of node i is the ratio between the number of edges E_i that exist among its nearest neighbours (nodes that are directly connected with node i) and the maximum number of these edges, where k_i is the number of nodes in the clique: (Latora and Marchiori 2001).

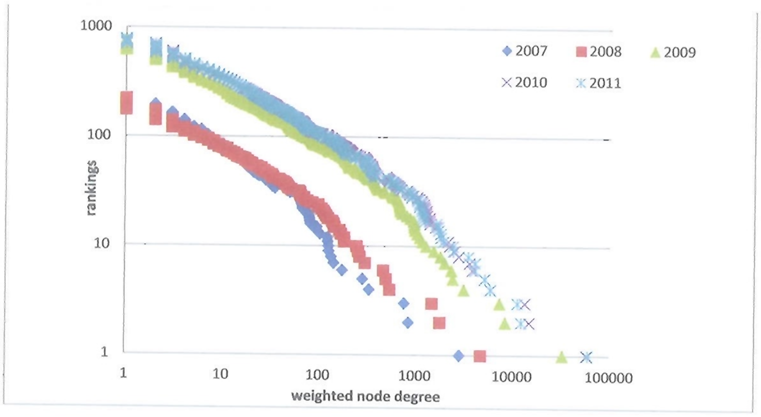

Figure 1. Cumulative degree distribution of Chinese cities based on IP links

The scatter plot reveals a common pattern throughout the study period: the degree distribution for every year is governed by a power function as indicated by the straight lines. The above visual observation is also supported statistically by curve estimations based on OLS and the relevant log-log transformations (Faloutsos et al. 1999; Gorman and Kulkarni 2004; Tranos 2011). The results of the OLS are presented in Table 5, in which two different forms are tested: exponential and power specification, respectively:

$$p(x) \propto e^{-ax}, \qquad (1)$$

$$p(x) \propto x^{-a}, \qquad (2)$$

Table 5. Degree distribution fit

Year	Exponential		Power		N
	R-squared	Coef.	R-squared	Coef.	
2007	0.314	-0.003	0.956	-0.629	218
2008	0.328	-0.002	0.965	-0.531	220
2009	0.161	-0.0003	0.974	-0.520	781
2010	0.158	-0.0002	0.967	-0.504	780
2011	0.150	-0.0002	0.970	-0.500	783

Note: OLS and the relevant transformations have been used to explore the fitness of different functions

Indeed, the OLS results confirm the visual observation that power functions better fit the overall distribution for the five-year study period. In spatial terms, this can be interpreted as an agglomeration effect of the digital connectivity in a limited number of cities that act as hubs for the Internet infrastructure in China. Thus, the Chinese digital urban network is a highly hierarchical one, and just like any other SF network, it is highly dependent on these hubs, which hold the network together by performing vital routing functions.

Nonetheless, this is not the case with the European part of the digital infrastructure. As discussed elsewhere (Tranos and Nijkamp 2013), the European subset of the global IP network, as captured by the DIMES agents, fails to form a clear power law. On the contrary, the CDF for Europe is ruled by a *power law with a cut-off*, which means that the power function does not fit the overall distribution, but only the most-connected nodes (Figure 2). In spatial terms, this reflects the existence of two parallel phenomena: on the one hand, an agglomeration effect of IP connectivity in a limited number of regions that act as hubs; and on the other hand, the exponential tail reflects the existence of a cluster of less-connected regions, which is more homogeneous in terms of IP connectivity than if a hierarchical and clear SF topology were present.

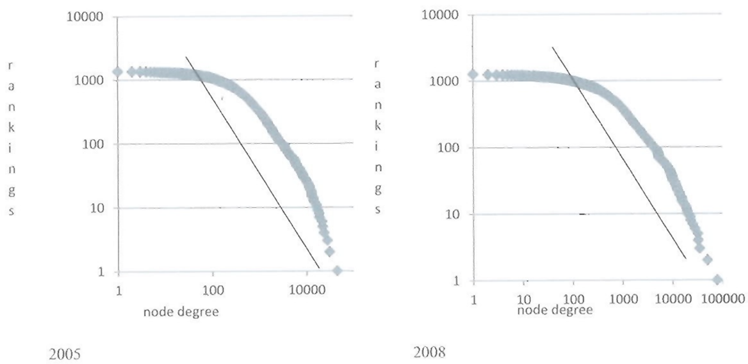

Figure 2. Cumulative degree distribution of NUTS-3 in European regions based on IP links
Source: Tranos and Nijkamp (2013)

The structural differences between the digital network in China and Europe reflect, to a certain extent, spatial configuration differences. Various mechanisms, which may relate to national policies and borders, prevent the formation of a network with a power law degree distribution in Europe. Owing to these policies, the least connected European cities enjoy a level of connectivity higher than the equivalent of an SF network. However, the absence of multiple national policies and the centralized infrastructure planning and building in China resulted in an SF network, which is ruled from only a handful of hubs: almost 50 per cent of IP connectivity in China was accumulated in only three cities in 2011: Beijing, Shanghai and Guangzhou. On the contrary, the three most connected cities in Europe are responsible for only 8.5 per cent of European cities' total connectivity.

Although the above analysis provides interesting insights into the nature of this infrastructural system, it does not provide insights into the mechanisms behind the creation of these links. Taking a step forward, the next section will explore the mechanisms behind the formation of this complex network in China.

14.5 The Determinants of Digital Connectivity within the Chinese Urban System

After gaining a structural understanding of the IP network in China, this section aims to shed more light on the spatial factors affecting the structure and the evolution of the Internet infrastructure in China. Using model (1) as the starting point, the effect of a set of explanatory variables, which reflect the space and time dimensions of the digital infrastructure network, is tested in this section. Taking a step further, the modelling results are juxtaposed with the corresponding results from Europe. This comparison will increase the robustness of our analysis and enable potential comparisons.

More specifically, model (1) can be further expanded into the following log-log form:

$$\ln(IP_{ijt}) = a_0 lnk + \gamma_1 \ln(IP_{ijt-1}) + a_1 \ln(distance_{ij}) + a_2 external_{ijt} + a_3 region_{ij} + a_4 periods_{ij} + \varepsilon_{ijt} \quad (3)$$

The dependent variable (IP_{ijt}) represents the connectivity between any two connected cities (*i* and *j*) in China in year *t*. The temporal dimension represents the five-year study period (2007–2011). Building upon the results of the global analysis, we expect that the physical distance (*distance*) between *i* and *j* will have a negative impact on the installed infrastructure between *i* and *j*. Then, a number of other structural explanatory variables are tested. Based on the above discussion about the importance of international digital connections, it is expected that the IP connectivity between two cities (*i* and *j*) will be positively affected, if both *i* and *j* have international gateway roles. To test this effect, we introduce here a dummy variable (*external*), which is equal to 1 when both *i* and *j* have international IP links during year *t*. Then, we test the impact of spatial structure and the importance of provinces in the formation of the Chinese digital infrastructure. Thus, another variable is introduced to test the impact of intra-province links: the variable *region* is equal to 1 when both *i* and *j* are located in the same province in China. Finally, the effect of the stability of the connectivity over time is also tested here. Although IP networks are physical networks, rewiring is possible within such networks in order for the supply to meet the demand (Gorman and Kulkarni 2004). In order to test this attribute, the effect of the variable *periods*, which indicates the number of years for which a link between cities *i* and *j* was present during the study period, is tested.

In order to take advantage of the bidimensional data on digital connectivity (IP links between *i* and *j* at year *t*), panel data specifications are adopted for the estimation of (3). Panel data models improve the researchers' ability to control for missing or unobserved variables (Hsiao 2003). Such an omitted-variable bias as a result of unobserved heterogeneity is a common problem in cross-section models.

While panel data introduce considerable gains, there are also methodological limitations to be addressed. For instance, two are the main options for estimating panel regressions: *fixed effects* (FE) and *random effects* (RE) models (Wooldridge 2003). The RE model would have been the preferred choice here because the first differentiation process of the within estimator (FE) would have resulted in the elimination of the time-invariant variables (*distance*, *region* and *periods*) (e.g. Brun et al. 2005; Etzo 2011). However, the efficiency of the RE model goes hand in hand with other limitations: the consistency of RE estimators depends on whether the unobserved random effects are uncorrelated with the regressors. For instance, some of the explanatory variables might be endogenous by being correlated with omitted variables, which affect the installation of IP links between cities (Baier and Bergstrand 2001). If this is the case, an instrumentation of the endogenous variables would be necessary in order to obtain unbiased estimators. However, such instrumentation is not an easy task given the complexity of the CP and the lack of prior empirical research in this area. Therefore, a two-way fixed-effects estimation is introduced here (Tranos and Nijkamp 2013). This specification is differentiated by the usual FE because it addresses unobserved effects in two dimensions (Baltagi 1995). Thus, the error term ε_{ijt} from (3) can be analysed as follows: . In this case, ω_{it} and ζ_{jt} are the *i* and *j* as well as the time-specific effects and υ_{ij} the remainder stochastic disturbance term. Thus, the two-way FE will address potential *i* and *j* time-specific effects (i.e. the time variant city-level effects that are not observed and are not of interest here) and enable the estimation of the structural effects (*distance*, *external*, *region*, *periods*).

