Evolution of urban hierarchies under globalisation in Western and Eastern Europe

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European cities may be regarded as having formed a system of well-interconnected entities over many centuries. The peculiarities of their hierarchical functional organization and territorial patterns have been extensively analysed. This study details a few contributions from the science of complex systems meant to formalize this knowledge. This includes a representation of the metropolisation process occurring within a system of cities with the help of scaling laws and network analysis. We define the metropolisation process – not at the local level of one metropolitan area but at a macro-geographical level – as the ability of larger cities to capture the activities related to innovation waves and to be the first to benefit from these in terms of population growth. A series of urban attributes are used to quantify, through exponents of scaling laws the differentiated behaviour of urban hierarchies when opening up to the global networks that characterize the most recent wave of innovation. Network analysis provides another type of formalism that helps us construct a better understanding of how globalization processes, especially the spread of multinational firms, have diffused in the Eastern part of the European urban system.

Introduction

This study provides a new elaboration from a set of investigations about the evolution of European cities. We define a system of cities as a set of intensely connected cities whose evolutions became interdependent and they co-evolve through their connections within multiple networks (Pumain 1997, Peris et al. 2018). We do not propose an entire review of this question, which is already well-documented by statisticians, demographers, geographers, and historians from Western Europe (e.g. de Vries 1984, Hohenberg–Lees 1995, Hall–Pain 2006, ESPON 2010, Atkinson 2019) and specialists from Eastern Europe (Dziewoński 1953, Korcelli 1992, Musil 1977, Enyedi 1996, Gerőházi et al. 2011, Szirmai 2012, Máté et al. 2013, Páthy 2017). We have summarized earlier on how European cities could be considered as

having formed a system over many centuries due to the multiple networks that have developed between them (Kohl 1841, Cattan et al. 1994, Pumain–Saint-Julien 1996, Bretagnolle et al. 2000, Bretagnolle–Pumain 2010). This hypothesis has been revisited many times, emphasizing the diversity of urban spatial patterns (Rozenblat 1995, 2009), the diversity and complementarity of urban attributes and functional trajectories (Rozenblat–Cicille 2003), and the polycentric structure of the system (Rozenblat–Pumain 2018). We focus on the more recent transformations of the European system of cities linked via globalization, especially those that have occurred since Eastern Europe opened up to the market economy in 1990.

Most authors who analyse globalization processes focus on larger cities. Europe is one of the most developed regions of the world. It has been urbanised for a very long time. However, due to the ancient fragmentation of its territory in many states, it does not have very big cities when compared to large Asian countries twice as populous (China and India), or even to less populous countries like the United States, Brazil, or Japan. Therefore it seems opportune to ask how the effects of globalization spread across Europe's urban hierarchy, not only by studying a few large cities but also by considering the system of cities as a whole, including small and medium-sized cities. Based on the evolutionary theory of urban systems (Pumain 1997, 2018), our major hypothesis is that the globalisation trend can be analysed as an innovation wave that challenges cities' capacity for adaptation. This adaptive urban co-evolution usually reinforces the hierarchical inequalities within systems of cities, resulting in a metropolisation trend (Robson 1973, Pred 1977, Pumain–Moriconi-Ebrard 1997, Pumain et al. 2015).

This study first recalls the peculiarities of the hierarchical structure of the system of cities in Europe, including its geographical variations. Then we examine how the recent literature on scaling laws may help in detecting a metropolisation process in urban hierarchies and link them to the hierarchical diffusion of innovation in urban systems, leading us to observe a West–East divide in the metropolisation trend linked to the recent diffusion of global networks within the European urban system (Rozenblat–Melançon 2013, Rozenblat–Pumain 1993, 2007). Finally, we deepen the interpretation of this last trend by conducting a zoom analysis on how multinational networks selected cities in Central and Eastern Europe after 1990 (Zdanowska 2018). The conclusion is that path dependence effects are important in urban evolution and offer a powerful explanation of the persistency of hierarchical and geographical peculiarities within systems of cities.

Hierarchical and geographical structuration of the European system of cities

The urban transition that massively moved populations from rural to urban areas starting with the demographic transition and industrial revolution in Europe around the end of the 18th century (Zelinsky 1971) has spread throughout all parts of the

world. The economic, technical, and social constraints that are now exerted on urban development seem to prevail globally, in all cities (World Bank 2009). This trend towards globalising urban issues is being amplified through the requirements and concerns associated with climatic changes and the mitigating transitional policies aimed at renewable energies and, more broadly, at environmental protection. However, the spatial structures within and between cities are still dependent on the long history of settlement systems. Traces of ancient spatial organization still differentiate the European urban system from others in the world and, to a lesser extent, differentiate between Western and Eastern Europe (Bretagnolle et al. 2000, Rozenblat–Pumain 2018). This is a very good example of 'historical chaining' or 'path dependence' in complex systems. This dynamic feature is very important because it determines the solutions that can be adopted in order to help cities adapt to socio-economic and technological transformation (UN-Habitat 2016).

Europe is a continent of small and mid-sized towns

Europe is a region of small towns due to an old settlement system, in which cities have developed relatively continuously with modes of spatial interaction governed by slow speeds and thus under strong proximity constraints. European urban agglomerations larger than 10,000 inhabitants are spaced an average of 15 km apart. As a result, almost half of Europe's population lives in agglomerations of fewer than 500,000 inhabitants, which makes Europe markedly different from the other continents (see Table 1). Conversely, the share of the population living in cities larger than 5 million inhabitants is rather small, lower than 5%, whereas this figure ranges from 10% to 15% in parts of the world with similar high rates of urbanization – in other words, where at least three quarter of the population is urban; this proportion will probably be reached quickly in the next two or three decades by countries in Asia and Africa that are undergoing accelerated urbanization.

Table 1

Distribution of total population in size classes of cities*

(%)

Size of cities	< 500 000	500 000–5 million	> 5 millions	Rural population	Total
Latin America	36	22	15	27	100
North America	30	35	12	23	100
Europe	47	22	4	27	100
Asia	20	14	7	59	100
Africa	23	11	3	63	100

* Cities considered urban agglomerations.
Source: United Nations (2014).

As a consequence, Europe has only two megacities (cities larger than 10 million inhabitants), Paris and London, and the continent does not need to manage gigantic human concentrations such as those that have developed in the megalopolises of Northeast America between Boston and Washington, or in Japan from Tokyo to Osaka, or those developing within the large Chinese deltas, each grouping now containing from 40 to more than 100 million inhabitants. Moreover, Asia is generating unprecedented mixes and nesting of urban habitats and manufacturing activities with rural ones, generating a specific pattern between cities and the countryside termed 'desakota' by McGee (2009). Such desakota forms are hardly found in the peri-urban areas of major European agglomerations.

A continent of moderately dense cities yet highly structured in systems of cities

Europe is different from the other continents not only in the distribution of its cities but also in its average urban densities. Europe's average urban density levels are intermediate between the extreme dilution of North American cities and the high concentrations of Asian cities. Urban planner Alain Bertaud (2004) has calculated average densities for about 50 millionaire cities in the world by dividing their populations by the built-up surfaces measured on satellite images (these measurements thus define 'urban morphological agglomerations'). The order of magnitude of these average densities is about 2,000 inhabitants per km^2 for North American cities, 10,000 to 40,000 for Asian cities, and 4,000 for European cities.

The built-up space of cities is organized with a more or less regular reduction in the intensity of land use from their centre to their periphery. This is due to the high social value of their centres, which are places of maximum accessibility and high identity prestige for businesses and residents. This form of 'urban field' is observed everywhere in the world but with large variations in intensity: Centre–periphery contrasts are accentuated in Asia and very weak in North America, while European cities are in an intermediate position. Strong urban density gradients in Europe often correspond to radio-concentric organizational plans, drawn by the access routes to attractive centres in several directions, combined with ring roads installed on ancient fortifications that were periodically enlarged.

This long-recognized form of spatial organization (Bleicher 1892, Clark 1951) has recently been formalised in terms of fractality (Batty–Longley 1994, Frankhauser 1994). The use of CORINE Land Cover images has made it possible to highlight the wide generality of a European model for the organization of built-up areas around urban agglomerations (Guérois 2003). While population densities, and especially urban land prices, draw out forms of centre–periphery decay modelled by negative power laws or exponential functions, the intensity of physical land occupation is distributed according to a double-linear gradient as a function of distance to the city centre. Built-up areas decrease regularly, not only in the densest parts built

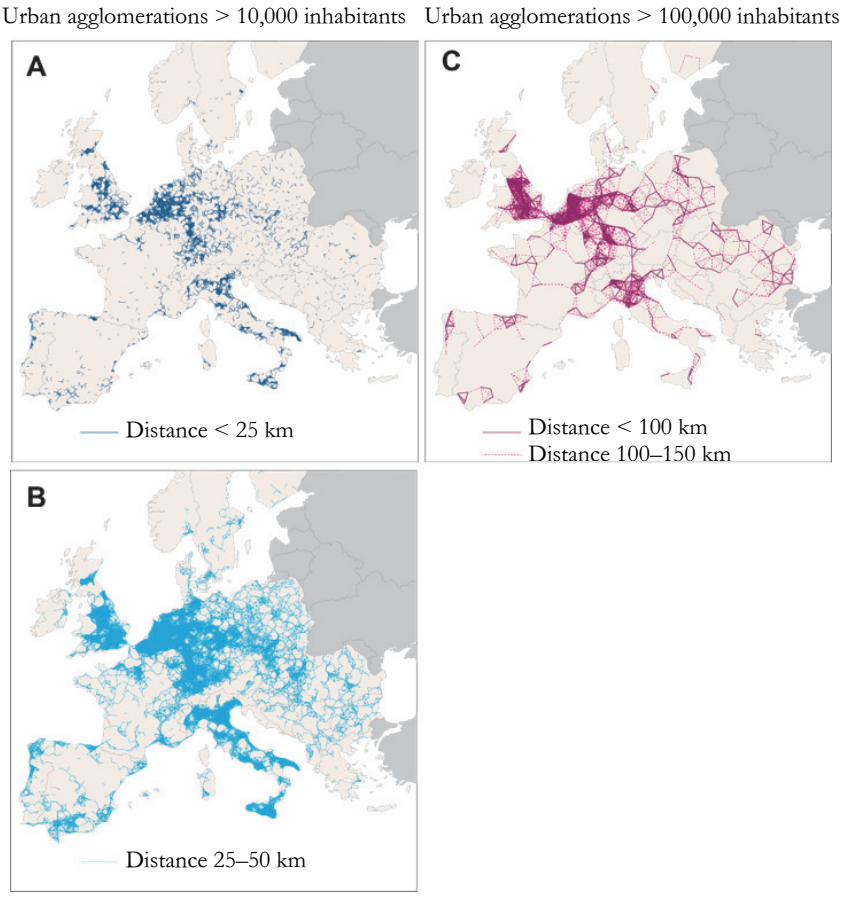
in continuity within the core of the agglomerations but also, according to a lower gradient, in peri-urban areas located in radii of 40 to 100 km depending on the size. Fractal measurements reveal dimensions with values between 1 and 2 for the central zones of built-up urban areas, while the peripheries of large urban areas often have fractal dimensions of between 0 and 1, according to scattered forms similar to the mathematical model of Cantor dust (Guérois–Pumain 2008).
Does the dual urban building gradient observed from the CORINE Land Cover data foreshadow the emergence of a new urbanization model on the outskirts of cities, or rather the gradual incorporation of these peripheries into the urbanized perimeter? The recent evolution of these gradients would seem to support the second hypothesis: Whatever the size of cities, the highest growth rates of built-up areas are observed at the boundaries of urban agglomerations. In Europe, urban sprawl occurs on the periphery of the zones already built in continuity more often than it colonizes more distant peripheries (Guérois–Pumain 2008, Denis 2020).

Regional variations of urban hierarchies

European cities exhibit comparable spatial structures at the local level, but there are internal variations in the statistical shape and spatial distribution of urban hierarchies that differentiate among three large urban settlement styles from the West to the East. Figure 1 presents a simple but striking image of both the persistence of the spatial organization of the systems of cities and of the coherence of these forms across scales of geographical space. Céline Rozenblat (1995) has linked European cities larger than 10,000 inhabitants (classified according to a harmonized definition of morphological agglomerations) using segments of varying lengths: less than 25 km on the first map (see Figure 1A), from 25 km to 50 km (see Figure 1B), and between 150 km and 200 km for cities 10 times larger (more than 100,000 inhabitants; see Figure 1C). The spectacular result shows the same large territorial areas on each of the maps: to the West, France and Spain, whose territories where centralized long ago in large kingdoms, exhibit a few high urban concentrations and highly contrasting spatial distributions; in the centre, a dense wrap of closer cities characterizes the states (Germany and Italy) whose lack of national unity, which occurred much later, allowed rival cities and the capitals of principalities or bishoprics to develop in competition over a long period (England, although centralized early on, belongs to this diagonal because of the intensity of its industrial revolution, which, in the 19th century, filled the urban void in the centre of the country by creating fairly large cities); Eastern cities are spaced much more evenly, as these regions were urbanized later but were systematically colonized between the 13th and 17th centuries, mostly by religious organisations. This simple representation is testimony to the strength and durability of the spatial integration of the socio-political structures established in urban interactions and the solid coherence of the resulting multiscalar spatial organizations.

Figure 1

Three settlement styles of urban hierarchies in Europe



Source: GEOPOLIS, F. Moriconi-Ebrard (1993).

Trends in the recent urban expansion

We use a restricted concept of *metropolisation* to describe a fundamental trend in the evolution of every system of cities (Pumain–Moriconi-Ebrard 1997). That systematic trend consists in growing contrasts among city sizes over time that lead to sharper inequalities in urban hierarchies. This trend is theoretically explained by two major processes: i) the hierarchical diffusion of innovations and ii) the space–time contraction (Janelle 1969). The first process leads to a concentration 'from the top' of the hierarchy because the largest cities capture the strongest economic and often demographic growth associated with the first stages of development of new products and services. The second process induces a 'bottom–up simplification' of urban hierarchies because, statistically, smaller cities are penalized in their growth, first in relative

terms and then in absolute terms, because their catchment areas are bypassed by the expanding range of larger cities linked to faster and more efficient transportation modes (Bretagnolle et al. 1998). This 'simplification from below' of urban hierarchies becomes even more visible when urban growth slows down. Inequalities in size and functional skills widen between cities, leading to new concerns for the fate of small towns, as well as those left behind due to their more or less 'obsolete' specialized activities. Statistically, this devitalization begins in small towns. Support for shrinking cities is beginning to be the subject of remediation policies in Europe (Martinez-Fernandez et al. 2012).

The expansion of European cities continues according to two contradictory processes that depend on the *geographical scale* of observation. At the national level, the movement of metropolisation produces a relative concentration of the innovative social and productive forms in the largest cities. At the local level, the trend towards urban de-concentration and sprawl has been dominant for at least several decades. This process has a long history, starting early in the largest cities for urbanistic purposes or hygiene reasons (e.g. as early as the end of the 18th century in certain Parisian districts), but has considerably accelerated because of the multiplication of motorized transportation, which allows arbitration in favour of lengthening access distances to the jobs and central services of urbanized areas at the cost of maintaining travel times.

The two contradictory spatial trends in the evolution of cities (metropolisation nationally and urban sprawl locally) must be reconsidered after demographic and urban transitions have been completed. Both transitions have been occurring in developed countries, especially Europe and Japan, since the 19th century; they began around 1950 in the developing countries, currently undergoing rapid urbanization. One may wonder if, when urban transition is complete, the metropolisation trend will continue or if a stabilization or even a reversal of that trend is possible. The technical instruments available due to recent developments in studies of urban scaling laws can help us measure more precisely the components of the metropolisation effects according to how urban attributes are changing across the urban hierarchies.

Scaling laws for measuring metropolisation effects and the European West–East divide

Scaling laws have been the subject of many studies. Physicists have successfully used this formalism to characterize the metabolism of living species (West et al. 1997). More recently, it has been applied to cities (Bettencourt–West 2010, West 2017). A recent special issue of *Environment and Planning B* (Rybski et al. 2019) offers many examples of applications to urban analysis. We summarize here the results of an experiment conducted on European cities, which develops a theoretical interpretation adapted to objects that, while subject to evolutionary processes, are not biological but social and historical.

An evolutionary interpretation of scaling laws

Scaling laws describe systematic relationships whose mathematical models are power functions between the size of entities and some of their functional attributes, what biologist d'Arcy Thompson calls 'allometry' (1952). According to physicists, scaling laws reveal physical constraints on the structure and evolution of complex systems. Biologists have identified systematic sub-linear relationships between species' metabolisms and their size, which reveals economies of scale in the construction of biological organisms during their evolution. They were able to explain this in terms of the spatial distribution of energy within organisms through fractal networks (West et al. 1997).

Applied to cities, scaling laws describe the variation of an attribute according to the size of cities, generally measured by their number of inhabitants (Lane et al. 2009). Physicists were surprised to discover that some exponents could be larger than 1, especially when considering attributes measuring urban productive outputs or concentrations of income and skills. Thus, instead of always considering economies of scale (which can be observed, for example, in urban technical networks), urban scaling laws are able to consider increasing returns to scale, when large cities have developed an attribute to a greater extent than small ones. This growing concentration of attributes along with city size, testifying to metropolisation, has been well known in urban science at least since the first formulations of central place theory to explain the increase in the number, status, and diversity of urban functions along with city size (Reynaud 1841, Christaller 1933, Robic 1982). Physicists translate this into a universal interpretation: '*cities are approximately scaled versions of one another*' (Bettencourt–West 2010). They suggest an explanation in terms of an '*increasing pace of life*' as city size increases. Moreover, they infer a longitudinal relationship from transversal data when claiming that '*on average, as city size increases, per capita socio-economic quantities such as wages, GDP, number of patents produced and number of educational and research institutions all increase by approximately 15% more than the expected linear growth*'. Such extrapolations are contested because ergodicity is not a property of urban dynamics, which is a historical process (Pumain 2012), and because there are no universal values for the empirically observed relationships, which are highly dependent on urban ontologies and measurement contexts and methods (Arcaute et al. 2015).

Explanations that may serve as alternatives to "physical" interpretations of urban scaling laws are related to former urban theories more strongly when they are linked to the processes of urban growth, inter-urban interactions and the spatial diffusion of innovations throughout systems of cities (Pumain et al. 2006). The theory of hierarchical diffusion of innovation (Hägerstrand 1952, Pred 1973, 1977) explains how new activities and social practices are captured first by large cities with the information level, financial support, productive structures, and employment skills required to adopt them at an early stage of development. Although these innovations

tend to percolate down the urban hierarchies, they provide slightly higher benefits in terms of economic returns and social capabilities to the cities that took initial advantage of the adaptation, supporting the historical metropolisation trend that reinforces urban hierarchies. This process was recently accentuated by the acceleration of globalisation, as revealed by experiments on the distribution of economic activities in cities using scaling laws (Paulus 2004, Pumain et al. 2006, Finance 2016). Indeed, the exponents of urban scaling laws vary over time according to the novelty's stage of diffusion in the system of cities: at the beginning of a new innovation wave, exponents increase to above 1 until a maximum is reached; then they stabilize at around 1 when the new activity or social practice becomes common; then they diminish to below 1 when mature activities or residual practices are found in the smallest towns. Thus, we decided that scaling law exponents could be used as reasonable proxies to detect the stage of diffusion of an innovation within a system of cities.

Dual process of innovation diffusion: the West–East divide of Europe

Previous studies of innovation diffusion in systems of cities have demonstrated that the process differs according to the type of urban hierarchy involved. Sophie Baudet-Michel (2001) observed how business services have percolated in three different systems of cities since the end of the 19th century. She demonstrated that in the first stage the concentration of the activity was higher in systems with a primate city, like France and the UK, whereas eight German metropolises had captured a significant amount of the novelty. In the second stage, the spatial expansion proceeding down the urban hierarchy was much broader in the French than in the German system of cities. Thus, hierarchical diffusion is not an even process according to city size but an adaptation of the whole system of cities that retains the originality of its structural features.

We assume that a variety of globalisation processes integrating European cities in multiple networks can be analysed as an 'innovation wave' that diffuses hierarchically in urban systems. Thus, we decided to analyse which stage had reached the diffusion of globalisation in the European system of cities as a whole and in its parts using scaling laws to provide a measurement of the intensity of metropolisation for a series of urban attributes. Regarding the globalisation process and its effects on European cities, we gathered a number of attributes that were comparable and available around 2010 for as many cities as possible and that many scholars argue indicate their possible or realized participation in global networks. These attributes were indicators of productive capacity, accessibility, attractiveness, centrality in investment networks and centrality in European research space, cultural influence, and access to European institutions. We shall not list again the 25 indicators measured for the 356 largest functional urban areas (in the European Union plus Switzerland and Norway), which are detailed at length in a recent publication (Pumain–

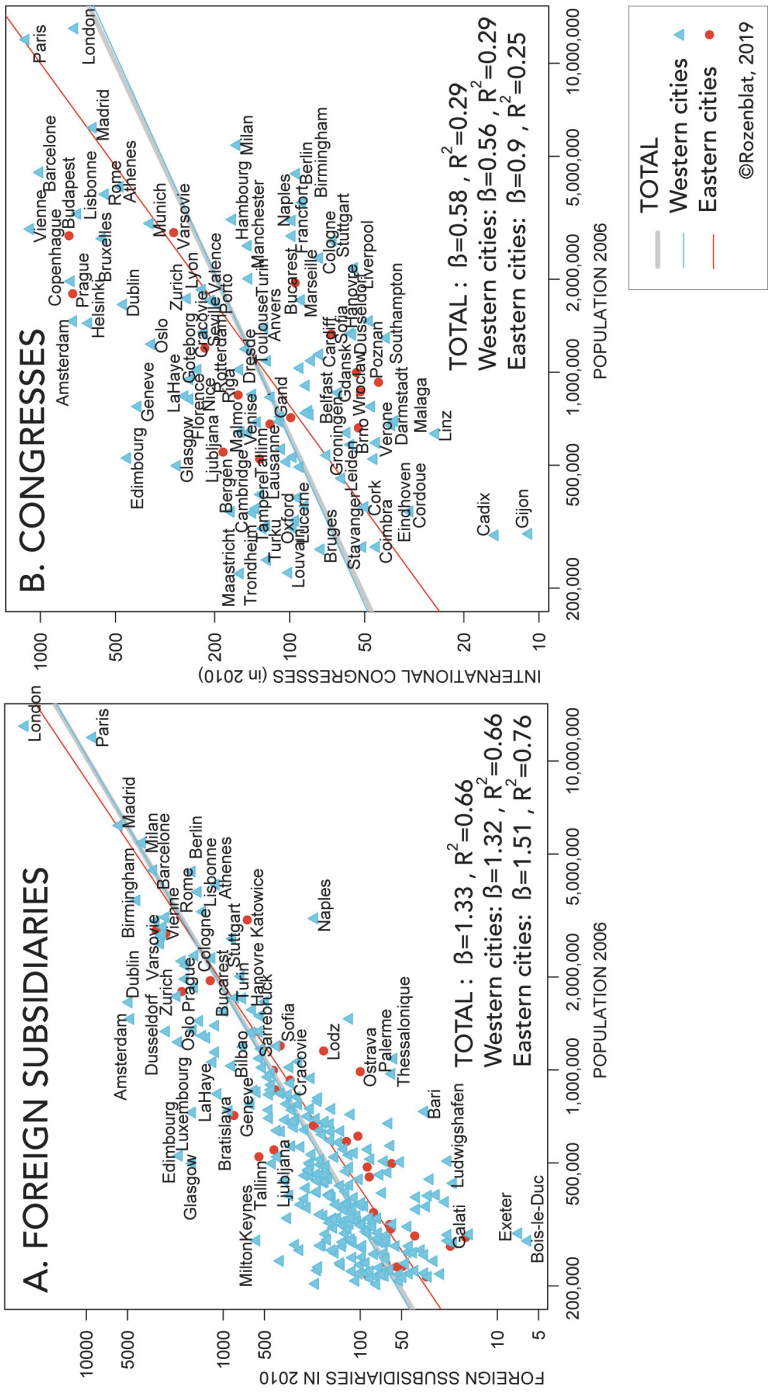
Rozenblat 2019). We provide an illustration of how scaling parameters are estimated in Figure 2 for two among these 25 variables. These two are opposite examples of the different types of qualitative scaling relationships.

The distribution of foreign subsidiaries among European cities is clearly the result of a hierarchical diffusion process at its initial stage: the exponent of 1.33 marks an overconcentration of this connection to the networks of multinational firms that favour the largest cities of the system in the first stage. Conversely, the number of international congresses scales sub-linearly with city sizes with an exponent of 0.58, indicating a relative overconcentration in smaller towns. This may partly reflect the location of many universities and research centres in smaller towns such as Oxford, Cambridge, Bergen, Lund, Turku, and Heidelberg. Congress activity is also sustained by international networks that may search for locations that are not as prestigious and expensive due to their economic power and that offer other amenities for hosting meetings, such as environmental resources or heritage landmarks.

Our study including the 25 indicators of metropolisation has confirmed the intensity of the penetration of global networks throughout the European urban system (Pumain–Rozenblat 2019). Most of these variables scale super-linearly with city size when adjusted as a power function of the population. This form of super-linear relationship demonstrates the greater ability of the largest cities to capture innovation benefits. In the second step, this study revealed two different stages of metropolisation due to the recent globalisation according to the location of cities in Western and Eastern Europe. While the hierarchical diffusion is almost complete in Western Europe and is reaching many medium-sized cities, the diffusion of global networks is clearly in an earlier stage in Eastern Europe and it is still concentrated in the largest cities, as attested by the much larger scaling exponent values for this region of the system. Thus, the scaling laws reveal a major difference between the Western and Eastern European hierarchical diffusion via globalization that has not been detected before (Pumain–Rozenblat 2019). We now investigate more deeply the evolution process among the Eastern cities.

Figure 2

Scaling relationships for two attributes measured on European cities



Differentiation within Central and Eastern Europe

We now focus on the Eastern part of the European Union, where metropolisation and globalisation have been delayed, first due to the more equalitarian urban policies during the socialist period and to their later opening to the market economy. The term 'Central and Eastern Europe', or CEE,[1] will be used to distinguish the region from Eastern Europe, which sometimes includes Belarus, Ukraine, and Russia in the literature.

Internal West–East gradient in the recent growth impulses probably given by adaptation to globalisation

To complete the vision of a purely hierarchical diffusion process that could be suggested by the high scaling exponents of the globalisation indicators in Eastern Europe, this sub-section tests the hypothesis of a possible uneven development of cities according to their location. These trends have been observed in the literature (Di Lello–Rozenblat 2014, Zdanowska 2015, 2016), but generally at regional level or for particular CEE countries (Lengyel–Szakálné Kanó 2012, Csete–Szabó 2014, Rechnitzer et al. 2019). Our hypothesis is that CEE cities' participation in globalisation has been enhanced or facilitated by their proximity to other European Union countries.

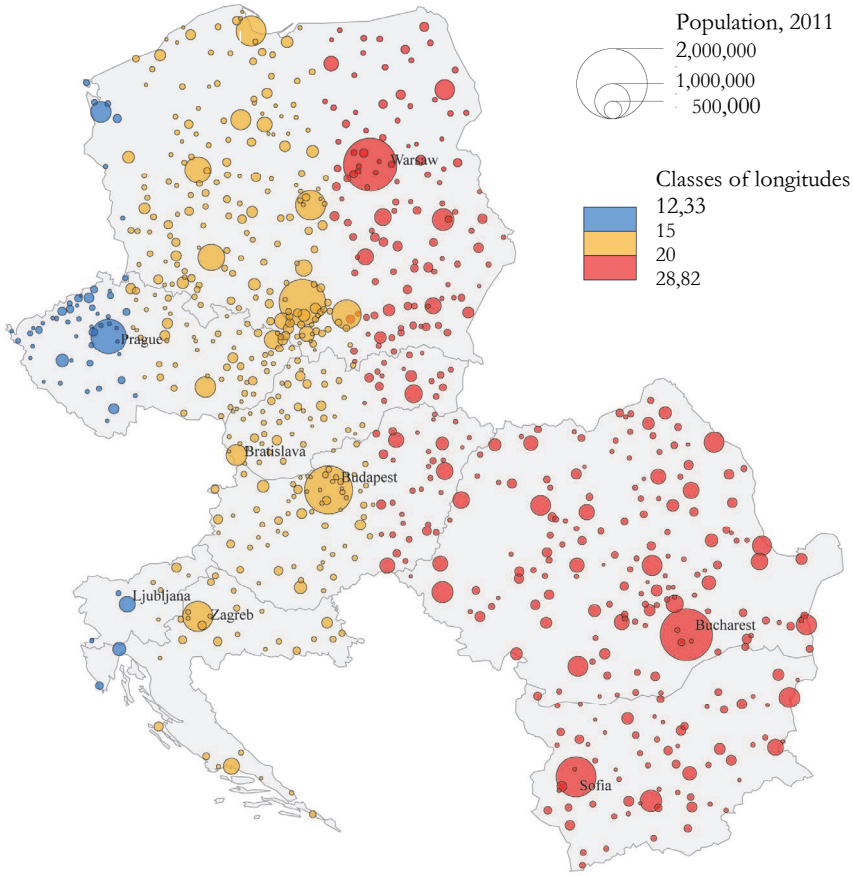
We have estimated this proximity by computing for each city its closest distance in km to their border with Germany, Austria, or Italy.[2] All CEE cities were then classified into three classes of geographical longitudes denominated 'Western', 'Central', and 'Eastern' facades. The average distances of cities to the German, Austrian, and Italian borders in each class are 33 km, 157 km, and 537 km respectively (see Figure 3). If our hypothesis is correct, we should observe higher urban growth in the Western class than in the Central and Eastern ones.

[1] Understood as the eight post-communist countries that are members of the European Union (Bulgaria, Croatia, the Czech Republic, Hungary, Poland, Romania, Slovakia, and Slovenia).

[2] In technical terms, in ArcMap software, this corresponds to the shortest distance from a point to a borderline, here defined as the shape of the CEE border with Germany, Austria, and Italy.

Figure 3

CEE cities' division into three zones of longitude according to their distance from the German, Austrian, or Italian borders



Source: TRADEVE database, Guérois et al. (2019).

We find that, until 1991, the cities located farthest away from the German, Austrian, and Italian borders had the highest growth rates (see Table 2). This situation can be explained by the former wave of the demographic transition – changes in cultural and familial behaviour whose spatial diffusion was roughly oriented from the west to the east. After 1991 and its major political changes, these Eastern cities exhibit the most negative growth rates relative to the Western facade. This reversed growth trajectory clearly underlines the extent to which the opening of CEE cities to the market economy and globalisation has created a West–East oriented gradient of urban growth, according to the growth-recovery logics (see Table 2). The political change instituted a complete reversal in the demographic

behaviour of Western and Eastern cities of the CEE region. This innovation wave may also have deepened the pre-existing contrast between Western regions, which followed the general post-war demographic transition trend early on, and Eastern socialist countries, where this trend has been delayed.

Table 2

Average annual growth rates of cities' population in Central-Eastern Europe per 10 year periods from 1971 to 2011 according to their distance to the border with Germany, Austria, and Italy*

(%)

Classes	1971–1981	1981–1991	1991–2001	2001–2011
1. 'Western' facade	1.57	0.71	0.02	0.05
2. 'Central' façade	1.82	0.99	–0.01	0.12
3. 'East' façade	2.19	1.26	–0.23	–0.11

* The first, second, and third classes correspond to an average distance of 33 km, 157 km, and 537 km to the nearest border. Thus, class 1 includes the most western cities of Central-Eastern Europe and class 3 the most eastern ones.

Source: Zdanowska (2018).

By contrast, the Czech, Slovak, and Slovenian Class 1 cities nearest to the German, Austrian and Italian borders had lower average growth rates up to 1991. These cities went through the 1990s without experiencing negative growth rates, unlike the cities of classes 2 and 3. The respective rates of the cities of the Eastern facade remained negative until 2011. This confirms the hypothesis of a West–East division of this space in terms of demographic behaviour. The demographic trends of the cities of the Western facade are similar to those of the old settlement systems in Western Europe, characterized by the end of the urban transition, while the cities of the East facade are still pursuing catch-up logics.

The 2000s are marked by the recovery of slightly positive growth rates relative to the previous decade, especially in the Western and Central façades. Some cities, such as Prague, Ljubljana, Varna, and many small and medium-sized cities in Poland were even growing during that period (Zdanowska 2018, Guérois et al. 2019). It seems that they have been able to absorb the external shocks suffered during the 1990s consisting of demographic displacements, intensive forced migrations to the West (Korcelli 1992, Drbohlav 2003, Kaczmarczyk–Okólski 2005), loss of fertility, population ageing, and high unemployment rates (Kovács 2004). We hypothesise that these cities have experienced new metropolitan opportunities and have increased their exchanges with other cities. Several cities that suffered from declining manufacturing sectors in the 1990s (Kiss 2004) have developed a metropolitan potential in the 2000s and are pursuing innovative activities, as in the military and air transport sectors in Rzeszów, Poland (Noworól et al. 2010).

It would seem, therefore, that the degree of urban development among cities in Central and Eastern Europe is related to their geographical proximity to more

economically developed areas such as Germany, Austria, and Italy. There is no correlation between the size of CEE cities and their growth rates, whatever the period, whereas a correlation is found in France (Paulus–Pumain 2000, Paulus 2004) and Russia (Cottineau 2014; see Table 3).

Table 3

Correlations between growth rate and city size for every 10-year period since 1961 for all cities of the CEE region

Year-period	Correlation coefficient	R^2
1961–1971	–0.035	0.0012
1971–1981	–0.059	0.0035
1981–1991	–0.067	0.0045
1991–2001	–0.057	0.0033
2001–2011	–0.019	0.0004

Source: Zdanowska (2018).

This result confirms our hypothesis that the resistance to political and economic upheavals is related to proximity to economically more developed cities, which constitute a source of economic exchange opportunities that stimulates growth, as well as the processes of metropolisation.

Economic interactions between the present and the past

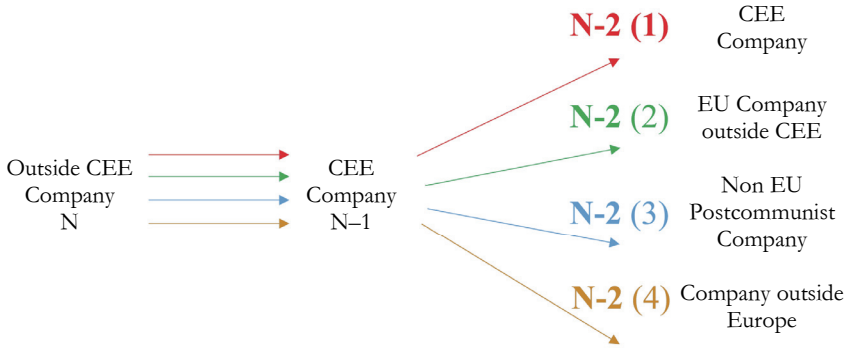
Along the same line of investigation, we checked if the population size of the CEE cities is a key factor in their position within the networks of multinational firms[3] that are driving the effects of globalisation.

First, a decomposition of the financial ownership linkages led to the identification of capital control chains at three levels, according to the following scheme (see Figure 4). A foreign firm (level N) controls the capital of a firm in a CEE city (level N-1). The latter firm owns the capital of another firm (N-2 level). The three-level subnetwork of multinational firms and their ownership links in CEE cities contains 2,312 firms and 1,562 ownership linkages.

[3] The ownership links of firms in 2013 at the city level are sourced from the BvD *ORBIS* database listing all the companies located outside the CEE that own the capital of CEE companies in all sectors. Information on CEE companies that control the capital of other CEE firms and those outside the CEE is also available.

Figure 4

Decomposition of the capital control links of CEE companies into several levels



Capital control of more than 50%

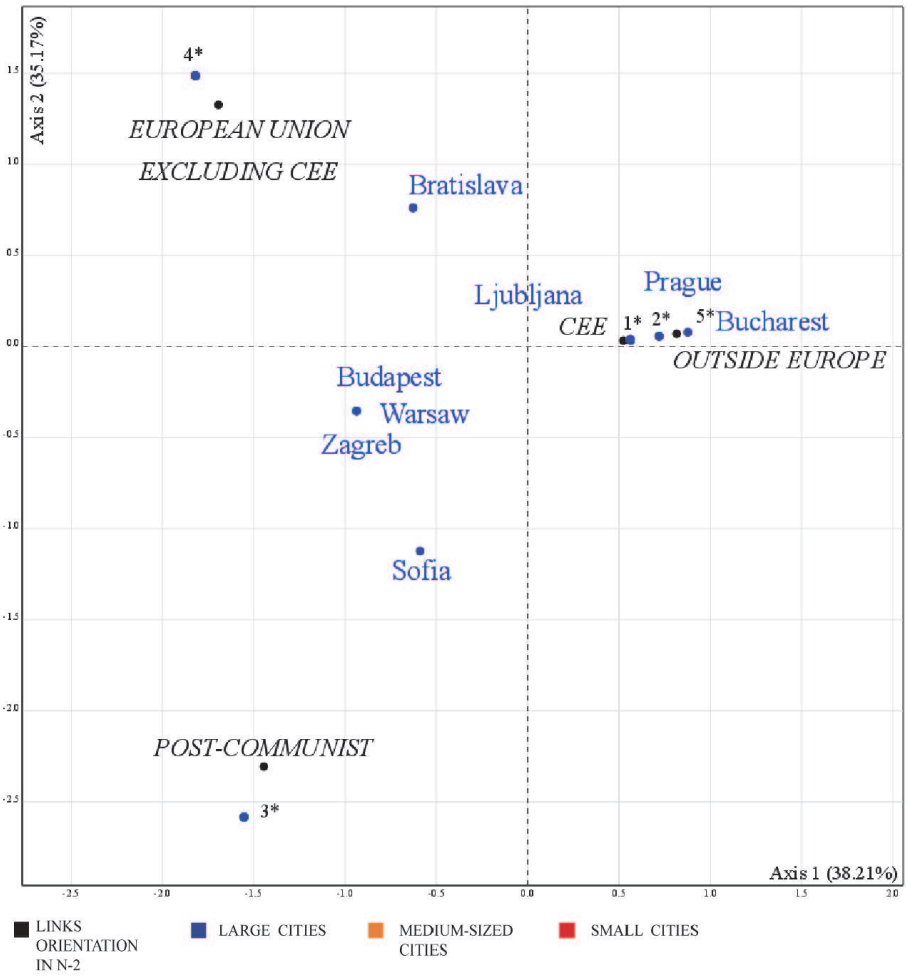
Source: Zdanowska (2018).

