

# Filling Some Black Holes: Modeling the Connection Between Urbanization, Infrastructure, and Global Service Intensity in 112 Metropolitan Regions across the World

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## Abstract

This empirical article combines insights from previous research on the level of knowledge-intensive service in metropolitan areas with the aim to develop an understanding of the spatial structure of the global service economy. We use a stepwise regression model with GaWC's measure of globalized service provisioning as the dependent variable and a range of variables focusing on population, infrastructure, urban primacy, and national regulation as independent variables. The discussion of the results focuses on model parameters as well as the meaning of outliers, and is used to explore some avenues for future research.

**Key words:** world cities, producer services, airline networks, urban population, stepwise regression

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## Introduction

In an article in this journal, Short (2004) develops an alternative way of looking at globalized urbanization: rather than merely discussing the points where the geographical unevenness of contemporary globalization is being (re)produced, he analyzes which large cities seem to be largely absent from these processes. To this end, he draws upon the well-known world city data of the Globalization and World Cities research network (GaWC), which uses the presence of globalized advanced producer services (APS) firms as an indicator of 'world city-formation'. Short (2004) uses this GaWC indicator as a yardstick for measuring the impact of population size on the presence of globalized APS firms. His major conclusion is that although urban population size has an impact on a city's involvement in the (re)production of uneven globalization, this relation is generally weak. There are thus major outliers at both sides of the spectrum, ranging from cities that are 'hyper-connected' in the office networks of globalized APS firms even when considering their size (e.g. London and New York), to 'black holes' that are hardly connected in the office networks of globalized APS firms despite their sheer size (e.g. Dhaka and Khartoum).

Although the prime purpose of Short's (2004) article is to develop a better understanding of cities that are 'off the map' of research on world cities (Robinson 2002), his analysis can also be positioned in the context of the rich literature that aims to explain the level of service intensity of cities. Taylor et al. (2007), for instance, use a similar methodological approach to assess the impact of airline infrastructure on cities' involvement in the office networks of APS firms at the global scale. The latter study, in turn, continues a long line of more comprehensive research at the national scale (especially in the United States). Debbage (1999), for instance, has shown that population size, service intensity, and airline infrastructure are major covariates in the US urban system. At the same time, however, given the specificity of the US market for services and air passenger transport, it can be expected that the actual

strength of the relations between these indicators may vary in different parts of the world (see Taylor et al. 2007).

Against this backdrop, the main purpose of this article is to develop a more comprehensive study of the driving forces behind cities' involvement in the globalized office networks of APS firms. To this end, we will use an updated GaWC measurement of world city-formation as the dependent variable in a stepwise regression model that involves the differential impact of infrastructure, population, urban primacy, and national regulation on this measure. Furthermore, modeling these relations supports the broader aim of this article to fine-tune the existing APS-heuristic in world cities research (Derudder et al., 2010), and disclose the spatial structure of the global service economy. However, due to the continued lack of comprehensive urban datasets at the global scale (Short et al. 1996), analyzing the relationships between indicators such as population size, service intensity, and airline infrastructure remains much easier at the national scale because of superior data. Hence, it is necessary to acknowledge from the outset that our effort is an exploratory one.

The remainder of this article is organized as follows. The next section briefly introduces the theoretical background of our empirical analysis: we discuss the relation between world city-formation and the presence of globalized APS, and draw on a literature review to explain which processes can be assumed to drive this presence. In the ensuing section we discuss our data and methodological framework, followed by a section outlining our results. The article is concluded with a discussion of the implications for research on globalized urbanization in general and world city-formation in particular.

## **Literature review**

Our analysis draws on arguments derived from sometimes very different literatures. This can initially be divided in two parts: (1) the analytical linkages between world city-formation and globalized APS provision on the one hand, and (2) the covariates of the intensity of APS provision in specific cities on the other hand. The latter literature in turn comprises very different insights at very different scales, but here we tie these together to develop a comprehensive framework of possible drivers of the presence of APS firms at the global scale.