Table 6. Determinants of digital connectivity within the Chinese urban system

Dep. Var. IP (ln)	(1)	(2)	(3)	(4)
IP (ln, 1 year lag)				0.373
				(1.95)*
distance (ln)	-0.056	-0.208	-0.216	-10.075
	(1.67)*	(4.42)***	(3.39)***	(2.09)**
External	1.026	0.241	0.228	-4.021
	(17.83)***	(2.91)***	(0.77)	(1.61)
Region	0.305	0.794	0.851	-40.843
	(3.31)***	(5.83)***	(4.56)***	(1.99)**
Periods	0.454	0.501	0.656	2.286
	(19.12)***	(15.68)***	(13.72)***	(2.64)***
time effects	yes	yes		yes
i,j effects		yes		
ij effects				
it and jt effects			yes	
Constant	-0.324	1.752	1.844	70.298
	(1.28)	(0.77)	(0.43)	(2.04)**
Hansen				2.15
Diff. Hansen				2.14
AR(2)				-1.16
R^2	0.23	0.60	0.71	
N	3,281	3,281	3,281	1,810

$^{*} p < 0.1$; $^{**} p < 0.05$; $^{***} p < 0.01$; standard error in parentheses

In columns (1)–(3), the results of OLS estimations with various effects are presented. Column (4) presents the two-step robust system GMM estimation. Hansen is the Hansen test for overidentification restriction; Diff. Hansen is the difference-in-Hansen test of exogeneity for the validity of additional moment conditions; and AR(2) is the Arellano–Bond test for serial correlation.

Columns 1–3 in Table 6 present the estimation of (3) using different effects. The results are consistent and some interesting conclusions can be drawn. First of all, a distance decays effect is present in the distribution of the Internet infrastructure across the Chinese urban system. The impact of distance increases with the use of specific effects, especially when the two-way effects are introduced. This is important, as the latter specification appears to be the most robust due to the lack of unobserved effects. Then, the importance of these Chinese cities, which act as gateways to the rest of the world, for attracting intra-China connectivity is reflected in the variable *external*. Indeed, when both connected cities share IP links not only with cities in China, but also with cities abroad, then the installed digital infrastructure between this pair of cities is expected to be higher. The positive sign of this variable remains unchanged across different specifications. However, the effect of this variable stops being significant when the two-way fixed effects are introduced. This is not surprising as the two-way effect probably masks the impact of the links between gateway cities because the gateway roles vary both among time and among space. Another important structural factor for the development of the Chinese IP network is regional connectivity as the location of two connected cities within the same province has a positive impact on the installed connectivity between them. Finally, an indirect assessment of the above-discussed *cumulative causation* process is achieved with the use of the variable *periods*. The consistent positive effect indicates that the number of years for which a pair of cities remains connected during the study period is positively related to the amount of installed infrastructure among these cities. In other words, early, and consequently lengthier, participation of a city pair in the Chinese IP network has a positive impact on the connectivity between these two cities.

A more direct estimation of the cumulative causation process or, in network terms, of the preferential attachment, can be made with the introduction of a dynamic framework. Therefore, model (3) is expanded to the following form:

$$\ln(IP_{ijt}) = a_0 lnk + \gamma_1 \ln(IP_{ijt-1}) + a_1 \ln(distance_{ij}) + a_2 external_{ijt} + a_3 region_{ij} + a_4 periods_{ij} + \varepsilon_{ijt} \quad (4)$$

The main difference from (3) is the inclusion of the autoregressive term (IP_{ijt-1}). This creates estimation complications, as OLS and conventional fixed- and random-effects estimators result in biased and inconsistent estimates because of the correlation between the autoregressive term and the error term. To overcome this, the generalized method of moments (GMM) technique is introduced here. The latter approach refers to Arellano and Bond's (1991) suggestion of using first differencing to eliminate individual effects and then using all the possible lags of the dependent and independent variables as instruments for the endogenous variables (in our case, only the lags of the dependent variable). A later suggestion by Arellano and Bover (1995) and Blundell and Bond (1998) concerns first differencing not on the regressors, but rather on the instruments, a choice that results in increased efficiency (Roodman 2006). The latter approach, known as *system GMM*, is used here.

Column (4) in Table 6 presents the estimation of model (4). The main finding is that there is indeed a preferential attachment process in the evolution of the Chinese intercity IP network, as the lagged value of the IP connectivity between two cities has a positive impact on the installed IP infrastructure between these two cities. Another important finding is that despite the inclusion of the autoregressive term, the distance decay effect is still present. The same applies to the indirect measure of the cumulative causation. The magnitude of these two effects is much higher than those in the static models. Nevertheless, the consistency in qualitative terms signifies their importance as structural elements of the Internet infrastructure across the Chinese cities. This is not the case for the effect of the variables *external* and *region*. While the former stops being significant, the latter has a negative and significant effect, which does not agree with the static models.

A crucial point in the above process is the validity of the instruments adopted for the GMM estimations. Three tests are performed here (Jiwattanakulpaisarn et al. 2009). Firstly, the orthogonality conditions of the instruments are tested using the Hansen test for over-identifying restrictions. Then, the validity of the additional moment conditions in levels is tested with the difference-in-Hansen test of exogeneity. Finally, the Arellano–Bond test for serial correlation is reported, the null hypothesis of which (no second-order autocorrelation in differenced residuals) verifies the validity of two or more order lagged variables as instruments. All of the reported tests support the validity of the instruments used in the system GMM estimation.

In total, spatial forces affect the structure of the digital infrastructure network. Physical distance and localization effects are valid for the case of China. What is more, the dynamic panel analysis confirms the preferential attachment or, in other words, the cumulative process in the IP distribution. Finally, the effect for the links between gateway cities reflects the structure of the Chinese digital network as only 10 per cent of the digitally connected cities (110 cities in 2011) share links with cities outside China. Apparently, these cities act as the main hubs of the Chinese Internet and are responsible for the SF nature of this network. The positive concentration of IP links between such nodal cities reflects the importance of these cities in holding the Chinese Internet together (see Doyle et al. 2005).

14.6 Conclusions

The combination of network analysis with econometrics resulted in some fruitful outcomes regarding the understanding of the symbiotic relation between urban and digital networks, both globally and in China. In addition to persistent urbanization trends, the urbanized world will also be a connected world, in which next to the physical infrastructure the digital infrastructure (in particular, the Internet) will also play a central role.

Despite the scale of the analysis, similar spatial forces have been identified as drivers of the digital infrastructural network. Physical distance, accessibility and localization effects are important factors behind digital connectivity. Thus, it is fair to say that the 'death of distance' discussion is not valid in the frame of the Internet infrastructure. Moreover, factors related to the knowledge economy and city size are also important factors in the allocation of the Internet's physical layer.

In addition, it became apparent that the digital infrastructure reflects specific attributes of urban systems. While the rather polycentric European urban system is facilitated by a digital network that resembles small worlds, the Chinese digital network follows a heterogeneous scale-free topology, with only a handful of super-connected cities. Thus, it can be argued that the highly centralized digital network, which underpins the Chinese Internet, reflects the centralized and regulative planning system in China.

Clearly, the sample of world cities used in our investigation could be extended. It would certainly be relevant to test the robustness of our findings by examining other – and perhaps more extensive – databases. A potentially useful area for further research is the utilization of data regarding digital flows instead of digital capacity. Online social media could be great candidates for data extraction. However, such data are difficult to extract for issues related to privacy and business strategies. Nonetheless, we would not expect that the results of such an analysis would be greatly differentiated by our present results.

Finally, the global connectivity among cities presupposes a world without strict borders. Open access is an important condition for a globally linked world, and communication policies should do their utmost to create effective legal frameworks for ensuring open-access conditions in a digital world.

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15 THE '*NEW URBAN WORLD*': RETROSPECT AND PROSPECT

15.1 Cities in Action

This study has focused the attention on an intriguing new phenomenon, called the '*New Urban World*'. In Chapters 3–14, a series of applied modelling studies on the '*New Urban World*' has been presented. The concept of an '*urban piazza*' acted as an integrating framework for the various analyses undertaken. In this final chapter, we will offer a synthesis, both in general terms and thematically, through a scoping of the findings of each individual chapter.

The aim of our research has been formulated in Chapter 1 as: '**Assessment of the (internal and external) characteristics and drivers of urban actors and/or cities in a competitive spatial-economic environment, with a view to a comparative analysis of their innovative and creative performance**'. This formulation means that our research is instrumental in nature. It serves to develop or apply appropriate – novel and existing – research tools for evaluating the behaviour of urban actors or urban systems in the '*New Urban World*', on the basis of well-defined performance criteria.

Our study centres on urban actors and cities as '*premier grand cru classé*' agents and a rich and diversified set of applied analyses. Modern metropolitan areas in an open and globalizing economy are powerhouses of creative ideas, innovative technologies, sustainable development and socio-economic wealth. They play a pivotal role in the future of the urbanized world, but they are also confronted with 'grand challenges', such as far-reaching demographic transformations (in particular, ageing, a rapid population rise on many continents and unprecedented migration flows), environmental decay and climate change (in particular, greenhouse gases, scarce resources, water management), unequal social participation (in particular, unemployment and poverty, cultural–ethnic tensions) and ever-rising mobility trends (in particular, commuting, long-distance travel, complex urban logistic changes). Cities and their actors have to respond to these challenges.