Then, a correspondence factor analysis was carried out on a matrix of data, counting the number of times a CEE city in N-1 is involved in the four different orientations of capital control links in N-2: in a city from another CEE country (1), in the European Union outside CEE (2), in the post-communist space outside the European Union (3), and outside Europe (4; see Figures 4 and 5).

Figure 5 displays the major geographical orientation of linkages between firms and their subsidiaries for all CEE cities. Some cities display limited participation in globalisation because their firms own links with other CEE cities only – such as Banska Bystrica, Bolatice, Bralin, Breclav or Cesky Tesin (class 1* in Figure 5) – or post-communist ones, such as Belisce, Koper, or Cracow (class 3* in Figure 5). These are mainly small or medium size cities. Conversely, large cities, such as Budapest, Zagreb, and Warsaw have links with European Union areas outside the CEE, CEE areas, and post-communist areas (see Figure 5). This is not the case for all capitals, however. For example, Ljubljana is positioned at links with other CEE cities, and Sofia is present only in post-communist and CEE configurations (see Figure 5). Bucharest is characterised essentially by non-European implications, which can be explained by its geographical position on the outskirts of the European Union.

Figure 5

Major implication of the CEE cities in N-1 according to the four types of orientation of the multilevel links in N-2



1* Large cities: Brno, Katowice, Lublin; medium-sized cities: Bourgas, Częstochowa, Legnica, Nitra, Plzen, Rijeka, Split, Usti nad Labem; small cities: Banska Bystrica, Bolatice, Breclav, Cesky Tesin, Cherven Bryag, Debrecen, Decin, Galanta, Gbely, Gheorgheni, Hodonin, Hradec Kralove, Hranice, Jablonec nad Nisou, Jászfényszaru, Jihlava, Kamenice, Karlovy Vary, Lazuri, Lesce, Letohrad, Logatec, Medvode, Mochov, Modrice, Mogosoaia, Nyíregyháza, Ostrava, Petrvald, Piestany, Połkowice, Poznań, Ptuj, Puchov, Rokietnica, Roznava, Skawina, Stefanestii de Jos, Stefanovo, Stupava, Szczecin, Tirgu Mures, Trnava, Turna nad Budvou, Vrable Wolica, Zatec, Zlin.

2* Large city: Łódź.

3* Large city: Cracow; small cities: Belisce, Koper, Liberec, Skofja Vas.

4* Large city: Wrocław; medium-sized city: Rzeszów; small cities: Kęzierzyn Koźle, Krusovice, Majosháza, Medias, Pilisszentiván, Rohoznik, Sumperk, Tarnów, Velenje.

5* Medium-sized city: Świebodzin.

Source: Zdanowska (2018), IGD–UNIL–BvD ORBIS (2013).

Small towns (of 10,000 to 50,000 inhabitants) develop most of their linkages with post-communist, Central Eastern, and European Union areas. Most medium-sized cities (of 50,000 to 250,000 inhabitants) have CEE orientations (see Table 4). This demonstrates that large cities (above 250,000 inhabitants) are not the only ones attracting capital links from abroad: small and medium-sized cities, often thought to be left behind by globalisation (Escach–Vaudor 2014), are also present in these international networks.

Table 4

Implication of small, medium, and large CEE cities according to the orientation of their firm linkages (expressed as a percentage of total localized linkages)

From cities:	Towards cities localized in:			
	EU[a)]	CEE	POST-COM[b)]	OE[c)]
Small	47	56	50	14
Medium-sized	24	29	10	0
Large	29	15	40	86
Total	100	100	100	100

a) European Union outside CEE. b) Post-communist. c) Outside Europe.
Source: Zdanowska (2018), IGD–UNIL–BvD ORBIS (2013).

Finally, we computed the betweenness centrality for cities in N-1 (= number of shortest paths passing through a node; Albert–Barabasi [2002]). This determines the number of times that a CEE city in N-1 is a crossing point relaying capital control links towards N-2. The higher this centrality is for a node, the greater its importance in terms of passage and its role as a gateway between chain levels. We then checked if population size is a decisive variable in the relaying of capital control links towards the four orientations of the links in N-2 (see Table 5).

Table 5

Characteristics of cities in N-1, according to the different orientations of links in N-2

	Among links oriented in N-2 towards cities located in:			
R^2 in N-1 between	EU	CEE	POST-COM	OE
POP & BETWEENNESS	0.75	0.41	0.15	0.24

Source: Zdanowska (2018), IGD–UNIL–BvD ORBIS (2013).

Regarding the links oriented toward the European Union outside CEE countries in N-2, the relationship between population and betweenness centrality is statistically significant (R^2=0.75). However, this relationship is much less significant for the Central Eastern and non-European orientations (0.41 and 0.24), and not at all significant for post-communist areas (R^2=0.15; see Table 5).

It can be inferred that the role of small and medium-sized cities is important in all orientations, except those towards the rest of the European Union, which shows

the importance of considering these links and including small and medium-sized cities in globalised networks.

Conclusion

The confrontation of several complex system processes leads to a deeper understanding of current trends within the Central and Eastern European system of cities. Between integration and diffusion the urban system faces both rapid changes and path-dependent forces.

Despite lacking very large cities, the CEE urban system is hierarchized by international functions more strongly than is the Western European urban system, with a growing concentration of metropolitan functions according to city size. Metropolisation forces are strong because they are in an earlier stage of global integration than Western cities are. However, aside from the size effect, the participation of Eastern cities in globalisation networks also depends on their distance to Western borders. In addition, historical specialisations confer to some small and medium-sized cities a more important role than would be expected in the network of multinational firms, which confirms the necessity of considering small and medium-sized cities in globalised network analysis. The capital investments generated from multinational firms between the largest cities and small and medium-sized cities inside the CEE are key factors of integration via globalisation. This stepwise integration is strongly influenced by the remaining historical linkages between CEE and post-communist cities, and much less intensively to other countries outside Europe. It is taking a long time for the CEE urban system to recompose inside the capitalist system, and the emerging complexity is largely based on long-term spatial, cultural, and political proximities, including the great importance of Western Europe through EU integration. This ongoing process of EU integration amid the general globalisation trend in the CEE urban economies demonstrates how changes can occur relatively quickly, over a period of 30 years through intense policies undertaken by the EU commission. A wide gap still separates Western and Eastern cities' development regarding metropolisation processes. This gap is due to the time lag in the urban system's adaptive cycle and from structural differences (i.e. the path-dependence of the dynamics), which will probably ensure the continued distinct development of the CEE's urban system. The relaunch of European cohesion policies in the new program after 2020 has taken this issue into account and will probably reduce the gap and enhance integration.

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Density-dependent population growth in Southern Europe (1961–2011): A non-parametric approach using smoothing splines

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A wealth of social, economic, historical, political, institutional, and cultural factors have been shown to affect the spatial distribution of resident populations, long-term settlement patterns, and demographic structures on the European continent. However, density-dependent mechanisms regulating population growth remain important drivers of socio-demographic dynamics at both the local and regional levels. In Southern Europe, a paradigmatic region with quite homogeneous population dynamics and urban structures, high within-country variability in the spatial distribution of the resident population and across-country differences in population density outline the distinctive demographic patterns at a regional level. A comparative analysis of the spatial distribution of the resident populations of three representative countries of Southern Europe (Spain, Italy, and Greece) contributes to identifying latent trends and density-dependent mechanisms of population growth over a relatively long time period (1961–2011) at the geographic level of local administrative units (LAUs). An explicit analysis of density-dependent spatial patterns of population growth permits a refined comprehension of socioeconomic mechanisms underlying demographic divides. The annual rate of population increase (or decrease) was non-linearly correlated with population density, highlighting the positive (or negative) impact of density variation on demographic growth when the population is sparse (or concentrated). An improved understanding of the density-dependent mechanisms of population growth contributes to a reconsideration of urban strategies and socio-demographic policies relating to heterogeneous regional contexts.

Keywords:
demographic trends, density-growth curve, municipalities, indicators, Southern Europe

Introduction

Demographic dynamics, local development, and socioeconomic divides are intimately interconnected issues (Antunez et al. 2017) and worthy of more investigation over sufficiently long time intervals that cover representative contexts at detailed enough spatial levels (Salvati–Gargiulo Morelli 2014). While providing information regarding local development trends, comparative analyses of such trends are relatively scarce for advanced economies and especially so for Europe (Kasanko et al. 2006, Kincses et al. 2014, Oueslati et al. 2015, Salvati–Carlucci 2016). Comparing local-level demographic trends across a continent such as Europe – where individual countries exhibit distinctive characteristics that derive from their intrinsic socioeconomic structure, history, and political/cultural background – is particularly interesting when analysing the latent mechanisms of urban growth (Salvati–Carlucci 2011, Zitti et al. 2015, Varga et al. 2016, Zambon et al. 2017). In this regard, multiple socioeconomic drivers have been shown to influence metropolitan expansion in Europe, including (i) globalisation, (ii) structural change from industry to advanced services, and (iii) accelerating demographic dynamics that are progressively less affected by the natural growth of the population and increasingly influenced by international migration (Haughton 1999, Moos–Mendez 2015, Tóth–Nagy 2017).

With regards to this, a wealth of factors have been demonstrated to shape the spatial distribution of resident populations, long-term settlement patterns, and demographic structures on the European continent (e.g. Duvernoy et al. 2018). However, density-dependent mechanisms regulating population growth remain important drivers of demographic dynamics at both the local and regional levels (Morelli et al. 2014). Local-level population density and the related demographic trends are probably some of the most pertinent variables, for which refined investigation may advance knowledge of the recent evolutions of European cities and regions (Gavalas et al. 2014). Empirical analysis in this field of research may reveal complex socioeconomic transformations and give more precise information on the density-dependent mechanisms of population growth, leading to distinctive models of urban growth and metropolitan expansion (Schneider–Woodcock 2008, Solon 2009, Zambon et al. 2018). A complex urban cycle was observed in Europe in the aftermath of World War II (Salvati 2014). While compact urbanisation driven by internal migration was associated with settlement concentration and high population density, dispersed urbanisation in more recent times stimulated residential mobility to suburban areas (Antrop 2004, Di Feliciantonio–Salvati 2015, De Rosa–Salvati 2016). Suburbanisation influenced metropolitan structures and socioeconomic functions, leading to population declines in central cities (Turok 2004, Bruegmann 2005, Paulsen 2014).

Analysis of relevant indicators of demographic dynamics at a disaggregated enough spatial level may outline recent, latent trends reflecting, for example, increased spatial mobility and preference for large dwellings in peri-urban locations

(Kiochos–Rontos 1999, Rodriguez-Pose–Fratesi 2004, Grekousis et al. 2013). In Southern Europe, a paradigmatic region with homogeneous population dynamics and urban structures, high within-country variability in the spatial distribution of resident populations and across-country differences in settlement density outline distinctive demographic patterns at the regional level (Salvati et al. 2018). In fact, regions of Southern Europe have experienced an intense cycle of urbanisation-suburbanisation-reurbanisation, accelerated by a rapid demographic transition towards lowest-low fertility, higher life expectancy, and immigration (Cuadrado-Ciuraneta et al. 2017).

Density-dependent mechanisms of demographic dynamics (growth or decline) are relatively well-studied in non-human populations (both in animals and plants), and underlie particularly complex regulatory processes (e.g. based on predator-prey relationships and other forms of biological control) at the community level (Mueller et al. 1991, Åström et al. 1996, Waters et al. 2013). For human populations, analysis of the density-dependent regulatory mechanisms of demographic dynamics is relatively more difficult because of the inherent complexity of the underlying background context and the wealth of socioeconomic factors and constraints influencing settlement density. Given the amplitude of recent urban transformations (Petrakos et al. 2005), spatial heterogeneity in local-level, density-dependent population dynamics has been relatively sparsely investigated across regions and countries in Europe (Serra et al. 2014, Pili et al. 2017, Salvati–Carlucci 2017).

Testing density-dependent population dynamics in Mediterranean countries may benefit from the operational definition of the Nomenclature of Territorial Units for Statistics (NUTS) classification system provided by Eurostat, the Statistical Office of the European Commission (European Environment Agency 2006). Considering cities and regions as units of the elementary analysis, a relatively vast amount of data, variables, and indicators is available for the last two-to-three decades, allowing for a proper between-country comparison, as far as basic demographic, social, and economic phenomena are concerned. By contrast, databanks including representative data and variables at more disaggregated spatial levels (e.g. municipalities or local districts) are rather scarce, and often need standardisation, validation, and control procedures (Salvati et al. 2012, Ceccarelli et al. 2014, Lauf et al. 2016). Considering a relatively long time period encompassing the last half century (between 1961 and 2011), the present study illustrates a comparative analysis of population growth derived from national census data.

By adopting municipalities as the unit of the elementary analysis, the impact of density-dependent mechanisms of population growth was investigated at the local level in three Mediterranean countries (Spain, Italy, and Greece) using a non-parametric approach based on spline regression. Integration of basic indicators of demographic change and fluctuations in population density may improve the basic knowledge of the intensity and spatial direction of urban growth, evidencing trans-

scalar dynamics over time (Méndez et al. 2016). Under the hypothesis that countries of Southern Europe present similar dynamics over a sufficiently long time interval (Carlucci et al. 2017), the results of the present study may highlight both internal and external factors shaping local-level demographic growth rates (Colantoni et al. 2016). Assuming that local-level population growth is positively correlated with population density, demographic dynamics were demonstrated to shape spatial divides with distinctive temporal patterns and intensity. In this way, a non-parametric, exploratory analysis of local-level population dynamics may inform strategies of urban development and containment, adapting to different socioeconomic and territorial contexts in Europe (Giannakourou 2005, Munafò et al. 2013, Crescenzi et al. 2016).

Materials and methods

Study area

Urban populations in the Mediterranean region have grown steadily from 89 million inhabitants in 1950 to 258 million inhabitants in 1995, and it is estimated to reach 416 million inhabitants in 2030. Urban populations are concentrated in major European countries like Italy, Spain, and Greece (Table 1). In 1995, urbanisation rates ranged between 59.2% (Greece) and 76.5% (Spain), and are predicted to increase (more or less markedly) by the year 2030 (United Nations 2019). Three countries, representative of the population dynamics in Southern Europe, were considered in this study (Spain, Italy, and Greece). These countries display heterogeneous population dynamics at a local level, different population sizes, and a variable number of municipalities. Italy and Spain were the biggest countries in terms of population size and total area, respectively. Italy and Spain also displayed the highest population density and the highest annual rate of growth over time, respectively. In all these countries, the densest locations coincided with central cities and the associated metropolitan areas, including capital cities (such as Madrid, Rome, and Athens) and regional urban centres of high economic relevance, such as Valencia, Seville, and Barcelona in Spain; Milan, Naples, and Turin in Italy; Salonika, Iraklio, and Patras in Greece. Urban primacy was particularly evident in Greece, since the metropolitan region of Athens has contained more than 30% of country's total population since 1951 (Cecchini et al. 2019).

Table 1

Selected demographic statistics by country

Country	Municipalities (2011)	Area, km^2	Population (2011)	Density, inhabitants/km^2	Annual population growth rate, % (1961–2011)
Spain	8,116	521,841	46,816,010	90	1.06
Italy	8,092	301,365	59,434,413	197	0.35
Greece	1,034	132,033	10,939,727	83	0.61

Spatial units of the analysis

A system of local administrative units (LAUs) introduced by Eurostat was adopted in this study. LAUs are the basic elements of the NUTS classification system, and include territorial units that are representative of local communities. To homogenise multiple country-based definitions of territorial levels of governance, local units were based on two existing spatial levels: (i) LAU level 1 (formerly NUTS level 4), defined for most countries as homogeneous local districts of administrative relevance; (ii) the lower LAU level 2 (formerly NUTS level 5), including municipalities, 'communes', or equivalent local units. LAUs play a key role in official statistics because of (i) large data availability from national censuses and (ii) relevance for the implementation of local strategies. With LAUs being subject to minor changes over long observation periods, Eurostat disseminated and regularly updated a homogenised list of spatial units and boundaries for cross-country comparison. More specifically, this study made use of a collection of population data disseminated by Eurostat and derived from national censuses carried out every 10 years at each LAU-2 unit for six time points encompassing 50 years between 1961 and 2011.

Data analysis

Population data were processed and analysed using spreadsheets to calculate two indicators: (i) population density, that is, the ratio of the resident population in the municipal area (km^2); (ii) annual percentage change in resident population over time (1961–1971, 1971–1981, 1981–1991, 1991–2001, 2001–2011). Scatter plots were used to investigate the relationship between population density and annual growth rate percentage by year and country. Assuming that the spatial variation in population growth rates is dependent on the socioeconomic background context (Morelli et al. 2014, Serra et al. 2014, Pili et al. 2017), the relationship between population increase and demographic density was preliminary analysed in this study using a pair-wise correlation analysis that compares parametric (Pearson product-moment) and non-parametric (Spearman rank) coefficients. Both coefficients range from 1 (the highest positive correlation between two variables) to –1 (the highest negative

correlation between two variables), with 0 indicating uncorrelated variables. Significant pair-wise correlations were tested at $p < 0.05$ after Bonferroni's correction for multiple comparisons. The absolute ratio of Spearman to Pearson coefficients by year and country outlines the main type of relationship (linear or non-linear). A particularly high ratio of Spearman to Pearson coefficient indicates a non-linear relationship between demographic density and relative population growth.

A smoothing spline, a sequence of third-order polynomials continuous up to the second derivative (de Boor 2001), was adopted here to construct a smooth curve that best fit local-level population data sets. Smoothing splines were used to explore non-linear, complex forms in the relationship between population density and the annual population growth rate percentage at the municipal level by year and country. An optimal smoothing run by a cross-validation procedure allows performing an estimation of the relationship between demographic variables and indicates a 10-order moving average as an appropriate estimator for all investigated countries and years. In this way, multiple data points at the same X value were collapsed to a single point by weighted average and calculation of a combined standard deviation.

Results

The relationship between population density and relative population growth in each municipality of the three countries investigated here was studied using a non-parametric correlation coefficient (Spearman) compared with a parametric coefficient (Pearson). Spearman rank coefficients were significant and high for all comparisons (Table 2). Moreover, Spearman coefficients were systematically higher than Pearson coefficients for all comparisons. The absolute ratio of the Spearman to Pearson correlation coefficient was particularly high since 1981, indicating that the density-growth relationship became progressively more complex and non-linear over time.

Table 2

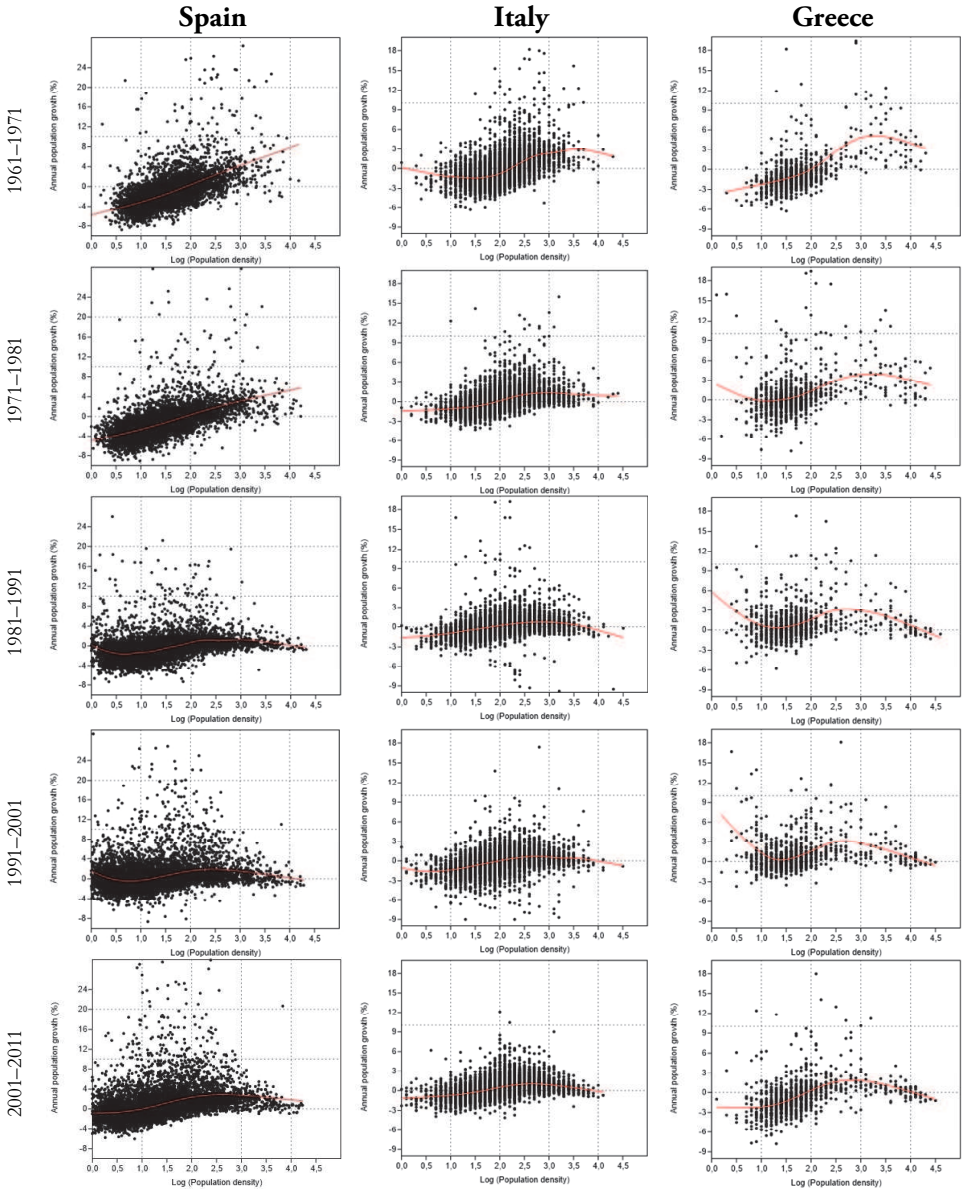
Distribution of Spearman non-parametric correlation coefficients between population density and annual population growth rate percentage in Southern Europe by country and time interval

Country	1961–1971	1971–1981	1981–1991	1991–2001	2001–2011
	Spearman rank correlation coefficient				
Spain	0.613	0.644	0.461	0.287	0.504
Italy	0.553	0.553	0.457	0.463	0.474
Greece	0.484	0.375	0.206	0.217	0.534
	Absolute ratio of Spearman to Pearson correlation coefficient				
Spain	1.30	1.32	2.22	1.95	1.61
Italy	1.21	1.19	2.10	1.26	1.23
Greece	1.18	1.51	1.98	3.44	1.46

Note: All coefficients are significant at $p < 0.05$ after Bonferroni's correction for multiple comparisons, and comparison with the related parametric, linear Pearson correlation coefficient.

Figure 1

Smoothing splines between population density (inhabitants/km², logarithm) and annual population growth rate (percentage by decade) at a municipal level by country and time interval



Results of the non-parametric smoothing splines by country and time interval are illustrated in Figure 1. A non-linear trend – with a more-or-less evident degree of complexity – was observed for all comparisons. Annual rates of population increase in all countries followed an inverse U-shaped relationship with population density, displaying a positive trend at lower densities and a negative trend at higher densities. The breakpoint indicating a shift between positive and negative density-growth relationships was relatively variable over time and space. Threshold densities decreased in all countries, from nearly 3,000 inhabitants/km^2 in 1961 and 1971 to 2,000 inhabitants/km^2 in the following decade. The consequent threshold rate of relative population growth varied from 3%–4% in the first two decades of investigation to 0.5%–1% in the last two-to-three decades.

Variable density-growth thresholds indicate that mechanisms of demographic growth typical of urban areas (i.e. a negative density-growth curve) involved an increasing number of peri-urban municipalities with fewer compact settlements and a lower intermediate level of population concentration. In contrast, mechanisms of growth typical of rural areas (i.e. a positive density-growth curve) were more specifically observed in locations far away from metropolitan regions, with medium-low values of population concentration and higher variability in relative growth rates. Finally, municipalities with very low population densities (< 100 inhabitants/km^2) in depopulated or marginal locations, have displayed a more mixed density-growth relationship, with heterogeneous and spatially variable patterns. In such contexts, demographic growth (or decline) was largely independent from the overall level of density, being influenced by other socioeconomic and territorial factors.

Discussion

European urban areas have grown by 78% in the last half century, with the resident population increasing by 33% (European Environment Agency 2006). Such changes have shaped the structure and functions of peri-urban landscapes around central cities (Russo et al. 2017, Biasi et al. 2015, Kazemzadeh-Zow et al. 2017), leading to spatial disparities and demographic divides (Mykhnenko–Turok 2008). Relatively few studies have compared population trends in European countries at a sufficiently detailed spatial level (e.g. Zambon et al. 2017). The original contribution of the present study lies in a diachronic analysis of long-term demographic dynamics (1961–2011) at the municipal level in three countries of Southern Europe, evidencing similarities and differences in recent urban-rural patterns and testing the hypothesis of a density-dependent population increase over time. In this regard, local-level settlement patterns common to different Mediterranean countries (e.g. population growth along coastal districts and a consequent demographic decline in inland, mountain districts) were assumed to consolidate a metropolitan hierarchy centred on large cities and dispersed urban conurbations in flat, accessible areas (Carlucci et al. 2017).

While identifying specific urban regimes at the local level, the empirical results of this study outline the intrinsic characteristics of each local context and a substantial similarity in the relationship between population density and demographic growth across time and space (Crescenzi et al. 2016). Assuming that population fluctuations reveal how people live and move around (Grekousis et al. 2013), demographic changes are mostly associated with economic agglomeration, being a key factor in land-use change and socioeconomic transformations (Munafò et al. 2013, Haase et al. 2016, Weilenmann et al. 2017). Sequential waves of concentration and de-concentration of urban nodes, together with (i) the expansion of peri-urban and rural/accessible districts, and (ii) the abandonment of marginal rural districts, consolidate demographic divides in high-density and low-density areas (Morelli et al. 2014). All these processes are at the base of a complex density-dependent mechanism of population growth observed in Spain, Italy, and Greece.

While evidencing a moderate divergence in the individual countries' demographic dynamics, results of smoothing splines indicate a generalised, non-linear relationship between population density and growth, with slightly different turning points as far as density and growth levels are concerned. A negative effect of density on relative population growth rates was observed at concentration levels higher than 3,500 inhabitants/km^2, declining slightly over time. The corresponding annual rate of population growth was relatively high in 1961 and 1971 (> 3%), decreasing fairly rapidly in the following decades to 0.5%-1%. This pattern was common to Spain, Italy, and Greece, although with small differences in the shape of density-growth curves.

Such findings are in line with the sequential waves of urbanisation, suburbanisation, and re-urbanisation characterising the post-war urban cycle in Southern Europe (Cuadrado-Ciuraneta et al. 2017). In other words, the density-growth relationship may reflect distinctive urban phases at a country and regional level, reflecting multiple factors of socioeconomic change (Colantoni et al. 2016, Pili et al. 2017, Duvernoy et al. 2018). Demographic dynamics and multifaceted urbanisation patterns – from compact expansion to sprawl – have played key roles in shaping the spatial distribution of resident populations. More specifically, location factors promote distinctive patterns of local development based on population density (Turok 2004). The positive annual population growth rate observed in rural areas (with densities generally below 2,000 inhabitants/km^2) counterbalanced the opposite pattern observed in urban areas. This result outlines a negative relationship between density and growth, likely reflecting congestion externalities and a subtle process of peri-urbanisation, observed since the 1960s and intensifying in more recent decades (Carlucci et al. 2017).

Long-term urbanisation processes in Southern Europe are representative of more general dynamics at the continental level. Consolidation of urban and rural poles, demographic divides along the elevation gradient, and a substantial density-

dependent mechanism of population growth are generalised phenomena of interest for urban and regional planning all over Europe (Petrakos et al. 2005). Moreover, a comparative analysis of local-level population dynamics may emphasise the inherent complexity of different European contexts and the importance of a diachronic investigation of demographic processes (Antrop 2004, Serra et al. 2014, Di Felicantonio–Salvati 2015). Although urbanisation processes tend to vary from country to country, our results indicate that population increase in Southern Europe was influenced by similar forces that should be better characterised in a comparative analysis of long-term demographic trends (Zambon et al. 2018). By reflecting similar regimes in the density-dependent mechanisms of population growth, these factors are more intense in demographically dynamic regions, and can be specifically investigated in specific areas of the studied countries.

Conclusions

Integration of basic socioeconomic indicators, including demographic growth rates and population density, allows identification of (apparent and latent) spatial divides, outlining long-term and more recent socioeconomic trends and their impact on settlement structure and urbanisation patterns. In this line of thinking, a comparative analysis of population dynamics clarifies the role of local contexts when designing and implementing joint strategies for spatial planning and regional development at both the country and continental levels in Europe. Population divides were easily identified at the municipal level, being associated with density-dependent processes of urban expansion, and consolidating the socioeconomic divide in accessible/dynamic regions and marginal/inland districts. In this regard, future research should integrate empirical results of density-dependent regulation mechanisms in biological systems and findings from exploratory analysis of human systems, comparing the results of different statistical approaches and theoretical models. Non-linear modelling and non-parametric statistical techniques considering spatial and temporal dynamics seem to be particularly appropriate to this direction. A refined analysis of socioeconomic contexts resulting from different demographic patterns and processes can also improve the reliability and accuracy of demographic forecasts. In this regard, geo-referenced databases with local-level, up-to-date information encompassing relatively long time intervals, are essential to provide the basic knowledge required to identify spatial regimes of demographic growth and the influence of population density. Results of this study encourage a refined, spatially explicit analysis of population dynamics in Southern Europe aimed at identifying differential patterns of urban expansion under spatially varying socioeconomic conditions and heterogeneous territorial contexts.

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What the overall Digital Economy and Society Index reveals: A statistical analysis of the DESI EU28 dimensions

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We build on the argument that measurement of digitalization is essential for effective public policy strategies in order to to govern digital transition. Developing this argument, we investigate the five principal dimensions of the European Commission´s Digital Economy and Society Index (DESI) using a series of multivariate statistics. The analysis can be divided into three groups. First, we analyse the linear relationships between dimensions by correlation analysis, partial correlation analysis, and principal component analysis. In the partial correlation analysis, causal relationships between the dimensions show high correlations. Second, we assign countries into groups with cluster analysis and multi-dimensional scaling. The groups obtained by the two methods are very similar. Finally, we rank the European Union (EU) countries using statistical methods and compare with the results obtained with the overall DESI index. The correlation between the two rankings shows a strong linear relationship. Based on these results we draw conclusions on how to effectively use the DESI data for public policy analysis.

Keywords:
digital transformation measurement, DESI index, correlation analysis, cluster analysis, multidimensional scaling

Introduction to digital transformation and problems of its measurement

During the past 25 years, with the emergence of e-business and the internet economy, several industries have been restructured with Information and Communications Technology (ICT) 'disruption', and we can hardly recognize some of them from their past perspectives. For instance, the internet has reformed media industries such as music, television and films; retail businesses such as books, newspapers, apparel and electronics; and services such as travel, banking or

insurance. Initially, the e-business revolution only took place in industries related to information or digital products, while others that were not influenced by the rapid disruptions in information technology remained intact. However, ICT is now more pervasive and affordable pressure on innovation has also become wide spread. Broadly, in this paper, we define this phenomenon as digital transformation.

Pervasiveness may be characterized by penetration, mobility, and access to computers, devices, and networks. We are very close to the scenario when this pervasiveness will increase connectedness of the entire world population. Significant progress has been made towards bridging the global digital divide, achieving universal and affordable access to the internet in the least developed countries. Affordability, on the other hand, implies costs and how the costs of hardware, software, and connectivity compare to incomes and general economic development per capita. We can expect to witness tremendous progress in this area, and not only will devices get cheaper but the rates of telecommunication services will also decline. However, ICT-based business transformation does not happen because of the economics of ICT, but it is due to the application of such technologies that allow us to do things fundamentally differently. In a fascinating monograph, former Google CEO Eric Schmidt and Jared Cohen (2013), a foreign relations and counterterrorist expert, paint an exciting new world of the future in the digital age – how ICT reshapes people, businesses, and countries.

In some industries, such as automotive and electronics, competitiveness of companies is already influenced by the efficient deployment of information and communication technology, the efficiency of innovation processes, co-operation of intelligent machines, and of people at all levels (including the shop floor), or by intertwining artificial intelligence/learning algorithms with everyday processes. Economic and technological trends, however, indicate that this development will not only shape the auto and machine industries, but will basically transform all businesses. A new ecosystem, labelled in several countries as Industry 4.0 or the era of the industrial internet, is emerging, and it not only encompasses the dilemmas of how ICT is embedded in blue and white collar processes leading to radical innovations but also draws attention to future work, new forms of financing, the changing landscape of international strategic management, organizational culture, and the need to transform leadership practices.

Notwithstanding the elimination of the classic elements of digital divide, such as barriers to ICT adoption, use of social media, or the uptake of current e-government services, new chasms have appeared, e.g. regarding privacy, cybersecurity, or the major challenge of how to deal with fake news and other forms of cyber manipulation. The appearance of this new 'digital divide' raises the concern for the need to reconsider the new relationship between governments and businesses, how public policies and science and technology programs influence digital transformation and, more importantly, how the new form of leadership must react to these challenges.

In the context of the European Union (EU), a universal scoring system – the Digital Economy and Society Index (DESI) – has been developed for measuring preparedness and progress of digital transformation. For capturing the complexity of the above socio-economic digital transformation, DESI collects and organizes the statistical data of 28 EU countries into five main dimensions: Connectivity, Human Capital, Use of Internet, Integration of Digital Technology, and Digital Public Services. Notwithstanding that DESI has been around since 2014, we intend in our paper to highlight two main dilemmas using the latest data available from DESI Report 2018 (European Commission 2018) for the five indicators. Of course, in addition to DESI, the EU also sets other similar indices and efficiency indicators in other areas of the economy and society based on EU databases. For example, the definition of an international reputation index is presented by Fernandez-Crehuet et al. (2019). Dudek and Sedefoğlu (2019) use material deprivation rates in the indicators in a European Union context.

Correlation and causality of the five dimensions

The European Commission accepts that the five principle policy areas of DESI are not isolated from each other and clearly show that digital transformation can only be achieved by a concerted effort that must be reflected in the DESI dimensions. This principle, however contradicts the requirement of avoiding redundancy that has led to both statistical and interpretation problems. Since the five DESI dimensions comprise several sub-indicators from statistical databases, we argue about the importance of investigating, in pure statistical terms, how strong this correlation is, how many different dimensions DESI measures, and how the dimensions impact each other. Our first set of research questions aim to answer these problems.

Problem of country clusters and ranking according to DESI

The typical use of the DESI measurement system – what the European Commission publishes with every new DESI data recording – is the grouping and ranking of countries, which is considered as comparison or 'scoring' of EU countries related to their digital transformation. It is interesting that while the term 'cluster' is used in this context, DESI reports do not apply a statistical form of cluster analysis or scaling methods; instead they prefer weighting of the five dimensions and publish country grouping accordingly. For instance, in one of the latest reports, the European Commission identified three so-called clusters, namely high, medium, and low performing EU countries with 9, 10 and 9 members belonging to them. We argue that without exploring how statistical clusters and scaling separates and ranks countries according to the raw DESI data, an unnecessary bias may distort member states´ position. In other words, by finding out how naturally DESI ranks and groups countries by using appropriate

multivariate statistical methods, we can reveal the inherent structure of EU countries and juxtapose it with existing reports. Our second set of research questions intend to contribute to this problem by analysing DESI data with cluster analysis and multidimensional scaling.

The paper is organized as follows. Section 2 presents a brief review of the existing literature on the analysis of DESI data. Section 3 presents the DESI overall index with the five indicators. Please note that the sub-dimensions and individual indicators of DESI dimensions are not examined in this paper. Section 4 covers the statistical analysis. The linear connections of the variables are examined with classical correlational analysis, partial correlation analysis, and principal component analysis. The countries are grouped with cluster analysis and multidimensional scaling. The following section is an application of the multidimensional scaling model to rank countries. These statistical results are then compared with the scoring model developed by the European Commission. Section 5 concludes the paper by presenting the results.

A conceptual review of the Digital Economy and Society Index

Measurement of digital transformation: introduction to DESI and other systems

There are several indices, scores, indicators, and measurement units that describe the status of the digital economy, society, public administration, and they are used as descriptors of digital transformation.

First, some of these scoring systems describe and compare the impact of global digitization. For instance, reports from the United Nations (UN), Organization for Economic Cooperation and Development (OECD), World Bank, or the International Telecommunication Union (ITU) serve similar objectives as the regular research projects of major consulting firms such as Forrester, International Data Corporation (IDC), Gartner or McKinsey.