## **World City Network Formation and APS**

GaWC's research on world city network (WCN) formation through the lens of APS firms' location strategies is based upon an extension of Saskia Sassen's (1991) well-known concept of 'the global city'. In her seminal book, Sassen essentially argued that there are a select number of cities that are strongly associated with contemporary globalization through their development of APS by firms offering customized financial, professional and creative expertise to corporate clients. The urban disposition of APS rests on the straightforward observation that, to keep ahead in their business, such firms require access to a skilled labor pool, information-rich and prestigious environs, and superior office, transport and telecommunications infrastructures, all of which are primarily found in major cities across the settled world. As the corporate clients of APS firms increasingly begun to globalize from the 1970s onwards, so also did the firms servicing them in APS such as commercial law, wealth management, corporate tax advice and advertising. The result has been that major cities became simultaneously markets for these services through corporate presences, and production centers of these services through innovative knowledge clusters. It is through the

expertise of APS firms in transnational servicing of their clients that cities became seen as the organizing nodes of economic globalization.

GaWC accepts Sassen's identification of APS firms at the cutting edge of the world economy through enabling transnational commerce and production, but has extended the argument beyond Sassen's focus on just a small number of select cities (Taylor 2004; Taylor et al. 2012). Typically, leading APS firms operate through office networks across a large number of cities, ranging from a few cities in the case of law firms to thousands of cities in the case of the big accountancy firms. Thus GaWC has moved away from an emphasis on a few nodes as 'global cities' to focus on the network relations of many more cities in the servicing of global capital. This is specified as the WCN, and in this article we will therefore – in parallel with Short (2004) – use a recent operationalization of this concept as indicator of a city's involvement in globalized APS networks.

## **Possible Drivers of the Presence of Globalized APS Firms**

### **Infrastructure**

Perhaps the single most researched variable in relation with the service intensity of metropolitan regions is that of infrastructure (cf. Taaffe 1962; Bird 1973; Warf 1989). Continuing this geographical tradition, Keeling (1995) lists a number reasons why, for instance, air transport is a key variable in explaining WCN-formation. The most pertinent ones are: (1) airline networks and their associated infrastructure are the most visible manifestation of world city-formation (Smith and Timberlake 2001); (2) the continued demand for face-to-face relationships in spite of the parallel development of (tele)communications (e.g. Denstadli 2004); (3) the observation that air transport is the preferred mode of inter-city movement for the transnational capitalist class, migrants, tourists (e.g. Bowen 2002); and (4) the fact that airline links are often important components of a city's aspirations to world city status (e.g. the flagship role of Emirates in the rise of Dubai).

The net result of these conceptual linkages is that, although far from being carbon copies, the relative and absolute importance of a globalized APS sector in metropolitan regions is known to be related to their airline connectivity. In addition to a number of general discussions of the role of airline connectivity in world city-formation (e.g. O'Connor 2003; Matsumoto 2004; Grubestic et al. 2011), the only analysis that explicitly links cities' airline passenger numbers to their involvement in global service provisioning is that of Taylor et al. (2007). In this article, the authors find that the number of airline passengers associated with cities explains up to 53 percent of the observed variance in GaWC's measure of WCN connectivity.

More empirical support for such strong relation comes from analyses of the relations between airline connectivity and knowledge-intensive business services at the national level, especially in the United States. Irwin and Kasarda (1991) found for a set of 104 U.S. metropolitan areas that changes in airline networks affect the employment growth in business services, while roughly a decade later Brueckner (2003) and Debbage and Delk (2001) obtained similar results. Furthermore, a recent contribution to this literature by Neal (2010) adds a new element by addressing the causality in the link between air transport and the importance of APS: his longitudinal analysis shows that, at least in the U.S. urban system, changes in airline connectivity tend to explain changes in the importance of advanced services in the labor market rather than the other way round, which lends further credibility to using the level of airline connectivity for explaining the presence of major APS firms<sup>1</sup>.

## **National regulation**

In their analysis, Taylor et al. (2007) do not concentrate on the results of the ‘general’ relation between air passenger travel and APS firm connectivity because U.S. cities seem to have a pattern that is consistently different from that of non-U.S. cities. The authors ascribe this to sheer size of the deregulated U.S. air passenger market as well as the relatively underdeveloped presence of ‘globalized’ APS firms due to a strong ‘national’ APS market. The net effect is that U.S. cities have generally far less ‘global’ APS involvement than can be expected based on their air passenger connectivity. As a consequence, in practice Taylor et al. (2007) assess the relation between the size of the air passenger market and WCN connectivity for U.S. and non-U.S. cities separately. The relevance of this choice is shown by the results, as the explained variance rises from 53 percent to 73 percent (U.S. cities) and 61 percent (non-U.S. cities) respectively.