Cities in many parts of our world generate great opportunities for economic development, employment and wealth creation, even though there are also shadow sides to their strategic importance. Although they only occupy 1 per cent of the global land surface, cities consume 75 per cent of the world's energy and generate 80 per cent of greenhouse gases (Satterthwaite 2008). Large urban concentrations also produce high levels of pollution, water and energy consumption, while they additionally face problems of access to high-quality health care, bottlenecks in transport and safety and waste management, among others, thereby impacting negatively on the quality of life of their citizens.

In general, however, cities are able to produce positive externalities in the form of density and proximity advantages (various production and consumption agglomeration benefits that accrue from economies of scale, localization and urbanization). Consequently, cities are able to generate productivity rises, entrepreneurial 'animal spirits', creativity and innovations, and knowledge achievements. The study of the socio-economic performance of urban systems calls for solid research on urban density and proximity economies, supported by reliable information systems on the urban growth and innovation potential. Our research offers a rich and diversified set of applied analyses of the performance conditions of urban actors and systems.

It should be noted that our research focuses mainly on the Netherlands, and therefore our conclusions have to be interpreted with some caution if they are generalized to other cases or countries. However, it seems plausible that the Dutch case is far from unique and is rather representative of the urban dynamics in many countries, in particular in the OECD part of the world. Therefore, most of our findings will prove to be valid elsewhere (see also Table 2 in this chapter).

This synthesis chapter is organized as follows. First, in Section 15.2, we will provide a concise overview of the main findings regarding the '*urban piazza*' architecture, with particular emphasis on messages, methodologies, general observations and empirical findings. This synthesis will mainly be presented in a tabular form. Next, in Section 15.3, we will present a series of more general observations, messages and ideas concerning the '*New Urban World*'. Section 15.4 will then offer a more strategic and integrated perspective on the future of the '*New Urban World*', while finally Section 15.5 will conclude with some general policy lessons.

15.2 Overview of the '*Urban Piazza*' Results

A wide variety of urban case studies, analysed by several quantitative research tools, has been used in our study, in order to provide an operational basis for the assessment aim of our study (see Chapter 1). An integrated overview of our research shows a collection of broadly composed quantitative research tools – with a clear differentiation in use – for investigating different types of empirical research issues at different spatial scale levels of urban areas (see also Figure 2 in Chapter 1). All these approaches serve to explore or explain the performance profile of urban actors and cities in the '*New Urban World*'.

Table 1 provides in 'staccato' form a systematic tabular overview of the messages, research methods, general observations and empirical findings in the individual Chapters 3–14. This comprehensive and succinct overview of the results of our research reflects a diversity of messages, methods, observations and empirical findings. Despite their pluriformity, they all confirm the proposition that cities are economic agents whose performance is enhanced by the presence of urban density and proximity.

This table offers the ingredients for answering the question of whether the research aim formulated in Chapter 1 has been achieved. We note that Table 1 uses the '*urban piazza*' architecture, which thus acts as the main navigation tool for assessing urban performance criteria under varying conditions, ranging from the micro-level (firms or cities) to the macro-level (global cities). These criteria are captured under the heading of the above-mentioned XXP framework.

Table 1. Overview of messages, research methods, general observations and empirical findings from the study

Parts	Chapters	Message	Methods	General observations	Empirical findings
A	3	• Location and distance matters for business • Space is essential for everyday business life	• Regional indicators regarding location characteristics and environmental factors • Micro-information on characteristics of firms Tools: • DEA • PCA • Regression • SEM • SPM • Geosience-based tools	• Geographical location of business firms influences their performance • SPM improves firms' competitive performance	• Significant differences in firms' performance • Significant differences in geographical position based on business performance • SPM critical to distinguish between high and low business performance • Contextual factors influence business performance, linked with geographical urbanized areas • Low-performance firms profit from localization economies and urbanization economies in Randstad and intermediate areas
	4	• Systemic complexity in space needs wealth of data • Urban area determines firms' performance	• Attributes of individual creative firms in the Netherlands • Regional and location-specific data (municipal and regional level) Tools: • DEA • SOM • PCA • SPM • Geosience-based tools	• Cities and regions are challenged to develop 'creative geographic space'	• Significant differences in spatial and functional firms' profile • Similar firms' size category is located in same regions • Regional location or degree of urbanization shows no strong systematic patterns
	5	• Firms' performance depends on spatial-economic context • Type and quality of capital resources affect firms' competitiveness in both local and international markets	• Micro-database on high-tech firms • Multilevel database on various forms of capital resources Tools: • PCA • Regression • SPM • Geosience-based tools	• Need for evidence-based analysis of various spatial capital assets	• Broadly composed capital resources contribute to business performance • Significant differences in relevant impacts of multilevel spatial capital resources on Dutch high-tech firms' performance

Parts	Chapters	Message	Methods	General observations	Empirical findings
B	*6*	• Migrant entrepreneurship emerges in new industrial districts in cities	• Data on migrant entrepreneurs Tools: • DEA • PCA • SPM	• Cities become multicultural melting pots • Variety of migrants leads to cultural diversity, mainly in urban agglomerations	• Significant differences in business performance among various migrant entrepreneurs • Significant improvement potential differs for each firm • Significant contribution to support decision making and planning for improvement of efficiency of the relevant agents involved
	7	• Urban areas are magnets for foreign migration	• Data on migrant effects Tools: • SWOT • SCM	• International migration becomes a phenomenon of worldwide importance • Developed countries (mainly large cities) are magnets for foreign migrants	• Shift towards new market niches • No single sufficient empirical evidence of negative effects on welfare in host countries • Clear socio-economic background in terms of income, wage and job motives
	8	• Migrant entrepreneurs are a source of new socio-economic opportunities in modern cities • Migrant entrepreneurs are a major component of SMEs	• Data on differences and similarities among migrant entrepreneurs' behaviour and attitudes Tools: • SOM • PCA • SPM • Regression	• Traditional sectors popular among first-generation migrant entrepreneurs • Supply of new services to a broad group of clients • Higher educational level and performance of migrant entrepreneurs	• Significantly different motives, attitudes and achievements regarding migrant entrepreneurship • Advanced producer services are emerging • Human capital, access to financial resources, language, access to business information and industrial orientation produce significant systematic differences among different migrant groups • Differences in sectoral specialization of migrant entrepreneurs • Shift towards new market niches • Driving forces for new market orientation formed by network support systems, personality and history, management and marketing skills and business attitude

Parts	Chapters	Message	Methods	General observations	Empirical findings
C	9	• Cultural heritage is critical for residents and visitors	• Extensive survey among residents of Amsterdam • Comprehensive picture of value sets of residents regarding cultural heritage Tools: • Regression • MSM	• Relative abundance of cultural heritage enhances the quality or attractiveness of places for both visitors and residents • Effective use of ICT contributes to local development	• Significant strong cultural heritage concentration in city centre • Residents of Amsterdam appreciate cultural heritage • New cultural heritage elements or activities planned are also successful for locations outside the city
	10	• Creative minds are critical for urban attractiveness • Historical urban atmosphere plays an important role in enhancing economic development	• Spatial moderator data at the meso-level from several sources Tools: • PCA • Regression	• Micro-behavioural attributes determine creative cities	• Creative classes are relatively strongly present in urban areas • Regional distribution of creative classes is caused by culture, nature, ethnic diversity and distance to large labour market • Share of creative professionals is positively related to regional productivity levels, and negatively related to ethnic diversity • No clear spatial pattern for creative professionals
	11	• Urban buzz finds its genesis in urban agglomeration advantages of various kinds • Buzz and socio-economic (cultural) diversity are closely connected phenomena	• Foursquare data • Data set on social network connectivity and spatial concentration in cities, based on location-sharing services Tools: • SOM • Regression	• Cities are a playground for competitive behaviour and rapid economic dynamics • Urban buzz reflects wealth-creating potential of urban areas	• Positive and significant effect of cultural diversity on level of buzz activity occurs in urban neighbourhood • Greater level of cultural diversity is associated with larger volume of check-ins

Parts	Chapters	Message	Methods	General observations	Empirical findings
D	12	• Cities become economic, logistic and political powerhouses	• Extensive database on global cities' performance Tool: • MAMCA	• Long-range urban development policy matters • Effective policies coping with negative externalities of cities are needed	• No single super-efficient solution in the set of alternatives • Several cities score higher on all indicators than others • Significant dominant cities • Cities create new urban histories
	13	• Urban efficiency improvement is important for urban policy strategy	• Data on achievement criteria for major global cities Tools: • DEA	• Differences between standard ranking and benchmarking procedures • Efficiency improvement of strategic urban policy	• Significant support contribution to decision making and planning for efficiency improvement • Level of intensity and direction of policy efforts needed to upgrade the efficiency profile of global cities
	14	• Urbanized world becomes connected world • Geography (and distance) still matters	• Global DIMES data set on Internet • GPCI data set Tools: • Regression • CAN	• 'Death of distance' not a valid frame for Internet infrastructure • Open access is an important condition for a globally linked world	• Physical infrastructure and digital infrastructure play a central role • Symbiotic relation between urban and digital networks (globally and in China) • Spatial forces are drivers of digital infrastructural network • Physical distance, accessibility and localization effects behind digital connectivity • Knowledge economy factors and city size drivers behind allocation of Internet's physical layer • Digital infrastructure reflects specific attributes of urban systems • Polycentric European urban system facilitated by a digital network that resembles small worlds • Chinese digital network follows heterogeneous scale-free topology

As mentioned, different methods are used in different cases. The frequency of the use of various research tools in Chapters 3–14 is presented in Table 2. It emerges that SPM, DEA, PCA and multiple regression play a dominant role in this context. All these tools – and their combinations – are essential in identifying, measuring, explaining and comparing (input and output) performance indicators describing the actors' economic achievement. Assessment is apparently not a single instrumental approach, but needs tools that are tailor-made for specific cases.