The second category of these measures focus on regional or well-defined country clusters belonging to a geopolitical area. Typical surveys of this type are the EU scoring boards: Digital Skills Indicator (DSI), Consumer Conditions Scoreboard (CCS) indices, or the Digital Economy and Society Index (DESI).

Finally, the third set of data collected for describing the impact of ICT are country-specific compilations conducted by the respective National Statistical Offices or domestic research firms.

The DESI report tracks the progress made by EU member countries with respect to their digitization. It is structured around five chapters (Table 1):

Table 1

Dimensions of DESI

Connectivity	Fixed broadband, mobile broadband, and prices
Human Capital	Internet use, basic and advanced digital skills
Use of Internet Services	Citizens' use of content, communication, and online transactions
Integration of Digital Technology	Business digitization and e-commerce
Digital Public Services	eGovernment and eHealth

Source: https://digital-agenda-data.eu

It is a widely used and quoted measurement system by experts and policy makers, however it has certain advantages and serious limitations. The main advantage is that it is measured in 28 countries, enables comparison, it is accepted by the European Union, allows compliance and provides the big picture of the digital ecosystem in the EU and its member countries.

Disadvantages are rooted in the same sources as the advantages. The fact that measurements are collected in 28 different countries entails that the methodology is determined to be general and applicable to all. Therefore the results are also general and not suitable for deep analysis and to explain certain phenomena. Specifically, the major drawbacks are that the measurement factors often have the impression of improvised choice in a given year and they change frequently. It often seems biased by industry lobbies, the period between data collection and publication is very long, thereby frequently resulting in outdated assessments. The composition of dimensions changes year-by-year, and this makes it difficult to compare time series performances because these corrections are often not emphasized. There are also significant differences between the statistical offices and data collection methods among countries.

Regardless of the problems, DESI´s method and collection system is still a robust approach, unavoidable in many instances, and it is considered as the best choice for mapping Europe's progress on digitalisation.

Literature review on conceptual questions of DESI

Stoica and Bogoslov (2017) compared the five indicators of DESI with the available data for Romania and the EU and analysed them over time. They concluded that Romania had undergone significant development during the period under review (2014–2017). However, they did not analyse what type of statistical correlations exist between the available data. Using data from Greece, Kontolaimou and Skintzi (2018) published a similar study. Their research was methodologically deeper, extended to human capital, including gender. Dynamic effects are presented in this analysis; in this case however it is difficult to test dynamic datasets due to limited data

availability. Mirke et al. (2019) analysed human capital elements of the Czech Republic and Latvia, and assessed the adult population's digital competence through learning.

Nikolov and Krumova (2019) considered the fifth element of DESI in their study, that is e-Government, and examined the countries of the European Union (EU) in their model. Scupola (2018) provided an overview of the state of digital transformation in Denmark. The study also reported experiences in e-Government. This paper appears to be very insightful as Denmark has been one of the best-performing countries in DESI rankings for several years. Urs (2017) also investigated the development of e-Government, focusing on local municipalities in Romania and highlighted that improving their service quality can be a daunting task for their understaffed and underfinanced IT departments, hampered by the lack of central coordination and deficient national infrastructure.

Russo (2020), following the European guidelines on the DESI index, applied them on the Italian region of Abruzzo to provide a local framework of technological development. Alonso–García (2018) analysed the digital economy in the context of entrepreneurship using DESI. Their research focused on how digitalization affects the entrepreneurial ecosystem and had found that digitalization changes not only the size of the entrepreneurial market but also its profitability. Curko et al. (2017) considered DESI from the perspective of smart business and examined the impact of Industry 4.0 on the digital economy. Similarly, Götz (2017) analysed the impact of Industry 4.0 on the economic relations between Germany and Poland, concluding that the digital economy can have a positive effect on German-Polish relationships.

These illustrative overviews indicate that the DESI has been used in academic research in order to understand how digital transformation works across different European countries, sectors, and social and economic dimensions. Thus, we argue that it is important to understand the statistical robustness of the DESI methodology, specifically the conclusions we can draw using the five dimensions in such contexts.

Research questions and methodology – statistical analysis of DESI 2018 indicators

To analyse the two problem areas, we propose five research questions (RQ): three related to the problem of correlation (RQ1-RQ3), and two assigned to the problem of country clustering and ranking (RQ4-RQ5).

RQ1: What are the linear relationships between the DESI dimensions?

RQ2: Based on their relationships can the dimensions be reduced? That is, do the dimensions measure different latent variables?

RQ3: Can we reveal any information on the causal relationship between the DESI dimensions?

RQ4: How can we cluster the European Union countries – as data points – using the DESI dimensions?

RQ5: By using the DESI dimensions how can we arrange the country data points – by creating a natural ranking – and compare this with the published DESI overall index?

For data analysis, our DESI dataset of 2018 was compiled from the EU Commission's website https://digital-agenda-data.eu (Table 2). This raw dataset for the five dimensions – synonymously referred to as variables in this context – is presented in Table 2 and used for the multivariate statistical analysis (Tabachnick et al. 2007):

Table 2

Raw DESI 2018 data for analysis

Country		Connectivity	Human Capital	Use of Internet	Integration of Digital Technology	Digital Public Services
Denmark	DK	78.482	70.413	75.085	61.283	73.219
Sweden	SE	75.985	74.227	73.370	56.367	70.765
Finland	FI	66.053	79.240	65.406	60.879	78.642
Netherlands	NL	81.132	74.254	66.458	52.338	70.550
Luxembourg	LU	80.053	71.311	65.864	33.175	56.208
Ireland	IE	65.118	61.706	52.316	60.017	64.719
United Kingdom	UK	68.848	71.631	62.395	39.962	58.244
Belgium	BE	75.128	57.452	53.310	54.560	57.872
Estonia	EE	64.112	61.375	61.607	37.065	78.103
Spain	ES	64.708	54.578	49.431	49.791	72.362
Austria	AT	63.725	64.365	47.568	44.145	66.468
Malta	MT	73.140	51.633	63.281	38.904	61.262
Lithuania	LT	64.895	48.526	56.845	47.455	68.217
Germany	DE	64.745	62.855	52.743	41.326	50.233
Slovenia	SI	60.337	52.009	44.938	47.866	57.350
Portugal	PT	67.383	45.824	46.344	41.928	59.643
Czech Republic	CZ	63.861	55.100	46.460	40.444	50.165
France	FR	56.404	59.069	42.247	37.828	58.371
Latvia	LV	65.932	43.840	54.777	27.027	65.185
Slovakia	SK	55.071	51.882	51.285	37.430	50.401
Cyprus	CY	60.632	43.027	51.136	37.674	54.815
Croatia	HR	49.436	49.807	54.075	35.439	44.351
Hungary	HU	61.728	47.978	53.638	25.082	40.390
Poland	PL	58.810	48.283	42.080	23.532	48.208
Italy	IT	52.826	40.810	37.364	36.821	52.503
Bulgaria	BG	54.906	34.832	41.684	24.424	49.717
Greece	EL	43.104	38.185	45.218	26.940	39.239
Romania	RO	58.119	32.065	34.964	17.756	41.362

Source: https://digital-agenda-data.eu

We used the IBM SPSS 20 Statistical Program Package to perform the following methodological calculations. For analysing the linear and causal relationships (RQ1 and RQ3), simple Pearson and partial correlation measures were used. Pearson correlation shows the strength and direction of the linear relationship between two variables, while the partial correlation provides information on the causal relationship between the two variables, but without the ability to deduce its direction. For RQ2, that is, basically for compressing information, we performed principal component analysis on the datasets, based on which we examined the latent variables describing the best returned variance. Basically, this calculation shows how many new variables characterize the existing five dimensions. In order to cluster the EU countries (RQ4) we used hierarchical cluster analysis. This method shows which countries are positioned relatively close to each other in the five-dimensional space determined by the original DESI variables. Multidimensional scaling was used to assess the stability of the cluster analysis; a method in which the elements of the five-dimensional space are represented in lower dimensions. We preferred the two-dimensional space for visualization, in accordance with the results of the principal component analysis. Finally, for answering our last research question (RQ5), we applied an extreme case of multidimensional scaling by mapping our country data points from the five-dimensional space to a one-dimensional space, which may be called a straight numerical order. This order can be turned into ranking, when and if this mapping shows a good fit.

Results and discussion

RQ1: Correlation analysis

Table 3 shows that there is a moderate to strong correlation between the variables. Each of these correlation coefficients has a positive sign, suggesting that the movement of variables is in a single direction; importantly, all the correlation ratios are significant at 99% confidence level. We consider this as an important consequence to any further use of the DESI dimensions, in which case the dilemma is about how orthogonal these dimensions are in terms of our understanding the digital economy and society. In other words, how will each of these dimensions add value to our assessment of the status of digital transition in the EU? In any case, a high correlation could be alarming in this respect, pointing towards little additional value for some variables in the DESI model.

Table 3

Correlation matrix between DESI variables

		Human Capital	Use of Internet	Integration of Digital Technology	Digital Public Services
Connectivity	Pearson Correlation	0.683**	0.736**	0.547**	0.605**
	Sig. (2-tailed)	0.000	0.000	0.003	0.001
Human Capital	Pearson Correlation		0.765**	0.709**	0.647**
	Sig. (2-tailed)		0.000	0.000	0.000
Use of Internet	Pearson Correlation			0.568**	0.616**
	Sig. (2-tailed)			0.002	0.000
Integration of Digital Technology	Pearson Correlation				0.726**
	Sig. (2-tailed)				0.000

**Correlation is significant at the 0.01 level (2-tailed).

RQ2: Application of principal component analysis

Principal component analysis reveals how the five – strongly correlated – DESI variables may be reduced. We used the principal component analysis method, without rotation, with VARIMAX rotation to answer the dilemmas raised as a result of RQ1, that is, to identify the group of variables that describe different aspects of the digital economy.

The Kaiser-Meyer-Olkin measure of sampling adequacy shows that our model is meritorious with 0.834 value, confirming its fitness. At the same time, Bartlett's test of sphericity is proven significant, further underscoring the goodness of our model. These tests support the acceptance of our model's results.

First, we report communalities values that are between 0.8 and 0.9, suggesting that the calculated components explain a large proportion of the variance. In our analysis, two components are sufficient for this purpose and they returned 84.280 percent of variance. Specifically, in the principal component model without rotation, the first component yielded 72.859 percent of variance, and the value of component weights was above 0.830, indicating that each variable strongly correlated with this component. In the case of our second component, each variable showed weak correlation, except Integration of Digital Technology, which showed weak-medium correlation of 0.451. The second component displayed 11.422 percent of variance. We obtained a rather insightful result, concluding that the second part of the principal component analysis, which was computed with the VARIMAX rotation of

the above results, yielded 84.280 percent of the variance on the two components. Table 4 summarizes the two components and their corresponding variables with the respective component weights.

The first component is strongly determined by Connectivity and Use of Internet variables, while the second with strong component weights such as Integration of Digital Technology and Digital Public services. We can observe that Human Capital shows moderate weights with both components, slightly higher with the first one. This suggests that both components have a medium linear relationship with the variable Human Capital. We will clarify this in more detail by calculating the partial correlation values between our dimensions. Table 4 is an important and somewhat intuitive outcome of our quantitative analysis, namely the five DESI dimensions can be reduced to two different variables describing the status of digitalization: one component provides the measure of 'preparedness' by integrating infrastructure and its use; while the other, more obvious component, measures what is actually happening with digital technologies, namely how it is integrated into businesses, social institutions, and public administration. However, the special status of Human Capital is somewhat counter intuitive, which one may have predicted as a 'preparedness' variable, but principal component analysis results do not provide strong proof on this issue.

Table 4

Rotated Component Matrix

	Component	
	1	2
Connectivity	0.862	0.300
Use of Internet	0.867	0.339
Human Capital	0.699	0.562
Integration of Digital Technology	0.302	0.895
Digital Public Services	0.387	0.818

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

These conclusions lead us to the third part of the correlation problem, that is, whether the data show any further relationship between the DESI dimensions in order to disclose the causality underlying our components.

RQ3: Partial correlational analysis

We report the results of partial correlation analysis in Table 5 by italicizing values that are significant at 5% level. Table 5 shows that six relationships do not affect each other by eliminating the impact of the other variables, and the values of the four significant polar correlations are between 0.4 and 0.5, which is considered a weak-medium linear relationship between these variables after filtering out the effects of the other three variables.

Table 5

Partial correlation matrix between variables after filtering

		Human Capital	Use of Internet	Integration of Digital Technology	Digital Public Services
Connectivity	Pearson Correlation	0.177	*0.411*	0.005	0.181
	Sig. (2-tailed)	0.397	*0.041*	0.983	0.387
Human Capital	Pearson Correlation		*0.454*	*0.407*	0.032
	Sig. (2-tailed)		*0.023*	*0.044*	0.880
Use of Internet	Pearson Correlation			–0.073	0.151
	Sig. (2-tailed)			0.727	0.470
Integration of Digital Technology	Pearson Correlation				*0.490*
	Sig. (2-tailed)				*0.013*

Numerical data from Table 5 can be translated into a graphical visualization shown in Figure 1. By acknowledging that partial correlation analysis only reveals causal relationships but does not provide information on its direction, we carefully avoided drawing arrows on the connecting lines. The answer to this research question suggests that DESI has two 'independent variables' (Connectivity and Human Capital), and three 'dependent variables', which are Use of Internet, Integration of Digital Technology, and Digital Public Services.

Figure 1

Causal relationships between variables

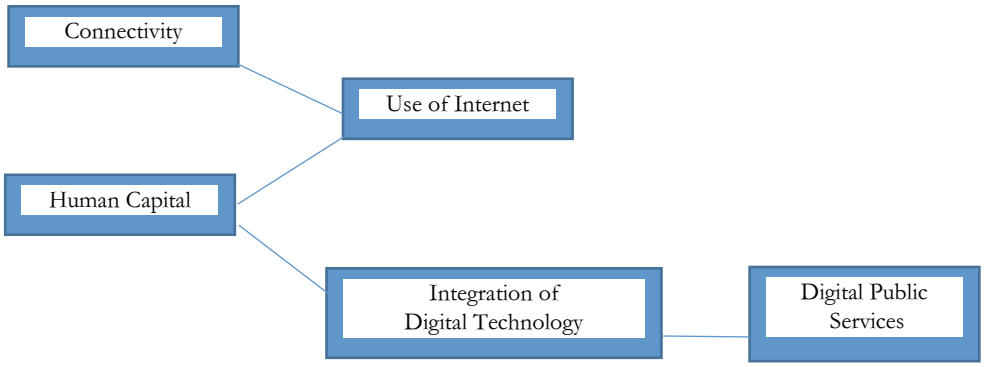


Figure 1 shows a somewhat unexpected result that needs further investigation and has ample consequences on the use of DESI for policy making. The data suggests that penetration and level of digital public services are only dependent on how digital technology is integrated into other business processes and it is not directly connected with internet use. Similarly, the integration of digital technology into business processes is in causality with human capital not significantly with connectivity, which we may consider as the basis for digital transformation. Elaborating on the consequences of these results – RQ1, RQ2, and RQ3 – is beyond the scope of this paper but causality mapping may be explored for more elaborate policy design in digital transformation.

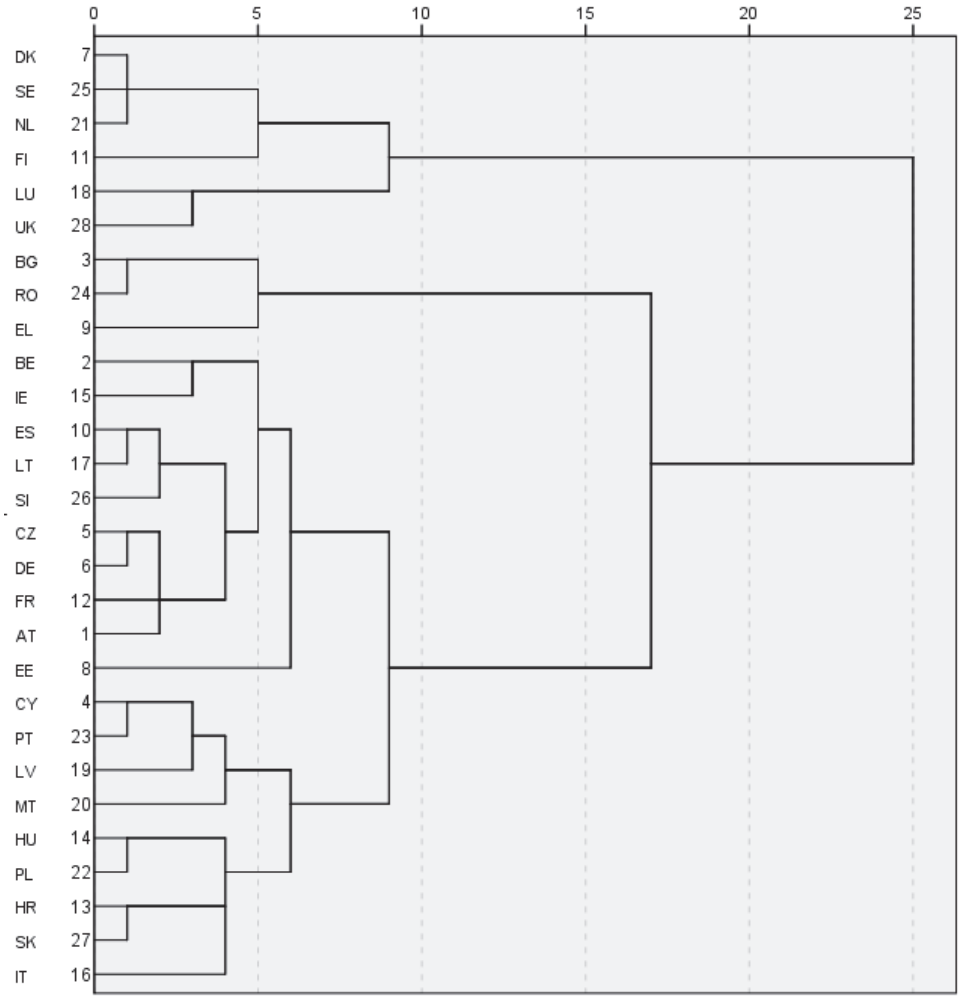
RQ4: Grouping countries with hierarchical cluster analysis

Cluster analysis is a statistical method for classifying observations, in this case regarding the EU 28 countries, in the space of the variables, that is, the five DESI dimensions. We argue that it is an important incumbent grouping of data points instead of choosing artificially defined 'leaders and laggards' categories according to predetermined DESI composite values. We must assign a group centre to determine the distance between countries in cluster analysis based on data metrics, which is the squared Euclidean distance in this paper, and our scale of measurement is an interval scale. We selected the hierarchical cluster methodology because it can be supported with the dendrogram visualization, and is an expressive demonstration of how distinctly different groups emerge as a result of creating clusters. Dendrograms enable the monitoring of cluster attachment and cluster spreading. The first result describes how closely data points belong to a given group, and the second shows how many different groups the data points may be divided into. The components of our dendrogram are shown in Figure 2, and its interpretation is presented with the

help of Table 6, which summarizes cluster membership and the sequence how clusters are formed.

Figure 2

Dendrogram of cluster analysis



First, the algorithm has separated the two clusters, basically the top performing countries in the digital economy from the remaining ones. These countries are Denmark, Sweden, Finland, Netherlands, Luxembourg, and the United Kingdom. Second, a more refined picture is seen when the rest of the population falls into two distinct groups, separating the low performers, namely Bulgaria, Romania, and Greece. Finally, in steps three and four a wider cluster spread can be defined by lowering the distance between the group centres. As a result, we can observe that

two countries are separated from the leading group, that is, Luxemburg and the UK, and the populated middle group falls into two subgroups comprising a somewhat more and a rather less developed one. In the former cluster, we have Ireland, Belgium, Estonia, Spain, Austria, Malta, Lithuania, Germany, Slovenia, Portugal, Czech Republic, and France, while Latvia, Slovakia, Cyprus, Croatia, Hungary, Poland, and Italy are grouped in the latter.

Table 6

Changes in cluster membership

Country		2 Clusters	3 Clusters	4 Clusters	5 Clusters
Denmark	DK	2	3	3	4
Finland	FI	2	3	3	4
Netherlands	NL	2	3	3	4
Sweden	SE	2	3	3	4
Luxembourg	LU	2	3	4	5
United Kingdom	UK	2	3	4	5
Austria	AT	1	1	1	1
Belgium	BE	1	1	1	1
Czech Republic	CZ	1	1	1	1
Estonia	EE	1	1	1	1
France	FR	1	1	1	1
Germany	DE	1	1	1	1
Ireland	IE	1	1	1	1
Lithuania	LT	1	1	1	1
Slovenia	SI	1	1	1	1
Spain	ES	1	1	1	1
Croatia	HR	1	1	1	3
Cyprus	CY	1	1	1	3
Hungary	HU	1	1	1	3
Italy	IT	1	1	1	3
Latvia	LV	1	1	1	3
Malta	MT	1	1	1	3
Poland	PL	1	1	1	3
Portugal	PT	1	1	1	3
Slovakia	SK	1	1	1	3
Bulgaria	BG	1	2	2	2
Greece	EL	1	2	2	2
Romania	RO	1	2	2	2

It may be observed that hierarchical cluster analysis provides a deeper insight into understanding country performance based on the Euclidean distance in the five-dimensional DESI space without setting artificial thresholds or group numbers. Depending on the scale of difference, we can identify country groups that are really and consistently similar – these are the results of the first two steps of the algorithm

– and we refine grouping also, by choosing lower Euclidean distance values as in the third and fourth step, resulting in more clusters but with less distinct difference between the middle group. Based on the structure of DESI data, we conclude that the EU 28 countries fall into five separate and relevant clusters as presented in Table 6:

1. Cluster (#4): Denmark, Finland, Netherlands, and Sweden,
2. Cluster (#5): Luxembourg and United Kingdom,
3. Cluster (#1): Austria, Belgium, Czech Republic, Estonia, France, Germany, Ireland, Lithuania, Slovenia, and Spain,
4. Cluster (#3): Croatia, Cyprus, Hungary, Italy, Latvia, Malta, Poland, Portugal, and Slovakia, and
5. Cluster (#2): Bulgaria, Greece, and Romania.

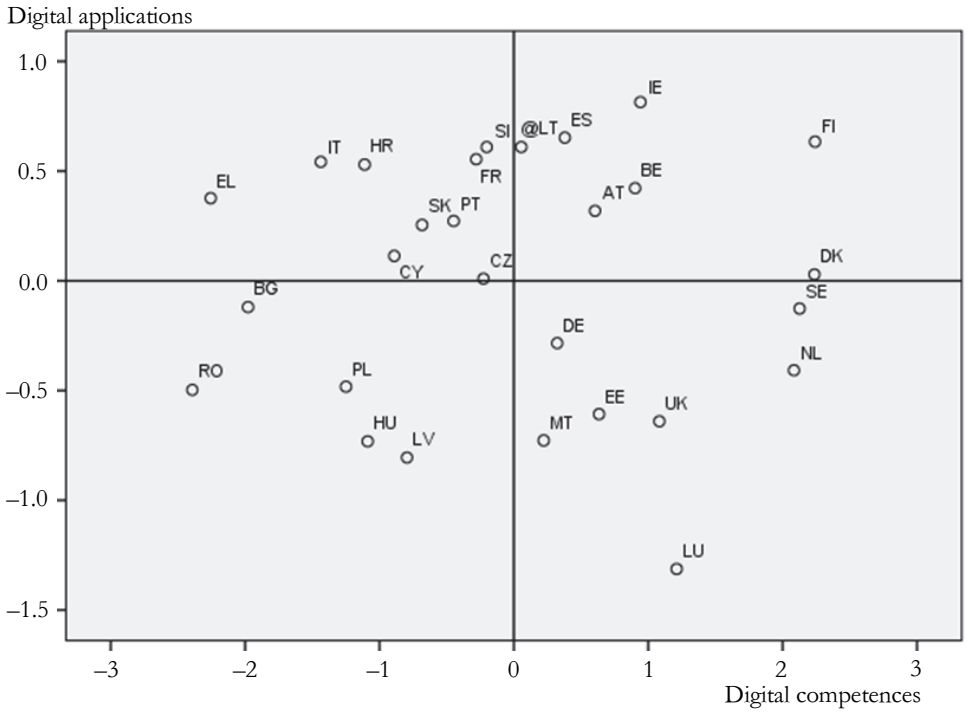
In the next section, clustering is performed using another method, the multidimensional scaling.

RQ5: Grouping countries by multidimensional scaling

When applying multidimensional scaling (MDS), we consider the smallest dimensional space in which the distances between observations can be best returned. Thus, our data are derived from the five-dimensional space into a smaller dimensional one, but preferably to the size that we can visualize. In our case, we transform our data into the plane, a two-dimensional space. This corresponds with the results of the principal component analysis that yielded two components condensing the five DESI dimensions. One of these components is 'digital application' and we may summarize the other as 'readiness' or 'digital competence', as indicated in Figure 3. The adequacy of dimension reduction is robust, since the stress value is very low at 0.103, which is the sum of the squares of the difference between the five-dimensional and two-dimensional distances.

Figure 3

Location of countries on the plane of principal components



The adequacy of the model is further confirmed by the R-squared value (R^2=0.958), which shows a strong linear relationship between the points in the two dimensional space, as R-squared over 0.900 linearity is considered to be very good.

For a very simple interpretation of Figure 3, we may conclude that the DESI measurement distributes the EU 28 countries into four quadrants based on their level of competency and application of digital technologies. The first quadrant in the upper right corner contains countries where both components are higher than average, that is, they perform well in both competencies (connectivity, use) and application (integration and public services). Moving clockwise, the lower right corner collects countries where applications lag the opportunities of competencies – the value of this latter component is negative. Countries which are lower than average in both components can be found in the lower left corner, which corresponds to the fifth and fourth clusters of the hierarchical cluster analysis showing the refined situation, as in Romania and Bulgaria; although lagging in terms of the competency component, they perform better in terms of the application dimension. Finally, the last quadrant is the upper left segment with countries that exploit applications of technology to a certain extent, that is, beyond the level of competency or their actual readiness.

In the second part of this research topic we apply MDS to generate ranking of data points measured by the DESI variables. Basically, this is an extreme case when the original data are projected into a one-dimensional space using MDS, that is, we assign values for each country lying on a numerical line.

It is important to note that this method is fundamentally different from the present logic of DESI ranking (or overall DESI), since applying a multidimensional scoring method involves weighing of the five dimensions and aggregating them accordingly. Hence DESI overall is a scalar multiplication of the DESI variables presented in Table 2, and a predetermined weight vector defined by the EU Commission is shown in Table 7.

Table 7

Weights of the variables for DESI overall index

Connectivity	Human Capital	Use of Internet	Integration of Digital Technology	Digital Public Services
0.25	0.25	0.15	0.2	0.15

The EU Commission´s website (https://digital-agenda-data.eu) provides a simulation tool where weight values may be changed and DESI ranking can be calculated by altering the weight of Connectivity for the benefit of Integration or Digital Public Services. No matter which values are set, however, the logic of multidimensional scoring always reflects the competence of the decision maker or the requestor for the ranking. On the other hand, MDS provides incumbent ranking based on the structure of data that are independent of any external utility assessment of the DESI dimensions. The results of MDS and its comparison with the existing scoring is presented in Table 8. The stress value in this case is 0.187, which is worse than that of the plane model in Figure 8, although still acceptable. Furthermore, the value of *R*-squared is still very high at 0.908, as in our two-dimensional model.

Table 8 shows that the result of the scoring model does not differ significantly from MDS. The correlation between the two rankings is 0.991, indicating a strong linear relationship between them. On the other hand, consistent with our previous cluster analysis results, we identify some important findings regarding the assessment of a few countries. Among the high performers, Finland´s position is different according to the two methods, which may indicate some interesting best practice observations and transfer. Also, there are slight positional differences between countries in the middle and lower groups.

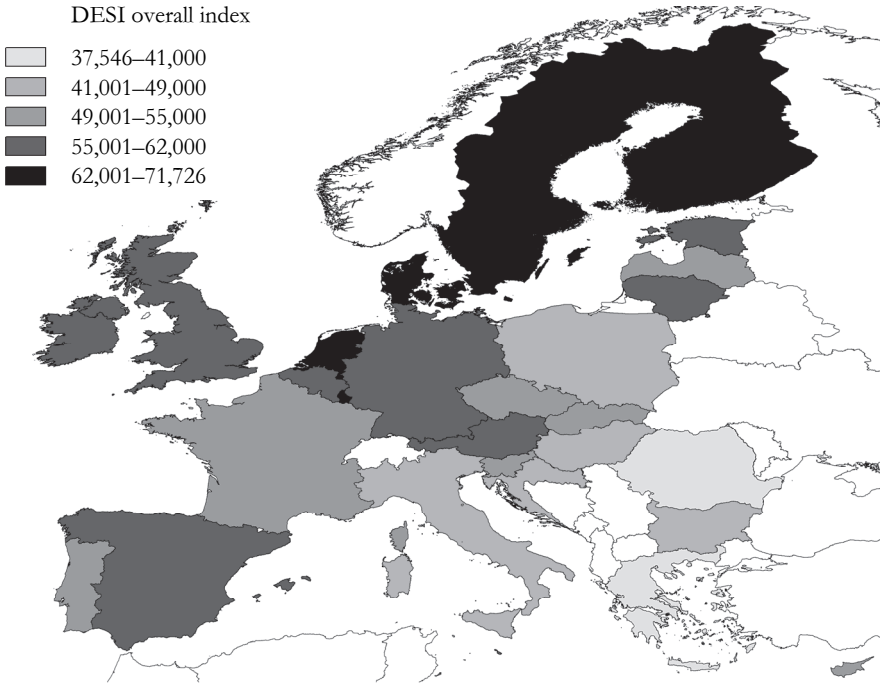
Table 8

DESI overall indicators with ranking

Country	DESI overall index	Ranking with DESI	MDS values	Ranking with MDS
Denmark	71.726	1	1.801	1
Sweden	70.447	2	1.638	3
Finland	70.106	3	1.780	2
Netherlands	69.865	4	1.493	4
Luxembourg	62.787	5	0.905	5
Ireland	61.264	6	0.760	6
United Kingdom	61.208	7	0.659	8
Belgium	60.735	8	0.544	9
Estonia	59.741	9	0.728	7
Spain	58.048	10	0.427	10
Austria	57.957	11	0.343	11
Malta	57.655	12	0.255	12
Lithuania	56.606	13	0.254	13
Germany	55.612	14	0.021	14
Slovenia	53.003	15	–0.186	15
Portugal	52.585	16	–0.283	16
Czech Republic	52.323	17	–0.312	17
France	51.527	18	–0.331	18
Latvia	50.843	19	–0.485	19
Slovakia	49.477	20	–0.487	20
Cyprus	49.342	21	–0.528	21
Croatia	46.663	22	–0.823	22
Hungary	46.547	23	–1.010	23
Poland	45.023	24	–1.062	24
Italy	44.253	25	–1.084	25
Bulgaria	41.029	26	–1.416	26
Greece	38.379	27	–1.675	27
Romania	37.546	28	–1.926	28

Figure 4

DESI overall indicators



Conclusions

Measuring the processes and results of digital transformation is important for policy making and for improving local, regional, and European level competitiveness. From 2014 onwards, the EU Commission has been using the Digital Economy and Society Index (DESI) as a complex measurement scheme for collecting data from member states in order to assess the business and social implications of digitalization status in the EU. Over the years, DESI has emerged as a reference point and a major source for policy making and comparing the performance of different countries. In our paper we analysed two major problems by defining five research questions of DESI that need more attention regarding its use.

Three research questions are used to analyse the first problem area covering the issues of correlation and causality of the five DESI dimensions. After running correlation tests, principal component analysis, and partial correlation computations, we concluded that the five DESI dimensions are strongly correlated, they can be reduced to two principal components covering the same scope of measurement, and there is a causality mapping the variables´ relationship. According to these findings there are two independent dimensions (Connectivity and Human Capital) and three

dependent ones, of which Use of Internet shows causality with both independent dimensions, and Integration of Digital Technology shows causality only with Human Capital. Furthermore, Digital Public Services clearly show a relationship with the Integration dimension, underlying the intuitive experience that applications, both in business and public services are creating a strong principal component while capabilities such as connectivity and human readiness create another.

In the second problem area two research questions examined the clustering and ranking of EU28 countries and juxtaposed the results of hierarchical cluster analysis and multidimensional scaling with the DESI overall indices. With the introduction of these two multivariate statistical methods we created an incumbent grouping of EU28 countries and mapped the groups on a two dimensional and one-dimensional (ranking) space. Our results confirm the usability and effectiveness of the DESI overall index – or weighted aggregate score – and also present a more subtle mapping and ranking of EU countries in the DESI dimensions.

Our paper has its limitations that require future research. A key limitation is that we ran the analyses based only on 2018 data. Therefore, in order to generalize our conclusions analysis should be extended to previous datasets as well. Furthermore, we focused on the five highest level dimensions, a more detailed picture can be gained using second-level data before aggregating them into the five top variables. Regardless we believe our contribution is relevant from at least two points. First, by extending the multivariate statistical analysis of DESI, the entire measurement system can be amended and improved – especially the correlation dilemma can be resolved. Second, based on our findings, a more refined public policy analysis, design and execution may be projected, as adequate knowledge of causality between variables helps decision makers to identify the root causes and actions for improvement.

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Volatility spillovers and time-frequency correlations between Chinese and African stock markets

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This study examines the volatility spillovers in time and frequency from China to five frontier stock markets in Africa (Kenya, Mauritius, Tunisia, Morocco and Nigeria). The authors consider the volatility spillover after the global financial crisis. A bivariate Generalized Autoregression Conditional Heteroscedasticity-Baba, Engle, Kraft and Kroner (GARCH-BEKK) model and wavelet coherence analysis are combined to obtain volatility spillover effects and time-frequency correlations. Empirical results reveal evidence of significant volatility spillovers between China and the five African stock markets, as well as time-frequency correlations for different market pairs. In general, wavelet coherence findings suggest that in most pairs, the China market was leading. Therefore, these results are positive signs for foreign investors to diversify their portfolio among China's and its trading partners' stock markets.

Keywords:
volatility spillover,
GARCH-BEKK,
wavelet coherence,
China,
African stock markets

Introduction

The increasing interdependency and market co-movement of stock markets among various countries have been examined in recent years because of globalization, liberalization of financial markets and international economic integration. These phenomena are causing international financial markets to become more correlated and connected than ever before. A better understanding of the connectedness and association among divergent financial markets is indispensable for global investors, financial institutions and governments (Zhou–Zhang 2012). In addition, it is necessary to fully comprehend the volatility spillover effects and time-frequency correlations of different regional integrations to better forecast stock return dynamics and outline mechanism to reduce financial risks. According to Ahmed and Huo (2018), greater stock market integration and financial cooperation result in policy changes and economic vulnerabilities unless the process is assisted by strengthened market institutions. In particular, the global financial crisis provides evidence that global stock markets are more likely to be interdependent and

influence the dynamics of investors' portfolio diversification behavior and financial stability of countries.

According to Sznajderska (2019), China plays a prominent role both in conventional international trade and in global supply chains, dealing with intermediate goods and re-exporting them to other regions. As a result, for some countries, the direct effects of the slowdown in the Chinese economy would be minor, whereas the indirect influences, primarily through its partners, might be significant. In recent years, China's engagement in Africa has been growing exponentially in many aspects such as trade, investment and aid (Donou-Adonsou–Lim 2018). The China–Africa relationship, which some people term win-win, is destined to help not only China (known as a fast-growing economy), but also African nations in terms of growth and development. As a result, early literature centres on the correlations between China and African financial markets (see for example: Alden 2005, Raphael et al. 2007, Gu 2009, Naidu–Mbazima 2008, Hung 2019b). The cited studies put forward that China has a substantial effect on African countries and has been building a powerful African partnership. This study is also stimulated by the fact that African economies are the primary recipients of Chinese foreign investment flows and are among the major international producers of oil and minerals.

In the last 20 years, with the development of emerging financial markets, many authors have become increasingly interested in the connectedness between emerging and developed markets. Several previous studies argue that increasing bilateral trade relations between countries can have a considerable effect on their stock market linkages. (Isakov–Pérignon 1999, Koutmos–Booth 1995, Cheung–Westermann 2001, Béres et al. 2019).

Literature review

Recent literature focuses on the correlations between China and other financial markets. For example, Kirkulak Uludag and Khurshid (2019) examine volatility spillover from the Chinese stock market to E7 and G7 stock markets using vector autoregression generalized autoregressive conditional heteroskedasticity (VAR-GARCH) frameworks. The results indicate significant volatility spillover from the Chinese stock market to the E7 and G7 stock markets, especially the highest volatility spillover occurs between China and Japan among G7 countries. Lee (2019) employs panel unit root tests and panel cointegration tests to investigate the common trends among Asian financial markets. The study shows that financial market returns among Asian countries are all stationary and panel unit root tests reinforce this conclusion, in particular, the Chinese financial market is not in sync with any other Asian financial markets through the sample period. Fang and Bessler (2018) empirically study whether China leads the downward co-movement in other

Asian markets during the 2015 China crash using a data determined historical decomposition method facilitated by the newly proposed LiNGAM algorithm. The findings show that the importance of China's market has improved along with its expanding economic size and rapid development in financial openness. Bissoondoyal-Bheenick et al. (2018) evaluate the stock market volatility transmission between three countries (the United States [US], China, and Australia) using a FIVAR model, provide evidence of significant bilateral causality between the countries at the market index level and across most the industries for the full sample period from July 2007 to May 2016. Aggarwal and Raja (2019) examine the co-integration among the stock markets of the BRIC (Brazil, Russia, India, and China) countries, and confirm that there is a long-term cointegrating interrelatedness between these nations. Lau and Sheng (2018) examine the inter- and intra-regional spillover effects across international stock markets in London, Paris, Frankfurt, Toronto, New York, Tokyo, Shanghai, Hong Kong, and Mumbai by using both symmetric and asymmetric causality tests. They point out that the asymmetric spillover effect is evident for price shocks originating from Asian markets and China's stock market is the least integrated of all nine markets considered.