Taylor et al. (2007) restrict the use of ‘national specificity’ in their model to the United States because of an assumed ‘American exceptionalism’ in this context. However, not only in the United States the relationship between infrastructure networks and the presence of globalized APS firm is driven by national peculiarities (for a more general appreciation of the role of states in WCN-formation, see Hill & Kim 2000; Olds and Yeung 2004). In China, for example, the state-processed economy is clearly crucial for understanding cities’ involvement in the office networks of globalized APS. For instance, in spite of the country’s WTO ascension in 2001, doing business continues to be tightly regulated. The most obvious example, of course, is that of banking in that most of China’s own financial institutions continue to be state owned and governed, while 75 percent of state bank loans continue to go to State Owned Enterprises (SOEs). China’s entry into the WTO has obviously created opportunities for foreign banks as well. However, there continue to be strict rules regulating foreign financial institutions’ possibilities, especially when it comes to doing business in the local currency (Pauly 2011).

The key point for the purpose of this article is that, although a high-end service sector is undeniably developing in most Chinese cities, the involvement of firms typically featuring in GaWC’s empirical framework is restricted by the regulatory context imposed by the Chinese state. Thus in addition to a specific pattern for US cities, one can also suspect a differential pattern for Chinese cities, and perhaps also for cities in other states. In our analysis, we therefore extend the framework of Taylor et al. (2007), not by ‘splitting’ the analysis in a set of sub-analyses, but by adding dummy variables for states with multiple cities in the data.

## **Population**

As mentioned in the introduction, Short (2004) has shown that metropolitan size is less-than-perfectly correlated with WCN-formation as measured through globalized service intensity (GSI). However, although not a major indicator, there is a size effect in that large cities have the tendency to be slightly more connected in the office networks of globalized APS firms. It therefore seems warranted to adopt this indicator in our regression analysis, if only as a control variable in our analysis for the effect of infrastructure: air passenger infrastructure is of course also positively related to population size.

## **National primacy**

A final indicator in our model lies on the intersection of population and national regulation indicators. Referring back to the Chinese example, it can be observed that the regulatory

context not only influences the involvement of globalized APS, it also imposes a specific kind of location-dependence. The restrictions for foreign banking in China, for instance, also have an important geographical dimension: restrictions on doing Renminbi-denominated business – the supposed golden grail for many foreign banks – have been phased out unevenly, with Shanghai amongst the first sites where this type of regulation was loosened. Unsurprisingly, foreign financial services firms have flocked to this city as it is the place in Mainland China where they can develop their China-centered businesses in the best circumstances in regulatory terms. Furthermore, in the face of this spatio-temporal unevenness in phasing out financial services restrictions, Shanghai has acquired a comparative advantage that is being reproduced as foreign banking involvement in China rises (see Lai 2011). This specific argument chimes well with Sassen's (2001) more general contention that we are increasingly witnessing a relative concentration of transnational command and control activities of APS firms in a select number of major cities. In addition to dummy variables for a city's state and metropolitan size *per se*, we will therefore use a dummy variable for a country's major city in a state to test whether (over and above size) major cities also house disproportionate levels of globalized APS.

## **Data and methodology**

The hypotheses emerging from this brief literature review have guided our empirical analysis. We subsequently discuss the data we used as our dependent and independent variables, some data transformations, and our modeling approach.

### **Dependent Variable: Connectivity in the Office Networks of Globalized APS Firms**

The dependent variable in our model is drawn from GaWC's research in which globalized APS provision is operationalized through collecting data on the office networks of such firms (Taylor et al. 2012). These data are readily available on firms' websites where they promote their 'global' status as a means of both impressing clients in a competitive services market and recruiting graduates in a competitive jobs market. This information was converted by simple coding to a so-called service value (ranging from 0 to 5), which depends on the size/relevance of the offices, to enable cross-firm comparisons. This resulted in a firm/city service values matrix that provides the basic raw material for GaWC's WCN analysis.

The data used in this article were collected in 2010, and provide information on the location strategies of 175 APS firms in 525 cities across the settled world. The firm selection is composed of 75 financial services firms and 25 each of accountancy, advertising, law and management consultancy firms. Firms were chosen using trade information ranking firms by size based upon the latest information available (e.g. on turnover) before the data collection (i.e. for 2009). A city's GSI is then computed by applying an interaction model as detailed in Taylor (2001). To the best of our knowledge, this is the most comprehensive indicator of the involvement of cities in the office networks of APS firms available at the global scale.