Table 2. Integrated methodological overview of the research

Part	Chapters	The '*New Urban World*' CHAPTERS 3–14	Methodologies and Tools										
			Exploratory Analysis			*Explanatory Analysis*				*Decision Support Tools*			
			DEA	SOM	PCA	MSM	REGRESSIONS	SEM	CAN	MCA/ MAMCA	SWOT	SCM	SPM
	1	*The 'New Urban World' – Opportunity Meets Challenge*											
	2	*The Architecture of the Study: The' Urban Piazza' Model*											
A	3	*In Search of Creative Champions in High-Tech Spaces – A Spatial Application of Strategic Performance Management*	X		x		x	x					X
	4	*High Performance in Complex Spatial Systems: A Self-Organizing Mapping Approach with Reference to the Netherlands*	x	x	x								x
	5	*Impacts of Multilevel Spatial Capital Resources on Business Performance*			X		X						x
B	6	*Urban Development and New Entrepreneurship: A Performance Analysis of 'Business Champions' among Migrants*	X		x								x
	7	*Strategic Choice Analysis by Expert Panels for Migration Impact Assessment*								x	x	x	
	8	*Migrant Entrepreneurs as Urban Health Angels – A Micro-Based Analysis*		x	x		X						
C	9	*Residents' Appreciation of Cultural Heritage in Tourist Centres – A Micro-Simulation Approach to Amsterdam*				X	X						
	10	*Creative Professionals and Cultural Ambiance in Urban Agglomerations*			X		X						
	11	*Socio-Cultural Diversity and Urban Buzz*		X			X						
D	12	*A Multi-Actor Multi-Criteria View on Global Cities*								x			
	13	*Exceptional Places: The Rat Race Between World Cities*	X										
	14	*Digital Urban Network Connectivity: Global and Chinese Internet Patterns*					X		X				
	15	*The 'New Urban World': Retrospect and Prospect*											

From the variety of studies it is evident that the current urbanization is an irreversible megatrend, posing unprecedented research and policy challenges. Issues of place and space will become increasingly interwoven, not only in the developed world, but also – and even more so – in developing and emerging economies. From the above tabular overview, our viewpoints and findings on the assessment aim of our study can be summarized in five observations based on a cross-sectional review of Table 1:

- Cities are powerful economic vehicles to ensure continued economic growth, especially in a period of economic recession;
- Population dynamics and migration do not necessarily affect the economic growth potential of cities, but offer a great opportunity for the future;
- Creative classes in cities may be an important condition for innovative development, but there are more important elements (such as the educational suprastructure, the connectivity infrastructure, cultural heritage);
- The monitoring of urban development – through systematically collected databases and benchmarking systems – is a critical vehicle for strategic urban policy in a competitive global urban environment;
- Flexible governance and focused amenity and land use policy are necessary to keep cities – or more generally, metropolitan areas – alive as engines of economic growth.

These research lessons can be made more specific by linking them to the individual chapters. This will be undertaken in Section 15.3, but in the light of the information contained in Table 1, we may already present our view on the future of the '*New Urban World*'. The '*New Urban World*' is clearly a dynamic phenomenon that will never be finished, but will always be in motion. The city is essentially a project that is never complete: it is a living organism – some sort of living lab – that is driven by 'challenge and response' mechanisms (see Toynbee 1946). This will be further considered in the next section (Section 15.3).

15.3 Synthesis of Specific Results from the 'Urban Piazza' Framework

Our assessment study of the performance of urban actors and cities is characterized by a quantitative methodology. The framework of our research on the '*New Urban World*' is formed by the '*urban piazza*' architecture. Our piazza is decomposed into four segments and two layers, which form the four major foci of our research. We will now concisely summarize the findings from these four 15.3.1 Parts (A–D) of our study.

15.3.1 Part A: Entrepreneurial Creativity

Part A zooms in on entrepreneurial creativity, taking the spatial-economic landscape in the Netherlands as an empirical case. The three chapters in Part A review and evaluate whether the geographical location of creative and innovative business actors in Dutch urban systems influences their economic performance from the perspective of complex spatial systems. Growing geographical markets and external changes in the dynamic turbulent business environment, such as in high-tech industries, call for creative entrepreneurship (information- and knowledge-based economic activities) and strategic locational decision making.

The empirical case studies in Chapters 3–5 adopt mainly a micro-business perspective on the organizational determinants of a firm's economic performance and its links with distinct spatial or urban entrepreneurship conditions and general economic moderator variables. The performance of these business actors appears to depend, *inter alia*, on the economic context in which these firms operate. For example, the growing importance of geographical markets and external changes in the high-tech industry call for creative entrepreneurship (information- and knowledge-based economic activities) and smart locational decision-making and spatial strategies.

In combination with the use of advanced management techniques, the type and quality of capital resources included in firms' production function crucially affect their competitiveness in both local and international markets. The integration of the external regional drivers of the performance (input and outputs) of individual firms with the internal strategic indicators leads essentially to a stylized dynamic cause–effect framework, which we called the 'flying disc' model, with a view to a comparative analysis of their innovative and creative performance. This systemic approach allowed us to assess systematically the regional patterns of spatial activities and to integrate and provide relevant information with a geographic component in order to enhance our insight into critical business and planning decisions on both localization and business performance. This holds in particular for the availability of information and communication technologies and modern and sustainable transport and logistic systems, especially for attracting and retaining these firms and for recruiting talented people in vibrant environments in modern and networked agglomerations. This means that modern cities and regions are also challenged to develop a 'creative geographic space' (see Tornqvist 1983; Andersson 1985; Cheshire and Magrini 2009; Kourtit et al. 2011), for example a healthy entrepreneurial climate; a specialized basis of industrial clusters; an ecologically sustainable urban environment; a high-quality research and educational infrastructure; and international accessibility through majors hubs for these business actors.

In the empirical part of our three case studies in Chapters 3–5, based on original micro- and macro-scale data, we investigated business actors' performance and their regional effects from both an exploratory and an explanatory perspective. For the analytical part, we used the SPM concept (extended with detailed spatial meso-attributes regarding the location characteristics of these firms) as the main methodology to evaluate their performance and complementing it with other analytical approaches, such as geoscience-based tools, SOM, (super-)DEA, PCA, SEM and spatial data analysis.

In doing so, Part A offers new conceptual and empirical insights into the relationships between the actors' location behaviour and performance and the drivers of urban development under uncertainty conditions that influence their performance and may prompt a creative bubble of mixed functionalities in Dutch urban areas, as well as a better and integrated understanding of the innovation dynamics – and limitations – of geographical location. These findings emerge from a fully tested empirical modelling approach, designed with a view to undertake a comparative analysis of the innovative and creative performance of various actors involved.

The empirical results also offer a wealth of insights into the determinants of the firms' achievements. The empirical findings show significant differences in the spatial and functional profiles of firms with different size categories that have adopted SPM (with a focus on the strategic approach, customer approach, leadership approach, business process approach, etc.), while their geographical position, across distinct geographical areas in the country, also plays a significant role. Furthermore, high-performance (efficient) versus low-performance (inefficient) firms seem to emerge due to a different focus on the various above-mentioned approaches. The various contextual factors (input) appear to influence business performance (output) linked to specific geographical or urbanized areas. It is plausible that low-performance firms profit from localization economies and urbanization economies in the Dutch Randstad and intermediate areas. For these business actors, a broadly composed capital base (including human and social capital and local or urban resources) turns out to contribute to their business operations and performance in a dynamic and challenging business environment.

The general *message* in **Part A** can be summarized in the following way. According to the assessment of the characteristics and drivers of urban actors and/or cities (see Chapter 1), 'location matters' (for example in relation to geographical and location-specific facilities, innovative and creative resources, accessibility), but more so for some businesses than for others. Space is an essential component of everyday business life, in which distance matters more for some businesses than for others at different stages and levels of the business actors' growth approach in relation to benchmarking. This observation is a clear outcome of the assessment outcomes in Table 1.
It emerges that there are significant differences in the spatial and functional profiles of large firms vis-à-vis SMEs across distinct geographical areas in the country. An integrated mix of SPM measures at both the micro firm level and the level of supporting regional moderator variables appears to be critical for the firms' performance. In conclusion, one may argue that a closer connection between industrial organization research and locational behaviour research may be fruitful for gaining advanced insights into regional dynamics and creativeness.