In the African context, Sugimoto et al. (2014) examine the return spillovers in seven African stock markets (Egypt, Mauritius, Morocco, Namibia, South Africa, Tunisia, and Zambia), using a spillover index with data from September 2004 to March 2013. Specifically, the study also focuses on the interrelatedness between developed stock markets (France, Germany, China, Japan, and the US) and individual African countries during the US subprime crisis and the European sovereign debt crisis. The results report that stock markets in African nations are dramatically influenced by transmissions from international markets and are insulated from the global crisis. In addition, the authors also shed light on the aggregated transmission effects of European countries to the African markets. In a similar fashion, Giovannetti and Velucchi (2013) find that South African and US innovations affect African financial markets considerably, and China has become more intercorrelated. They use a multiplicative error fully inter-dependent model and daily data from 2005 to 2012 for several African countries, including Botswana, Kenya, Nigeria, South Africa, Egypt, Tunisia, and global financial markets, namely the US, United Kingdom, and China to analyse the interconnectedness between them.

In the international volatility literature, the standard econometric methodologies for investigating international stock market co-movements are multivariate (GARCH) models to investigate international stock market co-movements. Andreou et al. (2013) use a quarto-variate VAR(1)-GARCH(1,1) model with the BEKK (Baba, Engle, Kraft, and Kroner) representation of Engle and Kroner (1995) to discuss volatility spillovers between stock and foreign exchange markets. Huo and Ahmed (2017) employ a bivariate VAR-BEKK-GARCH model to assess the

influence of the recently introduced Shanghai–Hong Kong Stock Connect. Wang and Wang (2010) examine stock market linkages between Greater China and the US and Japan in terms of volatility and price spillover. The estimations based on the Glosten, Jagannathan, and Runkle GJR–BEKK–GARCH model, show that volatility transmissions are stronger than price spillovers between these countries. Another interesting study is that of Gilenko and Fedorova (2014), who use a four-dimensional BEKK-GARCH-in-mean model to examine mean-to-mean, volatility-to-mean and volatility-to-volatility spillover effects for the stock markets of BRIC countries. The results are concurrent with Aggarwal and Raja (2019). In a similar vein, Li and Giles (2015) examine the linkages of stock markets across the US, Japan, and six Asian developing countries: China, India, Indonesia, Malaysia, the Philippines, and Thailand. In order to do this, multivariate GARCH-BEKK modelling of stock returns is employed to highlight the significant unidirectional shock and volatility transmissions from the US market to both the Japanese and Asian emerging markets. Kim et al. (2015), with a similar methodology, also find some evidence of financial contagion around the collapse of Lehman Brothers in September 2008.

However, the difference between short and long-term investor behaviour should be considered in a co-movement analysis. As a result, it may be significant for portfolio managers to investigate the frequency domain in order to provide a better understanding of stock co-movement behaviour at the frequency level (Aloui–Hkiri 2014). Moreover, analyses in the frequency domain are rare in the empirical finance literature. In recent years, with the improvement of financial econometrics, the increasing number of articles have employed wavelet analysis to examine the relationship between economic variables. For instance, Gourène et al. (2019) combine the generalized vector autoregressive framework and the maximum overlap discrete wavelet transform to obtain the spillovers from emerging and developed stock markets to seven African stock markets at different time scales. Aloui and Hkiri (2014) employ the wavelet squared coherence to assess the co-movement in both time-frequency spaces for all the selected GCC (Gulf Cooperation Council) markets. Gupta et al. (2018) examine the links between market returns and trading volume in a time-frequency domain using a wavelet-based vector autoregression technique. Their findings show that both Chinese and Indian markets display efficiency in the short to medium run. Specifically, the wavelet analysis has been used in a large number of studies on energy commodities such as Cai et al. (2017), Yang et al. (2016), Yang et al. (2017), Khalfaoui et al. (2015), Boubaker–Raza (2017), Martín-Barragán et al. (2015), Kocziszky et al. (2018), Mikhailitchenko (2016). In general, wavelet frameworks are considered as a powerful mathematical approach for signal processing that can give straightforward insight into co-movement among international stock markets via a decomposition of the time series into their time scale element.

In this study, we illustrate strong evidence from a GARCH-BEKK model to successfully capture the volatility spillover effects between China and five frontier markets in Africa after the global financial crisis. The results reveal that Chinese and African stock markets are showing signs of integration. In addition, the results of the wavelet coherence analysis show evidence of the changing nature in the co-movements of the markets over the sample period in the long term. The combination of GARCH-BEKK and wavelet techniques formally issue a more in-depth and robust analysis that reinforces a better understanding of the study under examination. This type of analysis might be significant for investors, portfolio managers, and policymakers to understand the volatility spillover effects and time-frequency correlation between China and the five African stock markets. To the best of our knowledge, this is the first empirical study to combine these econometric models to shed light on the dynamic interrelatedness between the stock markets in China and Africa.

A comprehensive review of existing literature reveals a gap in the studies on interdependency among stock markets in different countries. This empirical work provides a novel approach to the literature on financial integration and liberalization. The present study differs from the abovementioned studies in that the most common methodologies used for the dynamic linkage analysis between financial markets are vector error correction models, GARCH-family models and cointegration tests, which do not imply the fundamental time-frequency changes in the lead-lag structure. Hence, this study's principal purpose is to provide a fresh new look into multiple channels of the interconnectedness between the Chinese and African stock markets. As implied in the previous paragraphs, this study contributes to the literature in several dimensions. We provide a detailed account of potential spillover effects and time-frequency correlations between China and the selected African countries. Additionally, the economic modelling is based on bivariate GARCH-BEKK models together with wavelet coherence specifications, which is an innovative characteristic of this research area.

The remainder of this paper is structured as follows. Section 2 outlines the methodology, model, and data used in this study. Section 3 discusses the estimation results and discussion. Section 4 concludes the paper.

Methodology

Bivariate GARCH-BEKK Model

The examination of volatility spillover effects between China's stock market and five frontier stock markets in Africa is implemented using the bivariate GARCH-BEKK model developed by Engle and Kroner (1995). The model allows the interrelation among conditional variances and covariance, the positive conditional

covariance matrix is generated, and it renders significant parameter reduction in the estimation.

$$R_t = \alpha \Gamma R_{t-1} + u_t \quad (1)$$

$$u_t | \Omega_{t-1} \sim N(0, H_t) \quad (2)$$

where the return vector for the stock market variables is given by $R_t = [R_{1,t}, R_{2,t}]$, and the vector of the constant is α, which presents as a 6 x 1 vector. The residual vector, $u_t = [\varepsilon_{1,t}, \varepsilon_{2,t}]$, is bivariate and a conditional normal distribution. Ω_{t-1} is the market information set available at time t–1. H_t represents the conditional covariance matrix and is a function of lagged cross products of errors.

Suppose for a bivariate GARCH model, the covariance matrix $H_{ij,t} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix}$, and its BEKK model as follows:

$$H_t = C'C + A'\varepsilon\varepsilon'A_{11} + B'H_{t-1}B \quad (3)$$

$$\begin{bmatrix} h_{11,t} & h_{12,t} \\ h_{21,t} & h_{22,t} \end{bmatrix} = \begin{bmatrix} c_{11,t} & c_{12,t} \\ c_{21,t} & c_{22,t} \end{bmatrix}' \begin{bmatrix} c_{11,t} & c_{12,t} \\ c_{21,t} & c_{22,t} \end{bmatrix} + \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix}' \begin{bmatrix} \varepsilon^2_{1,t-1} & \varepsilon_{1,t-1}, \varepsilon_{2,t-1} \\ \varepsilon_{2,t-1}, \varepsilon_{1,t-1} & \varepsilon^2_{2,t-1} \end{bmatrix} \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix} + \begin{bmatrix} \beta_{11,t} & \beta_{12,t} \\ \beta_{21,t} & \beta_{22,t} \end{bmatrix}' \begin{bmatrix} h_{11,t-1} & h_{12,t-1} \\ h_{21,t-1} & h_{22,t-1} \end{bmatrix} \begin{bmatrix} \beta_{11,t} & \beta_{12,t} \\ \beta_{21,t} & \beta_{22,t} \end{bmatrix} \quad (4)$$

where C is the 2x2 upper triangular matrices. Matrix A reflects the ARCH effect of volatility, and the element of α_{ij} indicates the effect of market i volatility on market j. By contrast, matrix B is related to the GARCH effect of volatility, the element of β_{ij} shows the persistence of the volatility spillover between markets i and j.

In order to estimate the GARCH- BEKK parameters under the assumption of normally distributed random errors, a quasi maximum likelihood (QLM) estimation is applied. Bollerslev and Woodridge's (1992) QML function has the following form:

$$L(\theta) = -Tn/2 + \ln(2\pi) - \frac{1}{2}\sum_{t=1}^{T}\left(\ln | H_t | + \varepsilon' | \frac{1}{H_t} | \varepsilon_t \right) \quad (5)$$

where T is the number of observations, n is the number of markets, and θ is the vector of estimated parameters.

Wavelet coherence

To supplement the GARCH-BEKK models, the wavelet coherence approach allows us to evaluate the co-movement between China and the five African stock markets in both time-frequency spaces. The wavelet technique used by Grinsted–Moore-Jevrejeva (2004), utilizes a bivariate framework, which is based on a continuous wavelet transform, allowing for different forms of localization. As per Nagayev et al. (2016), the wavelet method allows us to analyse correlation patterns between financial data during various regimes without having to sub-divide the data into different sample periods. A brief note on wavelet coherence is defined as follows:

$$R_n^2(S) = \frac{\left|S\left(s^{-1}W_n^{XY}(s)\right)\right|^2}{S\left(s^{-1}\left|W_n^X(s)\right|^2\right).S(s^{-1}\left|W_n^Y(s)\right|^2} \tag{6}$$

where S is a smoothing operator. Smoothing is achieved by convolution in time and scale.

$$S(W) = S_{scale}\left(S_{time}\left(W_n(s)\right)\right) \tag{7}$$

where S_{scale} and S_{time} illustrate smoothing on the wavelet scale axis and in time, respectively. The smoothing operator that we use in this study is the Morlet wavelet, therefore, Torrence and Webster's (1999) definition is the most suitable.

$$S_{time}(W) = \left(W_n(s) * c_1^{\frac{-t^2}{2s^2}}\right)\Big|_s \text{ and } S_{time}(W)_s = \left(W_n(s) * c_2\Pi\left(0.6s\right)\right)_s\Big|_n \tag{8}$$

where c_1 and c_2 are normalization constants, Π is the rectangle function, and the scale decorrelation length for the Morlet wavelet is 0.6

The wavelet coherence coefficient measures the local linear correlation between two stationary time series at each scale and ranges $R_n^2(s) \in [0,1]$.
$W_n^{XY}(s)$ is the cross-wavelet power. This can be seen as the local covariance between the two time series at each scale. Given time series *x(t)* and *y(t)*, the cross-wavelet power can be written as

$$W_n^{XY}(s) = W_n^X(s)W_n^{*Y}(s) \tag{9}$$

where $W_n^X(s)$ and $W_n^{*Y}(s)$ are continuous wavelet transforms of the two time series *x(t)* and *y(t)*. The symbol * represents a complex conjugate.

The wavelet coherence phase is defined as

$$\phi_n^{XY}(s) = \tan^{-1}\left(\frac{I\left\{S\left(s^{-1}W_n^{XY}(s)\right)\right\}}{R\left\{S\left(s^{-1}W_n^{XY}(s)\right)\right\}}\right) \tag{10}$$

where I and R are the imaginary and real parts of the smooth power spectrum.

Data

This study investigates volatility spillovers and time-frequency correlations between stock markets in China and five African countries including Kenya, Mauritius, Morocco, Nigeria and Tunisia. Daily stock index prices for each country are obtained from the Bloomberg Terminal. We take daily data covering the period from April 2008 to April 2019, and all indices are measured in domestic currency to avoid problems associated with transformation. The stock indices used are the Shanghai stock exchange (SSE), Nigerian stock exchange (NGSE30), Tunisia stock market (TUNINDEX), Mauritius stock exchange (SEMDEX), Kenya stock market (NSE20), and Casablanca stock exchange (CSE). Some of the reasons for our choice of these markets as case studies are that their capital stock markets are known as frontier markets (five countries in Africa) and emerging markets (China) (www.msci.com), and emerging and frontier capital markets have vastly different characteristics than developed capital markets (Hung 2019a). Recently, there have been a large number of studies pointing out that the Chinese stock market has been much related to other African markets (Kirkulak Uludag–Khurshid 2019, Lee 2019, Fang–Bessler 2018). Daily returns of the indices are calculated by taking the logarithm of the ratio of the price at time t and price at $t-1$. There are 2443 observations across the markets, which is less than the total number of observations because joint modelling of the six stock markets requires matching returns. Figure 1 plots the daily stock market prices and percentage returns for the selected countries.

Table 1

Descriptive statistics of index returns from April 2008 to April 2019

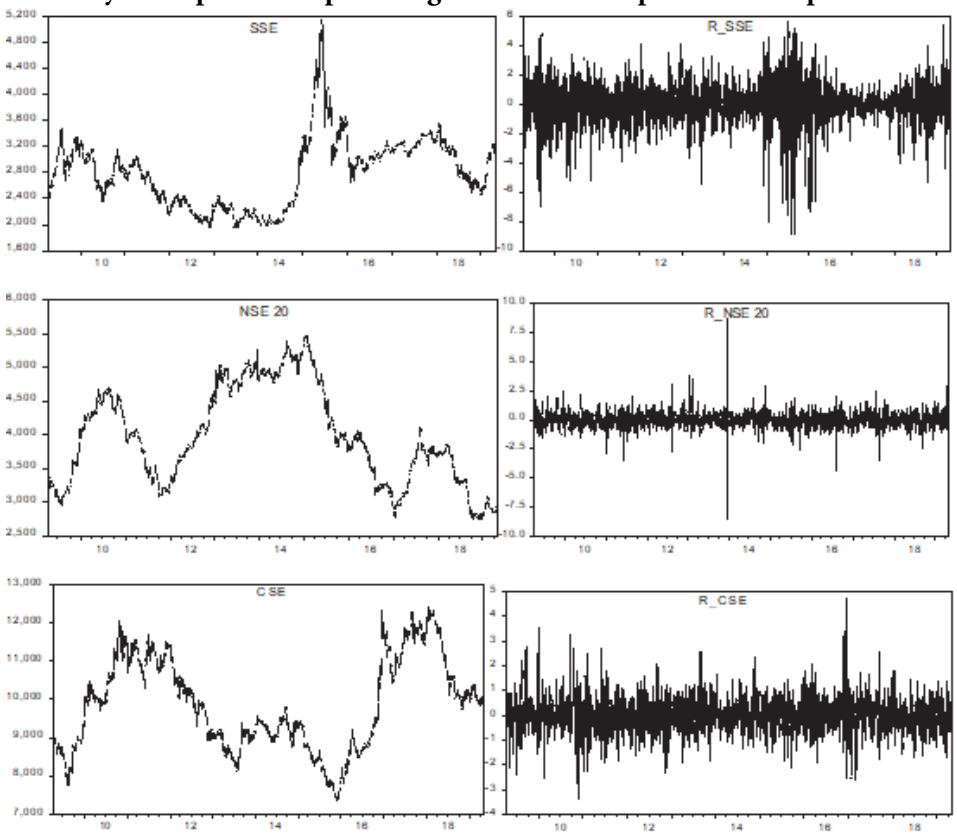
	China	Kenya	Mauritius	Morocco	Nigeria	Tunisia
Mean	0.008183	–0.006055	0.017603	0.004768	–0.004282	0.025939
Median	0.065040	–0.000873	0.002536	0.000000	–0.013677	0.019410
Maximum	5.603612	8.634439	3.311208	4.693722	13.27018	4.108560
Minimum	–8.872906	–8.602158	–3.232378	–3.379210	–15.55468	–4.143924
Std. Dev	1.421352	0.691352	0.370234	0.714662	1.469785	0.534045
Skewness	–0.884874	–0.042344	0.116811	0.271715	–0.760379	–0.586326
Kurtosis	8.332160	25.04220	11.31375	5.679289	26.80581	15.05768
Jarque-Bera	3,212.946*	49,457.10*	7,041.243*	760.7813*	57,875.04*	14,939.22*
PP test	–47.69523*	–41.39208*	–37.16656*	–43.19425*	–41.58053*	–38.18816*
ADF test	–47.64320*	–27.68536*	–38.10299*	–43.03630*	–12.39489*	–38.13599*
ARCH test	91.71117*	515.2678*	539.3525*	199.4662*	564.1907*	691.0085*
Observations	2,443	2,443	2,443	2,443	2,443	2,443

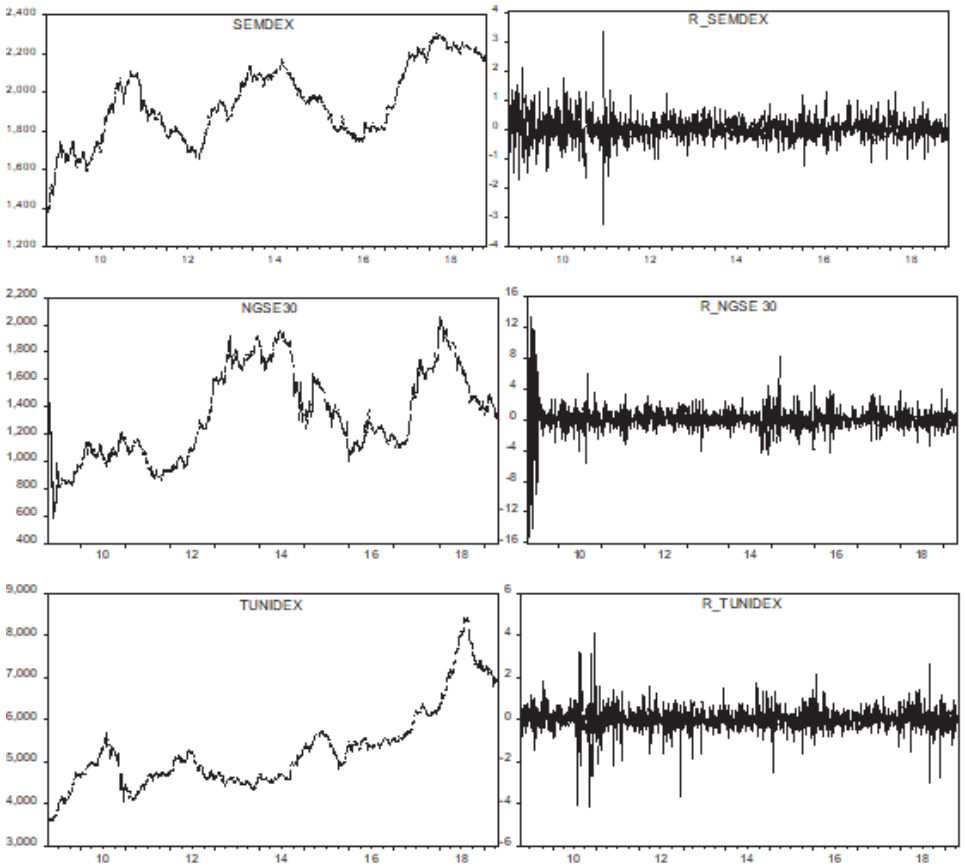
Notes: * denotes significance at the 1% level. All returns are expected in percentages. The ADF and PP tests represent the augmented Dickey Fuller and Phillips Perron stationarity tests respectively. The ARCH test is employed to test the presence of the ARCH effect in the data sets.

Table 1 depicts the preliminary statistics for the daily returns of the six stock markets as well as the statistical testing for normality, stationarity, and independence. The sample mean returns for all markets are not statistically different from zero, whereas standard deviation is relatively large in the Chinese and Nigerian markets, a common result with financial data. The measures for skewness and excess kurtosis demonstrate that the six return series are skewed and highly leptokurtic with respect to the normal distribution. The Jarque-Bera test statistics officially confirm this. In particular, all stock return series are found to be stationary at level (I(0)) at the 1% significance level according to the PP and ADF statistics. Similarly, we examine the autoregressive conditional heteroskedasticity ARCH) effect in the data sets to employ the GARCH-BEKK model. The findings indicate the presence of the ARCH effect in the sample data, meaning that the data is suitable for further statistical analysis.

Figure 1

Daily stock prices and percentage returns from April 2008 to April 2019





We represent the sample correlations for all markets in Table 2. It is clear that the unconditional correlation between China and Mauritius is highest (0.0452), followed by the correlation between China and Kenya in the period from 2008 to 2019. Conversely, the figure describing the correlation between China and Tunisia is negative (–0,00321). Overall, the correlation coefficients among financial markets are relatively low.

Table 2

Correlation matrix between index returns from April 2008 to April 2019

Country	China	Kenya	Mauritius	Morocco	Nigeria	Tunisia
China	1					
Kenya	0.00632	1				
Mauritius	0.04526	0.055375	1			
Morocco	0.002019	0.007835	0.013606	1		
Nigeria	0.002425	0.043768	0.035438	0.011222	1	
Tunisia	–0.00321	0.029016	–0.024761	0.040877	–0.037174	1

Results

We first represent the typical bivariate GARCH-BEKK estimation results in Table 3 as a benchmark to track the volatility transmission effects between China's stock market and five countries in Africa. We then apply the wavelet coherence technique to investigate the interrelatedness between China's market and the selected nations in Africa in a multi-scale, time-frequency domain.

Volatility spillovers between China and other stock markets

The results from the daily return series using the GARCH-BEKK model are reported in Table 3. The coefficients of $\alpha(i,i)$ and $\beta(i,i)$ are the corresponding ARCH and GARCH parameters associated with market i. Similarly, the squared GARCH parameters $\beta(i,i)$ capture the volatility responses in market i to past volatility in pairs of China and each of the five selected countries (Hung 2019a). Starting from the mean equation, the first order serial dependence is insignificant in all of the markets, which means that the findings do not reveal the first moment interdependencies or price spillovers from China's market to the five African stock markets. This result is consistent with Wang and Wang (2010).

Turning to the conditional variance equation, Table 3 reports that all of the diagonal elements in matrices A and B are statistically significant above the 1% level for each pair of stock markets during the research period. The ARCH effects illustrate that the volatility of China's stock market is strongly dependent on its own past innovations. Moreover, the small size of the ARCH coefficient estimates indicates that conditional volatility has not been changed remarkably under the impulsions of return innovations (Vo–Ellis 2018). The results show strong GARCH effects, which drives the variances of each pair of concerned stock markets in our sample. As to the off-diagonal elements, which measure the second moment interconnectedness or risk spillover effects, the findings document that the parameter estimates of α_{12} are statistically significant for Kenya and Tunisia. This simply means that the past innovations of China's stock market significantly influence the present volatility of stock returns in Kenya and Tunisia, but not vice versa. This scenario implies that an increase in the shock to China's stock market changes the volatility of stock returns in Kenya and Tunisia after the global financial crisis. In the opposite direction, Nigeria's past shocks have a significant effect on the conditional volatility of China's stock market returns. As far as matrix B is concerned, we find a bidirectional volatility spillover between China and Mauritius throughout the sample period, and a unidirectional volatility transmission from China to Kenya and Tunisia. Additionally, there is the volatility spillover from Morocco and Nigeria to China. These spillover effects are plausible given that African stock markets are primarily traded by international investors. Briefly, the GARCH-BEKK estimation results show strong evidence of volatility transmissions from China to the five African countries during the study period.

Table 3

GARCH-BEKK model: Stock market returns from April 2008 to April 2019

	China–Kenya	China–Mauritius	China–Morocco	China–Nigeria	China–Tunisia
	Conditional Mean				
μ_1	0.000421304	0.013643588	0.018238425	0.015781416	0.011780024
μ_2	0.011986076	0.054387569	–0.013933923	–0.013290316	0.033056481
	Conditional Variance				
c_{11}	0.071496212 *	0.077165824*	0.073806138*	0.062018997*	0.077381195*
c_{21}	0.029926985 *	–0.033433332***	–0.093487307	0.046685569	–0.099799011
c_{22}	0.251922499 *	0.090697362*	0.341341507*	0.283889737*	0.227194297*
α_{11}	0.197390770*	0.206487516*	0.213112197*	0.202635796*	0.204187878*
α_{12}	0.014535925***	0.001190415	–0.002025676	0.008286909	–0.025500069**
α_{21}	–0.031809590	–0.055641815	–0.048052857	0.039832737**	0.014493361
α_{22}	0.450402599 *	0.387371280*	0.452775500*	0.436040975*	0.613509627*
β_{11}	0.979579656*	0.976988980*	0.976074508*	0.978113657*	0.978024459*
β_{12}	–0.003785203***	0.000512284***	0.001576344	–0.000892135	0.004512539**
β_{21}	0.009960703	0.050726558 ***	0.038925472***	–0.023008822*	0.033509599
β_{22}	0.820984280*	0.878577708*	0.739778241*	0.863533786*	0.621490869*
	Diagnostic test				
ARCH	59.96 (0.06704)	71.99 (0.06047)	78.95 (0.10031)	75.16 (0.03019)	101.76 (0.01151)

Notes: *, **, *** represent the 1%, 5%, and 10% levels of significance, respectively. p-values are given in parentheses.

The last rows of Table 3 report the results of the robustness for the accuracy of the daily in-sample GARCH-BEKK estimates for the five pairs of stock markets under consideration. The ARCH effect is employed to test the conditional heteroskedasticity and the fundamental null hypothesis is that there is an ARCH effect in the model (Tsay 2005). The findings of the ARCH test demonstrate that there is no ARCH effect for all models considered at the 1% significance level among the five pairs. As a result, modelling the GARCH-BEKK specifications can perfectly capture the price and volatility spillovers between China and the five African stock markets. However, in order to capture the lead and lag structure amongst variables as well as to supplement our analysis, we used the cross-wavelet transform to seek regions in time-frequency space from which the series represent high common power. The divergent interconnection structures are elaborated in the following sections.

Wavelet coherence

Wavelet coherence measures how much two time series co-vary and captures time-frequency features (Khalfaoui et al. 2015). Figure 2 below describes the wavelet coherence estimation and the phase difference for all five pairs under study. Time is

exhibited on the horizontal axis and frequency is shown on the vertical axis – regions in time-frequency space where two concerned variables co-vary are located by wavelet coherence. Regions with significant relationships are represented by warmer colours (red), whereas lower dependence between variables is signified by colder colours (blue). Cold regions beyond the significant areas show frequencies and time with no dependence in the series. Both the frequency and the time intervals where the pairs of concerned variables move together significantly can be identified. An arrow in the wavelet coherence plots displays the lag phase connections between the examined variables. Because the wavelet coherence coefficient is squared, we cannot differentiate between negative and positive correlations, therefore we use the wavelet phrase differences, which reveal delays in the oscillation between the two examined time series. The two variables move together on a particular scale if the values of the wavelet phase difference range to zero. Arrows point to the right (left) when the return series are in phase (anti-phase), simply meaning that they move in the same direction when the two series are in phase, and they move in the opposite direction when the two series are in anti-phase (Nagayev et al. 2016). Put another way, the series move in-phase if the wavelet phase $\phi_{XY}(\lambda_i,t) \in \left[0, \frac{\pi}{2}\right]$ and the time series X is led by time series Y. Conversely, if the wavelet phase $\phi_{XY}(\lambda_i,t) \in \left[-\frac{\pi}{2}, 0\right]$ then X is leading. And if we have the a wavelet phase of π or $-\pi$ then we have an anti-phase nexus (negative correlation). Furthermore, wavelet coherence plots can provide straightforward insights into the behaviour over time of the interactive relationships amongst the variables and across frequency. Regarding the statistical significance, it is delimitated by the bold black line for the 5% significance level.

Overall, we can easily observe that the power dynamics of most of the regions in the cross-wavelet power spectrum are relatively low, so we can conclude that the cross wavelet recommends a weak nexus between China and the five selected financial markets. However, wavelet transform coherence is employed to recognize both frequency bands and time intervals within which a pair of series co-vary together (Afshan et al. 2018). The results of the wavelet transform coherence are presented in Figure 2.

The plot of the pair of the Chinese and Kenyan stock markets documents that the arrows are right down in the period from 2010 to 2013, suggesting that China and Kenya were exhibiting in-phase relatedness with both leading and lagging simultaneously in the market. By contrast, the arrows are left down in the small period in-between 1 to 4-week cycle during 2015 and 2018 indicating an out-phase connection with China leading. For almost the entire research period in the long scale, the study evidence shows strong coherence between both variables. In general, there is unidirectional causality from China to the Kenyan stock market. This scenario is valid for the case of the China and Mauritius pair. However, the

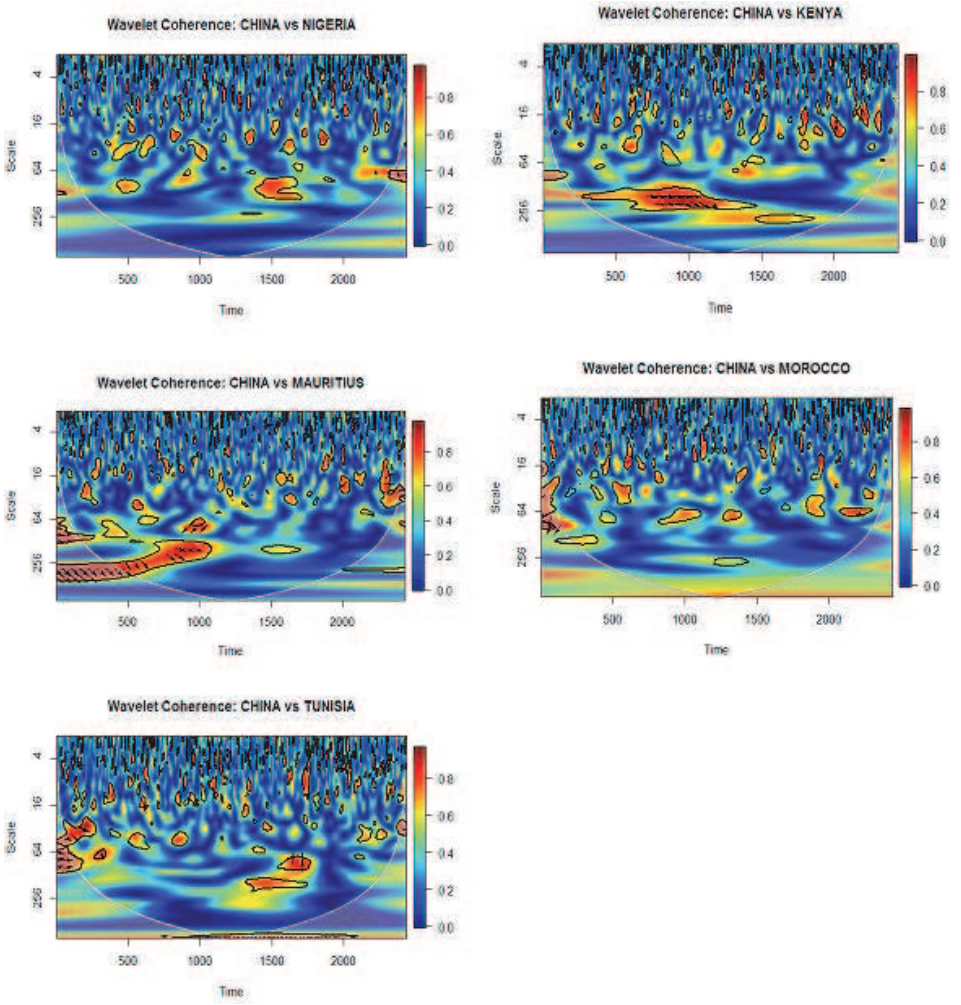
arrows are right up between 2018 and 2019, which indicates that variables are in phase with China lagging. These results are in accordance with the latest findings (Ahmed–Huo 2018, Gourène et al. 2019).

We continue to consider the case of the Chinese and Tunisian stock markets. In the medium period in-between 5 to 12-week cycle during the period from 2008 to 2010, the arrows are right down showing that variables are in-phase with China leading. However, in the 2 to 6-week cycle during the period from 2015 to 2016, the arrows are left up meaning that the series are out-phase and showing anti-cyclic effects with China leading. Further, no causality can be concluded between China and Tunisia in any small and long periods. Finally, we consider the pairs of the Chinese and Moroccan, and the Chinese and Nigerian stock markets. It is clear from the graph that there is a weak correlation between them. In particular, the findings for the long period fail to identify bidirectional causality between the variables.

Overall, the estimates of the GARCH-BEKK model together with the wavelet coherence analysis do not show notable differences in the interrelatedness between China with Kenya, Mauritius, Tunisia, Morocco and Nigeria. Our findings are consistent with the extant literature. For example, Gourène et al. (2019) report that the volatility spillover from emerging and developed stock markets to African stock markets depend on time scales and the integration in African stock markets remains weak and located at large scales. In a similar vein, Ahmed and Huo (2018) confirm that Chinese and African stock markets are showing signs of integration, and China's stock market now plays a prominent role across African stock markets. Gil-Alana et al. (2018) point out that evidence of cointegration is found for African countries against China. Zhou and Zhang (2012) put forward that the volatility of the Chinese stock market has had a significant influence on other markets since 2005. Recently, volatility spillover between China and Southeast Asian countries has been investigated by Hung (2019b), the findings also report that the association between China and other markets seems to be significant after the global financial crisis. Briefly, our results suggest that China is becoming a substantial economic partner of the African region. This finding is also supported by Li's (2007) study as well as the global centre hypothesis in which China, as the new economic powerhouse, will play a significant role in the information spillover and financial effect. Similarly, our result is supported by Majdoub and Sassi (2017) who provide evidence of significant positive and negative return spillover from China to selected Asian Islamic stock markets. Specifically, we consider the interconnection in terms of innovations and volatility transmission effect from five African stock markets to China, suggesting that the African stock markets are tightly integrated with China because of the increasingly close economic and trade ties between the two regions. These results are thus in line with the studies of Sugimoto et al. (2014) and Giovannetti and Velucchi (2013). These studies confirm that China and global financial markets have significant effects on the stock markets in Africa.

Figure 2

Wavelet coherence results from April 2008 to April 2019



Notes: This figure presents the wavelet coherence of China's stock market (SSE) and the five frontier stock markets in Africa in pairs. Time and frequency are displayed on the horizontal (period from April 2008 to April 2019, with 500 = 2008–2010, 1,000 = 2011–2013, 1,500 = 2014–2016, 2,000 = 2017–2019) and the vertical axis, respectively. Frequency is covered in days. The warmer the colour of a region, the greater the coherence is between the pairs. The solid black line isolates the statistical significance area at the 5% level.

The documented evidence has significant implications for policymakers and market participants. First, policymakers in these countries need to be aware of the economic changes because these time series will adequately reflect on their stock market performance and interconnectedness. In addition, this study also provides positive significance for the problem of bilateral trade connectedness and stock market interaction. Market participants should pay more attention to evaluating the

significant relationships among the markets as well as their volatility spillovers. International investors should diversify their investment portfolio and hedging in order to maximize returns and minimize risks.

Conclusion

This study investigates the volatility spillovers and time-frequency correlations between Chinese and African stock markets. The models used to examine the first and second-moment interdependencies for each pair of stock markets are GARCH-BEKK models together with wavelet coherence analysis. These econometric analyses provide a fresh novel look into the time-frequency interconnection between China and five frontier stock markets in Africa (Kenya, Mauritius, Tunisia, Morocco, and Nigeria). We summarize our results as follows:

The bivariate GARCH-BEKK model might be an appropriate estimation for examining the volatility spillovers between China and other countries. Namely, we find that there is a bidirectional volatility spillover between China and Mauritius during the research period, and unidirectional volatility spillover from China to Kenya and Tunisia. Conversely, there is a volatility transmission from Morocco and Nigeria to China.

The wavelet coherence methodology shows a refinement in analysis and allows for the investigation of the time and frequency varying co-movements of the pairs of stock markets within a unified framework. We find evidence of a changing nature in the co-movements of the Chinese and African stock markets for almost all pairs over the sample period in the long term. In the short term, market interdependencies are somewhat weak at best. Interestingly, non-persistence of bidirectional causality was not found in the long-term scale. Furthermore, the arrows are pointing both right up and right down showing that our time series provide straightforward insight into in-phase interconnectedness with mutually leading and lagging the market.

Finally, the analysis conducted provides a better understanding of the time-frequency causality between stock markets in China and African countries for investors and portfolio managers who are interested in these financial markets.

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Regional price dynamics in Argentina (2016–2019)

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This work investigates compliance with the Law of One Price (LOP) across regions of Argentina. A convergence and cointegration analysis of the 2016–2019 period is conducted using the series of the Total Basic Basket (TBB) and the Consumer Price Index (CPI) published by the National Institute of Statistics and Census (INDEC in Spanish) on a monthly basis for six regions in Argentina. The results suggest the existence of convergence in prices and cointegration across regions, which is consistent with compliance with the LOP. This is especially relevant for its potential impact on regional poverty disparity. Indeed, if poorer regions with lower prices tend to have a greater increase in price levels – and therefore convergence is observed – this may imply an increase in regional disparities.