### **Independent Variables**

Although there are quite some data sources detailing the participation of cities in air passenger networks, not all sources are equally pertinent. One major example would be that most airline statistics do not contain origin-destination data, but rather give information on the way in which airlines organize their networks. Using such data would, for instance, overvalue the importance of cities comprising 'airports' acting as switching points for passengers. To

circumvent this problem, we use data derived from the Sabre Airport Data Intelligence (ADI) database. ADI is a so-called 'Global Distribution System', which contains worldwide booking information on passenger flights. The database contains information on passenger flows between airports through airport codes. In contrast to most other statistics, this data source contains information on actual origins and destinations as well as information on the connections of low-cost carriers.

The population data used in our analysis are collected by Brinkhoff (2011), whose website lists up-to-date census data of urban agglomerations with more than 1 million inhabitants. Cities located in countries with at least four cities in the final dataset (see below) were brought together in set of national dummy variables (e.g. China and the United States), after which the remaining cities were brought together in regional dummy variables (e.g. Latin America and Sub-Sahara Africa). And finally, we inserted an urban primacy variable for the most populous city in a country with at least two cities in the final dataset.

### **Data Transformations**

The initial data were – where necessary – transformed in three different ways to arrive at a consistent framework. A first problem related to the territorial definition of the cities in our analysis. Our population data defines cities primarily in a morphological sense (i.e. urban agglomerations), while airline data entail a functional city-regional approach (i.e. the London airports serve the entire Southeast England), and GaWC data in practice often refer to economic activity contained within specific grids of business activity (e.g. most of the GaWC firms in London are located in 'the City'). To circumvent this problem, we transformed our data by adopting a territorial working definition for our 'cities' that is as coherent as possible and transforming our data to fit this operationalization.

In practice, this implies a focus on metropolitan regions (MRs) that are reminiscent of American CMSAs (Consolidated Metropolitan Statistical Area). As there is no agreed upon global operationalization of this approach, we have tried to devise a list that follows the CMSA logic as closely as possible. For instance, the Dutch cities are combined into a single 'Randstad' measure. However, we concede that this approach is far from clear-cut. For instance, it is hard to make a clear-cut partition of the urban spheres of influence in, say, China's Pearl River Delta (with Hong Kong, Guangzhou, and Shenzhen as major nodes), as airports, urban centrality and morphology in this region exhibit a highly complex and overlapping interplay. In the event, we have chosen to retain Hong Kong as a separate MR, and combine the remainder of the Pearl River Delta as a single region because of the 'one state, two systems' logic. We used existing, official designations of CSMA-like metropolitan regions when available. This territorial working definition implied – where necessary - combining urban populations, retaining the highest service value of a MR's constituent nodes, and aggregating origin/destination volumes of the airports.

The second problem relates to the uneven coverage of our datasets. We therefore decided to exclusively focus on MRs that scored at least 10 percent of the highest value on each of the (transformed) measures for population (Yangtze River Delta centered on Shanghai), airport connectivity (London Metropolitan Area), and GSI (London Metropolitan Area). This resulted in a total of 112 MRs. And third and finally, as each of the distributions of our continuous datasets is heavily skewed, we logged the data so that the distributions become normally distributed and can be used as an input to regression analysis.

## Stepwise Regression Analysis

We analyze our variables with a stepwise multiple linear regression. This is a systematic method for adding and removing variables from a multi-linear model based on their statistical significance in the regression. An initial model is stepwise expanded by variables that have the smallest  $p$ -value, but in every step the variables that are no longer significant are removed. This iteration terminates when no single step further improves the model. Only the significant variables (here at the 0.05 significance level) thus remain.

For our purposes, two sets of relevant information are drawn from the model, i.e. (1) the regression model parameters proper, such as the degree of explained variance ( $R^2$ ) and the relative importance of each of the variables (standardized  $\beta$ -coefficients); but also (2) the deviations from the model predictions (standardized residuals), which can be used for exploring processes not captured within the model.