Figure 1. A 'content cloud' of the key concepts in Part A

The previous integrated, substantive conclusions from **Part A** can be further supported by use of a visual content analysis of the key concepts in Chapters 3–5. To that end, we use a 'content cloud' analysis. A 'content cloud' offers a hierarchically decomposed and visualized presentation – often in a multi-colour format – of the most relevant terms used in a scientific text, based on the frequency of their use. It is not a research tool in itself, but merely a visualization method of qualitative contents. The 'content cloud' related to Chapters 3–5 of **Part A** is presented in Figure 1. The results in Figure 1 show that various core concepts in our case studies, e.g. creative people, business, growth, regional factors, efficiency, spatial aspects and labour, appear rather prominently. These are clearly the key terms used in the analysis of entrepreneurial creativity in relation to sustainable regional growth. These results confirm the essence of our applied research on the success conditions of cities and their actors, from the perspective of the '*urban piazza*' model.

1.5.3.2 Part B: Cultural Diversity

Part B, on cultural diversity, covers a rich variety of relevant contributions ranging from micro- to meso- and macro-urban networks on the appearance and quality of a global, mixed culture of migration – or, more generally, cultural diversity – that has over the past years become a significant component of the vitality of the '*New Urban World*'. The influx of various migrant groups, such as highly skilled and talented workers and entrepreneurs, is likely to have a considerable welfare-enhancing impact on the city, in particular contributing to innovation and local growth, creating new jobs for less favoured population groups, advancing the benefits from cultural diversity and reinforcing the economic opportunities related to international connectivity.

Chapters 6–8 of **Part B** provide new insights from an impact assessment of the 'urban diaspora' worldwide, seen from an international perspective. Starting from a broad analysis of migrant behaviour, the chapters zoom in on a specific category of migrants, viz. migrant entrepreneurs. An important fact is that migrants are not uniformly dispersed in their host country, but have a strong urban orientation. As a result, the emergence of urban migrant diasporas can be observed, which are based on ethnic bonds or social networks, with both negative and positive implications. At the micro business level, our investigation addresses in particular the growth and risk strategies of migrant entrepreneurs in large Dutch cities. The chapters provide a general account of the backgrounds and socio-economic implications and other specific and general contextual factors of this new business formation, the so-called 'colourful' or new entrepreneurship, and emphasize the heterogeneity among them.

Part B offers a systematic analysis of the positive and negative socio-economic effects of migration on the host country or city. Considerable attention is given, at the micro-level, to the business achievements and the growth and risk strategies of migrant entrepreneurs, by assessing the measurable impact of personal and contextual factors on the business performance of migrant firms in large cities, with a particular emphasis on the Netherlands.

In the analytical part, we used a combination of techniques from our toolbox, such as SCM, (super-)DEA, SOM and regression analysis. Our analytical findings bring to light that in our modern and globalizing urban world, migration flows tend to lead to the emergence of new 'diasporas'. Such concentrations of migrant groups in distinct urban districts prompt the rise of various seedbed conditions for self-employment and entrepreneurship. The empirical findings show that migrant entrepreneurs – especially second-generation migrants – make up a significant share of the urban business economy and contribute considerably to urban vitality. They are a solid and, in the meantime, established part of the normal urban economic business sector, and as such are indispensable. They offer many job opportunities in a modern city, and often 'jump' towards higher market segmentation. This holds for both first- and second-generation entrepreneurs, although the second generation clearly demonstrates a more knowledge-oriented business attitude. There is a rising business performance of second-generation migrant entrepreneurs in mainstream segments of modern urban economies.

In **Part B**, the general *message* from the assessment exercise in our study (see Table 1) is that the variety of migrants and their different motives, attitudes and achievements (e.g. regarding migrant entrepreneurship) lead to great cultural diversity, mainly in urban agglomerations, and high performance levels. It is plausible that the variety – more than the sheer absolute numbers – generates many benefits. In particular, self-employment opportunities, SMEs and the globalization of the city may play a central role in creating new (urban) economic vitality.

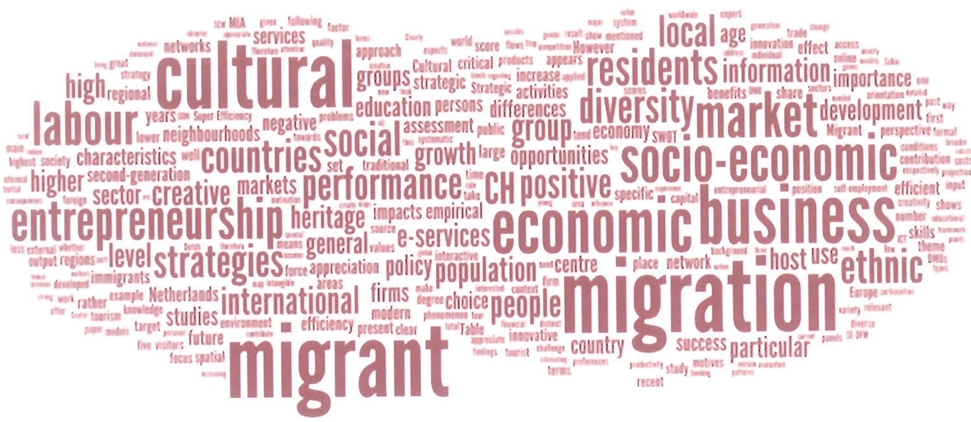

Figure 2. A 'content cloud' of the key concepts in Part B

The 'content cloud' related to Chapters 6–8 of Part B is presented in Figure 2. Figure 2 shows that the key concepts here are migration or migrants, cultural diversity, socio-economic effects, entrepreneurship and diversity. It is clear that here the focus is more on concepts related to the quality of collective welfare of society.

15.3.3 Part C: Urban Ambiance

Part C, concerning urban ambiance, exploits and analyses the potential impacts of the presence of urban ambiance-related phenomena, in a way that helps to improve and enhance the attractivity, quality of life and sustainability of places (for potential users) to live and work ('urban buzz'). Each chapter focuses on specific attractivity factors and the presence of specific actors, and therefore uses diverse approaches to the study of urban ambiance in relation to the presence of historical or cultural heritage. Additionally, the relationship between the share of creative minds – a heterogeneous group – and cultural heritage at the level of municipalities is addressed. We find that multiple components and drivers, effective support and the use of ICT tools nurture cultural heritage attractivity and the richness of cultural diversity in many urban systems for various users.

Chapters 9–11 present an analytical framework that links the opportunities provided by urban ambiance in the Dutch urban system to the level of attractiveness of these areas, i.e. a favourable and inspiring concentration in geographical space (clusters) for various (potential) stakeholders (e.g. residents, businesses and visitors). In the empirical part, different analytical approaches are adopted (e.g. SOM, MSM, the econometric (ordered logit) modelling approach, etc.), because of the different levels of stakeholder involvement and the multiplicity of issues related to urban ambiance. Our empirical findings show that modern cities with a relative abundance of cultural heritage and urban ambiance tend to enhance the quality or attractiveness of a place to various stakeholders (e.g. visitors, residents, professions, migrants, firms). In particular, actors who are part of the creative core appear to be attracted by – and hence over-represented in – urbanized areas, notably in the Dutch Randstad, with its relatively high presence of culture, nature, ethnic diversity and short distances to markets with job opportunities. This observation – in line with Table 1 – brings us to the general *message* from **Part C** of our assessment study: urban buzz offers wealth-creating potential for cities, as a result of the density, connectivity and proximity advantages among the creative minds – including distinct migrant groups – that reside in modern cities. Creativity and diversity appear to be key factors in the dynamic performance conditions of such areas.

Figure 3. A 'content cloud' of the key concepts in Part C

We will now again identify the key concepts from **Part C** by means of a 'content cloud' analysis (see Figure 3). The results in Figure 3 show that interesting key terms like diversity, professionals, urban and buzz appear in a dominant way. Apparently, the blend of cultural activity concepts and general overhead concepts assumes a prominent place in **Part C**.

15.3.4 Part D: Competitive Urbanity

Finally, **Part D** addresses competitive urbanity. It offers a novel contribution to the competitive assessment of the socio-economic performance of world cities, including their level of digital connectivity worldwide, from a comparative perspective. As argued before, modern cities tend to become engines (or even power plants) of knowledge, innovation and technology in a global context. It is certainly recognized that urban performance does not only depend on the city's endowment with hard infrastructure (such as transport facilities, ICT infrastructure, public amenities), but also on the availability and quality of knowledge and creativity infrastructure. An extensive set of world cities has been used to identify the relative position (strengths and weaknesses) of various important large cities on the basis of distinct assessment criteria and the perceptions of important classes of stakeholders on the performance outcomes of the various cities involved. We employ various assessment tools from our toolbox (e.g. super-DEA, MCA/MAMCA, multiple regressions, CAN) to arrive at a relative performance ranking of these cities.

In the analytical part, based on a multiplicity of diverse cities, Chapters 12–14 focus in particular on assessing the comparative performance and success factors of these cities. Furthermore, they aim to find handles for improving their competitive performance in relation to the level, availability and high quality of their spatial resources, from the perspective of vitality and attractiveness to various actors. We find that urbanity becomes the dominant model for conducting business, living and working in our society. At the same time, we live in the age of connectivity, in which networks of all kinds and all scale levels become the dominant organizational focus of the socio-economic activities on our planet. Therefore, Chapter 14 zooms in specifically on the digital connectivity and networks among these global cities, with a particular focus on the Chinese urban system.