Keywords:
Law of One Price, convergence, regional disparities

Introduction

In economics, the Law of One Price (LOP) states that the price of the same good expressed in the same currency in two different markets should be the same under conditions of competition and without considering transport costs or tariffs (Krugman–Obstfeld 1991). Compliance with the LOP has frequently been studied through analyses comparing price convergence in different countries (Hyvonen 2004, Busetti et al. 2007, Dreger et al. 2007, García-Hiernaux–Guerrero 2015) but to a lesser extent at the intra-national level (Cecchetti et al. 2000; Honohan–Lane 2003, Beck et al. 2009, Gómez Aguirre–Rodriguez Chávez 2014).

Verification of the LOP is more feasible at the intra-national level given the lower transport costs in relation to international trade, the absence of barriers to domestic trade, and the use of the same currency (Dayanandan–Ralhan 2005, Liu et al. 2018). Non-compliance with the LOP at the intra-national level is especially relevant since it implies the presence of regional imbalances, the poor allocation of resources, and differences in the cost of living, which must be taken into account in the system of government transfers (Vashchuk 2003). Further, the persistence of intra-national regional imbalances is of growing interest among researchers (Csete–Szabó 2014).

Much research has been conducted to empirically verify the LOP. In this regard, Liu et al. (2018) find evidence of price convergence across Chinese provinces between 2003 and 2015 using a sequential panel selection method. Convergence across cities in Mexico has been reported for the periods 1982-2000 using unit root tests (Sonora 2005) and 1982–2012 through ordinary least squares regression (Gómez Aguirre–Rodriguez-Chávez 2014). Similar results have been found among cities in the United States (Sonora 2008, Huang et al. 2012, Hegwood–Nath 2013). Also in the U.S., empirical evidence has shown the positive effect of e-commerce on regional price convergence (Cavallo 2018).

On the other hand, cointegration techniques have frequently been used to test the validity of the LOP (Goodwin 1992, Jung–Doroodian, 1994, Alavalapati et al. 1997, Kuiper et al. 2002, Silverstovs et al. 2005, Yang et al. 2015, Arruda et al. 2018). Thus, if compliance with this law is accepted, prices in different regions or countries are expected to follow a common long-term trend (that is, they have a similar dynamic) and, therefore, be cointegrated. In this regard, Marcal et al. (2003) found no evidence of cointegration across provinces of Brazil for the 1980–1994 period when using the Johansen cointegration test (1996). Palaia and Holand (2010) extend the analysed period (1980–2006) and admit the possibility of structural breaks following Gregory and Hansen (1996). However, they find no evidence of cointegration.

Lema and Brescia (1998) analyse the cointegration of agricultural prices between Argentina and the United States for 1991–1997 using the test proposed by Engle and Granger (1987) and find results consistent with the idea of cointegration of the series. Also, for Argentina, Daruich and Kozlowski (2019) analyse prices of 22 grocery chains between 2016–2018. Interestingly, a price variance decomposition shows that most of the variance is due to differences across chains and to a lesser extent due to regional differences across stores in the same chain. The above suggests a uniform pricing across regions consistent with the LOP. However, some caveats must be made: these chains have a small number of stores in the poorest areas and they may use subdivisions within the chain to discriminate prices.

Argentina is widely recognized for its territorial disparities; the provinces of northern Argentina have a lower level of development than their central and southern peers. Northern Argentina (Norte Grande Argentino, [NGA]) includes the Noreste ([NEA], Misiones, Corrientes, Chaco, and Formosa) and the Noroeste ([NOA], Salta, Jujuy, Tucumán, Santiago del Estero, Catamarca, and La Rioja). Disparities can be observed in indicators such as infant mortality, life expectancy, gross domestic product (GDP), access to basic services, and poverty (Longhi–Osatinsky 2017, González–London 2018, González 2019).

The wide regional disparities have also manifested in price differences within Argentina. In fact, the provinces of the NGA have presented lower prices and costs

of living than the other provinces (INDEC 2002). This translates, for example, into lower monetary poverty lines for the NGA (INDEC 2019a).

After its re-normalization, INDEC published monthly reports in 2016 on the cost of living disaggregated by region.[1] These monthly reports confirmed that the provinces of the NGA have the lowest price levels, while the provinces of Patagonia have the highest levels. Previously, it was only possible to approximate regional price differences based on household expenditure surveys carried out at irregular intervals of 5–8 years such as the National Household Expenditure Survey (ENGHo in Spanish) conducted in the years 1996/97, 2004/05, 2012/13, and 2017/18.

In this context, the present work seeks to analyse compliance with the LOP across regions of Argentina considering the 2016–2019 period. For this, regression techniques are used to test convergence in the cost of living as reported by INDEC. In addition, a cointegration analysis of the series is considered. Hereinafter, section 2 presents the methodology and sources of information. Section 3 describes the results, and section 4 discusses the main conclusions.

Methodology and sources of information

Considering the objective of this work, ordinary least squares regression analysis is used to test the existence of convergence. This estimation strategy has the advantage of generating more reliable results in small samples than other strategies such as the Generalized Method of Moments (Bao–Dhongde 2009). In particular, the following equation is estimated (Vashchuk 2003, Gómez Aguirre–Rodríguez-Chávez 2014):

$$\ln\left(\frac{P_{it}}{P_{i,t-1}}\right) = \alpha + \beta \ln(P_{i,t-1}) + \rho_i + \sigma_t + \varepsilon_{it} \quad (1)$$

where ln (P_{it}) is the natural logarithm of the chosen price variable (P) in region i in month t; ρ_i are region fixed effects; σ_t are time fixed effects; and ε_{it} is the error term of the model. If there is price convergence, a negative β coefficient is expected. In turn, the speed of convergence can be estimated as (Egri–Tánczos 2018, Halka–Leszczynka-Paczesna 2019):

$$\lambda = -\ln(1 + \beta) \quad (2)$$

A related measure is the *half-life* indicator that reflects the number of periods – months, in this case – after which 50% of the price shock is eliminated:

$$o = \ln(2)/\lambda \quad (3)$$

While price indices are often used to test convergence, Vashchuk (2003) states that they should be used with caution. In particular, assuming that the price level of all observational units (cities, regions, countries, etc.) being the same in the base

[1] INDEC's reports between 2007 and 2015 should be considered with reservations, as demonstrated by Miranda-Zanetti et al. (2019) and González (2020).

period may not be realistic. The foregoing may introduce bias in the choice of the base period and is a reason to prefer the use of nominal prices instead of indices. The following section describes the price variable (total basic basket) used in the regressions.

Sources of information and regionalization

In the Argentine case, INDEC publishes monthly reports that attempt to approximate the cost of living (in local currency) through the use of a total basic basket per equivalent adult, which includes food and non-food expenses, for regions of Argentina. The considered regions are: the NEA, NOA, Cuyo (Mendoza, San Juan, and San Luis), Centro (Córdoba, Entre Ríos, Santa Fe, La Pampa, and Province of Buenos Aires), Gran Buenos Aires – also known as region Metropolitana – ([GBA], the City of Buenos Aires, and its suburbs), and Patagonia (Rio Negro, Chubut, Neuquén, Santa Cruz, and Tierra del Fuego). The value of the total basic basket is used as input for the construction of a price panel by region. The period under study covers April 2016 to June 2019. Therefore, the panel has 228 observations (region-month combinations).

Simultaneously, since December 2016, a consumer price index has also been made available for regions of Argentina published by INDEC (INDEC 2019b). The CPI quantifies monthly variations of the price level. Unlike the TBB, which is a weighted average of prices, the CPI is an index and therefore has no unit of measure. In addition, the CPI attempts to capture changes in the prices of all goods and services in the economy and therefore has greater breadth than the TBB.

As presented in Figure 1, the Argentine regions cover 24 provinces, including the City of Buenos Aires. The Centro region has the largest proportion of GDP and population, with 66% and 75%, respectively (INDEC 2004, 2010). On the other hand, the NOA and NEA regions have a lower participation in the GDP than their population contribution, with 4% and 6% of GDP and 9% and 12% of population respectively. This accounts for the existence of deep regional disparities in Argentina.

Figure 1

Argentine regions

Source: National Institute of Statistics and Census.

Results

First, the results that arise from estimating equation 1 for regions in Argentina are presented in column 1 of Table 1. Column 2 presents alternative estimates for absolute β-convergence (without regional fixed effects):

Table 1

Convergence in prices across regions of Argentina (2016–2019)

	(1) Coefficient	(2) Coefficient
Estimated β	–0.0384*** (0.00599)	–0.0003** (0.00013)
Regional fixed effects	Yes	No
Time fixed effects	Yes	Yes
N	228	228
R^2 overall	0.14	0.98

Note: * significant at 10%, ** significant at 5%, *** significant at 1%.
Source: Author's elaboration based on INDEC.

A negative and significant estimated coefficient is observed in both cases, which is consistent with the idea of price convergence across Argentine regions. When considering an absolute β-convergence specification (column 2), the estimated coefficient is considerably closer to zero compared to the conditional specification with regional fixed effects, which denotes a lower convergence rate. The estimated coefficients of regional fixed effects of equation 1 (Table 5 of the Annex) confirm that Patagonia has the highest prices and the NEA and NOA regions have the lowest ones, on average. Also, the results are robust when considering alternative periodisations (Table 6 of Annex).

Using the previous results to estimate equations 2 and 3, the following is obtained: the average convergence rate is 3.9% monthly, that is, 3.9% of the deviations from the average are eliminated each month. In turn, the half-life indicator suggests that after 17.7 months, 50% of the distortions are eliminated.

Second, and as a robustness exercise, equation 1 is re-estimated using the consumer price index published by INDEC as the dependent variable. As mentioned above, the choice of the base period may bias the estimates and, therefore, should be considered with reservations.

Table 2

Convergence in prices considering the CPI for regions of Argentina (2016–2019)

	Coefficient
Estimated β	–0.0347*** (0.00900)
Regional fixed effects	Yes
Time fixed effects	Yes
N	204
R^2 overall	0.93

Note: * significant at 10%, ** significant at 5%, *** significant at 1%.
Source: Author's elaboration based on INDEC.

When using the CPI as the dependent variable in the regression, the result of convergence across the regions of Argentina is repeated. Interestingly, the estimated coefficient is similar to that presented in Table 1. The goodness-of-fit of the model improves significantly compared to the previous case. When estimating equations 2 and 3, a slightly lower convergence rate is observed: 3.5% of the deviations from the mean are eliminated every month and the average life indicator is 19.6 months. This shows that the pace of convergence is higher among goods with greater weight in household spending, such as food and beverages, and included in the TBB than among the overall set of prices in the economy.

A complementary cointegration analysis of the TBB regional series was then conducted. First, the order of integration of the series is analysed and it is observed that all are integrated in order 1; that is, they are not stationary in levels but in first differences. Table 3 presents the results of the Dickey-Fuller test ([ADF], (Dickey–Fuller, 1979) considering a trend component. Alternatively, other specifications were considered obtaining similar results.

Table 3

P-values for price stationarity analysis by region with ADF test

Region	First difference
GBA	0.0177
NEA	0.0073
NOA	0.0053
Cuyo	0.0097
Centro	0.0142
Patagonia	0.0076

Note: the null hypothesis of the ADF test is that the series have a unit root and therefore are non-stationary.
Source: Author's elaboration based on INDEC.

It is observed that all series are stationary in first differences at 5%. Thus, given the evidence that the series have the same order of integration, we proceed with the formal analysis of cointegration following the proposal of Engle and Granger (1987):

Table 4

Cointegration of regional price series in Argentina (2016–2019)

Region	GBA	NEA	NOA	Cuyo	Centro	Patagonia
GBA	--	–3.656**	–3.297*	–3.686**	–3.148	–3.800**
NEA		--	–3.756**	–3.527**	–3.367*	–2.892
NOA			--	–3.785**	–3.172*	–2.967
Cuyo				--	–3.318*	–3.275*
Centro					--	–3.904**
Patagonia						--

Note: the null hypothesis of the cointegration test is that the series are not cointegrated. The critical values of the test are: –4.2 (at 1%), –3.5 (at 5%), and –3.158 (at 10%). Since the matrix is symmetric, the complete matrix is not presented to avoid duplication.
Source: Author's elaboration based on INDEC.

The cointegration hypothesis is maintained for regions of Argentina at 10%. The exceptions are the cases of Greater Buenos Aires-Centro (although with a statistic value very close to the critical value) and Patagonia-NEA/NOA. This is expected considering that Patagonia has the highest price levels, while the provinces of northern Argentina (NEA and NOA) have the lowest prices.

Conclusions

This work has analysed Argentine regional price dynamics between 2016–2019. It was observed that Argentina has wide territorial disparities, which translates into worse living conditions, income, and education, among others in the northern provinces of the country (Noreste and Noroeste regions).

Since 2016, the national institute of statistics (INDEC in Spanish) has published monthly reports on the cost of living in Argentina by region. At the same time, INDEC began to elaborate price indices by regions (previously only a representative index of the Gran Buenos Aires region was calculated). These data allowed compliance with the Law of One Price across Argentine regions to be empirically tested.

First, a formal convergence analysis was carried out considering the cost of living in Argentine regions. The results showed evidence of conditional and absolute β-convergence for the analysed period. The convergence rate was estimated at 3.9% monthly, equivalent to a half-life of the discrepancies of 17.7 months. As a robustness exercise, the previous estimate was reiterated considering the consumer price index (CPI) for Argentine regions. The results were consistent in sustaining the convergence hypothesis, although at a slower rate (estimated speed of 3.5% per month). All of the above suggests compliance with the Law of One Price in Argentina.

Second, the existence of a stable long-term relationship in regional price dynamics was verified. By using the test proposed by Engle and Granger (1987), which allows comparisons to be made between pairs of regions, evidence consistent with the idea of cointegration of the series was obtained. The exception was given by the Patagonia-NEA and Patagonia-NOA pairs, which is expected, given that northern Argentina has the lowest price levels and Patagonia the highest.

In the future, the implications of this price convergence should be analysed in terms of regional poverty disparities. Indeed, in addition to income differences across regions, if prices in the poorest regions increase more rapidly, this implies that poverty disparities are increasing. In the case of Argentina, it was verified that prices are, on average, lower in the poorest regions (the NEA and NOA) and that these tend to converge at some common level with the prices of other regions. On the other hand, and in order to strengthen the results, it is appropriate to extend the period under analysis and, eventually, disaggregate the findings from the subperiods.

Annex

Table 5

Regional fixed effects from equation 1

Region	Coefficient
NEA	–0.0069***
	(0.00108)
NOA	–0.0082***
	(0.00129)
Pampeana	–0.0003***
	(0.00007)
Patagonia	0.0059***
	(0.00094)
Cuyo	–0.0019***
	(0.00030)

Note: * significant at 10%, ** significant at 5%, *** significant at 1%. The Gran Buenos Aires region is the base category.

Source: Author's elaboration based on INDEC.

Table 6

Convergence in prices across regions of Argentina (2016–2019) with quarterly data

	Coefficient
Estimated β	–0.0258**
	(0.01047)
Regional fixed effects	Yes
Time fixed effects	Yes
N	13
R^2 overall	0.18

Note: * significant at 10%, ** significant at 5%, *** significant at 1%. The values of the total basic basket per equivalent adult were averaged per quarter.

Source: Author's elaboration based on INDEC.

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Regional inflation dynamics and its persistence – The case of selected regions in Indonesia

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It is difficult to say whether adopting inflation targeting leads to converged regional inflation rates. This paper observes the dynamics of regional inflation rate in the case of three selected cities (Medan, Jakarta, and Makassar) in Indonesia during the regional autonomy and fiscal decentralisation era. We used monthly inflation rates data between January 2001 and December 2018 to achieve this. We found that there is no significant difference between regional and national inflation rates. However, the inflation rate differences occurs both between-months within a year and between-months across years. The speed of adjustment is found to be unchanged after the adoption of inflation targeting. It seems that inflation targeting fails to reduce the volatility of inflation rates both at the regional and national levels. Since the regional inflation rate is typically generated by supply-side, those results suggest that managing inter-region cooperation in the supply-chain will stabilise and reduce the national inflation rate.

Keywords:
regional inflation,
persistency,
inflation targeting,
speed of adjustment

Introduction

Over the last two decades, inflation targeting (IT) has become the dominant monetary policy regime both in developed and emerging economies (Svensson 1999, 2000, Kocziszky et al. 2018). Following the Asian crisis of 1997–1998, some countries in Asia, like Korea, Thailand, the Philippines and Indonesia, adopted IT. The monetary policy is directed to achieve and maintain inflation at low and stable rates.

While the successful adoption of IT both in both developed and emerging countries for the purpose of maintaining stable inflation rate is well documented, the effectiveness of IT in reducing persistent inflation fluctuations has been inconclusive. The IT that may reduce the persistence of inflation fluctuations is typically derived from aggregate inflation or sectoral inflation rates. However, the opposite conclusion is based on regional inflation data.

The high regional inflation rates contribute to the high persistent national inflation. However, the co-movements and heterogeneity in inflation rates at regional and national levels have not been analysed systematically so far (Beck et al. 2006). This makes it difficult for the monetary authority to address the issue as the characteristics of regional inflation differ from region to region. Accordingly, the implementation of monetary policies in order to address inflation at the national level may be ineffective in the regional context (Mehrotra et al. 2007).

Furthermore, the effectiveness of the response to shocks depends on its persistence on inflation. Inflation persistence is sometimes defined as the tendency of price shocks to push the inflation rate away from its steady-state, including an IT, for a prolonged period. The degree of persistence may have a negative sign meaning that inflation moves in the opposite direction as in the previous period, referring to a correction process. However, over shorter periods, various macroeconomic shocks temporarily move inflation away from its long-run trend. The effects of these shocks on inflation can be persistent and lead to persistent deviations of the level of inflation from its mean representing price stability.

Allocation, stabilisation and distribution are the other regional political-economic issues consistent with fiscal decentralisation. Price stabilisation is a prerequisite achieving equal income distribution across the region. Most developing countries in the world fail to maintain prices (Prud'homme 1995). Moreover, at the early periods of decentralisation, they suffered unequal regional income distribution (Sepulveda–Martinez-Vazquez 2010). Hence, reconsidering issues arising from regional price stabilisation will encourage the central bank in emerging markets to reduce inflation volatility by adopting an active monetary policy.

Recognising the inflation persistence at the regional level is critical. For policymakers, deviations of the inflation rate, the speed of reaction of implementing correction measures, and the output cost of implementation determine the different types of policies. For academics, the underlying dynamics of inflation and how the theory fits the facts are crucial. In developing countries, such persistence would have important policy implications including domestic stabilisation policy, poverty reduction, inequities in wealth distribution and growth, and the development implications thereof (Alagidede et al. 2014).

Indonesia is a good case study for this investigation. In a country as geographically diverse as Indonesia, studying inflation persistence, particularly at the regional level is useful from a monetary policy point of view. The institutional differences among regions may not be fully reflected in aggregate output and inflation trends. Differences in inflation persistence might be reflective of the structural rigidities (Zsibók 2017) that could reduce each region's capacity to adjust to shocks and the corresponding policy responses.

In the context of fiscal policy, since 2001, Indonesia has been transforming itself into the most decentralised country in the world (Alm et al. 2001). Accordingly,

some economic tasks have been devolved to the local governments including price stabilisation. Furthermore, since July 2005, Indonesia has adopted an IT regime. The policies are directed to achieve the goal of monetary policy by stabilising the inflation and the currency exchange rates.

Also, coordinated by the Central Bank of Indonesia, the local governments are involved in the Regional Inflation Controlling Task Force (RITF), to ensure stable and lower regional inflation rates. Inflation is a monetary phenomenon where a demand-pull factor is dominant, while some studies emphasise that the supply side factors influence regional inflation in developing countries (Hossain 1996, Mohanty–Klau 2001, Brodjonegoro 2004, Hakkio 2009).

Local governments have more knowledge and information on the sources and factors of inflation in their respective regions, and they have the authority to allocate fiscal resources and coordinate other resources, including local policies or regulations to support stable and low level inflation. Price stability is part of the local government task in Indonesia in an effort to improve public welfare. Therefore, we analyse the behaviour of the regional dynamics of the inflation rate and its persistence. Lessons from Indonesia, which implemented the IT frameworks ahead of the fiscal decentralisation policy, will be useful to develop a better design of the inflation rates' stabilisation policy for developing countries.

This paper studies the regional dimension of IT; that is, the consequences of IT for regional inflation persistence. Understanding the dynamic patterns of inflation is a crucial issue for modern economies as it impacts economic efficiency and wealth. We focus on Medan (the capital of North Sumatera), Jakarta (the capital of Indonesia), and Makassar (the capital of South Sulawesi) as the case study to understand regional inflation. The remainder of this paper is organised as follows. The next section explores the literature and related empirical studies. The research method is explained in the third section, followed by the results and discussion. Finally, some concluding remarks are drawn.

Literature review

The concern about inflation is usually at the national level while the attention in the regional level is relatively rare. This is because there is no established theoretical framework that considers inflation differences between regions within a country. Therefore, knowledge of regional inflation developments is limited. Nevertheless, existing studies can be classified into two groups. The first is based on the theory of purchasing power parity and the second refers to the hedonic price theory.

The earlier analysis of the regional inflation rate is covered in the price differential proposition. The prominent idea in this regard is the law of one price and purchasing power parity (Rogoff 1996, Krugman–Obstfeld 2000). The conventional demand and supply interaction across the region equalises the price

levels. Accordingly, price levels across the region are relatively equal and, therefore, there is no substantial regional price or inflation rate differential.

Recent economic studies analyse the regional dynamic inflation and price convergence. In this framework, the higher price level regions tend to grow slower than that of the lower price level regions. As in the growth convergence (Barro–Sala-i-Martin 1995), the price levels and inflation rates converge and eventually tend to be equal across the region. The assumption behind these two propositions is free mobility either input or output which are rarely met in the real world.

Another strand of literature tries to explain why price convergence does not take place. Price disparity might be associated with the rigidities in wages or exchange rates (Becker 2011). Any factor that prevents the nominal exchange rates and wages from adjusting in response to an economic shock could be a reason for inflation differentials (Becker 2011). Finally, asymmetric economic shocks can change either the demand or the supply conditions in different countries and can cause dispersed price movements (Weber 2004, Tunay–Silpagar 2007).

The divergence of prices could be related to the hedonic price theory. The hedonic price theory proposes that certain socio-economic regional characteristics form the prices in a region. It means that prices represent the value of quality. Different regions have their socio-economic characteristics. Consequently, price differentials exist. Consistent with regionalism and globalisation in the last two decades, the theory of the hedonic prices has become a popular mathod to explain regional inflation rate differentials worldwide.

The Balassa-Samuelson effect is another way to study regional inflation differences (Balassa 1964, Samuelson 1964). It suggests that an increase in wages in the tradable goods sector of an emerging region leads to higher wages in the non-tradable (service) sector of the economy. The accompanying increase in prices makes inflation rates higher in faster-growing regions than in slow-growing or developed regions. It implies that the optimal rate of inflation will be higher for developing regions as they grow and raise their productivity.

Furthermore, the idea of an optimal currency area (Mundell 1961) can be adopted to explain the regional inflation dynamics. The theory speculates that there is an optimum geopolitical area which should share a currency. An integrated labour market allows workers to move freely throughout the area and smooth out unemployment in any single zone. The flexibility of pricing and wages, along with the mobility of capital, would eliminate regional trade imbalances. The wealthy parts of the region may wish to distribute their surpluses among those that have no such oversupplies. As a result, regional price differences converge.

Recent studies have been directed to discuss these issues. Beck, Hubrich, and Marcellino (2006) observed the regional inflation dynamics within the euro area and the US. They found that the disaggregate regional inflation information, summarised by the area-wide factors is important in explaining aggregate euro area and US

inflation rates, even after conditioning on macroeconomic variables. Therefore, monitoring regional inflation rates within the euro area provides relevant additional information for the monetary policymakers.

Vaona (2008) and Vaona and Ascari (2012) considered a sample of 70 Italian regions in a single country. The two studies go beyond the assumption that there exists a unique core inflationary process in a macro-economy. They show that the local long-run inflation rates can display remarkable variability. On the one hand, they are negatively correlated with productivity growth. On the other hand, the less competitive is the local retail sector, the higher is a long-run inflation.

In the case of emerging countries, Tillmann (2013) based on data for Korean cities and provinces showed that the adoption of IT leads to (i) a fall in inflation persistence at the regional level; and (ii) a reduction in the cross-regional heterogeneity in inflation persistence. A factor model lends further support to the role of the common component and the monetary policy for regional inflation persistence.

Danvee and Basilio (2009) analysed the regional inflation persistence in the Philippines using uni-variate models of inflation as well as panel unit-root tests and applied these tests to regional headline inflation between 1989 and 2008. They found that inflation in the individual regions reverts to the long-run path after a shock. The regional inflation rates tend to converge toward the cross-sectional mean in the long run except during periods of generalised shocks. In such cases, underlying cross-sectional factors (e.g., geography, income development, among others) could be playing an important role in the regions' inflation processes. They also found that food price inflation appears to have a relatively lesser persistence.

In the case of India, Kundu, Kishore, and Bhoi (2018) reveals the presence of wide dispersion in inflation across states, largely driven by food price inflation. State-level inflation tends to converge with the national average over time. However, it validates the choice of national-level consumer price inflation as the nominal anchor for monetary policy in India. These findings underpin the choice of the national-level consumer price index inflation as the nominal anchor under India's flexible IT framework.

In the case of Indonesia, Arimurti and Trisnanto (2011) measured the persistence of inflation level in Jakarta. Their study intended to find out the source of inflation persistence and its implication on regional inflation control. The analysis of regional inflation behaviour is explored at the commodities level. The empirical result indicates that the level of inflation persistence in Jakarta is relatively high, and stems from a high level of inflation persistence for most of the commodities that construct inflation. Their study is consistent with Winkelried and Gutierrez (2015) who studies the case of Lima, Peru.

Tirtosuharto and Adiwilaga (2013) conducted an empirical analysis to determine the effect of decentralisation on regional inflation in Indonesia and whether

institutions play a role in the recent downward trend of inflation in Indonesia as a whole. A panel data that includes 33 observations of the Indonesian regions (provinces) is constructed with a dummy variable representing the existence of an institution. In addition this study analyses whether decentralisation supports the convergence in regional inflation and also the pattern of spatial correlation in regional inflation. This paper finds that decentralisation has an impact on regional inflation in Indonesia, where an increase in the degree of fiscal decentralisation also increases the volatility of regional inflation.

Kusuma (2013) employed disaggregated data on inflation combined with Factor Augmented Vector Auto Regression to explore the price behaviour in Indonesia. The main finding of this analysis is that price behaviour in Indonesia exhibits heterogeneity. This is evident not only in terms of the magnitude but also in the direction and the speed of adjustment to the new equilibrium in response to interest rate shock. Price volatility is mainly related to sector-specific shocks instead of macroeconomic shocks. Another finding is that price puzzle weakens once IT framework is adopted.

Purwono, Tasin, and Mubin (2020) investigated the inflation convergence of 82 Indonesian cities and discussed the remarkable regional inflation programmes in Indonesia. By employing a dynamic panel data regression, they show that Indonesia experienced an inflation convergence from 2013 to 2018. An intriguing finding is that the cities in Java-Bali, the densest area, experienced a slower speed of convergence than that in cities outside the Java-Bali.

Based on the above empirical studies, the link between regionalism and decentralisation with inflation as one of the key aspects of macroeconomic stability is generally inconclusive. However, decentralisation correlates with lower inflation in developed countries and vice versa. Its correlation with higher inflation in developing countries has received conventional wisdom. Hence, the remaining issues to be considered are as follows. First, the most common measure of inflation persistence suggested in the literature is based on a uni-variate time-series model that assumes an auto-regressive process. Second, inflation persistence that is measured as the sum of the autoregressive coefficients is time varying. Third, the performance of the expected inflation rates, i.e. backward- or forward-looking behaviour types. Forth, the time perspective has to be covered.

Our study deals primarily with the last issue. We contribute to the literature in three aspects. First, unlike other studies that draw a comparison between regions within the country, our regional analysis is related to the national inflation rates. Regional inflation rates in general are poorly synchronised with national inflation rates (Hakkio 2009, Ciccarelli–Mojon, 2010, Auer et al. 2017). Second, the study will use analysis of variance (ANOVA) to evaluate the dynamics of regional inflation rates from an inter-month and inter-year perspective in the regional autonomy and fiscal decentralisation era. We also compare them in the pre- and post-IT adoption.

Third, our study uses a city instead of a province as the unit of analysis. The use of the smallest administrative area in calculating inflation reduces the aggregation bias.

Research method

ANOVA is used to investigate whether there is a mean difference between three or more population groups. Here, we use a two-way ANOVA because we analyse two factors, within-variation and between-variation. Variance is the squared differences of values and its averages, which is derived from the differences of total average and column or row average. The first variance is the total sum of squares (SST). The second variance is the sum of square columns (SSC) and the sum of square rows (SSR). The differences between each value and its total mean value ($\bar{X}$) squared, give us the SST.

$$SST = \sum_{i=1}^{a}\sum_{j=1}^{b}\left(X_{ij} - \bar{X}\right)^2 \tag{1}$$

Through the differences between each column values and the mean of that column ($\bar{X}_i$), we obtain SSC, and the same logic is applied to obtain the SSR ($\bar{X}_j$).

$$SSC = a\sum_{i=1}^{a}(\bar{X}_i - \bar{X})^2 \tag{2}$$

Therefore, the sum of the square error (SSE) is the difference between SST and the two variances obtained.

$$\text{SSE} = \text{SST} - \text{SSC} - \text{SSR} \tag{3}$$

Each variance value must be corrected by its degree of freedom. The SST value is divided by N–1, the SSC value is divided by (a–1), and SSR value is divided by (b–1), and SSE value is divided by [(a–1)x(b–1)]. At this stage, ANOVA is run by comparing column and row variances with undefined variances:

$$Fstat(1) = \frac{SSC\ /\ (a-1)}{SSE\ /\ [(a-1)x(b-1)]} \tag{4a}$$

$$Fstat(2) = \frac{SSR\ /\ (b-1)}{SSE\ /\ [(a-1)x(b-1)]} \tag{4b}$$

N = number of data; a = number of columns; b = number of rows

The inequality of differences in the time frame, monetary regime, and unit analysis are evaluated by using multivariate analysis of variance (MANOVA). MANOVA is simply an ANOVA with several dependent variables. Thus, ANOVA tests for the difference in means between two or more groups, while MANOVA tests for the difference in two or more vectors of means.

MANOVA can be used to investigate the dimensions on which the groups differ. Next, we examine the effects of independent variables (IV) across several dependent measures. MANOVA can be used to examine all the DVs at the same

time. Additionally, MANOVA controls Type 1 error (the probability of rejecting the null hypothesis when it is true) across all the DVs in the model.

The generic model of MANOVA can be written as:

$$X_{ij} = \mu + \tau_i + \varepsilon_{ij} \quad (5)$$

where X is the vector of observation, μ is the mean, τ is the treatment, and ε is the error term for i = 1, 2, 3, …, n and j = 1, 2, 3, …, m.

The vector of observation can be decomposed once again as follows:

$$X_{ij} = \bar{X} + (\bar{X}_i - \bar{X}) + (\bar{X}_{ij} - \bar{X}_i) \quad (6)$$

where the first term on the right-hand side is the grand mean, the second term is the effect of treatment, and the last is the residual.

A multivariate analysis of variance tests the null hypothesis against the alternative hypothesis:

$$H_0 : \tau_1 = \tau_2 = \cdots = \tau_k = 0 \quad (7a)$$

$$H_a : \tau_1 \neq \tau_2 \neq \cdots \neq \tau_k \neq 0 \quad (7b)$$

Instead of a uni-variate F value, we obtain a multivariate F value (Wilks' λ) based on a comparison of the error and the effect variance or covariance matrices. Other statistics may be used, including Hotelling's trace, Pillai-Bartlet's criterion, and Roy's largest root.

Unlike multiple ANOVA, MANOVA accounts for the co-variances of the other dependent variables, which could increase statistical power. Thus, MANOVA has the potential to be a more powerful test than uni-variate ANOVA because it considers both the variances and covariances of the dependent measures.

The 'co-variance' is included here because the two measures are probably correlated and we must consider this correlation when performing the significance test. Testing the multiple dependent variables is accomplished by creating new dependent variables that maximise group differences. These artificial dependent variables are linear combinations of the measured dependent variables.

The general assumptions for MANOVA design are (1) independence of subject responses in each between-subjects condition; (2) multivariate normal dependent measures in the population; and (3) equality of population variance-covariance matrices in groups defined by between-subjects factors. Additionally, the multivariate approach to repeated measures does not require the sphericity assumption (Tabachnick–Fidell 2007).

Neither ANOVA nor MANOVA can identify the degree of persistence. The inflation persistence and speed of adjustment are measured by testing using a uni-variate approach. The uni-variate auto-regression process is represented as follows:

$$P_t = \alpha + P_{t-1} + \varepsilon_t \quad (8)$$

where P = consumer price index and ε = random disturbance error term.

$$Z_t \equiv Inf_t = \frac{P_t}{P_t - P_{t-1}} \approx \Delta \log P_t \quad (9a)$$

$$Z_t = \alpha + \sum_{1}^{j} \beta_j Z_{t-j} + \epsilon_t \tag{9b}$$

where Z = inflation series at time t (measured as month-on-month growth of consumer price index) and ϵ = random disturbance error term.

To observe the degree of persistence in terms of the sum of AR coefficients, equation (9) may be re-written as

$$Z_t = \alpha + \rho Z_{t-1} + \sum_{1}^{j} \beta_j \Delta Z_{t-j} + \epsilon_t \tag{10}$$

The persistence parameter τ of an inflation time series is computed as the sum of the coefficients from the estimated uni-variate AR(k) time series model. It is interpreted as the speed with which inflation goes back to its equilibrium value after a shock. To reiterate, it represents the time it takes to fully dissipate the effect of a one percent rise in inflation due to a shock. Similarly, equation (10) may be expressed in a different form

$$\Delta Z_t = \alpha + \phi Z_{t-1} + \sum_{1}^{j} \beta_j \Delta Z_{t-j} + \epsilon_t \tag{11}$$

which is a basic ADF specification to test for the presence of a unit-roots and where $\phi = (\rho - 1)$.

The ADF procedure tests the null hypothesis that the process has a unit-root (ρ=1). When ρ=1, the inflation series is a random walk, non-stationarity, and therefore highly persistent because of the autocorrelation with its lags. Shocks will tend to have long-lasting effects on the behaviour of the series and may take a long time to converge back to its long-run equilibrium or may even diverge from its long-run path permanently.

Willis (2003) defines ρ as the speed with which inflation returns to baseline after a deviation. The intuition behind this is that if ρ is relatively high (close to unity), during high inflationary regimes inflation will be stubbornly high, while during periods of low inflation, a highly persistent inflation time series will result in consistently low values of inflation (Vladova–Pachedjiev 2008, Dossche–Everaert 2005, Vaona–Ascari 2012).

However, if the absolute value of the parameter ρ is less than 1, then the inflation series is broadly stationarity and returns to its mean. If ρ is close to 0, the speed of adjustment of the inflation series to its long-run trend is high. Dossche and Everaert (2005) notes that for values ρ=0.5 and below, the inflation series is considered to have a relatively low persistence. Járosi (2017) suggests the use of spatial econometric methods to neutralise all the previously discussed bias sources.

We cannot adopt spatial econometrics since the three regions in our study are geographically far from each other. The appropriate choice of lag length is crucial for the ADF tests, as using different information criteria produces varying lag lengths which heavily influences the behaviour of the point estimate for ρ. Vladova

and Pachedjiev (2008) suggest that an ADF test can be conducted with an automatic selection of lag length (e.g., Akaike information criteria or Schwartz information criteria).

It is noteworthy that persistence cannot be measured without knowledge of the long-run path of a stationarity inflation time series, represented by the mean. As pointed out by Alberola and Marques (2000) and Marques (2004), deviations from this long-run path provide the basis for evaluating the persistence of a series. Thus, to gauge the behaviour of a region's inflation in response to a shock, we must know the path inflation would have taken had the shocks not occurred.

Observing the long-run path reveals that changes in the mean are common due to structural breaks (i.e., change in monetary policy regime, significant events). Failing to account for changes in the mean of the series could produce biased estimates of ρ. Hence, assuming a constant mean implies that the series is insensitive to structural changes in the mean of inflation or to possible changes in the persistence parameter itself. Spatial imteractions and spillover effects also determine the magnitude of convergence speed (Tánczos–Egri 2018).

Empirical results

The procedures outlined in the previous section are applied to test the inflation rates using national and regional level data. The regional data cover Medan, Makassar, and Jakarta (as explored by Arimurti–Trisnanto 2011), each chosen to represent western, eastern, and the capital regions of Indonesia, respectively. Both Medan and Makassar provinces have the highest non-oil and gas GDP contributions and are the most developing regions outside Java (BPS 2019). Jakarta is the nation's capital. Different from Purwono, Yasin, and Mubin (2020) who used all 82 cities in the panel to analyse price convergence, we use only three prominent regions to assess the price convergence in each city. Eventually, they are expected to explain the fluctuation of the inflation rate at the national level.

The chosen dimensions on which groups differ is month-year, respectively. This study captures data on monthly inflation rates from January 2001 to December 2018. The January 2001 period is set as the beginning of observation related to the implementation of regional authonomy and fiscal decetralisation policy. The total observations include 216 sample points for each region. The inflation rates are based on the relative changes in monthly consumer price index comprising hundreds of goods and services. They are stated in percentage. All of the data are taken from the Central Agency of Statistics.