## Results

The model derived from our data is:

$$\text{Ln\_GSI} = 2.003 + 0.473 \text{ Ln\_passengers} + 0.063 \text{ Ln\_population} + 0.231 \text{ First City} + 0.332 \text{ Latin America} - 0.520 \text{ Japan} - 0.296 \text{ United States} - 0.521 \text{ China} + 0.327 \text{ Sub-Saharan Africa}$$

**Table 1: Results from the stepwise regression model**

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	$\beta$	t	p-value
(Constant)	2.003	0.604	-	3.316	0.001
Ln_passengers	0.473	0.034	0.920	13.889	0.000
ln_population	0.063	0.031	0.106	2.035	0.044
First City	0.231	0.054	0.238	4.288	0.000
Latin America	0.332	0.099	0.179	3.357	0.001
Japan	-0.520	0.128	-0.201	-4.075	0.000
United States	-0.296	0.070	-0.249	-4.209	0.000
China	-0.521	0.129	-0.202	-4.045	0.000
Sub-Saharan Africa	0.327	0.133	0.141	2.460	0.016

The first major result of our analysis is that, in line with our hypotheses, the combined effect of airline connectivity, population size, and national specificities provides strong predictors of MRs' involvement in the office networks of globalized APS firms: 74.5 percent of a MR's variation in GSI can be explained, which is considerably more than in previous research in which only passenger data and/or population size were used as explanatory variables (Short 2004; Taylor et al. 2007). In general terms, this confirms that the complex web of interrelations between knowledge-intensive services, infrastructure and population previously observed in metropolitan areas at the national scale (especially in the United States) is also apparent at the global level.

To disentangle the relative role of each of the independent variables, Table 1 lists the  $\beta$ -coefficients<sup>2</sup>. The table shows that although each of the independent variables is retained within the stepwise regression model (and therefore contributes to explaining differences in GSI), there are major differences in terms of their explanatory power. In line with Short's (2004) conclusions, population is a rather modest conjecturer of the presence of globalized APS firms, especially in comparison with air passenger connectivity, which is by far the most important variable in our model. Although the complex interrelations between these variables are reproduced at the global level, there seems to be a diminishing importance of population size, which can be attributed to global differences in economic development.

Furthermore, this global pattern is also complicated by national/regional tendencies. Three national dummies have negative  $\beta$ -coefficients (the United States, China, and Japan), which implies that MRs in these countries have smaller levels of GSI than expected in the 'global' pattern sketched above. For the United States this is explained by the combined effect of a major 'national' market for APS firms and a well-developed airline market (Taylor & Lang 2005), while for China and also Japan the main reason seems to lie in the (continued) tight regulation of the economy. This appreciation is in turn confirmed by the relatively sizable effect of the 'first city' dummy variable, which shows that – over and above the importance of size – being a country's most important MR leads to high levels of GSI. The likes of Greater Tokyo Area and Yangtze River Delta with Shanghai (but also, say, Karachi Metropolitan Area and Greater Sao Paulo) attract offices in the networks of globalized APS firms more so than could be expected only on their population sizes and passenger numbers alone, which corroborates Sassen's (2001) reading of concentration of GSI in a limited set of metropolises.

Latin American and the (few) Sub-Saharan African MRs in our analysis have higher levels of GSI than can be expected based on the global pattern. MRs such as Greater Buenos Aires, Greater Sao Paulo, Tschwane Metropolitan Area (i.e. Johannesburg and Pretoria) typically function as the sole attractors of virtually *all* of the globalized APS firms, acting as service gateways for entire regions. This turns the major MRs in these regions into important sites of GSI relative to the other criteria in the model.

The second major set of results from our analysis stems from the observation that about 25 percent of the variance in metropolitan GSI levels is not being accounted for. This can, of course, in part be related to the transformations needed to make our datasets comparable, as well as lingering data deficiencies at the global level (Short et al. 1996; Taylor 1997). However, above all this suggests that some of the processes behind GSI geographies are outside of the model. To aid in exploring these processes, we use Table 2, listing the major deviations from the model (i.e. all MRs with a standardized residual above 1 or below -1). Large positive (negative) values signify that a MR has a rather high (low) level of GSI when considering the combined size of enplaned passengers, size, and – if relevant – national/regional status. Four observations can be made.