In the empirical part, the various chapters identify important and smart key performance indicators that are instrumental to maximizing the cities' competitive advantages and connectivity. Our empirical findings show that compared with standard ranking and benchmarking procedures, significant performance differences may emerge. In particular, the new methods to achieve unambiguous DEA ranking results provide interesting findings on the relative position of cities, if we standardize the population size.

Our results allow us to explore the perception and experiences of various stakeholders and actors and to clarify the dependencies between the different assessment criteria and the criteria that really make the difference to the socio-economic performance of global cities. This will allow cities to identify the criteria to work on, and by doing so, to find out how to increase their attractiveness. Based on Table 1, the general *message* of **Part D** is: modern cities in an open and globalizing economy are becoming powerhouses of creative ideas, innovative technologies, sustainable developments and socio-economic wealth. This is due to a strong worldwide urbanization trend that emphasizes the need for a repositioning of cities, a process in which they are increasingly involved due to a competition on their integral performance. In addition to persistent urbanization trends, the urbanized world will also be a virtually connected world, in which next to the physical infrastructure the digital infrastructure (in particular, the Internet) will also play a central role.

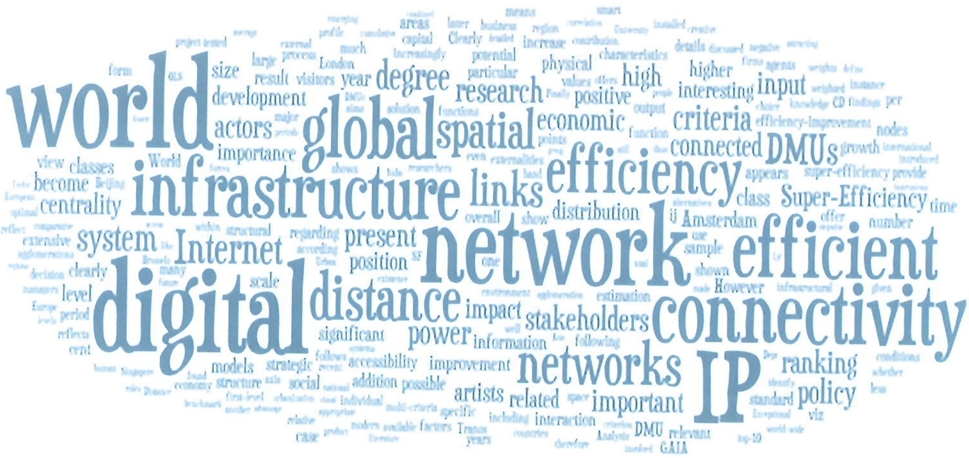

Figure 4. A 'content cloud' of the key concepts in Part D

Finally, we will again highlight our findings by using a 'content cloud' analysis (see Figure 4). The results in Figure 4 show that the focus here is more on the key concepts that are related to the socio-economic performance patterns of regions and cities, for example networks, digital world, distance, efficiency or global connectivity. These findings are confirmed by the information contained in Table 1.

15.4 Cities in an Integrated Perspective

The overarching aim of our study was: '**Assessment of the (internal and external) characteristics and drivers of urban actors and/or cities in a competitive spatial-economic environment, with a view to a comparative analysis of their innovative and creative performance**'. In other words, we developed and applied modern assessment tools to urban case studies. What have we learned from the research in our study? The wealth of research findings highlighted in Sections 15.2 and 15.3 has brought to light that the urban space economy is a multidimensional dynamic phenomenon with many characteristics of a complex economic, social and cultural nature. Cities are evolving systems driven by a multiplicity of actors and stakeholders. Hence, there is no one single unambiguous assessment tool. The aim of our study has been achieved by introducing on a fit-for-purpose basis various advanced assessment tools and combinations thereof. These results can be found in the previous Tables 1 and 2.

From a general perspective, we note that modern cities turn into multifaceted agglomerations with unprecedented dynamics. Urban dynamics, however, is as yet a poorly understood global phenomenon that deserves full-scale policy and research attention. The caveats to be kept in mind and the lessons to be drawn from the above observations are manifold. In particular, the following issues can be mentioned from a strategic perspective on the future of the '*New Urban World*':

- Cities show a great *variety in size and socio-economic structures* that may offer each specific city a unique market niche opportunity with a distinct competitive advantage;
- Cities may be important *engines of high performance and entrepreneurship* through their unique combination of human, socio-economic and cultural capital;
- Cities in many countries exhibit a great diversity of *cultural heritage* that enhances their general appearance; this may be threatened by technological progress and rising land use claims, but a focus on their sustainability may also create unprecedented future opportunities (e.g. for tourism and creativeness);
- Cities are often faced with severe *environmental issues*, although their agglomeration advantages are likely to be able to create the necessary conditions for a competitive profile;
- *Public policy* may focus on cities as spearheads of new economic development, which may generate unprecedented benefits to society at large. Effective urban planning systems are a *sine qua non* for building a better city.

It goes without saying that cities have many 'faces'; they are not uniform or identical. Is the heterogeneity of cities hampering an integrated angle on future urban systems?

To test whether coherence exists between the various phenomena and concepts used in Chapters 3–14 and to obtain an integrated and informed view on the various studies, we again use the exploratory information retrieval tool called 'content cloud' analysis. As mentioned, this technique summarizes and compares in a visual way the contents and information from different studies on the theme of the '*New Urban World*' by depicting the key words that appear most frequently, in size – and colour-varying – ways, within the cloud (see Figure 5).

A general strategic observation may be relevant here. Cities of the future may be confronted with many policy issues from local to global long-term megatrends as well as transitions in socio-economic parameters that may have long-term effects. Furthermore, urban governance systems may help to tackle these strategic questions. This would mean that the challenge is not to stop urbanization or migration, but to manage and govern them, by continuously anticipating changing circumstances and by translating and transforming threats into opportunities. This will be further discussed in Section 15.5.

In conclusion, the urban mode of living and working needs a broad explanatory assessment framework that is able to encapsulate the motives and behaviour of citizens, visitors, firms and other stakeholders.

15.5 General Policy Lessons

The current rate of urbanization mirrors a very complex set of many socio-economic forces that are closely interwoven with demographic, sociocultural, political, economic and technological drivers at all geographic scales (from local to global) that may influence the locational behaviour of firms, residents, migrants and 'creative minds'. This megatrend offers various great opportunities for urban development, but at the same time puts enormous pressure on our urban areas, by inducing negative externalities, such as pollution, congestion, security issues and social degradation, as well. This trend will be influenced by both natural population increase and large migration movements in various parts of the world. It is an important fact for urban policy making that the future settlement pattern will be urban. Hence, spatial and regional policy should have a clear urban component.

Next to the sunny side, cities are also faced with negative externalities. Cities clearly have many shadow sides, such as congestion, low-quality environmental conditions, social stress and segregation, high crime rates, etc. Such negative externalities have to be coped with in order to keep the net balance between positive and negative externalities on the positive side. From the viewpoint of urban policy, in the past decade, an endogenous growth perspective – sometimes in combination with the new economic geography – has evolved, in which the endogenous forces for enhancing growth potential (e.g. knowledge infrastructure) and for reducing environmental threats (e.g. environmental taxation) are combined in one analytical framework (see e.g. Verhoef and Nijkamp 2008). This attention to urban environmental conditions and the urban ecology has prompted a movement towards sustainable city development, leading to a balance between positive (e.g. agglomeration economies, specialization and diversity, R&D and innovation, shared infrastructure, social capital, spatial networks) and negative urban quality conditions (e.g. urban environmental decay, diseconomies of agglomeration, social exclusion, poverty, social economic inequalities, unemployment, criminality, urban quality conditions). This is essentially based on the XXQ principle referred to above several times. From a policy perspective, urban agglomerations will only meet their strategic objectives as engines of sustainable development if due attention is paid to negative urban externalities.

Our research on the '*New Urban World*' has clearly demonstrated that agglomeration benefits are partly economic in nature, but also partly social, cultural or technological. To exploit such benefits, innovative urban strategies are necessary to lay the future foundations for modern cities that are sustainable, inclusive and competitive. This new perspective on the future of our planet clearly originates from the cornerstones of the '*New Urban World*'. As a cross-section of the various findings in the different chapters of our study, four broad, interconnected applied research issues on urban development can be identified that hold for cities in both the developed and the developing world (see also Chapters 1 and 2):

- The *quality of life* in cities, in the context of environmental sustainability concerns and long-range climate change;
- *Social cohesion and equity* in cities to cope with future risks of social tensions and to ensure harmonious living together in renovated areas with a broad social mix;

- The *economic competitiveness* of cities as a source of new opportunities and socio-economic vitality in a global economy;
- *Land use and facilities* planning in urban areas, which may help to cope with urban sprawl and slums, while ensuring the availability and effectiveness of the infrastructure, public transport and public amenities.

Managing urban development at a global scale in the '*New Urban World*' will clearly be one of the biggest challenges in the twenty-first century. Issues like housing policy, infrastructure and logistics, environmental sustainability, urban land use, smart energy use, ageing, human health, social segregation, negative urban externalities and international migration will all require novel insights and policy strategies in order to make the future city 'a place 4 all'. Indeed, the achievement of high urban productivity – measured in appropriate dimensions as developed in the previous study – is key to urban performance. In a policy context, this calls for clear comparative and quantitative benchmark principles for urban systems in a competitive world.