Table 1 summarises the inflation rates in the three selected cities in Indonesia. Overall, the average monthly inflation rate in Medan (0.58) is the highest among the three cities, even at the national level (0.55). Its volatility, represented by the

coefficient of variance (CV) – standard deviation to mean ratio – is also the highest (1.9382 compared to 1.4305 as a benchmark).

When we divide them into pre- and post-IT adoption, the conclusion is the same. The average mean inflation rates are lower but are more volatile. Given this analysis, we infer that IT adoption is successful in reducing the magnitude of regional inflation rates, unlike the result of the study by Kusuma (2013). This is further detailed using statistical devices.

Table 1

Statistic descriptive of inflation rates, January 2001 to December 2018

	Medan	Jakarta	Makassar	Indonesia
Mean	0.5862	0.5319	0.5382	0.5517
Median	0.4950	0.3900	0.4100	0.4350
Maximum	11.8900	7.9300	9.4400	8.7000
Minimum	–1.3600	–0.4100	–1.7400	–0.4500
Std. Dev.	1.1361	0.7340	0.9937	0.7892
CV	1.9382	1.3798	1.8463	1.4305
Skewness	4.6650	5.3294	3.6214	5.5531
Kurtosis	46.7058	50.1625	31.7347	54.5817
Observations	216	216	216	216

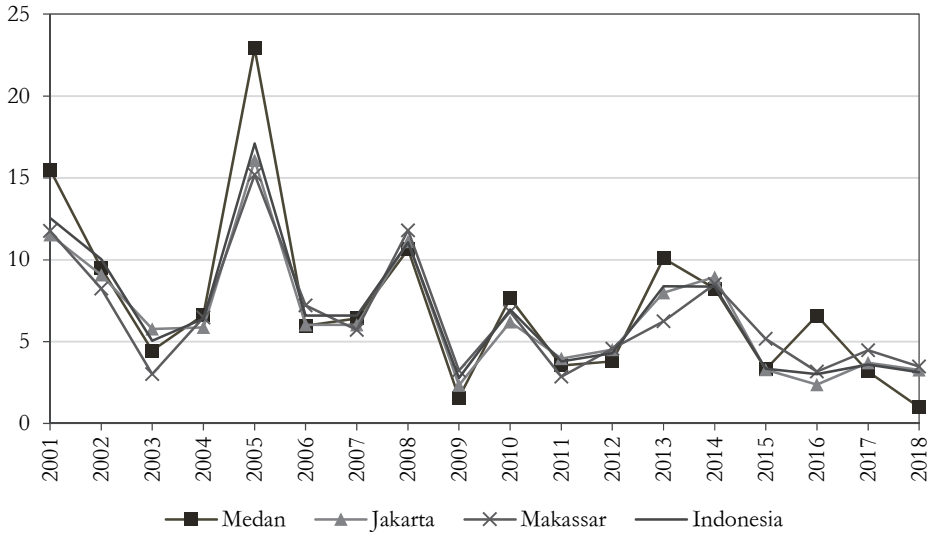
Source: Central Agency of Statistics (processed).

Does the regional monthly inflation rate performance apply for annual aggregation? Figure 1 presents the configuration of annual inflation rates in three selected cities and the national level over the last decade. It is observed that regional and national inflation rates are not far enough from each other, although the year 2005 is an exception. The annual inflation rate differential is substantial primarily in Medan. After the steep increase in oil prices, the inflation rate was remarkably high. Thus, we can say that the regional inflation rate is more sensitive to economic shocks than that of the national level.

It is noted that there is no significant difference in inflation rates between pre- and post-IT adoption. The pattern is highly synchronised implying that the three inflation rates are close to each other. The coefficient of correlation is high, 0.88 is the average. Again, it seems that the IT adoption has not yet stabilised the prices fluctuation both at regional and national levels.

Figure 1

Annual inflation rates in the three selected regions and Indonesia



Source: Central Agency of Statistics.

Table 2 presents the correlation matrix of the regional monthly inflation rates among three regions and the national level. The correlation coefficient between Jakarta and Indonesia is the highest both in the pre- and post-IT (0.92 and 0.96 respectively). It means that the inflation rate fluctuation in Jakarta is the most representative on the national level. Therefore, paying more attention to Jakarta is necessary in order to maintain the national inflation rate. This finding is consistent with Arimurti and Trisnanto (2011) and Winkelried and Gutierrez (2015). This evidence supports the view that by targeting Jakarta's inflation, the central bank has effectively, albeit indirectly, targeted national inflation.

Table 2

Correlation matrix of inflation rates
Pre- and post-IT

	Medan	Jakarta	Makassar	Indonesia
Medan	1.0000	0.8167	0.7434	0.8800
Jakarta	0.6091	1.0000	0.8495	0.9688
Makassar	0.5572	0.6958	1.0000	0.8931
Indonesia	0.7517	0.9273	0.7795	1.0000

Note: the highlighted cells show the coefficient of correlation for the post-IT.

Table 3 breaks down the comparison of the regional monthly inflation rates for each year and month. By employing the two-way analysis of variance, the test

proves that there is no significant difference in monthly inflation rates across regions and among subnational and national regions. These results are consistent with the correlation matrix, as presented in Table 2, since the coefficient of correlation is stronger for all cases.

In contrast, the difference in monthly inflation rates across the month is statistically significant at 1 per cent confidence level. Similarly, the difference in monthly inflation rates across the year exists at the same confidence level. These findings are consistent with the graph presented in Figure 1. The difference in monthly inflation rates may be attributed to the difference in seasonal inflation in each region over a year. Similar patterns are found for inflation rates across a year per economic cycles.

Table 3

Two way analysis of variance inflation rate in three selected cities and Indonesia, January 2001 to December 2018

Tests of between-subjects effects					
Source		df	Mean square	F	Sig.
Region	Hypothesis	1	38.94	1.514	0.219
	Error	431	25.71		
State	Hypothesis	1	4.98	0.188	0.668
	Error	26,717	26.42		
Month	Hypothesis	11	412.09	3.994	0.000
	Error	59,716	103.19		
Year	Hypothesis	17	216.87	2.370	0.005
	Error	88,393	91.50		

The two-way ANOVA cannot incorporate additional attribute IT as it is limited for two dimensions only. Table 4 and 5 comprehensively compares the regional and national monthly inflation rates data using multivariate analysis of variance with the IT regime as a covariate. We infer that a significant difference in monthly inflation rates across the month and the year exist at both the regional and national levels. It holds for all types of tests, including Wilks, Hotelling, Pillai-Bartlet, and Roy criterion, thus supports the previous analysis.

Advanced analysis of the IT regime gives a different conclusion. As displayed in Table 5, the IT adoption does not differ across the monthly inflation rate both at the regional and the national level. The exception is applied in the case of Medan. In the latter, the monthly inflation rates across a month substantially differ over a year. The highest mean value of monthly inflation rate and CV in Medan, as explained in Table 1, could be a explanation.

Table 4

Multivariate analysis of variance of inflation rate in three selected cities and Indonesia, January 2001 to December 2018

Multivariate tests						
Effect		Value	F	Hypothesis	Error	Sig.
Month	Pillai's Trace	0.072	4.082	4.00	209.00	0.003
	Wilks' Lambda	0.928	4.082	4.00	209.00	0.003
	Hotelling's Trace	0.078	4.082	4.00	209.00	0.003
	Roy's Largest Root	0.078	4.082	4.00	209.00	0.003
Year	Pillai's Trace	0.046	2.542	4.00	209.00	0.041
	Wilks' Lambda	0.954	2.542	4.00	209.00	0.041
	Hotelling's Trace	0.049	2.542	4.00	209.00	0.041
	Roy's Largest Root	0.049	2.542	4.00	209.00	0.041
IT	Pillai's Trace	0.019	0.996	4.00	209.00	0.411
	Wilks' Lambda	0.981	0.996	4.00	209.00	0.411
	Hotelling's Trace	0.019	0.996	4.00	209.00	0.411
	Roy's Largest Root	0.019	0.996	4.00	209.00	0.411

Table 5

Multivariate analysis of variance of month-year inflation rate in three selected cities and Indonesia, January 2001 to December 2018

Tests of between-subjects effects						
Source	Dependent Variable	Type III Sum of squares	df	Mean square	F	Sig.
Month	Medan	985.00	1	985.00	8.233	0.005
	Jakarta	40.03	1	40.03	0.767	0.382
	Makassar	22.49	1	22.49	0.244	0.622
	Indonesia	80.33	1	80.33	2.712	0.101
Year	Medan	770.69	1	770.69	6.441	0.012
	Jakarta	478.97	1	478.97	9.184	0.003
	Makassar	469.76	1	469.76	5.106	0.025
	Indonesia	211.14	1	211.14	7.130	0.008
IT	Medan	197.51	1	197.51	1.651	0.200
	Jakarta	118.61	1	118.61	2.274	0.133
	Makassar	356.29	1	356.29	3.873	0.050
	Indonesia	20.96	1	20.96	0.708	0.401

We found that statistically there is no significant difference in monthly inflation rates in the period of pre- and post-IT adoption. These results confirm the previous analysis that the monetary policy is only effective on the national scope. In the lower layers, in this case sub-national, the monetary policy would be ineffective unless some specific aspects embodied in each region are considered. Therefore, to

solve these issues, a strong commitment from the leaders of these regions and the availability of accurate data are the necessities for exploring cooperation between regions.

As the regional inflation rates are typically generated by supply-side (Tirtosuharto–Adiwilaga 2013), the leaders of the regions need four strategic measures to maintain regional control or the '4K' (in Indonesian: *Ketersediaan, Keterjangkauan, Kelancaran, Komunikasi*), namely supply availability, price affordability, distribution smoothness, and expectation communication (Governor of Bank Indonesia 2014). Accordingly, certain institutional aspects reduce the disparity of regional inflation. Thus, monetary methods alone were ineffective in controlling inflation and recommendations were made for improving regional anti-inflationary policies.

Next, we focus on the time series properties of each series. Each series is examined twice using ADF unit-roots test for pre- and post-IT regimes to ensure that all of the components are stationarity. We assume that the underlying data are non-stationarity. Both tests conclude that all the variables are not entirely stationarity in their level. Hence, the ADF tests are applied again to the transformed series of each variable to check for the possibility of stationarity in the first differences.

The results concerning the stationarity of the variable of interest are reported in Table 6. The tests confirm the stationarity of all series on the first difference. In other words, in the first-difference forms, all the variables become stationarity. Overall, the structural break arosed around the year 2005 when the oil prices were increased by the government to repress the fiscal burden on the energy subsidy.

Table 6

Unit-roots tests

	Pre-IT		Post-IT		Total	
	Coeff.	Breakpoint	Coeff.	Breakpoint	Coeff.	Breakpoint
Medan	–6.7838	2002M03	–9.1376	2007M01	–12.5699	2005M10
Jakarta	–5.5715	2002M04	–10.6336	2014M12	–12.0525	2005M10
Makassar	–7.8763	2002M02	–10.4877	2006M11	–11.4231	2005M10
Indonesia	–5.4556	2002M02	–8.8270	2008M09	–11.4154	2005M10

The null hypotheses of non-stationarity can be rejected, which does not demonstrate the existence of a trend in the series. All the variables were found to be stationarity at 1 percent significance level implying that the series data have unit-roots and the behaviour of the variables fluctuates around the mean value and are invariant overtime (Enders 2004). The occurrence of unit-roots in the series gives a preliminary indication of shocks having a permanent or long-lasting effect, thus making it difficult for traditional stabilisation policies to survive.

Table 7 reports the ordinary least squares (OLS) estimation results of the four models specified in the previous section. We start with the simple model directly connecting the growth rates of consumer price index (CPI) and the past value based on the Akaike and Schwartz information criteria. In the period of pre-IT adoption, the corresponding coefficient is insignificant in the case of Makassar, i.e. random walk phenomenon, suggesting dynamic instability. In other cases, the coefficient is statistically significant at the 1 percent confidence level. They suggest that past inflation rates adjust to the current inflation rate up to approximately 76–92 percent.

Estimation of the same model for the period of post-IT adoption offers similar coefficients. The speed of adjustment, in general, is slightly higher, except in the case of Medan. However, this test speed of adjustment in all cases is high, about 80 percent, to achieve the intended rate of inflation. This supports the result supplied by ANOVA. We infer that IT adoption successfully reduces the magnitude of the regional inflation rates instead of its volatility.

During the period of observation, the inflation persistence, considered as a measure of the degree of dependence on the current behaviour based on the past developments, ranges from 0.14 to 0.24, implying that only 14 to 24 percent is partial-adjusted. The higher coefficient of the speed of adjustment for Makassar and Medan support Purwono, Yasin, and Mubin (2020). In other words, the regional inflation rate tends to be less persistent than the national data. This result supports the conventional wisdom that national inflation data is less persistent than the regional data.

Our findings of the low inflation persistence are similar to the findings of Kundu, Kishore, and Bhoi (2018). However, our study challenges Tillmann (2013). The empirical results in Table 7 show that the adoption of IT does not lead to a reduction in the cross-regional heterogeneity in inflation persistence. The underlying cross-sectional factors (e.g. geography, income development among others) could insignificantly influence the different regions' inflation processes, which confirm the results of multivariate ANOVA above.

Table 7

Estimation results of speed of adjustment

	Pre-IT	Post-IT	Total
Medan	0.9474	0.8323	0.8515
Jakarta	0.7499	0.8313	0.8104
Makassar	–	0.8870	0.9219
Indonesia	0.7347	0.7721	0.7590

Note: All coefficients are significant at 99 percent confidence level.

Robustness check

Furthermore, the lagged dependent variable in the estimation model is not entirely significant, indicating that our estimated inflation rate model is not well specified. Next, it is necessary to check the stability of the inflation rate function, as it is necessary for an effective monetary policy. Therefore, it has to be tested whether the estimated inflation rate equation has shifted over time.

Moreover, the estimation results presented in Table 7, primarily in Makassar violate some classical assumptions. Re-estimating the basic model using OLS with breakpoints suggests that structural break exists around the mid-2000s, as found in the unit-roots test. Besides the OLS estimators are sensitive to the presence of observations that lie outside the norm of the regression model of interest.

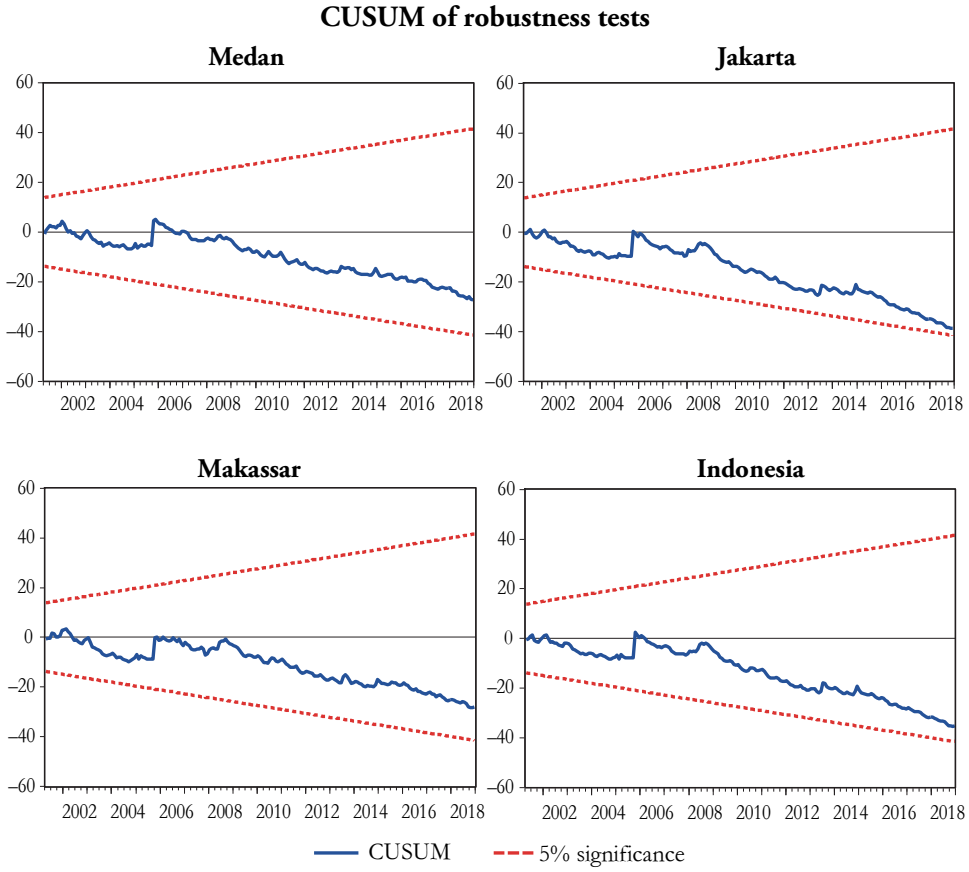
The sensitivity of conventional regression methods to these outlier observations may result in coefficient estimates that do not accurately reflect the underlying statistical relationship. Altissimo, Ehrmann, and Smets (2006) distinguished three basic sources of inflation persistence: one that is inherited from persistent fluctuations in the determinants of inflation (extrinsic persistence); the dependence of inflation on its past (intrinsic persistence); and persistence due to the formation of inflation expectations (expectations-based persistence). Therefore, it is necessary to conduct robustness tests.

We use the cumulative sum (CUSUM) tests as a measure of robustness measure for empirical results, to test for the stability of the model. CUSUM stands for cumulative summation of recursive residual generated by the regression equation. If the CUSUM values are within the tolerated lower and upper bands, the regression function is said to have a constancy of parameter regression.

As shown in Figure 2, CUSUM falls within the 95 percent confidence band, which verifies the stability of estimated parameters in all cases, meaning that they do not change overtime. Overall, the three regional and the national inflation rates have a stable function further implying that it can be used for prediction and policy simulation purposes.

Another robustness approach is by including a dummy variable for the global financial crisis (Delbianco et al. 2019) in the models as a control variable for external shocks. It is noted that this does not affect the magnitude and significance of our estimators, indicating the earlier models encompasses to the current models. However, comparing the pre- and post-IT regime, the results support the presence of failure effects of IT on the volatility of the inflation rates reduction in the fiscal decentralisation era.

Figure 2



Concluding remarks

The main objective of this paper is to identify the regional inflation persistence and the speed of adjustment in the case of three selected cities and the country as a whole. This research is motivated by the empirical result that the IT adoption can reduce the persistence of inflation fluctuations, it is derived from aggregate inflation or sectoral inflation rates. However, the opposite conclusion is based on regional inflation data.

Unlike other studies, we compare them in the pre- and post-IT adoption with July 2005 as the breaking time. We also compare them to the national level. In this study, we used monthly inflation data from January 2001 to December 2018 published by the Central Agency of Statistics. Using the analysis of variance, we found that the monthly inflation rates in Medan, Jakarta, Makassar, and Indonesia vary within a month but are stable over the year. Employing standard time series

econometric procedures, we found that there is low inflation rate persistence and therefore a high speed of adjustment. The speed of adjustment is found to be slightly higher in the post-IT adoption.

However, the stability tests of the parameter constancy present that there is no significant difference between the pre- and post-IT adoption. It implies that IT adoption has not yet changed the inflation persistence neither at national nor sub-national levels, suggesting weak coordination among the monetary authority, the fiscal authority, the RITF, and regions (local governments) in controlling regional price levels. This indicates that the local authority must focus on the short-term regional price fluctuations, while the monetary authority should be concerned with the long-term national price fluctuations. Therefore, the economic policy should consider the local wisdom to overtake related problems. Accordingly, a common inflation rate cannot be achieved uniformly for each region. As the regional inflation rate is typically generated by supply-side, the results suggest that managing inter-region cooperation in the supply-chain will foster stability and reduce the national inflation rate. Indeed, price level stabilisation in the regional autonomy and fiscal decentralisation era is one of the greatest obstacles for any economy in the world.

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Outlining the historical framework of the aviation sector in Turkey: A spatiotemporal approach

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The fast-growing, capital-intensive, and fragile structure of air transport makes the aviation sector crucial for national economic growth and regional development. Over a century old, Turkey's aviation sector has undergone a remarkable transition from a state-regulated market to a liberal, competitive one. This fundamental change has created an urgent need to quantitatively outline the historical and contextual framework of Turkey's air transport network in order to grasp its structural dynamics and thus obtain insights into the drivers of regional and air transport development. This paper uses time-series analysis to outline the historical framework of the aviation sector in Turkey based on air traffic and spatiotemporal data at the national and regional levels. The aim is to detect outlier changes in the historical air transport timeframe at both the national and regional levels and to define discrete periods in the history of Turkey's aviation sector. The results, discussed through the prism of transport policy and regional economies, provide structural insights into the dynamics of the Turkish aviation market. The findings reveal that the periods derived from the time-series analyses are consistent with the major changes discussed in the literature.

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Introduction

The aviation sector comprises an ecosystem of air transport-related service providers, such as airline companies, maintenance services, ground services, and airports. The evolution of the aviation sector in many countries has been driven by the power of neo-liberalisation, the transformation from state regulation to market-driven development (Palley 2005, Saad-Filho–Johnston 2005, Friedman 2009). The socioeconomic and political framework of this transformation has been the subject of many analyses focused on the United States (Button 1989), Europe (Button 1996, Barrett 2000), Australia, India (Hooper 1998), China (Wand et al. 2016), the UK, Spain (Lucio et al. 2001), Hungary (Béres et al. 2019), and Turkey (Cetin–Benk 2011). Neoliberal policies are driven by the forces of the free-market economy and privatisation (Polyani 1944). Under the policies, the state does not have a significant regulatory role but sometimes participates as an actor in the aviation market (Palley 2005, Friedman 2009).

In Turkey, aviation has become a dynamic, innovative, adaptive, and fast-growing sector, with an increasing share in both domestic and international air-transport demand and supply (Logothetis–Miyoshi 2018). Turkey's aviation market has been called 'successful' and part of the nation's 'soft power' (Selcuk 2013, Anaz–Akman 2017). Aviation activities in Turkey started in the 1900s with the construction of two hangars and a small runway in Istanbul. Today, Turkish Airlines (THY) is one of the fastest-growing airline companies in Europe, and Istanbul Airport is one of the biggest airports in the world (Erdem et al. 2019).

The deregulation of economy of Turkey and the privatisation of its state-owned enterprises (e.g. factories, refineries, roads, harbours) have accelerated the growth of the national economy and have helped restructure it according to liberalisation norms (Karaevli–Yurtoglu 2018).

According to the World Bank (2018), the Turkish economy is ranked 17th worldwide, with annual growth of about 6.7% on average. Since 2003, the Turkish aviation sector has grown at an annual rate of about 8.2% (Cetin–Benk 2011), and a growth of 10% is expected for 2020 (Georgieva et al. 2015). According to the International Civil Aviation Organization (ICAO 2017), Turkey is ranked 11th worldwide and 5th in Europe in the number of airline passengers. Moreover, the geopolitical location of Turkey is very important, because it is located at the meeting point of Europe and Asia.

Turkey's aviation sector is thus a unique case, and examining it can foster a better understanding of the forces underlying the 'market–state dichotomy' (Bruff 2011) and of their economic and political aspects (Boratav 2008, Pamuk 2014, Togan 2016). However, this sector has not been sufficiently studied. A large portion of the research – including Pamuk (2014), Togan (2016), Tekeli (2009), and Eraydın (2006) – have focused on the economic aspects of the transformation in Turkey, especially on the

restructuring of the market in accordance with neoliberal policies. Further research is needed into the political, geographical, and socioeconomic configuration of Turkey's aviation sector. Thus, this study quantitatively outlines the historical framework of the air transport network in Turkey (TAN) using air traffic time data at both the national and regional levels to detect outlier changes in the historical air transport timeframe and identify milestones in the sector's history. This assessment can help us to understand the discrete periods in the history of Turkish aviation and lead to a deeper understanding of the dynamics driving the national and regional aviation markets in the country.

The remainder of this paper is organised as follows. Section 2 describes the methodological framework and data used by the study. Section 3 presents the results of the analysis concerning the configuration of the time periods in the long-term history of the aviation sector in Turkey. These time periods are then discussed and evaluated in Section 4. Finally, Section 5 concludes the paper.

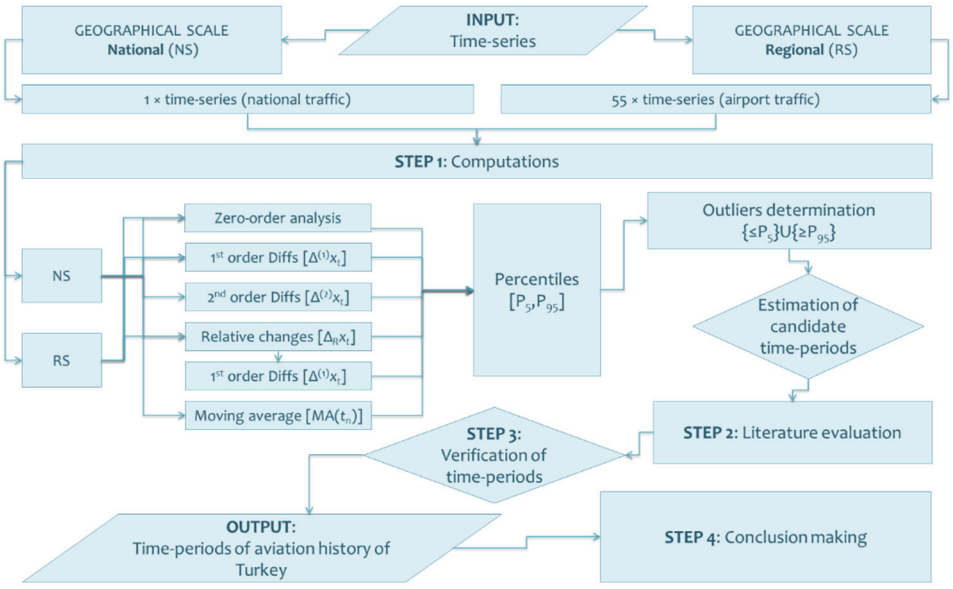
Methodology and Data

The methodological framework of the study is based on time-series analysis (TSA). A time-series dataset can be considered as a vector **x** of successive real (P) data $\mathbf{x} = (x_1, x_2, \ldots, x_n)$, which is arranged into time order $t(x_1)<t(x_1)<\ldots<t(x_n)$ and illustrates the temporal evolution of an attribute X expressed by the vector-variable $X = \mathbf{x}$ (Das 1994). The TSA generally includes methods and techniques for modelling the time distribution of attribute X and thus at extracting structural information from the available data ($x_1, x_2, \ldots, x_n$; Das 1994, Box et al. 2015).

In this study, TSA is used to extract the information required to classify the long-term history of the aviation sector into discrete periods. This is achieved by employing various TSA methods and techniques to produce outlier time points or cutting-points (thresholds) in the timeframe of the TAN's history. The discrete time periods are obtained by evaluating the frequencies and historical reference of these outlier values. The proposed methodological framework is the first to employ quantitative methods to classify historical events. As the flowchart shown in Figure 1 indicates, the overall approach is organised into two layers reflecting geographical scale (national and regional) and four computational steps: the *computations*, where the critical points (milestones) of the TAN's aviation history are estimated; the *literature evaluation* of the estimated critical points; the *verification* of the estimated time periods; and, finally, the *conclusion making*.

Figure 1

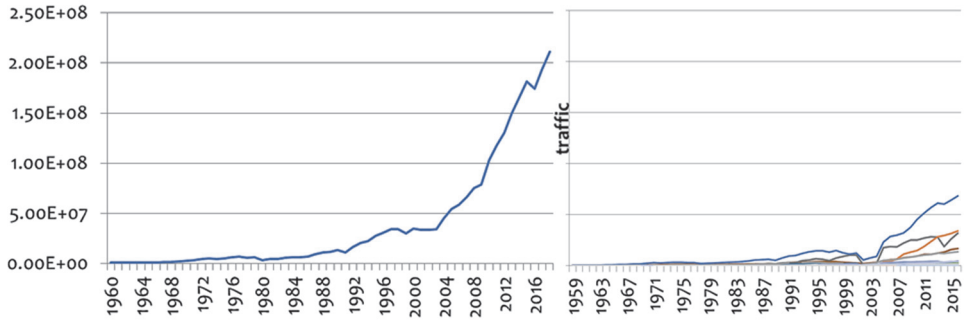
Flow chart of the study's methodological framework



The TSA is based on annual passenger data, measured as the number of passengers transported in domestic and international flights from 1959 to 2018 (GDSAA 2018). The data are available at both the national (NS) scale (the aggregate domestic and international traffic in the country) and at the regional (RS) scale (for each of the 55 operating airports in the country), as shown in Figure 2. The data are obtained from the Turkish Statistical Service (TURKSTAT 2010) and the General Directorate of State Airports Authority (GDSAA 2018). Air passenger traffic is an effective proxy for air transport supply and can be used to examine the dynamics of the history of Turkey's aviation market and identify its main historical and contextual periods, as demand is heavily dependent on social, political, technological, and economic changes (Tsiotas–Polyzos 2015, Polyzos 2019).

Figure 2

Time series of (left) the national (NS) and (right) regional (RS) air-passenger traffic in Turkey for 1960–2018



Source: GDSAA (2018).

Prior to the TSA, a stationarity assessment of the available time-series database is applied. Although an absence of stationarity is clearly observed in Figure 2, for the sake of completeness, an augmented Dickey–Fuller test (ADF) for a unit root (Shumway–Stoffer 2017) is applied to examine the hypothesis (H_o) that a unit root is present in the model's time-series data:

$$y_t = c + \delta t + \phi \cdot y_{t-1} + \beta_1 \cdot \Delta y_{t-1} + \ldots + \beta_p \cdot \Delta y_{t-p} + \varepsilon_t \quad (1)$$

where Δ is the differencing operator ($\Delta y_t = y_t - y_{t-1}$), p is the (user-specified) number of lagged difference terms, c is a drift term, δ is a deterministic trend coefficient, ϕ is an autoregressive coefficient, β_i are regression coefficients of the lag differences, and ε_t is a mean zero innovation process.

According to the expression shown in equation (1), the unit root hypothesis testing is expressed as follows (Shumway–Stoffer 2017):

$$H_o : \phi = 1 \text{ vs. } H_1 : \phi < 1 \quad (2)$$

and the (lag adjusted) test statistic DFt is given by the following formula (Shumway–Stoffer 2017):

$$DFt = \frac{N(\hat{\phi} - 1)}{(1 - \hat{\beta}_1 - \ldots - \hat{\beta}_p)} \quad (3)$$

where the uppercase symbol '^' expresses the estimator of the variables.

The first step of the TSA is a computation of the fundamental time-series measures. The first method is based on computations of the first-order differences according to the following formula (Das 1994, Box et al. 2015):

$$\Delta^{(1)} x_t = x_t - x_{t-1}, \; t = 2, \ldots, n \quad (4)$$

where x_t is the value (score) of the time series at time t and x_{t-1} at time t-1. The first-order differences capture the changes of attribute X without removing the scale of the variable **x**. These differences serve as a discrete analogy of the first derivative of

a function and thus provide information about the monotonicity of the time series (Das 1994, Box et al. 2015).

Next, the relative changes of the time series are computed according to the following formula (Polyzos 2019):

$$\Delta_R x_t = \frac{x_t - x_{t-1}}{x_{t-1}} = \frac{\Delta^{(1)} x_t}{x_{t-1}},\ t = 2, \ldots, n \tag{5}$$

where $\Delta^{(1)} x_t$ are the (previously defined) first-order differences. The relative changes $\Delta_R x_t$ express the first-order differences $\Delta^{(1)} x_t$ divided by the magnitude of the past-points x_{t-1}. In finance, the measure of relative changes is similar to the measure of logarithmic returns (Hudson–Gregoriou 2015), but the latter is defined for a certain time period between the initial and final (closing) values of a share. Therefore, the measure of relative changes is useful because it is scale-free (Tsiotas 2019): It does not include the magnitude of the x_t values since it expresses changes as percentages of the past-points x_{t-1}.

Next, the (simple) moving average statistic (Das 1994, Box et al. 2015) is computed as follows:

$$MA(t_n) = \frac{(n-1) \cdot MA(t_{n-1}) + x(t_n)}{n} \tag{6}$$

where $MA(t_2) = \frac{x(t_1) + x(t_2)}{2}$, and n is the number of time-series nodes considered in time t_n. The moving average is used to smooth the short-term fluctuations and highlight the long-term effects in the time series (Das 1994, Box et al. 2015), which is useful for defining the long-term historical framework of the aviation sector in Turkey.

Additionally, the sign (or signum) function (Yun–Petkovic 2009) is considered in the analysis using the following equation:

$$\operatorname{sgn}(x) = \frac{d}{dx}|x_t| = \begin{cases} +, \text{ if } x > 0 \\ 0, \text{ if } x = 0 \\ -, \text{ if } x < 0 \end{cases} \tag{7}$$

where $\frac{d}{dx}$ is the derivative operant, and x_t is a time-series node at time t. When applied, the sign-function 'binarises' (in absolute terms) the time series, since it transforms the time-series data into a set of values belonging to a discrete set {–1,0,1}. This transformation is useful for grouping values of the same sign in order to define historical time periods based on the time-series data.

The final task in the first step is computing the outlier values extracted from percentiles P_k defined according to the following formula (Walpole et al. 2012):

$$P_k = \{x_i \in \mathbf{x} \mid x_i \leq p_k\} \tag{8}$$

where **x** is the time-series vector, k is the bound of the percentile, p_k is the score of the corresponding percentile belonging to the interval $p_k \in [\min(\mathbf{x}), \max(\mathbf{x})]$, and $|\mathrm{P_k}| = \frac{k}{100} \cdot n$ is the cardinality of the set P_k. The outlier values are searched within 10% of the borderline cases, which are defined from the P_5 and P_{95} percentiles as follows:

$$x_{\text{outlier}} \in \{\mathrm{P5} \bigcup \{\mathrm{P100} - \mathrm{P95}\}\} \tag{9}$$

The outliers, the outcome of the described procedure, are the candidate critical points (milestones) in the long-term history of the TAN. Based on their frequency in the overall analysis, the candidate milestones are further filtered to divide the long-term history of Turkish aviation into candidate time periods. In the second step of the methodological framework, these candidate time periods are submitted to a literature evaluation in order to determine whether they have real-world meaning for Turkish aviation history. To this end, a literature review is conducted to detect the historical events recorded simultaneously with the reference time of the candidate milestones, and correspondences are identified. In the third step, the two previous steps (TSA estimation of time periods and literature evaluation) are jointly considered to validate the historical time periods of the aviation sector in Turkey, which produces verified time periods in the long-term history of the TAN. Finally, in the fourth step, the overall approach is evaluated and discussed, and conclusions are drawn.

Results and Discussion

Time-series analysis at NS level

An ADF (Shumway–Stoffer 2017) for a lag of three periods (t_o, t_1, and t_2) is performed to examine whether the available data belong to a stationary time series. The results (see Table 1) indicate that this test fails to reject the null hypothesis of a unit root against the autoregressive alternative. Thus, the TAN time series is not a stationary verification of the initial visual evaluation of the raw time-series data.

Table 1

Results of ADF test on TAN stationarity

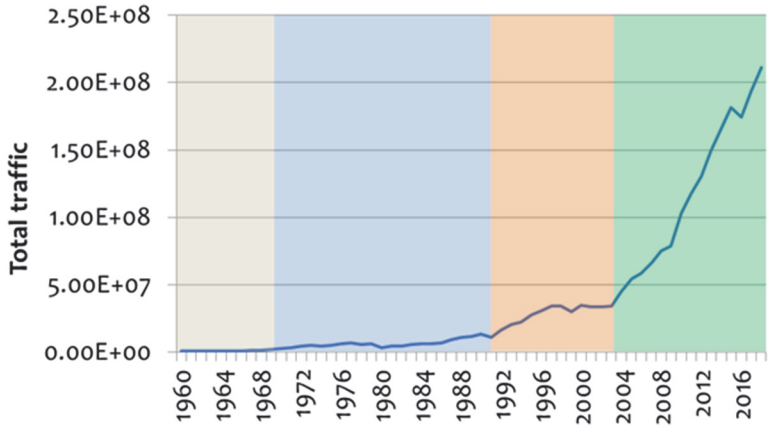
	Lag (p)		
	t_o	t_1	t_2
h[a)]	0	0	0
p-value	0.9990	0.9990	0.9990
stat	3.1188	2.5907	2.2653
c-value	–3.4921	–3.4934	–3.4946

a) h = 0 indicates failure to reject the unit-root null (non-stationary). h = 1 indicates rejection of the unit-root null in favour of alternative model (stationary).

Observing the raw time-series data in Figure 3 reveals four reference periods based on a numerical scale. These periods are defined by the years 1969, 1991, and 2004. The diagram shows that, before 1969, the evolution of Turkey's air traffic appears almost stationary; after this year, an increasing trend begins. Starting in 1991, the slope of the increase grows and then rises steeply from 2004. Regarding scale, prior to 1969, air traffic averaged 1,012,217 passengers per year; then it averaged 6,079,715 passengers per year for [1969, 1990], almost six times greater than in the first period; 28,012,648 passengers per year for [1991, 2003], almost eight times greater than in the second period; and 120,317,704 passengers per year after 2004, almost four times greater than in the third period.