**Table 2: Metropolitan regions with large positive and negative residuals**

Metropolitan region	Residual	Metropolitan region	Residual
Greater Beijing Region	2.009	Las Vegas	-3.258
Singapore Extended Metropolitan Region	1.422	Dhaka	-2.928
Delaware Valley (Philadelphia)	1.394	Greater Orlando	-2.525



Tshwane Metropolitan Area (Johannesburg, Pretoria)	1.385	Naples	-1.977
Jakarta Metropolitan Area	1.353	Pearl River Delta (Macao, Guangzhou, Shenzhen ...)	-1.928
Grand Montréal	1.247	Fukuoka	-1.717
South Florida Metropolitan Area (Miami)	1.211	Bangkok Metropolitan Area	-1.676
Chicago-Naperville-Michigan City CSA	1.195	Guadalajara	-1.561
Flemish Diamond (Brussels, Antwerp)	1.158	Rome Metropolitan Area	-1.503
Hong Kong	1.043	Chengdu	-1.464
Metropolregion Hamburg	1.015	Seoul National Capital Area	-1.368
Dubai-Sjarjah Metropolitan Region	1.009	Phoenix-Tucson	-1.258
Pune	1.002	Berlin-Brandenburg Metropolitan Area	-1.251
		Salt Lake City Metropolitan Area	-1.051

First, the large negative residuals for Las Vegas and Greater Orlando (but also, to a lesser degree, Bangkok Metropolitan Area, Berlin-Brandenburg Metropolitan Area, and Rome Metropolitan Area) are very probably due to tourism (in the broadest sense). Tourism is an ancillary function of globalizing MRs, and in some cases even comes to dominate the functional tissue of these city-regions (as is clearly the case for Las Vegas). GSI is obviously related to a narrower conceptualization of globalized urbanization (Grant and Nijman 2002; Robinson 2002), and it is therefore no surprise that MRs in which the tourism function equals or even dominates that of GSI-related business activities attract far less globalized APS firms than predicted by the number of airline passengers and population sizes.

Second, there is a diverse category of MRs that have large positive or negative residuals because of national peculiarities that cannot be reduced to (and are therefore not measured by) a mere 'national primacy effect'. This includes, for instance, Rome Metropolitan Area's negative residual because of the well-documented domination of Milan Metropolitan Area. In spite of its smaller size, the latter MR serves as the de facto leading MR in Italy for global business, which results in the choice for Milan Metropolitan Area over Rome Metropolitan Area for a lot of global APS firms that might otherwise open an office in Rome Metropolitan Area. A similar observation can be made for Berlin-Brandenburg Metropolitan Area, where Germany's 'flat' urban hierarchy as well as Frankfurt-Main Region's position as a leading international business center result in a MR with less GSI than might be expected. The Pearl River Delta probably also falls within this category, with nearby Hong Kong assuming some of the region's potential.

These peculiarities can also give way to positive residuals. Greater Beijing Region's high positive residual, for instance, can be related to China's emerging world city system centered on three major MRs (see Yulong & Hamnett, 2002; Derudder et al. 2010; Lai 2011). Thus in addition to Hong Kong's continued role as a quasi-offshore financial center for China and Pacific Asia, as well as Yangtze River Delta's role as a strategic MR for connecting China to the global economy through finance and trade since the late 1980s, Greater Beijing boasts a large residual GSI because it accommodates the institutions responsible for managing and determining the economic and political life in the country (Lai 2011). Furthermore, because the Yangtze River Delta centered on Shanghai is China's largest MR, this political primacy is not accounted for in the model. Somewhat less spectacular, but equally notable is Grand

Montréal's high residual, possibly because of language-driven idiosyncrasies in the location strategies of globalized APS firms (e.g. the presence of French financial services firm BNP Paribas in Grand Montréal, but not in Greater Vancouver Regional District).

Third, Short's identification (2004) of black holes re-emerges in the negative residuals, with a MR such as Dhaka having far less GSI than expected. However, this designation of 'black holes' can be extended beyond its implicit Third World connotation: Naples in Italy, Fukuoka in Japan, and Guadalajara in Mexico can also be dubbed black holes in that, even after taking into account the general effect of national primacy on globalized APS presence, Milan Metropolitan Area, Greater Tokyo and Mexico City Metropolitan Area still exercise a major shadow effect: these MRs are so dominant in their GSI that other MRs in their countries attract very little such firms, despite being large and having sizable airports.

Fourth and finally, the model's focus on 'national domination' through an indicator of 'national primacy' does not pay sufficient attention to the presence of what can be dubbed 'regional primacy', especially in terms of MRs functioning as major business gateways for wider regions. Thus Singapore Extended Metropolitan Region, Hong Kong, Tshwane Metropolitan Area, South Florida Metropolitan Area (Miami) and Dubai-Sjarjah Metropolitan Region have large positive GSI residuals as these MRs perform major functions in Pacific Asia, Sub-Saharan Africa, Central America, and the Middle East respectively. Thus the contrast between Greater Orlando and South Florida Metropolitan Area, where the latter MR has by far a superior level of GSI because of its 'extra-mural' economic function, especially when compared to its size and number of enplaned passengers.