Global urbanization processes inevitably also involve far-reaching issues relating to the institutional governance of powerful urban mega-structures that transcend by far the relevant administrative regional and national borders. New regulatory and logistic systems may be needed to reap fully the fruits of our urban century. This holds not only for migration dynamics, but also for global technology developments, human health care systems and sustainable development. Here, the dilemma of self-regulation versus planning will play a critical role. The current concept of self-organizing urban complexes may provide new ideas, but it is clear that much intellectual effort and many creative and smart courageous policies are needed to govern global urban systems effectively and efficiently. Urban governance is in the end a blend of self-organization and intervention.

Given the strategic importance of cities for the sustainable future of our world, balanced and alert urban governance is needed. The success of policy interventions on the urban level depends on three major background determinants:

- *Institutional factors* (the management and organization of the urban administration, public–private modes of cooperation, etc.);
- *Attitudes and behaviour of citizens* (lifestyles, mobility patterns, environmental awareness, etc.);
- *Urban structure and morphology* (population density, urban form, transportation networks, etc.).

Local authorities have the possibility to exert both a direct and an indirect influence on these determinants, but need a fresh perspective. Future perspectives on urban systems should not only be inward looking, i.e. from the internal functioning of systems *per se*, but should also be driven by the identification of possible and plausible drastic changes in the external world. Local policies should find their orientation in both supporting local actors (the 'internal orientation') and being alert to global changes (the 'external orientation').

Our study has focused on the strategic role of modern cities, which house a wealth of human social, entrepreneurial, creative, cultural and infrastructural capital that gives them a strong hub role, with both centripetal and centrifugal forces. The creation of attractive cities – from both a socio-economic and a cultural perspective – will, therefore, be one of the most important challenges for urban policy in the future. This is in line, for instance, with the European 'smart city' movement.

Cities create suitable conditions for competitiveness, and national, regional and local governments are responsible for ensuring that the institutional frameworks foster competitiveness. However, the concept of competitiveness is nowadays changing as well, and is no longer limited to purely economic issues like productivity, economic specialization versus diversity, efficiency in employment creation or the ability to generate a high GDP per capita. Other indicators may have to be added, such as cultural and environmental parameters, different types of urbanization, regeneration options and other factors representing the performance profile and physical shape of modern cities. This calls for pro-active and open-minded governance structures, with all the actors involved, in order to maximize the socio-economic and ecological performance of cities and to cope with negative externalities and historically grown path dependencies.

It is, therefore, desirable for modern cities not only to direct their urban policies solely towards solving the most obvious immediate problems, but also to generate a favourable physical, technological, social, environmental and institutional context for attracting and engaging in economic activities that generate long-range competitive advantages over other cities. Local government action in political, economic and social matters can be critical when it comes to mobilizing or attracting investment, advanced services and qualified labour and promoting the development of production activities that generate wealth, employment and well-being. In this context, cities compete with each other by offering a favourable space for engaging in economic activities. Urban policy is not only 'here and now', but also strategic and long range in nature.

Our study has focused on assessment methods for urban systems analysis, against the background of the Dutch reality. Although the Netherlands obviously has its own peculiarities, it seems plausible that the urban dynamics in the Netherlands does not follow a unique pathway, but shows many similarities to the development of urban systems elsewhere, certainly in OECD countries. It is, therefore, not too daring to say that many findings and conclusions also have validity for other countries.

In conclusion, cities are becoming the geographical heartlands (virtual and real) of a modern networked space economy. These hotspots are the source of progress and global orientation, and hence deserve the full-scale attention of economists, geographers, planners, sociologists, political scientists and urban architects. The policy and research challenges for modern cities are vast, but proactive policy may find support in the following quotation: *'The city is not only the place where growth occurs, but also the engine of growth itself'* (Duranton 2000). With more people on our planet living in cities, there is a need to look at the economic geography of our world from a broad urban systems perspective. The '*New Urban World*' needs to develop a world perspective and to transcend a local basis.

> *"If you want to escape from society, then you better go to a city, because this is the only place where you can still find a desert".*
>
> (Albert Camus, l'Homme Révolté, 1951)

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"We will neglect our cities to our peril,

for in neglecting them we neglect the nation."

- John F. Kennedy

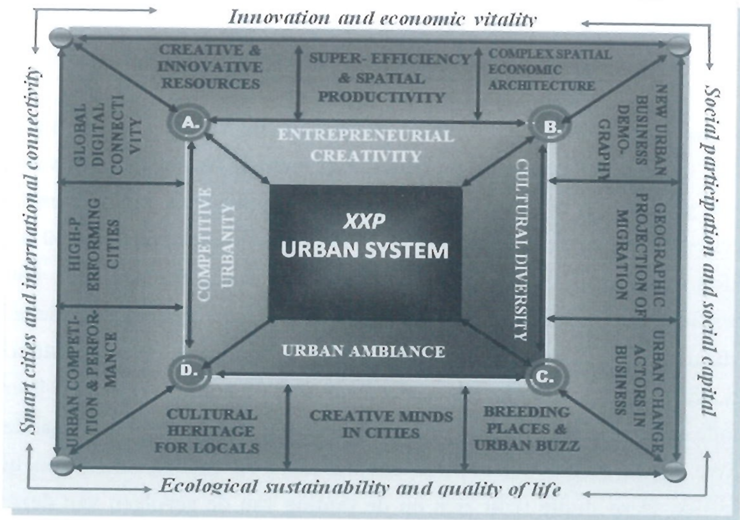
(Statement to Congress. January 30, 1962)

DUTCH SUMMARY

De groei van de wereldbevolking, de grote demografische verschuivingen tussen landen en continenten, en de alsmaar groeiende mobiliteit van mensen in een tijdperk van globalisering hebben de basis gelegd voor een uniek fenomeen in de geschiedenis van de mensheid, namelijk een sterke verstedelijking over de gehele wereld. Momenteel woont meer dan 50 procent van de wereldbevolking in steden, en deze urbanisatietrend gaat onverminderd door. Dit verschijnsel wordt in deze studie de '*New Urban World*' genoemd. Deze megatrend uit zich niet alleen in grote dichtheden, maar ook in de opkomst van zogenaamde 'mega-cities' en polycentrische stedelijke agglomeraties. Uiteraard groeien niet alle steden even snel (in sommige gevallen is er zelfs sprake van zogenaamde 'shrinking cities'), maar de hoofdtrend is er toch een van doorgaande urbanisatie.

De '*New Urban World*' vormt voor onderzoekers en beleidsmakers een uitdaging van de bovenste plank. Deze studie richt zich op de raming van de gevolgen van deze wereldwijde grootschalige ontwikkeling. Het doel van dit dissertatieonderzoek is ***Evaluatie van de (interne en externe) kenmerken en drijfveren van stedelijke actoren en / of steden in een concurrerende ruimtelijk-economische omgeving, met het oog op een vergelijkende analyse van hun innovatieve en creatieve prestaties.*** Deze formulering betekent dat ons onderzoek instrumenteel van aard is. Het dient kwantitatieve onderzoeksinstrumenten – te ontwikkelen en toe te passen voor het evalueren van het gedrag van actoren in stedelijke systemen in de '*New Urban World*', op basis van SMART gedefinieerde prestatiecriteria. In ons onderzoek worden verschillende methoden gebruikt voor diverse case studies gekenmerkt door verschillende onderzoeksvraagstukken.

Het onderzoekskader voor de '*New Urban World*' wordt gevormd door de '*urban piazza*' architectuur (zie Figuur 1). Dit '*urban piazza*' model fungeert als een belangrijk navigatie-instrument voor de evaluatie van stedelijke prestatiecriteria onder wisselende omstandigheden, variërend van micro-niveau (bedrijven of steden) tot macro-niveau ('global cities'). Het maximaliseren van deze prestatie-indicatoren wordt in deze figuur aangeduid met 'XXP'. De stedelijke piazza kan in vier segmenten worden verdeeld; deze vormen de vier belangrijke hoekstenen van ons onderzoek. Het piazza-model leidt in wezen tot een complex gelaagd conceptueel model voor het verwerven van nieuwe inzichten, te beginnen bij **A** en dan via **B** en **C** naar **D**. De bevindingen in elk deel **A–D** van onze piazza bieden uiteindelijk ook de ingrediënten voor het beantwoorden van de vraag of ons onderzoeksdoel is bereikt.



Figuur 1. Kennisarena van de 'urban piazza' in de '*New Urban World*'

Deel A biedt nieuwe conceptuele en empirische inzichten in de relaties tussen het locatiegedrag en de prestaties van actoren en de determinanten van stedelijke ontwikkeling in Nederlandse stedelijke gebieden. De prestatie van bedrijven blijkt mede afhankelijk te zijn van de ruimtelijk economische context waarin deze bedrijven opereren. Het gebruik van geavanceerde strategische management-technieken (gebaseerd op de strategische performance management techniek (SPM)), alsmede het type en de kwaliteit van 'capital resources' in bedrijven oefenen een cruciale invloed op de concurrentiekracht van bedrijven in zowel lokale als internationale markten. Voor het analytisch deel wordt daarom hier het SPM concept gebruikt (uitgebreid met gedetailleerde ruimtelijke meso-attributen met betrekking tot de locatiekenmerken van deze bedrijven) als een instrument om de prestaties c.q. de productiviteit van actoren te evalueren. Deze analyse is vervolgens aangevuld met andere analytische technieken en methoden, zoals geoscience-based tools, SOM, (super-) DEA, PCA, SEM en ruimtelijke data-analyse.