Figure 3

Time periods derived from (raw)
Turkish air passenger traffic data at NS level

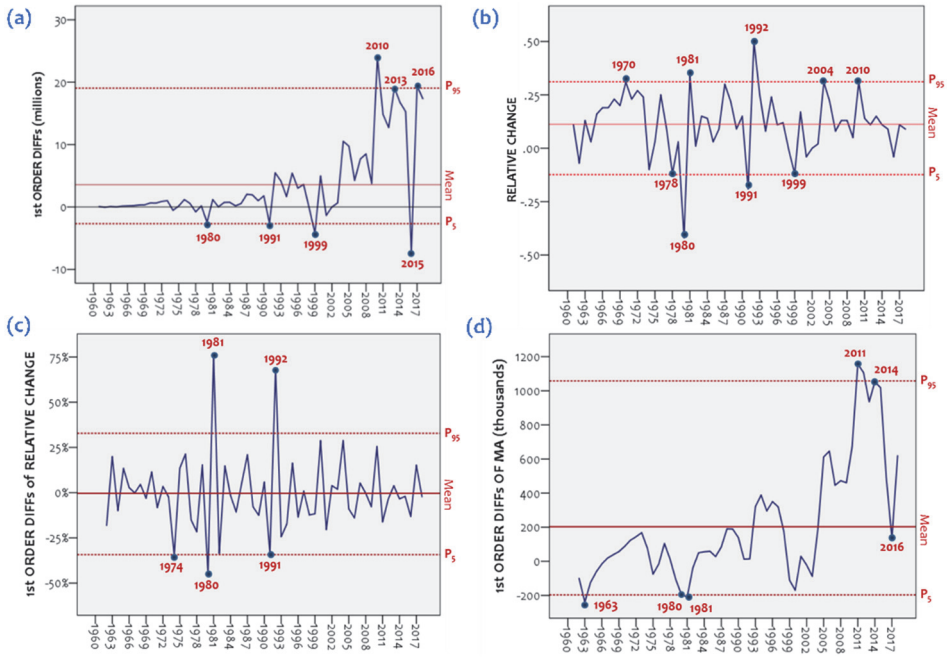


Note: based on numerical scale data.

The results derived from the TSA expressed in numerical values are shown in Figure 4 and those expressed in terms of signs are shown in Figure 5.

Figure 4

The results derived from the TSA expressed in numerical values

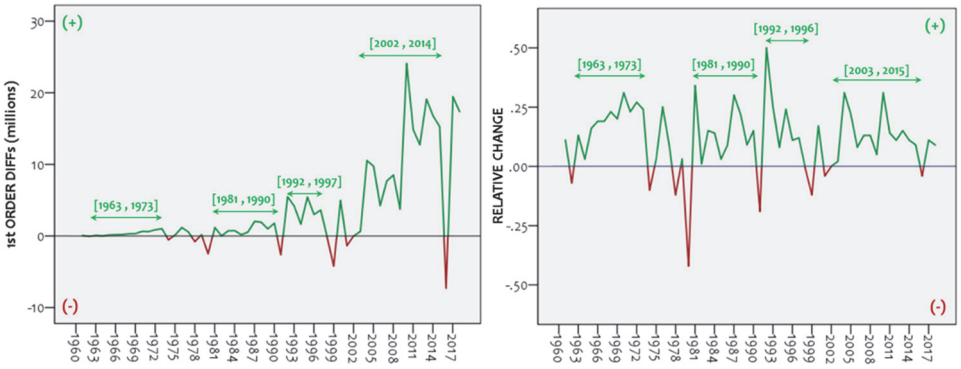


Notes: Outlier values exceeding the range [P_5,P_{95}] between the 5th (P_5) and 95th percentiles (P_{95}) for the distribution of (a) first-order differences, (b) relative changes, (c) first-order differences of relative changes, and (d) first-order differences of the moving average (MA), all of which are computed using time-series data of NS air passenger traffic in Turkey. These outliers suggest candidate milestones in the long-term history of Turkey's aviation sector.

The outliers produced by the TSA are the candidate milestones in the history of the TAN. We can observe outliers due to first-order differences $\Delta^{(1)}x_t$ (see Figure 4a) in 1980, 1991, 1999, 2010, 2013, 2015, and 2016; due to relative changes $\Delta_R x_t$ (see Figure 4b) in 1970, 1978, 1980, 1991, 1992, 1999, 2004, and 2010; due to first-order differences of relative changes $\Delta^{(1)}\left(\Delta_R x_t\right)$ (see Figure 4c) in 1974, 1980, 1981, 1991, and 1992; and due to first-order differences of the moving average $\Delta^{(1)}\left(MA\left(t_n\right)\right)$ (see Figure 4d) in 1963, 1980, 1981, 2011, 2014, and 2016. Next, the signum function analysis of the long-term history of TAN (see Figure 5) produces time periods composed of sequential years with the same sign. The signum function consideration of the first-order differences $\Delta^{(1)}x_t$ produces four discrete time periods with a positive sign: [1963, 1973], [1981, 1990], [1992, 1997], and [2002, 2014]. The signum function consideration of the relative changes $\Delta_R x_t$ also produces four discrete time periods with a positive sign: [1963, 1973], [1981, 1990], [1992, 1996], and [2003, 2015].

Figure 5

The results derived from the TSA expressed in terms of signs



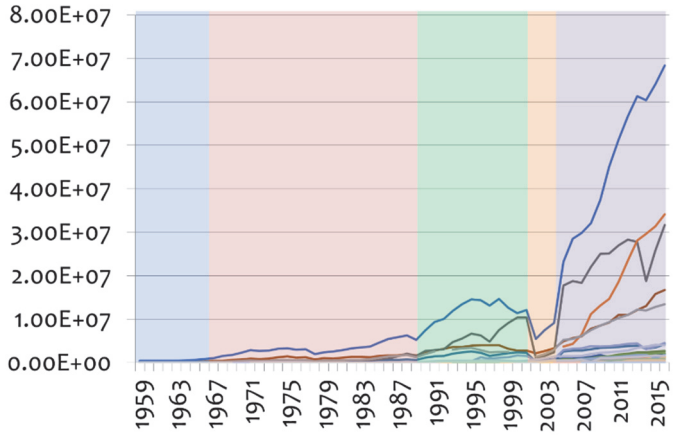
Notes: Time periods defined by the sign functions of first-order differences (left) and of relative changes (right) computed using time-series data of NS air passenger traffic in Turkey.

Time-series analysis at RS level

As in the NS analysis above, we examine the raw time-series data at the RS level. Their numerical scale enables us to identify five reference periods in the cluster configured by the 55 RS time-series diagrams (see Figure 6). These periods are defined by the years 1966, 1989, 2001, and 2004. For the period prior to 1966, air traffic averaged 14,743 annual passengers per airport. Afterwards, air traffic averaged 88,550 passengers per airport per year for [1966, 1988], almost six times greater than in the first period; 432,788 passengers per airport per year for [1989, 2000], almost five times greater than in the second period; 584,623 passengers per airport per year for [2001, 2003], comparable to the third period; and 2,076,780 passengers per airport per year after 2004, almost four times greater than in the third and fourth periods. The decay observed for [2001, 2003] concerns only the maximum outlier cases (airports) and not the majority of airports, since the average number of passengers was not affected.

Figure 6

**Time periods observed from (raw)
Turkish air passenger traffic data at RS level**

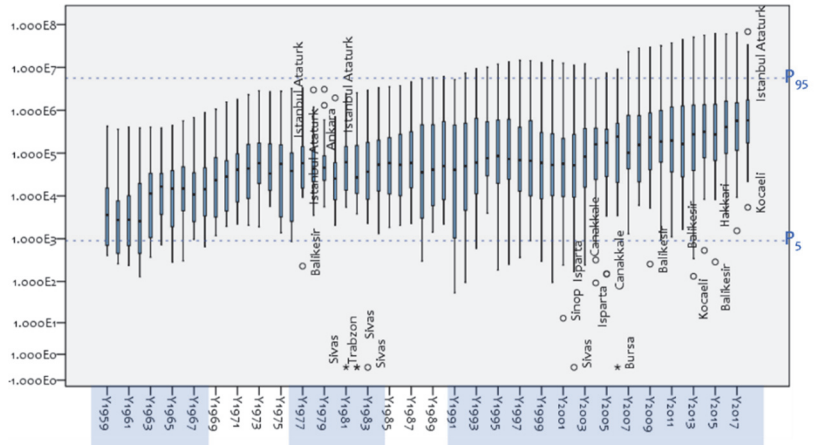


Note: based on the numerical scale.

We configure the time sequence (1959–2018) of the boxplots shown in Figure 7 to obtain a sharper picture of the time distribution of the regional data. In contrast to the previous consideration, we apply a log transformation to the vertical axis of the diagram. This approach allows us to configure the time periods in the history of regional TAN traffic based on the years wherein the whiskers of the boxplots exceed the P_5 and P_{95} borderlines. We can observe that three time periods exceed the percentile borderlines: [1959, 1968], [1976, 1984], and [1991, 2017].

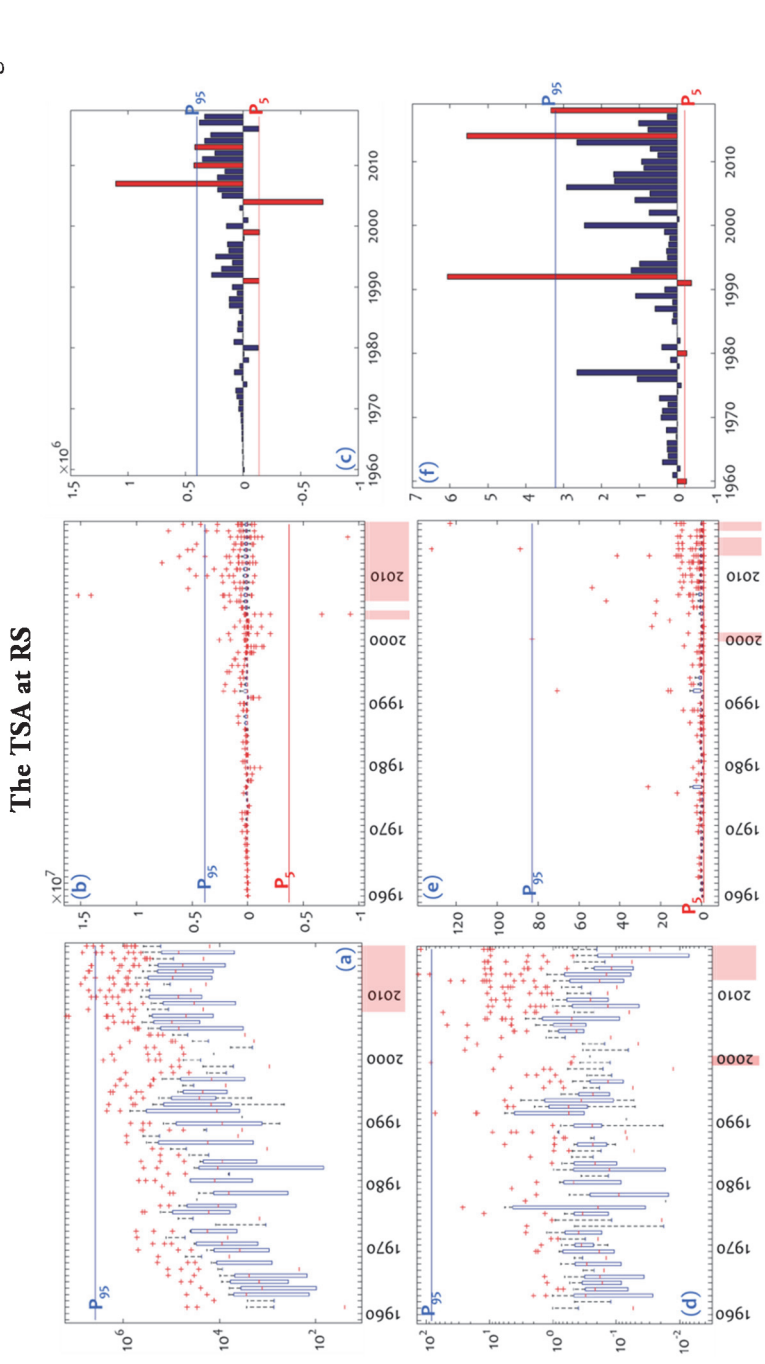
Figure 7

Diachronic distribution of airport network traffic for 1959–2018



Notes: Boxplots computed using regional TAN data (airports). Periods with outlier values exceeding the interval [P_5, P_{95}], computed using aggregate traffic data (for all available years), are shown within a coloured frame (vertical axis appears in log scale).

Figure 8



Notes: (a) Boxplots of first-order differences (log scale); (b) Boxplots of first-order differences (metric scale); (c) Barcharts of average first-order differences (metric scale); (d) Boxplots of first-order relative differences (log scale); (e) Boxplots of first-order relative differences (metric scale); (f) Barcharts of average first-order relative differences (metric scale), all of which are computed using annual TAN RS traffic data (airport traffic) for 1959–2018. Years exceeding the interval [P_5, P_{95}], computed using aggregate traffic data (for all available years), are shown within a coloured frame.

The TSA at RS is shown in Figure 8. The first-order differences in log (Figure 8a) and metric scales (Figure 8b) and on average in metric scale (Figure 8c) are shown, along with the first-order relative differences in log scale (Figure 8d), in metric scale (Figure 8e), and their averages in metric scale (Figure 8f). Candidate milestones are detected in 1980, 1990, 2004, and 2008.

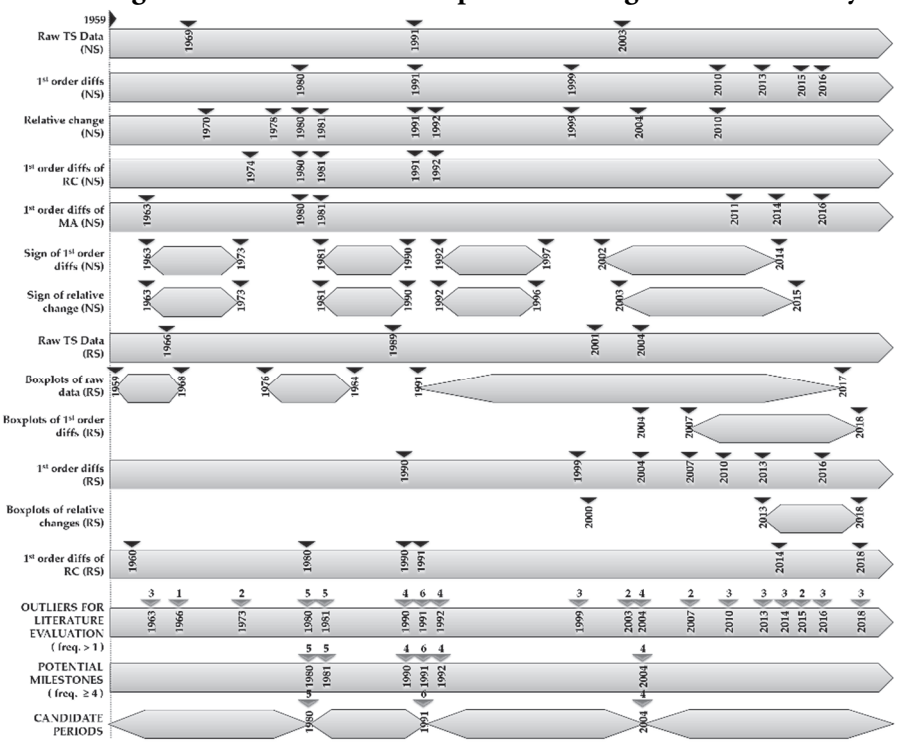
Configuration of time periods in TAN history

Estimation of candidate time periods

Based on the previous TSA at the NS and RS levels, we configure the diagram shown in Figure 9 summarising the potential milestones in the TAN's long-term history. The frequency with which a case appears in this aggregate diagram is considered a measure of importance (i.e. a potential milestone). To facilitate the literature review, we reduce the data resolution by focusing on cases appearing more than once in this aggregate diagram. The cases of greatest importance (≥ 4) are apparently more likely to suggest a historical TAN milestone.

Figure 9

The configuration of candidate time periods in long-term TAN history



Note: The frequency with which a case appears in this aggregate diagram is considered a measure of importance (i.e. a potential milestone).

The analysis shown in Figure 9 indicates that the potential milestones to be examined in the literature evaluation are in 1963, 1966, 1973, 1980, 1981, 1990, 1991, 1992, 1999, 2003, 2004, 2007, 2010, 2013, 2014, 2015, 2016, and 2018. The most important of these are 1980 (*freq.* = 5), 1981 (*freq.* = 5), 1990 (*freq.* = 4), 1991 (*freq.* = 6), 1992 (*freq.* = 4), and 2004 (*freq.* = 4). The literature on the history of Turkey's aviation sector is thus reviewed to investigate these potential milestone years.

Literature evaluation

The historical events concerning the TAN and their importance according to the TSA are summarised in Table 2. The historical periods that dominated the history of the TAN are summarised in Table 3. We see that aviation activities in Turkey began with the construction of two hangars and a short runway in 1912 in Sefakoy, Istanbul (Bakirci 2012), an area close to Ataturk Airport. Aviation activities then developed in accordance with the environment and the priorities driven by the Second World War. THY, Turkey's flagship carrier, was established as a state-owned enterprise in 1933, and Istanbul Ataturk Airport was selected as its operational centre (Sarilgan 2016). The first civil flights operated between Istanbul and Ankara airports in 1933, with a capacity of five aircraft and 28 seats (Bakirci 2012). This route connected the old imperial capital city of Istanbul to Ankara, the new capital city. Located in central Turkey, Ankara was new and modern, while Istanbul was regarded as un-modern. Izmir and Adana airports were completed in 1939 (THY 2018). The geography of Turkey's airports and its air routes were expanded to the western (Mediterranean) parts of the country. In 1943, Van airport was added to the network (Bakirci 2012). The growth and development of Turkey's aviation sector accelerated amid the political and technological environments of the Second World War. Airports were constructed in Sivas, Erzurum, Malatya in eastern Turkey; Diyarbakir, Gaziantep, and Urfa in south-eastern Turkey; Konya and Kayseri in central Turkey; Antalya and Iskenderun in southern Turkey; Samsun in northern Turkey; and Bursa in western Turkey from 1945 to 1947 (THY 2018). These airports expanded the geography of the aviation sector beyond major cities (e.g. Istanbul, Ankara, Izmir) to include secondary regional hubs (Tasligil 2014).

After 1947, the capacity of the aviation sector increased in terms of both aircraft and seats, and Turkey's aviation activities expanded to the international level. In line with the Westernisation of the nation, Turkey's first international flight took place in 1947, between Ankara and Athens with a connection at Istanbul. In 1951, the TAN's international destinations increased to four (Athens, Rome, Frankfurt, and Vienna), the number of aircraft to 33, and the number of seats to 1,120 (THY 2018). The growth of the aviation sector continued in parallel with technological developments, decreasing oil prices, and increasing capital investments, leading to the emergence of new lines from Turkey to the Middle East and Europe (THY 2018). In 1963, flights from Turkey to the United States began, and new European destinations were

included in the TAN (Orhan–Gerede 2013). Until the 1980s, Turkey's aviation sector was state-regulated and developed mainly through public investments. Several public-owned enterprises providing ground handling, catering services, and mechanical services were established in this period. The THY, airports, and supplementary services (e.g. ground handling, catering services, and mechanical services) were maintained as strict monopolies (Orhan–Gerede 2013).

After 1980, the Turkish economy was exposed to rapid and uncontrolled liberalisation (Pamuk 2014). These liberalisation policies meant that the state was no longer the sole regulator of the economy; rather, regulation occurs in accordance with the priorities of capital groups and the market (Boratav 2008). The Civil Aviation Law was issued in 1983, and many airline companies started operating in the aviation market without entry restrictions. With the help of free market-oriented deregulation and an increased number of TAN airports, 16 private airline companies were established between 1980 and 1990 (Battal–Kiraci 2015). However, six of these companies soon ceased operations (Cetin–Benk 2011, Kiraci 2018). In line with the increasing domestic and international demand, the number of airports in Turkey increased to 38 in this period (Bakirci 2012). The market liberalisation fostered demand for airlines, and the aviation sector developed rapidly. Domestic air ridership more than quadrupled between 1980 and 1990 (TUIK 2010, GDSAA 2018). However, the overwhelming majority of the flights were between the major airports in western Turkey. Flights to airports in northern, eastern, and southern Turkey were limited and seasonal. To overcome this problem, several regulations aimed at balancing the flight differential between the regional airports were implemented (Orhan–Gerede 2013). Any aviation company entering the Turkish market had to operate at least one flight to secondary airports.

After the 1990s, the TAN's liberalisation was interrupted by the protectionist measures taken in response to the national economic crises in 1988–1989, 1994, and 2001; the Gulf War in 1990, and the Asian Crisis in 1997 (Pamuk 2014, Battal–Kiraci 2015). Privatisation policies were applied to state aviation institutions in the late 1990s (Togan 2016). In this period, 18 new airline companies entered the market to meet both domestic and international demand. The total number of airline companies increased to 28. However, 19 of these companies exited the market between 1990 and 2000; high competition, poor market strategies, lack of experience, and high taxes led to their bankruptcy. Additionally, regulations were implemented by state aviation authorities in order to protect THY's market share. The 'THY Is First' strategy included provisions requiring new companies to operate only on lines that THY was not operating on or that THY could not service. These measures reduced the competitive power of emerging aviation companies (Orhan–Gerede 2013).

In 1989, Sun-Express joined in partnership with THY and Lufthansa to operate as a leisure airline providing charter flights between Turkey and Germany (Bakirci 2012). The main hub of the company was in Antalya, a major tourism destination in Turkey. In 1998, Antalya airport was expanded with a terminal constructed for

international flights via public–private cooperation on a build-operate-transfer (BOT) model (Acar–Karabulak 2015). This was the first use of the BOT model for infrastructure investments in the aviation sector. Konya and Istanbul Sabiha Gokcen airports began operating in 2000 and 2001, respectively, and the total number of airports in Turkey had increased to 40 by 2003. Sabiha Gokcen Airport, completed in 2001, was Turkey's first privately operated airport (Bakirci 2012).

The privatisation of public Turkish aviation enterprises began in the 1990s. In this period, the nation's economy and its domestic and international aviation activities were affected by the 1988–1989 economic crisis and the Gulf War (Battal–Kiraci 2015). Ucak Servisi Anonim Sirketi (USAS), the public supplier for ground handling services and catering, became the first privatised public aviation company in Turkey. Togan (2016) stresses that 70% of the catering services were privatized in 1989, and the remaining 30% were privatized in 1993, additionally, 60% of the ground handling services were privatized in 1995 and the remaining 40% were privatized in 1998. Turkey's economy also experienced several major milestones just before the 2000s; the Asian Crisis affected international flight demand in 1997, and catastrophic earthquakes and economic crises occurred in 1999 and 2001, respectively.

Starting in the 2000s, neo-liberalisation policies came to the fore, a process fostered by the neoliberal agenda being pursued across the world (Togan 2016). These processes have been particularly brutal in developing countries. The liberalisation program of the government led to crucial privatisation and deregulation measures like the privatisation of national refineries, industrial areas, and factories (Togan 2016). The government's motto has been 'Every Turkish citizen will board at least once' since the 2000s began. This period consists of three sub-periods (see Figures 5 and 6). The first sub-period covers 2000 to 2004; this can be considered a period of transition to a liberal market driven by the deregulation policies known as 'Dervis Policies', after the Minister of Economic Affairs who initiated the IMF liberalisation program. After 2002, this liberalisation program was fostered by the new government, which is still ruling Turkey (Türkan–Ozel 2019). In 2003, the aviation market was deregulated.

In this period, several old airports were restored to service, and new airports were constructed. The geography of the aviation sector was expanded to include all parts of the country, increasing demand for domestic flights between the peripheral small cities and the major airports (Orhan–Gerede 2013). The market deregulation accompanied by the increasing domestic demand attracted the attention of private companies. After 2003, several low-cost carriers servicing both domestic and international destinations entered the market with varying strategies. Legislation deregulating the market and eliminating the price advantages and privileges of THY were the main impetus for this process (Tasligil 2014).

Table 2

Summary of historical TAN events and their importance according to TSA

Year	TSA Importance	Related historical events	References
1912	–	Construction of two hangars and a short runway in Sefakoy, Istanbul and then in Esenboga, Ankara.	Bakirci (2012)
1933	–	Establishment of THY; THY starts operating from Istanbul Ataturk to Ankara Esenboga airport	Bakirci (2012) Sarilgan (2016)
1939	–	Construction of Izmir and Adana airports	THY (2018)
1943	–	Construction of Van airport	Bakirci (2012)
1945–1947	–	Construction of new airports in all regions (LTAR, LTCE, LTAO, LTCC, LTAJ, Urfa, LTAN, LTAM, LTAI, Iskenderun, LTFH, LTBE)	THY (2018)
1951	–	Increase of international destinations (Athens, Roma, Frankfurt, and Vienna)	THY (2018)
1963	3	First flights from Turkey to the U.S.; New European destinations started	Orhan–Gerede (2013)
1973	2	Establishment of the aircraft industry in Kayseri, Turkey	Eriksson (2016)
1980	5	Military coup	Pamuk (2014)
1981	5	Trade liberalisation program	Pamuk (2014)
1983	–	Issue of Civil Aviation Law	Togan (2016)
1989	–	Sun-Express partners with THY	Bakirci (2012)
1990	4	Gulf War, global economic crises	Pamuk (2014); Battal–Kiraci (2015);
1991	6	Privatisation of the state-based institutions	THY (2018)
1992	4	End of Gulf War	Korul–Kuçukonal (2003)
1999	3	National economic crises	Pamuk (2014)
2003	2	Major barriers for market entry were eliminated; total number of airports increased to 40	Bakirci (2012); den Hartigh–Kucukonal (2012)
2004	4	Deregulation of aviation market	Orhan–Gerede (2013)
2006	–	New international terminal at Izmir's Adnan Menderes Airport opened; many airports reopened	THY (2018)
2007	2	New airports (LTAS, LTCS, LTAK, LTAO) entered TAN, many airports reopened	THY (2018)
2008	–	THY joined Star Alliance; new airports (LTAP) entered TAN	THY (2018)
2010	3	New airports (LTFG, LTFK) entered TAN; major improvements to Balıkesir Koca Seyit Airport	THY (2018)
2011	1	New airports (LTBQ) entered TAN	THY (2018)
2012	–	New airports (LTBZ, LTCT) entered TAN	THY (2018)
2013	3	New airports (LTCV) entered TAN; major improvements to Kastamonu Airport	THY (2018)
2014	3	New domestic terminal at Izmir's Adnan Menderes Airport opened	THY (2018)
2015	2	Subsidies for promoting lines between secondary and major airports	DGCA (2014)
2016	3	Holiday bans from Russian government in response to the war aircraft crisis	Ersen (2017)
2018	3	Istanbul Grand Airport	THY (2018)

The second sub-period covers 2004 to 2008. These were the golden years for the growth of the aviation sector in Turkey in terms of both domestic and international passengers. THY increased its capacity substantially and started to focus on international operations through a strategy of expanding to all continents with the help of technological and political changes in the global aviation sector (Orhan–Gerede 2013). The company managed to meet the high share of domestic demand until the 2008 creation of Anadolujet (Sarilgan 2016), a low-cost carrier and THY subsidiary established to help meet domestic demand (THY 2018). THY entered into partnership with the Star Alliance in 2008 in order to service new destinations in the global market. This was perhaps the most significant development in the sector. The passenger volume of domestic flights almost quintupled between 2003 and 2010 (see Figure 3).

The third sub-period ranges from 2008 to the present. As Figure 3 shows, the growth rates in the number of both domestic and international passengers were interrupted by the increases in oil prices and the economic and political environments created by the 2008 global crises (Togan 2016). After 2010, the growth of Turkey's aviation market boomed due to new developments in the sector, in line with the growth of the Turkish economy (Duran–Erdem 2017, Shinnar–Zamantili 2019). The aviation sector was supported by budgetary allocations as well as the BOT model of public–private partnerships. Two subsidies were provided by the government to increase and enhance the connections between secondary and major airports in 2013 and 2015 (DGCA 2014). This growth pattern was interrupted by the Syrian war and the political tensions between Turkey and Russia in 2016, which affected the tourism sector and international flights (see Figure 3). Nevertheless, the volume of domestic passengers continued to grow significantly.

Domestic flights had departed from seven centre hubs (Ataturk, Sabiha Gokcen, Izmir, Adana, Trabzon, and Antalya) to 49 airports and from two centre hubs (Ataturk and Ankara) to 26 airports. The BOT model was used frequently for the renovation, construction, and expansion of the airports. Zonguldak, Gazipasa, and Aydın airports were constructed via the BOT model, and are to be operated for 20 years by the private sector. The terminal buildings of Ataturk, Izmir, Antalya, Milas-Bodrum, and Dalaman airports are being rented for varying durations, from 15 years to 26 years. Under the BOT model, airport terminal construction and operations were transferred to the private sector (Acar–Karakulak 2015, Tasligil 2014).

Subsidies were used to increase connections between smaller and major airports, promoting new flight lines in 2013 and 2015. Accordingly, the number of domestic lines from the seven centre hubs increased to 52 by 2013 (DGCA 2014). Five regulations were established in 2013. The first stipulated the minimum number of flights that must be provided by companies assigned to new lines: The number of weekly flights cannot be fewer than three during the summer and two during the winter for each line. The second requirement concerns the date on which flights

begin: Flights had to start in the summer of 2013. The third requirement concerns the duration of the allocation of the lines: If a company was assigned a line, no other company was allowed to fly on it for two years. The fourth requirement was designed to promote new domestic lines through international lines: If a company had started adequate flights in new domestic lines, priority would be given to servicing international lines. If a domestic line was cancelled, the allocated international line would also be cancelled. The last requirement regulated the rights of passengers on new lines: Any company found to be using its current position against passengers or charging excessive prices would be taken off its line (DGCA 2014).

Table 3

Summary of historical TAN periods

Denomination	Pre-1980	1980–1991	1991–2004	After 2004
Period name	State-dominated period	Liberalising transition period	'State-regulation revisited' period	Liberalised market period
Contextual	Import-substitution industrialisation based closed economy	Liberalisation; Opening up to international trade, uncontrolled trade liberalisation	Liberalisation; Opening up to international trade, uncontrolled trade liberalisation	Fast liberalisation, Privatisation of the public-owned enterprises, integration with European Union
Socio-economic	Market monopoly of THY, state dominance	Uncontrolled deregulation of aviation market, THY-first privileges, institutions have strong regulation power	Uncontrolled deregulation of aviation market, new regulations for saving the position of THY in the market	Deregulation of the market, emergence of new low-cost-carrier firms in the market
Market players	THY	THY and 27 new companies entered market; 19 of these declared bankruptcy	THY, 8 of the companies declared bankruptcy	THY, Pegasus, Sunexpress, AnadoluJet, Borajet, Izair
Regulations	Strong regulation/control of state and state-owned institutions, airports operated by state-owned institutions	Deregulated market, state-owned institutions control the airports and market	State-regulation revisited, public offering of %1 share of THY, privatisation of ground and catering services,	Free market environment, public–private partnership for construction of airports, airports operated by private companies
Regional airports	Istanbul Atatürk and Ankara	Istanbul Atatürk, Ankara and Izmir	Istanbul Atatürk, Ankara, Izmir, Antalya	Istanbul Grand, Istanbul Sabiha Gökçen, Ankara, Izmir, Antalya, Trabzon, Samsun, Kayseri

The regulations in the 2015 legislation are similar to those in the 2013 legislation. However, the second and fourth regulations in 2013 were changed in the 2015 version (DGCA 2015). The 2015 version set June 1, 2015 as the start date for flight service;

failure to start on that date would lead to allocation cancellation. Moreover, the 2015 version made provisions for both the cancellation and suspension of domestic flights. The 2015 Circular on Promoting New Flight Lines has led to new lines between major airports and secondary and small airports (DGCA 2015).

Turkey has been a very attractive destination for Russian and European tourists, especially during the sea–sand–sun tourism period in 2010 when visas were mutually lifted for the citizens of Turkey and Russia. However, the unstable and unpredictable environment caused by the Syrian war (which started in 2011 and turned into an international crisis in 2015), high volumes of refugees escaping ISIS violence in 2015, a failed coup attempt in 2016, and the tension between Turkey and Russia following the shooting down of a Russian warplane near Turkey's Syrian border in 2016 have affected Turkey's tourism sector and air passenger volume substantially (Ersen 2017). The failed coup attempt in 2016 led to an unstable economic environment that severely damaged Turkey's aviation sector, as well as other economic sectors. For example, Borajet, servicing smaller airports via a regional aviation strategy, exited the market in 2017 (DGCA 2017).

However, Turkey's aviation sector is growing fast, and the demand for new fleets, airports, and ground services are increasing daily along with technological developments. This has caused a need for a new airport. Istanbul Airport, the city's third airport and projected to be the largest in the world, is being constructed in the northern part (the European part) of the city in four phases. The first phase began in 2019 after an almost two-year delay. When Istanbul Airport is completed, it is expected to serve over 200 million passengers annually. Istanbul Airport is also being constructed through the BOT model under a state guarantee. Ataturk Airport is now closed.

Conclusions

Turkey's aviation sector has transitioned from a state-dominated structure to a liberalised market. This transition has been remarkable, and its geographical and historical mechanisms and patterns are worth analysing. This study's time-series analyses reveal the existence of four main developmental periods based on market dynamics, aviation policies, and regulations.

The state-regulated period is the longest of the four. It covers Turkey's initial aviation-based investments, such as those for airport construction and ground services. In this period, Turkish aviation activities were controlled solely by state-owned enterprises, institutions, and organisations – consistent with Turkey's overall economy. The liberal transition period (1980–1990) started with the military coup of 1980, which led to a major change in Turkey's economic environment, and this uncontrolled liberalisation period continued till to the 1990 Gulf War. The state's control over the economy decreased due to the new liberalisation programs, which

were mainly based on free market principles. The aviation sector was also liberalised in 1983. New companies started providing aviation services on both domestic and international lines by competing with THY. During the Gulf War, new regulations were implemented to protect THY's market share and position. This began a new period of state regulation. This period starts with the Gulf War and ends with the new neoliberal agenda implemented in 2003 by the government that has been ruling the country since 2002. This liberalised market period starts with the deregulation of the aviation market. In this period, new low-cost aviation companies entered the market, and new airports were constructed. The aviation market enjoyed a boom due to increased demand for air passenger services. Istanbul Airport, considered the largest airport in the world, opened in 2018.

Though state regulation and control still play direct and indirect roles in Turkey's aviation sector, the sector was deregulated consistent with the neo-liberalisation of the national economy. The aviation sector boomed after the 2003 deregulation, but wide disparities persist across the TAN. Most major airports are located in the major cities, whereas there are few airports in the rest of the country.

This study showed that milestones in the history of Turkey's aviation sector can be identified via time-series analysis using simple and easily accessible data. The results reveal that the periods derived through the time-series analyses are consistent with the major changes discussed in the literature. The main drawback of this study is that, due to the unavailability of data regarding passenger traffic between airport pairs, we cannot measure how Turkey's deregulation and regulation policies affected the spatial configuration of the TAN. This issue should be addressed in future research.

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The prospects of regional market place developments in economic geographical perspective

Case study of Balaton Resort Area, Hungary

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Today's investments can be accomplished by involving numerous sources either with the aim of stimulating the local economy with an infrastructural project, the innovative development of a service activity or a land rehabilitation interference. The European Regional Development Fund, the European Social Fund or the community initiative LEADER can be found among the EU sources. My study introduces the group of the present Hungarian tender sources which, utilising the above mentioned sources, create primarily a basis for preserving the local workplaces with infrastructural investments by assisting the accessibility of local products and producers to the markets. The secondary analysis of the literature sources, city development strategies and the data on webpages of the applications was applied. With my empirical survey I partially keep track of the 2007–2013 EU investments with similar objectives, demonstrating their usefulness. The data of the investments supported by LEADER in the Balaton Accentuated Tourism Zone (BATZ) (sample area) was recorded with the help of interviews made with the representative and employees of the local government.

The results show that from the point of view of the maintainer the operation of the market places is not cost-efficient, without the developments the infrastructural circumstances with long term pay-off would have remained unsolved. The projects directly contribute to the advantageous assessment of the investors of the analysed region and the indirect strengthening of the local economy.

Keywords:
tender sources,
rural development,
Balaton Accentuated Tourism Zone (BATZ),
LEADER, market places

Introduction

The Balaton region as the internationally recognised and highlighted tourism destination of Hungary is the location for numerous investments. Both private capital and state investments aim to boost the regional and local economy, but the concentration of the tourism demand makes it further necessary to complete projects which would decrease the impacts of seasonality in the region. The reasonableness of the infrastructural developments is a complex issue in the Balaton region but it is inevitable that the economic payback of these investments should be visioned in the long run. The legal and economic status of the investors is varying within the framework of certain financing solutions: while a purchasing power parity (PPP) investment – for instance – is based on the agreement of the private and public sector, developments aim the organisations belonging to the state or its subsystems (e.g. local governments, organisations of public utility, public bodies) and are realised by the financial backing of the state sector. Both the physical and human infrastructure developments contribute to the development of the local economy by orienting toward the needs of the local actors. The financial allocation establishes the opportunity to create one or two market places or renew public parks or public institutions, but the analysis of social-economic sustainability is inevitable in order to manage the costs of maintenance (e.g. making a cost benefit analysis). It is valid both for the state and the local level and it promotes the comparison of the tenders and the preparation of the decision about the applications (Fleischer 2002, McCann–Shefer 2005, Rietveld 1989, Trenecon Kft. 2017).

One of the present initiatives regarding the revitalising of rural life, adapted in Hungary as well, is the assistance given to local producers to reach the local markets. Among the numerous alternatives the development of market places and market areas play a highlighted role in the sectoral policy providing a financial framework for their establishment and development. The financial framework that can be spent on these initiatives appeared in the recent years both in the Hungarian and the European Union (further on EU) co-financed programmes trying to provide an answer for the needs of the settlements and settlement groups. The popular consumer trends of the Western European countries such as the healthy and environment friendly behaviour, the support of the local economy and producers, or the lifestyle slowdown came into general use in the Hungarian practice as well.