## Conclusions

In this article, we have tried to extend previous, predominantly *national* research on the complex impact of (airline) infrastructure and population on the level of knowledge-intensive services in metropolitan regions to the *global* scale. An important conclusion of this analysis is that this impact is sizable, albeit that – given major geographical differences in economic development – air passenger connectivity seems to be a much better predictor than mere population size. Furthermore, these interrelations are geographically specific in that they often depend on national/regional particulars.

When cast in the context of the literature on 'world cities', a relevant feature of this article is that neither London Metropolitan Area nor New York-Newark-Bridgeport CSA, the pinnacles of the world city network (Taylor 2004), have come up in our discussion (i.e. both metropolitan regions have small residuals). Put differently: our analysis suggests that, given their population, infrastructure, and the fact that these are the major metropolitan regions in the United States/United Kingdom, their level of GSI is not exceptional at all! In contrast, it is a metropolitan region such as Delaware Valley, centered on Philadelphia, which has a high level of GSI when considering some of its other characteristics. In this case, the positive deviation points to Delaware Valley's liberal "onshore offshore" status, which makes it an attractive site for regulatory arbitrage for global financial institutions (Houlder et al. 2011). Equally so, much of the service connections of Singapore Extended Metropolitan Region, Hong Kong, and Dubai-Sjarjah Metropolitan Region can be linked to their role as international financial/offshore centers. This observation clearly opens up the possibility of rethinking some of our assumptions on 'world city formation'. One possible way is to trace the discussion back to Sassen's global city thesis, in which she greatly stresses the *internal* dynamics of the global financial complex (i.e. global financial institutions and auxiliary

services such as accounting, auditing, and law), whose geographies are increasingly spatially detached from service sectors that feed into global production networks. As such, the analysis here performed also seems fit to detect processes of world city formation that are more closely linked to spatialities of regulatory arbitrage and broader dynamics of global financial markets than to the provision of a seamless service to the productive sector per se.

Our analysis has thus shed some new empirical light on the above-mentioned literatures, but at the same time it needs to be emphasized that this is merely a first and exploratory step. Arguably the weakest point of this article, and therefore also an obvious avenue for future research, is that in spite of the use of some of the best data on globalized urbanization and our subsequent transformations to arrive at coherent datasets, there is still much room for improvement. Some of these issues can be clarified by considering the positive residual of Pune, a major metropolitan region in West India. Its high residual is essentially explained by its modest airline connectivity, which is in turn an artifact of the relative proximity of Mumbai Metropolitan Area. Mumbai Metropolitan Area's international airport likely acts as main gateway for Pune passengers. As a consequence, in spite of our data transformations, there is clearly a degree of overlap and fuzziness when defining metropolitan regions, especially at the global scale: adding Pune to Mumbai's metropolitan region would have been justifiable, just as retaining both metropolitan regions as separate entities is. In general terms, this clearly reveals some of the continued practical problems when researching globalized urbanization in spite of the progress made since Short et al. (1996) and Taylor (1997).

In addition to refining and developing new datasets, a further avenue for future research lies in the interpretation of the residuals. There seems to be a fair degree of overlap that is hard to disentangle. For instance, Rome Metropolitan Area's negative residual is probably due to both tourism flows and the peculiar role of what is theoretically the 'second city' in Italy (Milan Metropolitan Area), but the model obviously does not allow distinguishing between both. Future research could provide 'interpretation keys' by including extra variables in the model, albeit that the well-known data problems re-emerge here.

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## NOTES

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1. Air transport infrastructure is obviously not the only relevant infrastructure network. However, in addition to Keeling's (1995) observations regarding the actual and perceived primacy of air transport in the infrastructural component of world cities, there is also research that has shown the network topologies of other infrastructure networks (that of the Internet's backbone in particular) to be very similar to those of airline networks (Devriendt et al. 2010; Tranos 2011).

2.  $\beta$ -coefficients are the model estimates resulting from an analysis carried out on variables that have been standardized so that their variances are 1. As a consequence,  $\beta$ -coefficients refer to how many standard deviations a dependent variable will change, per standard deviation increase in the independent variable.