De algemene boodschap in **Deel A** kan als volgt worden samengevat. In de evaluatie van kenmerken en drijfveren van stedelijke actoren en/of steden, speelt 'locatie' een belangrijke rol (bijvoorbeeld met betrekking tot geografische en locatie-specifieke faciliteiten, innovatieve en creatieve voorzieningen, toegankelijkheid). Daarnaast blijkt ook afstand ('distance') een essentieel onderdeel van het dagelijkse 'business life' te zijn.

Deel B biedt vervolgens nieuwe inzichten in de evaluatie van de 'stedelijke diaspora', vanuit een internationaal perspectief. Veel aandacht wordt gegeven aan bedrijfsprestaties en groei en risicostrategieën van migranten-ondernemers op micro-niveau in de vier grote steden in Nederland. De influx van specieke migrantengroepen, zoals getalenteerde werknemers en ondernemers, heeft in het algemeen een aanzienlijke welvaarts-verhogende invloed op de stad, in het bijzonder door de bijdrage aan innovatie en lokale groei, het creëren van nieuwe banen voor minder begunstigde bevolkingsgroepen, het bevorderen van de voordelen van culturele diversiteit, en het versterken van economische kansen met betrekking tot internationale connectiviteit. In het analytische deel is daarbij gebruik gemaakt van een combinatie van technieken uit onze toolkit-box, zoals SCM, (super-) DEA, SOM en regressie-analyse. Onze analytische bevindingen brengen aan het licht dat in onze moderne en globaliserende stedelijke wereld, migratiestromen neigen te leiden tot het ontstaan van een nieuwe 'diaspora'. De empirische bevindingen tonen aan dat allochtone ondernemers – vooral de tweede-generatie migranten – een aanzienlijk deel van de stedelijke bedrijvigheid vormen en positief bijdragen aan de stedelijke vitaliteit.

De algemene Top of Form boodschap van onze evaluatie in **Deel B** is dat de variëteit van migranten en hun verschillende attitudes, houdingen en prestaties (bijvoorbeeld met betrekking tot ondernemerschap) leiden tot een grote culturele diversiteit, met name in stedelijke agglomeraties, en tot betere bedrijfsprestaties. Het is interessant dat culturele diversiteit vele voordelen genereert, in het bijzonder voor de 'self-employed' en SMEs.

Deel C presenteert een analytisch kader gericht op de 'stedelijke ambiance' in Nederland, gericht op de vraag of steden een gunstige en inspirerende geografische ruimte (via clusters) bieden voor verschillende (potentiële) stakeholders (bijv. inwoners, bedrijven en bezoekers). In het empirische deel zijn daarom verschillende analytische benaderingen (bijvoorbeeld SOM, MSM, ruimtelijk-econometrische modellen (ordered logit), enz.) toegepast. Deze analyse richt zich op actoren op verschillende niveaus en op diverse mogelijkheden voortvloeiend uit de stedelijke ambiance. Onze empirische vindingen tonen aan dat moderne steden met een relatieve overvloed aan cultureel erfgoed en stedelijke ambiance essentieel zijn voor de kwaliteit en de aantrekkelijkheid voor verschillende groepen stakeholders (bijvoorbeeld bezoekers, bewoners, creatieve beroepen, migranten, bedrijven). In het bijzonder actoren die deel uitmaken van de 'creative core' worden aangetrokken tot – en zijn dus oververtegenwoordigd in – stedelijke gebieden met een relatief hoge aanwezigheid van cultuur, natuur of etnische diversiteit.

Dit brengt ons tot de algemene boodschap van **Deel C**. De 'stedelijke buzz' heeft een welvaartsscheppend potentieel voor steden, als gevolg van dichtheids-, connectiviteits- en nabijheidsvoordelen voor creatieve 'minds', inclusief verschillende migrantengroepen. Creativiteit en diversiteit zijn hier belangrijke factoren voor verbetering van de dynamische prestatievoorwaarden in stedelijke gebieden in Nederland.

Tot slot, **Deel D** is met name gericht op een vergelijkend evaluatie van diverse prestaties en succesfactoren van 'global power cities'. Het blijkt dat stedelijke prestaties niet alleen afhankelijk zijn van stedelijke voorzieningen, zoals harde infrastructuur (bijv. vervoer, ICT-infrastructuur, openbare voorzieningen), maar ook van de beschikbaarheid en kwaliteit van de kennis en creativiteitsinfrastructuur. In het algemeen worden moderne steden steeds meer de motor van kennis, innovatie en technologie worden in een mondiale context. In dit deel van onze studie maken we gebruik van verschillende evaluatie-instrumenten uit onze toolbox (bijv. super-DEA, MCA / MAMCA, multiple regressie, CAN) om tot een relatieve prestatierangschikking van steden te komen. Onze empirische vindingen tonen aan dat in vergelijking met standaard rangschikkingen en benchmark procedures, significante prestatieverschillen kunnen ontstaan tussen steden.

De algemene boodschap van **Deel D** is dat moderne steden in een open en globaliserende economie steeds meer de motor van creatieve ideeën, innovatieve technologieën, duurzame ontwikkeling en sociaal-economische welvaart worden. De huidige sterke wereldwijde urbanisatietrend roept de behoefte op aan een herpositionering van steden, een proces waarin zij steeds meer betrokken raken door de concurrentie rond hun integrale 'performance'. Naast doorgaande urbanisatietrends, zal de verstedelijkte wereld ook een virtueel verbonden wereld zijn, waarin naast de fysieke infrastructuur de digitale infrastructuur (met name het Internet) een centrale rol zullen spelen.

Onze onderzoeksresultaten brengen aan het licht dat stedelijke ruimtes een multidimensionaal dynamisch fenomeen vormen met vele complexe economische, sociale en culturele karakteristieken. Steden zijn evoluerende systemen, aangedreven door een veelheid van actoren en belanghebbenden. Het spreekt voor zich dat steden vele gezichten hebben; ze zijn niet uniform of identiek. Onze studie richt zich op evaluatiemethoden voor stedelijke systemen. Het lijkt aannemelijk dat de stedelijke dynamiek in Nederland niet een uniek pad volgt, maar veel overeenkomsten vertoont met de ontwikkeling van stedelijke systemen elders, zeker in de OECD-landen. Het is daarom niet te gewaagd te stellen dat veel vindingen en conclusies ook geldig zullen zijn voor andere landen. Het onderzoeksdoel van onze studie gaat uit van een 'fit-for-purpose' benadering op basis van verschillende geavanceerde evaluatie-instrumenten en combinaties daarvan. Evaluatie is niet een eenduidige instrumentele benadering, maar heeft instrumenten die op maat gemaakt zijn voor specifieke gevallen.

Uit de verscheidene studies komt naar voren dat de huidige verstedelijking een onomkeerbare megatrend is, met ongekende onderzoeks- en beleidsuitdagingen. Onze bevindingen over het evaluatie-doel van onze studie kunnen worden samengevat in vijf algemene observaties:

- Steden zijn krachtige economische motoren om aanhoudende economische groei te verzekeren, vooral in een periode van economische recessie;
- Populatie-dynamiek en migratie beïnvloeden niet per se de potentie van de economische groei van steden in negatieve zin, maar bieden een grote kans voor de toekomst;
- Creatieve klassen in steden kunnen een belangrijke voorwaarden vormen voor innovatieve ontwikkeling, maar er zijn daarnaast ook andere belangrijke elementen (zoals de educatieve suprastructuur, transport-infrastructuur, cultureel erfgoed);
- De monitoring van stedelijke ontwikkeling - door het systematisch verzamelen van databases en benchmark systemen - is een kritische voorwaarde voor de gelijk en strategisch stedelijk beleid in een concurrerende wereldwijde stedelijke omgeving;
- Flexibele organisatie en ruimtelijke ordening zijn nodig om steden – of meer in het algemeen, metropolitane gebieden – te handhaven of te positioneren als motor van economische groei.

Ons onderzoek naar de '*New Urban World*' 'heeft duidelijk aangetoond dat agglomeratievoordelen deels economisch van aard zijn, maar deels ook sociaal, cultureel of technologisch. Om deze voordelen te benutten, zijn innovatieve stedelijke strategieën noodzakelijk om een toekomstige basis te leggen voor moderne steden die duurzaam, inclusief en concurrerend zijn.

Deze nieuwe kijk op de toekomst van onze planeet is een interessante les uit de '*New Urban World*'. De beleids- en onderzoeks-uitdagingen voor moderne steden zijn groot, maar een pro-actief beleid kan steun vinden in het volgende citaat: "*De stad is niet alleen de plaats waar de groei plaatsvindt, maar ook de motor van de groei zelf*" (Duranton 2000, p.291-292). Met meer mensen op onze planeet die in de stad leven, is er een noodzaak om de economische geografie van onze wereld te bekijken vanuit een breed stedelijk systeem-perspectief.

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