In rural areas mostly the returning farmers or the ones who are changing their lifestyle are capable of putting the new approaches into the everyday practice. This social capital will contribute to the existence of the countryside, creates and reformulates the local communities as an organising force and improves the population retaining ability. The population living in the Hungarian rural areas,

being less mobile in social and regional aspects, adapts these trends slowly; however they can be the active participants in implementing settlement initiatives. A local producer community or co-operative can concentrate the knowledge needed for the management and the participation of the population can be realised in the producing of the products. The absence of social capital is, however,a recurring problem, the presence of which could promote the validation of the interests of the local communities through its social-economic network (Farkas 2002, Póla 2014). Taking into consideration the above mentioned social and financial directions it should be investigated what kind of tender opportunities were available so far in order to create (develop) local markets influencing landscape utilisation and what kind of local results were achieved by these investments.

The study researches the major indexes of the local economy development sources available at the sample area of BATZ and the role of the local LEADER[1] organizations (Magyar Kormány 2009). The topic of local producers and products could also be a driving force in maintaining the population and rural development aspects of the settlements situated farther from the lake. The planned and factual appearance of the seasonally fluctuating consumer demand could show a direction towards future developments.

Theoretical background

The investments into linear and physical infrastructure are indispensable for the promotion of value chains, but their degree and multiplier effects must be kept in mind during the determination of developments. Among today's site choosing decisions the level of construction of the infrastructure plays a highlighted role, so they have to be given a place in the development of the local economy (Csoma 2018, Fleischer 2002, Nellthorp–Mackie 2017).

During the configuration of the project, besides their own capital investment, the organisations securing financial background for the investment will get a chance to attain tender sources, which mean today developments realised by domestic and EU co-financed sources in Hungary. The target areas of the domestic and co-financed tenders cover the improvement of the cultural opportunities of social groups, the fostering of their economic positions, making more effective the activities of the economic, non-profit and civil organizations and further on the development of infrastructural points and networks.

Before joining the EU Ruttkay (1998) appointed that the investments co-financed by the EU could increase the leeway of the Hungarian budget fostering the stimulation of the local economy. The infrastructural investments, employment, tax

[1] LEADER: Liaison Entre Actions pour le Developpement de l'Economie Rurale. Its meaning: Links between actions for the development of the rural economy. Source: http://www.terport.hu/videkfejlesztes/leader (downloaded: 21 February 2019)

paying or the production connected to financial transfers are mentioned among such necessary investments. During the preparation of joining the European Union it has been stated by researchers that the local governmental investments which could go hand in hand with long term results and even income are blocked by the own source (own contribution). The compulsory tasks of the local governments can partially be financed by the budget's support sources, thus the possibly available own sources may be withdrawn from further profitable development opportunities (Horváth et al. 2014, Perger 1998, Pálné Kovács 2016). Nevertheless, the 2011 modification of the act on local governments motivated the reorganisation of the management of the local governments and so the characteristics of the task-financing as well. In compliance with it local governments can spend the earlier budgetary support exclusively to activities connected to the targeted task for which they have to account for (Bencsik 2017). In the research carried out in the sample area analysing the benefits of the application sources the representatives of the settlements affirmed that callings for tender do not always meet with local needs; and the availability of the own contribution is depending from the allocation of the settlement, the labour force market positions of the local population and the economic opportunities of the settlement (Dombi et al. 2018). In the settlements along Lake Balaton – as a primary tourism attraction – the income of the local government is more significant so they have more opportunities in the realisation of investments than the lagging behind small and micro villages allocated in a 5-10 kilometres distance from the lake. These latter are characterized by the aggregation of the opportunity disadvantages of the labour market (Alpek−Tésits 2014, 2019a, 2019b, Alpek 2017, Alpek et al. 2018, Kóti 2018). The integrated town development strategies (ITDS) of the tourism zone, in accordance with the community objectives, make it clear that those settlement developing projects should be supported with the community sources which would be profitable in the long run (Hévíz Város Önkormányzata 2008, Equinox Consulting Kft. 2009, Zamárdi Város Önkormányzata 2009, Völgyzugoly Műhely 2012).

Empirical researches in the Balaton region pointed out that in the planning and realisation of those projects which involved market place renewal or formation, such factors influence directly the opportunities of the local producers and local products to be able to appear on the markets as accessibility, the quality of the road surfaces, the presence of the attendant infrastructural buildings and the assurance of the high quality sales points (Nezdei et al. 2017, Nezdei–Mohos 2017, Nezdei–Alpek 2018). The results of the consumer demand surveys emphasized the infrastructural renewals and the increase of the processed, craftsmen-made and home-made product selections. The demand which increases in the summer months creates seasonal conflicts among the local dwellers and the people being present only temporarily (e.g. the point of view of product price policy) and at the same time it overloads the linear networks. Because of this the transport lines become

overcrowded or the accessibility of the market place and the number of parking places become seasonally inadequate. The survey of Nezdei (2018) among the producers attracted attention on the fact that improvement of the physical circumstances would make the sales activity of the producers easier, since with the establishment of the stands and market place buildings sales would be partially independent of weather conditions (roofed sales points, improvement of road surface, broadening the distance between the stands in order to improve traffic). Nevertheless, the needs of the producers and consumers and the factual investments do not match in all cases.

The definition of local product has various meanings depending on the countries. This research uses G. Fekete's (2009) definition: on one hand, local product is based on local resources, made according to local traditions, recipes and mainly in small scale, On the other hand, it means a product made by local workforce to supply the local population. It is closely related to farmers markets, which ones have the following content according to the Hungarian law: a market where a small farmer sells an agricultural or food product from his farm anywhere in the country where the site of his farm is located, or within 40 km of the market, or in the case of a market in Budapest (law CLXIV of 2005, 2. § 5a).

Data and methods

During the elaboration of the study I analyzed two types of background materials for the applications in order to analyze the secondary data. Out of the application documentations those calls and annexes of the 2014–2020 budgetary period's Rural Development Program (RDP) and the Spatial and Settlement Development Operative Program (SSDOP) were elaborated which contained market place and market area development (Farkas−Kovács 2018). Within the SSDOP framework the application for industrial park and industrial areas development, local economy development, tourism development, brown field areas, green city programme and the employment-co-operation pact was analyzed as the creation of the producers' market infrastructure. In the case of the RDP application opportunities were provided through the support of co-operations, the development of the infrastructure of the markets, the development of product supply and product processing. The Economic Development and Innovation Operative Programme (EDIOP) urged the networking of the products and the small and medium sized enterprises (SME sector) making place to the appearance of the market places. All the supporting system also presents the preference for the sectoral policy.

For the market place applications realised with EU co-financing I used the data published on their homepage. In the search programme of the supported projects the application design was available which made it possible to identify the application background with documentations, the sum and the intensity of the assistance. One could determine the timespan necessary for concluding the

developments based on the date of the supporting decision, the existence of the closing documents of the projects and also by the published data on the homepages of the settlements and the personal field surveys. The location of the project, the support intensity depending on the type of investment and the legal status of the applicant indicated local resources.

I carried out the tender source-oriented analysis of the web page content of the homepages concerning the applications financed by domestic and mixed sources, which latter were part of a complex project (e.g. inner city rehabilitation of Keszthely, Fonyód, Balatonfüred or Tapolca (it is based on the local producers' partnership) and the recent development processes in Hévíz or Siófok). [2]

My empirical survey focused on two target groups: on the experience of market places realized in an earlier LEADER design and on the target areas of the LEADER organizations. The application documentations have been reviewed and categorized by the author according to the subject, eligible group and the context of marketplaces. There are ten LEADER groups in action on the settlements of BATZ. Following my request, I was able to conduct a written interview with six organizations and personal interviews at two of them. The responses included the types of application opportunities and gaps, the utilization experiences, the effectiveness of previous similar developments, and support for other forms of short supply chain (REL) types. In view of the previous application types, co-operation-based or involving several municipality development efforts were supported in the 2014–2020 period. Based on the request of the organizations, the study summarizes the different opinions. The support of the local products and local producers can also be found in the applications of the local LEADER action groups well demonstrating the central preferences of this development activity, the aim of stimulating local economy. The local application calls of the LEADER organizations are covering a wide spectrum providing the elaboration and support of complex solutions for the assistance of local producer structures (Magyar Államkincstár Mezőgazdasági és Vidékfejlesztési Ügyfélszolgálat 2019). I requested the local governments of the settlements for the survey on the economic potential of the market places. The answers of the representatives and co-workers led to a better understanding of the background motivations of the investments and the previously planned and the factual consumer group. The categorized answers responded for the differences of the local and the tourism demand and the appearance of the modern consumer habits. The availability of the complete financial cover (such as the matter and method of own contribution) of the investments revealed the economic situation. Although the completion contributed to the management of the settlement façade as well, however the return of the project (especially prevailing in the case of calling in own contribution) and its

[2] The accessibility of the electronic content of the referred development projects can be seen at the sources section.

socio-economic sustainability cannot be judged on the everyday level by an external observer. The economic operation was revealed by the ratio of revenues and expenditures, the degree of the annual producer capacity utilisation, the issue of function change and the yearly revenues of the previously closed three economic years. The negative side of the analysis of the application sources was that the complete project costs are not univocal based on the review of these data banks. It can appear even in the case of an investment with complete support intensity that the effectuation costs of the project will exceed the available sources. With the restriction of the borrowings of the settlements the involvement of own contribution will baulk further project ideas or will make settlements to co-operate with each other.[3]

The illustration of the projects were ensured by own photo documentation. The demonstration and analysis of the data was carried out with Microsoft Excel.

Social expedience, environmental sustainability and infrastructural necessity

Market places as tools of rural development advance the local economy by passing the local producers to the markets so they have a direct effect on the stimulation of the local economy.

In the last 6 years, among others, local producers' markets were established on the southern shores of Lake Balaton in Balatonfenyves, Balatonmáriafürdő, Balatonboglár, Balatonföldvár, Zalakaros and Ságvár and in Badacsonytördemic, Köveskál, Gyenesdiás, Balatongyörök, Balatonakali, Révfülöp, Litér on the northern shores. Within the framework of these investments – partly because of the assumptions of the calls – energetics investments (solar cells) and accessible infrastructure developments (ramp, accessible parking place, sanitary units) were realised. The activities for accessibility and the project elements aiming to improve the energy efficiency were established because the tender calls have been fitted to meet the community principles of the EU.

The public interest and the sustainable operation of markets raise the issue of ranking, sithence the resource allocation should be be more efficient. To prioritize locations to be developed, numerous evaluation points have to be taken into account based on the author's empirical experiences. However, the evaluation of the market places is not the aim of this paper, the most important ones are the following:

- elapsed time between the consumer demand and the opening of the market place,
- the volume and seasonal differences of the consumer demand,
- the location of the investment,

[3] The interviews are summazired in the paper because of the limited number of characters.

– it's transport connection with other settlements,
– the awareness of the market and/or settlement (e.g. Tihany, Káptalantóti) or just
– the legal status of the investing organization (e.g. municipality, civil or church organization, enterprise, etc.).

The main challenge in evaluating the market place is to find the stakeholder group which has the most information and data about the network of the market places. Ranking could be based on it. Some factors of the ranking are presented below.

The *location* is a decisive factor in the utilisation of the market place developments since the capacity occupancy rate of a location with advantageous traffic conditions could theoretically operate the community space as a profitable investment. In a transport-toriented geographical approach we can differentiate the local producers' markets based on the following examples:

– The producer and gastro market of Balatonfenyves can be found in the periphery of the settlement in Imremajor on a weekly basis. It can be approached with the local narrow gauge railway and by car as well on a road with a partly disadvantageous allocation but on a road surface with good quality. The terminal point of the local small railway is also the market place which makes it suitable for a gastro tourism program every Sunday.
– The allocation of the producers' market in Balatonmáriafürdő is favourable since it can be found at the west end of a small street beside busy shops, but the signs indicating the market and the directions should be improved. The non-profit organisation realised a successful infrastructure development through tender sources, so the physical conditions (the presence of further selling points) are provided for helping income generating for the new primary and small-sized producers with the broadening of the selling points.
– The renewal of the market at Balatonboglár was carried out in 2013, when it was relocated next to the central crossing and park of the town. The producers' market of Ságvár is similarly located in the settlement centre, providing an advantageous opportunity for the local and nearby farmers to access the consumer market. It shall be assumed that the excellent accessibility of the market and event place of Zalakaros will result in a profitable investment.
– The favourable location of the producers' market of Balatonföldvár is due to the vicinity of the train station, the road leading to the shores of the lake and its allocation next to the commercial unit (means of transport/transport junction).

The producers' markets/market halls of Balatonszárszó, Somogybabod, Zamárdi, Ságvár, Hévíz and Vonyarcvashegy to be established and/or renewed can be realised in the next 1–1.5 years. The investments could directly result in the improvement of the life quality of the local and nearby population, with the greater

amount of space in the markets, the objectives focusing on the local- and bio products and through the co-operation with the local producers.

The 2017–2018 producer survey of the author called the attention on the doubtful consequences of the capacity resource utilisation of the market places:

1. The *preference of further types of product distribution channels*. If the farmer sells his products for about 10 years to the same micro enterprise or restaurant, than the already formed group of consumers will not be replaced by the market place salesmanship. Out of the producers of the region those farmers who are dealing with animal husbandry (cattle, horse, sheep, pig) and sell living animals, raw meat and milk or wool are also selling their products elsewhere. Deriving from the product profile, for some farmers the market place is not the adequate location. Similar sales habits were revealed by the survey of the Balatoni Integrációs Közhasznú Nonprofit Kft. (Balaton Integration Non-profit Ltd.) (BIKN Kft., 2017) as well.
2. Nevertheless the demand for *specialised* and niche products in Hungary and in the sample area (confirmed by the consumer survey of the author as well) is increasing, but the volume of the product demand may question the financial and social sustainability of the farms. The quantity and quality of products made by the farmers influence the attainable wage, so in a rainy or in a droughty growing season even the whole yield could perish. One of the bio almond producers of the region said that for 4 years there was no almond yield on his plant what he could take to market. Such an income loss could make his farm bankrupt if this were be the only income for living by. With product diversification in farming the income of the producer can be stabilised.
3. Beside their high composition value the specialised and processed niche market products carry a high added value. The producers of the region can partly validate it in the *price of the product* because they make the production alone or by involving 1-2 persons. The concerned farmers emphasized in the interview that the blocking factor for the significant consumer demand for some products made based on their own recipes (e.g. pickles) is the lack of human resources, this is the reason why they are unable to make larger quantities. As a result a part of their crops will be spoiled. Their narrow financial resources will limit the purchase of new and modern technologies and equipment. We have to state that this is contradictory to the economic advantages provided by the tender sources – presumably because of the legitimacy criteria. We have to pay regard to the price sensitivity during the determination of the specialised, niche market products which, after all, is related to the social status, income positions and the relation to the settlements of the visitors to the market. So the local dweller who is in a higher social status with higher income positions will probably be a returning consumer in the local (producers') markets. Within the scope of the local

population with lower incomes, buying in the market is a rare occasion and further on the intermittent dwellers do not necessarily mean a stable and calculable market for the farmers. In their case ordering and purchasing online would be an alternative or even other types of short supply chains, such as purchase community, box system, sales from the house.

Due to their location and fitting to the buildings of the settlements they are multifunctional, capable of making events suited to the characteristics of the settlement façade as well. The renewal of the old-fashioned façade and technology of the earlier established market places – market halls or traditional shopping areas – is a relevant objective (e.g. the market building of Siófok, Marcali and Tab). The remained buildings as architectural reminders of the socialist era fall short in regard to modern technological, architectural and engineering expectations (Siófok ISDS[4]). The subsidiary and operational costs can be decreased with a more efficient energy use and further on the sense of comfort of the consumers can be increased with modernization. Accordingly, the results of the survey carried out by the author among the consumers indicated that the greatest need is for the infrastructural developments in these allocations (51.1%) (Figures 1–2.).

Figure 1

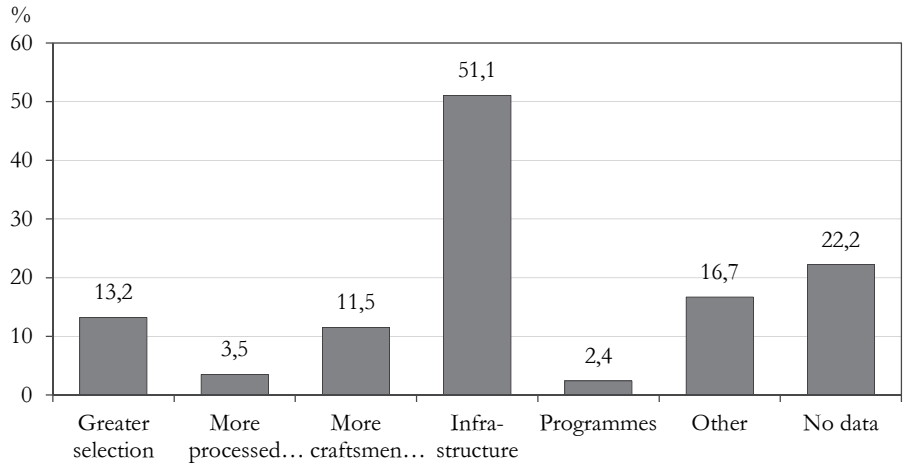
The present façade of the market and market hall in Tab (left) and the market hall in Siófok

Photos: Own pictures, 2018.

[4] ISDS means Integrated Urban Development Strategy. Terra Studio Ltd. (2014): Settlement development conception and integrated urban development strategy of Siófok. Vol. III.: Integrated urban development strategy. Financed by project DDOP-6.2.1/K-13-2014-0002, „Operated program of South Transdanubian – Sustainable Settlement Development in small-scaled and middle-scaled towns" – Elaborating Intergrated Settlement Strategies. Source: http://archiv.siofok.hu/files/3_sz_its.pdf, (downloaded: 20 February 2019).

Figure 2

The developments that were judged to be necessary during the consumer survey



In the first phase the reparation of the surface of the internal roads, the diverting of the precipitation, the accessibility of the stands, the modernisation of public toilets and the number and quality of the parking places should be modernised in the open market places.

Financial background

It is necessary to establish the financial cover for the needs towards the market places and its return as well – by making the market place sustainable. During the former EU budgetary period the local producers' markets were passed on the debit of the LEADER applications[5] partly based on the local and partly on the tourism demand. For example the producers' markets of Gyenesdiás, Balatonföldvár, Ságvár and Zalakaros were developed from LEADER sources which provide an opportunity to sell on the market every day of the week in most cases.

Nowadays, the financial coverage of the projects were guaranteed exclusively from domestic sources and from domestic sources complemented with EU co-financing besides the own contribution of the settlements and the already mentioned credit facilities. In the 2014–2020 budgetary period the detached sources of the SSDOP and the RDP make it visible that, taking into consideration spatial

[5] In the calls of the present LEADER organisations – depending from the different LEADER organisations – the market places which support the local products intended to be available at the markets, the service and accommodation development, acquisition of equipment and machines and the local product processing and/or sales developments were indicated.

aspects, the sums intended to be spent in the BATZ appropriates tourism purpose investments in Veszprém and Somogy counties from the regional sources of the EDIOP, while in Zala county no detached appropriation was appraised for the development of the region.

The measures providing the chance to establish local economy development and further market places were determined in the sources that could be tendered by any settlement of the county. It should be emphasized that the resource development of certain frames is influenced by spatial planning. The concerned parties could plan market and market hall developments based on the following tender calls of the sub-measures of the 2015 and 2016 EDIOP:

- Establishment of industrial parks, industrial areas (EDIOP-1.1.1),
- Local economy development (EDIOP-1.1.3),
- Sustainable tourism development from the point of view of social and environmental aspects (EDIOP-1.2.1),
- Rehabilitation of brown field areas (EDIOP-2.1.1),
- Creation of a green city (EDIOP-2.1.2),
- Employment agreements, employment and economy development co-operations on the county level (EDIOP-5.1.1).

Local governments of the settlements, the companies partly or totally owned by the settlements, the local ethnic governments and their executive bodies and budgetary organisations can apply for the sources of these operative programmes. The type of organisation that can be supported covers the organisations realising long term investments, so the participation of the private sector and the profit oriented organisations is not reasonable at these calls. Considering the liquidity and the capitalisation of the sub-systems of the state budget, the support intensity of the local governments was 100%, so the investments could be realised from a non-refundable subsidy totally covered by the support – depending on changes in market prices. The actual utilisation of sources allocated to tenders, modernisations did not always take place. The overloaded supporting decision making process, the making of the contract as well as the participating players (profit-oriented organisations such as construction companies or firms providing related services) in numerous cases inhibited the transaction of the investments. In the latter years the real estate developments were actuated by the interventions of the family policy which further increased the workload and lack of capacity of the construction sector.

Out of the traditional market places governed by law, the locations in Fonyód, Tapolca, Keszthely and Balatonfüred have been renewed: new building structures and pavings have been built, parking places were configured, doors and windows have been replaced, the external facades were renewed, parks were created and further on clear, modern market stands were allocated for sellers. The spaces of the traditional markets were enlarged in all cases, market-dues have been lifted. The settlement images of the inner cities have been improved due to the developments: such locations were delivered which where fitting the local needs and aesthetic

expectations. In the case of Tapolca and Keszthely the rebuilding of the great markets and market halls were realised as part of city rehabilitation as well as expansion of employment and regional co-operation developments. Besides the renewal of the market of Tapolca a local product trademark was introduced by which the producers within the 40 kilometres surroundings of the town could indicate their aim to join in. The support content of the investments related to market places was around 200–300 million HUF (approx. 603,555 – 905,332 EUR[6]) per project. Due to the Hungarian economy development programmes and the flagship policy measures, the prices of the raw materials and wages increased between the time period of the awarding of the support and the setting off of the constructions. All this necessitated the cities to increase the involved sources (Fonyód, Keszthely and Tapolca) (Table 1). In regard to the known market place developments that are due in the near future, the degree of the awarded support is very much altering (Table 2) which is influenced by the volume of the investment, the floor space and the buildings of the infrastructure that should be built. The high amount of support for Tab is explained by the collective development of the market hall and the market and further on the material use can result in a much higher effectuation cost (covering the road with paving-blocks or asphalt). With the renewal of the market of Hévíz a more modern, greater capacity development is planned, although this latter is in better condition than the one in the city of Tab (see Figure 1).

Table 1

The tender subsidy frames for the renewal of markets

Settlement	Number of inhabitants, 2019	Tender design/ source	Date of the award of the source	Sum of the obtained support, EUR
Fonyód	4,813	EDIOP-1.1.3-15	2018	907,575.8
Tapolca	14,988	HU11-0012-A1-2013	2017	809,384.0
Keszthely	19,289	WTOP (Western Transdanubia Operative Programme) - 3.1.1/A-09-1f-2009-t0001	As part of the city centre's renewal; 2009	1,634,790.3 (complex programme, only a part of it is the cost of the market place) [a)]
Balatonfüred	12,800	unknown	2011	606,060.6 [b)]
Révfülöp	1,084	EDIOP-1.1.3-15	2018	214,393.9

a) The renewal in Keszthely was carried out as part of the rehabilitation programme of the inner city. Based on the electronic sources the exact sum spent on the market cannot be estimated.

b) Based on the electronic sources the cost of the renewal of the market hall in Balatonfüred is only approximate.

Source: Based on the homepages of Tapolca, Keszthely, Fonyód and the Probio Zrt./cPlc. own editing.

[6] Exchange rate: 1 EUR = 330 HUF.

With the emerging integrated, multifunctional spaces, the applied renewable energies, the green infrastructure elements and the concept of the compact city the ongoing investments of the region connected to city rehabilitation or the establishment of a green city will make way to a sustainable settlement. All this promotes the strategic aims of the region, such as "Innovative Balaton!", "Have a Balaton product on the table!", "Natural Balaton! Healthy environment, clean Balaton!" and "Health and renewal at Balaton!".

Table 2

The main data of the infrastructural projects to be realised with European Union sources in the near future

County	Settlement	Number of inhabitants, 2019	Tender design	Rate of the support intensity, %	Sum of the obtained support, EUR[a)]
Zala	Hévíz	4,523	EDIOP-1.1.3-15-ZA1	100	732,560.6
Zala	Vonyarcvashegy	2,280	EDIOP-1.1.3-15-ZA1	100	187,878.8
Somogy	Zamárdi	2,501	EDIOP-1.1.3-16-SO1	100	148,924.8
Somogy	Ságvár	1,817	EDIOP -1.1.3-15-SO1	100	363,560.6
Somogy	Somogybabod	420	EDIOP -1.1.3-15-SO1	100	163,636.4
Somogy	Tab	4,238	EDIOP -1.1.3-15-SO1	100	1,515,151.5
Somogy	Balatonszárszó	1,997	EDIOP -1.1.3-16-SO1	100	154,349.8
Somogy	Kéthely	2,261	EDIOP -1.1.3-16-SO1	100	259,874.6
Somogy	Siófok	25,708	EDIOP -2.1.2-16-SO1	100	606,060.6
Somogy	Andocs	1,002	RDP6-7.2.1-7.4.1.3-17	75–95	31,839.2
Somogy	Balatonszentgyörgy	1,547	RDP6-7.2.1-7.4.1.3-17	75–95	151,515.1
Somogy	Balatonfenyves (Majorka)	125	RDP 6-7.2.1-7.4.1.3-17	75–95	149,522.1
Veszprém	Kővágóörs	681	RDP 6-7.2.1-7.4.1.3-17	75–95	138,488.1
Veszprém	Szentantalfa	483	RDP 6-7.2.1-7.4.1.3-17	75–95	68,919.1
Altogether			*not relevant*	*not relevant*	*4,672,281.2*

a) In case of the cities of Tab and Siófok, the complete costs of the project contain partly market place development, partly further investment elements. The appraised value of the formation of the market is not known. Exchange rate: 1 EUR = 330 HUF.

Source: Based on www.palyazat.gov.hu own editing.

During the renewals the adaptation of modern technologies provides an advantageous situation for energy efficiency (building in solar cells) and accessibility approaches. This latter viewpoint sums the age specific characteristics of the present consumers of the market as well as the support of the ecological sustainability. Theoretically the support intensity of the development sources provides a more advantageous situation on the debit side of the budget of the EDIOP, than on the budget of the RDP, however, due to the already mentioned advances in prices, quite frequently the settlements had to guarantee own contribution even in case of 100% support sources. According to the opinion of the local farmers the infrastructural developments have a new, aesthetic appearance but the stands are not practical, only partially serve the needs and comfort of the producers and consumers. The tight construction causes problems in the loading, the structure of the stands provide no shelter from the weather, so the product becomes wet and the precipitation is dropping on the consumers. Due to this in a windy and rainy weather the sales activity is paused since the customer will find a more comfortable shopping place in a roofed store, while the producers intend to spare the products obtained and harvested with hard work. During the formation of the market places it would be necessary at the projects which are still under formation to make more practical buildings that are adjusted to the needs of the producers and the customers, safeguarding from the weather conditions, especially at the permanent buildings.

Apparently the RDP tenders provide a chance to increase the product selection and to raise the attention of the consumer to the local products with high added value. By means of the source allocation the locals have a chance to broaden the product selection both made with traditional- or biotechnology. For all this a total of 2 billion HUF promotes the local entrepreneurs and the micro and small enterprises (the type of economic organisation: Ltd.) (Table 3).

The processing plants are specialised to vegetable, fruit, meat and milk products production, which would make the product selection of the market more varied and also would introduce market products in greater quantity and higher added value. The ratio of processing is oriented to the consumer demands for processed, ready comestibles. By this the investments are fitted to the long term spatial development aims of the sample area: high ratio of processing, employment creation/ preservation, the improvement of life quality in the background settlements. Because of the profit oriented activity of the investments the support intensity is much lower than at the EDIOP.

Table 3

Some data of the deposited sources of the RDP call, entitled "Value increase of agricultural products and promotion of their resource efficiency in the processing"

County	Settlement	Number of inhabitants, 2019	Tender design	Rate of the support intensity, %	Sum of the obtained support, EUR
Somogy	Marcali	11,142	VP3-9.1.1-17	10-10-9-8-7	1,515.2
Somogy	Marcali	11,142	VP3-4.2.1-15	25-50	1,702,833.1
Somogy	Balatonboglár	5,456	VP3-4.2.1-15	25-50	354,681.2
Somogy	Látrány	1,330	VP3-4.2.1-15	25-50	69,206.9
Somogy	Karád	1,440	VP3-4.2.1-15	25-50	188,573.9
Somogy	Andocs	1,002	VP3-4.2.1-15	25-50	45,072.7
Zala	Vindornyalak	59	VP3-4.2.1-15	25-50	261,229.8
Veszprém	Óbudavár	41	VP3-4.2.1-15	25-50	2,417,602.3
Veszprém	Dörgicse	235	VP3-4.2.1-15	25-50	64,005.3
Veszprém	Tapolca	14,988	VP3-4.2.1-15	25-50	552,835.6
Veszprém	Káptalantóti	477	VP3-4.2.1-15	25-50	284,378.8
Veszprém	Köveskál	321	VP3-4.2.1-15	25-50	325,188.6
Veszprém	Balatonfüred	12,800	VP3-4.2.1-15	25-50	10,730.4
Veszprém	Vászoly	258	VP3-4.2.1-15	25-50	8,727.6
Veszprém	Balatonszőlős	648	VP3-4.2.1-15	25-50	n.d.
Altogether			*not relevant*	*not relevant*	*6,285,065.5*

Source: Based on www.palyazat.gov.hu own editing.

In order to increase the ratio of processing of the agricultural products 17 projects were awarded in 14 settlements in the upper mentioned RDP calls on the area of the BATZ. Out of them Veszprém county can afford the most (59.3%) sources for the development of market products, the opportunities of Somogy and Zala (37.6%; 4.2%) lag behind it. It can be stated that 94.2% of the subsidies are used by the municipalities located further from the lakeshore, and only the 58,3% of the total subsidy went to the villages with risk of population decline. The rates suggest that the small villages lack social resources and have a low ability to assert their interests. Summing up the utilization of the subsidies, the broadening of the product selection and the modern, up-to-date infrastructural conditions accomplish a complex local economy development. The production of the niche market products fit well into the sustainable landscape use principles of the spatial development concept such as the expansion of ecological farming. The volume of the development sources influences both the diversification of local farmers' activity and the façade of selling points positively. Despite the favourable directions, the

already evolved buyer groups and supply chains and the multi-channel use by consumers cause a competitive disadvantage for market places and their operators. The tender sources mean a great help in the effectiveness of the rural, local initiatives, since without them the majority of the settlements would not be able to have enough own contribution for such a volume of investment (assessments without project). The supported design of the RDP is the operation and activity of LEADER organisations, bringing into prominence the development directions for the services sector and human resources development. Within the RDP the separate announcement of the LEADER tenders provide a chance for the villages to establish physical infrastructure, while the sources for the Local Action Groups (LAG) are decided by the organisations related to their Local Development Strategy for the 2014–2020 period.

Rural development and communities: LEADER

The local action groups organically take part in the operation of the region with legal entities of (rural development) associations. These LEADER organisations also decide to award the sources by tenders. In the 2007–2013 budgetary period, among others, market place developments were realised in the sample region from LEADER sources, while in the present 2014–2020 period their presence is only minimal. Out of the financed target areas the developing of local population into a community, the economic recovery, indirectly the retention of the population and employment creation come up. It has to be added that in the present period the development sources decreased to 20%, significantly restraining the operation of the local organisations and their development perspectives. The LEADER organizations supported the market place developments made by the local governments in the 2007–2013 period; most marketplace developments have been proposed by them. The local demands of the market place, the actual business plan, data on the operating of the market were also main selection criteria. Because of the spending limits the groups prioritized those project ideas which lead the diversification of micro and small enterprises and support the regional development (e.g. thematic hiking line). In the 2014–2020 period there was no demand for opening new market places, partially because of the low number of the primary producers.

The settlements of the BATZ cover the activity of 10 LEADER organisations:

- Bakony és Balaton Keleti Kapuja Közhasznú Egyesület (Bakony and the Eastern Gate of Balaton Non Profit Association) (12),
- Balatongyöngye Vidékfejlesztési Egyesület (Pearl of Balaton Rural Development Association) (30),
- Hévíz-Balaton-Zalai Dombhátak Leader Egyesület (Hévíz-Balaton-Zala Rudge of Hills Leader Association) (22),

– Koppányvölgyi Vidékfejlesztési Közhasznú Egyesület (Koppány Valley Rural Development Association) (31),
– Vidékünk a Jövőnk Szövetség (Our Countryside is Our Future Association) (7),
– Vulkánok Völgye Egyesület (Valley of Volcanoes Association) (27),
– Zala Termálvölgye Egyesület (Zala Thermal Valley Association) (2),
– Éltető Balaton-felvidékért Vidékfejlesztési Egyesület (Vital Balaton Highlands Rural Development Association) (32),
– Innovatív Dél-Zala Vidékfejlesztési Egyesület (Innovative South Zala Rural Development Association) (10),
– Közép-Zala Gyöngyszemei Vidékfejlesztési Egyesület (Pearls of Central Zala Rural Development Association) (3).[7]

The ten organizations involved in the BATZ invited 45 applications in 17 themes (Table 4).

Table 4

Themes of LEADER applications between 2014 and 2020.

Themes of applications:	
1. marketing	10. „open farms"
2. tool development / asset purchase	11. energy development support
3. organisation development	12. green tourism development
4. development of micro enterprise	13. creation of purchase points
5. landscape rehabilitation	14. enterprise development with internship programs
6. touristic service development	15. creation of community spaces, base points
7. education actions	16. coordinator community enterprise
8. support for processing activities	17. development of model farms
9. increase capacity	

Source: https://www.mvh.allamkincstar.gov.hu/leader-helyi-felhivasok (downloaded: 10 May 2019).

With the applications reopened in 2019 these 10 organization announced 54 calls covering the major supported activity groups, such as marketing, equipment development or purchase, development of micro enterprises, tourism service development, educational activity, the promotion and support of processing and the increase of capacity. With the support of the model farms and the open lodges a good practice of the Western European countries (primarily in France and Germany) can be realised with the chance of impacting the everyday life of some functioning local farms. The access to the markets is promoted by the establishment of receiving- and acquisition points, community spaces, basic points which, besides the market places, can provide adequate infrastructural circumstances to the local farmers. The broadening of the professional knowledge of the human resources was

[7] See Internet sources.

drafted in the tools of organisation development (e.g. supporting productive communities, community co-ordinating enterprise). With the enterprise development connected with the apprentice programme the LEADER sources could release the lack of human resources at the small enterprises and micro enterprises and can increase their capacity. Landscape reconstructions, water management, recultivation of illegal waste disposal areas are examples for landscape planning and landscape rehabilitation. The energetics and green tourism developments urge environment friendly solutions, sustainable energy management and the development of certain groups of settlements.

The LEADER organisations consist of non-profit, civil-, church and for-profit organisations and local governments and the scope of the claimants for support are determined in their announcements accordingly. Their announced tenders in the present budgetary period have characteristically 50% support intensity, but this varies from organisation to organisation.

Regional characteristics from the point of view of the management – opinions about the LEADER

In the 2014-2020 budgetary period of the EU the aims of the local action groups in the area of the BATZ were laid out in the local development strategies (Nagy-Molnár−Lendvay 2018). All this was preceded by a complex socialization process. During the formation of the strategies the need for market hall creation and developments did not appear in the competence area of the local action groups, so they cannot be found in the presently available applications either. The above mentioned SSDOP and (RDP) LEADER tenders guaranteed application opportunities for the villages so there was no need for further calls by the local action groups. An actual need was experienced in the region for the capacity increase for local producers, the development of crop processing and the creation of model farms and open farms related to village tourism. The majority of the market area applications were not successful in the last budgetary period: either there was no incoming tender, or the actual supply and demand side was not covered. With the co-operation between the former LEADER organisations (short supply chain [SSC] co-operation) in Zala (partly covering the sample area) four market places have been built. The market places of Zalakaros and the nearby Felsőrajk are the locations for regular markets, but as further utilisation opportunities other events can also be organised there. The management' point of view is that it is a basic problem that the continuous availability of the local products is not solved, the producers can only cover partially the consumer demand (e.g. home-made pasta, the continuous presence of fruits and vegetables oriented to the season, mushrooms, eggs). The narrow producer capacity is generated by the presence of the primary producers (with products that can be sold in markets) and

the quantity of the products that can be produced. Being integrated into a producers' community plays a role in the sales activity of the primary producers.

Theoretically the LAG would support the formation of other short supply chains or the development of already available networks, but as the demand is lagging they did not focus on this or only dealt with the problem in a varied degree. Besides tit should be highlighted that Hungary applies the EU's minimum conditions concerning rural development, so it guarantees a maximum of 5% of the development sources, the remaining amount supports the agricultural activities. Out of the restricted financial opportunities those were supported which were able to reach a greater target audience. The leaders of the work organisations see no chance for any future market hall developments – exclusively by actual requisites – in the 2021–2027 budgetary period. The already functioning traditional and local producers' markets (e.g. Hévíz, Tihany, Káptalantóti, Veszprém, Fonyód, etc.) are sufficient for the farmers to be able to appear in the markets. From the point of view of the primary producers the size of the enterprise should be considered since it is not necessarily guaranteed that by increasing the enterprise or firm the maintenance and subsidiary costs can be well managed with the amount of the income. That is why they would rather choose the family farms remaining at the scale of the market place sales. From the point of view of the management it is a future aim to further improve the quality of the product and the verification of the laws from the point of view of the legislator and the verification of the tender calls from the point of view of the responsible persons inviting for tender as well.

Another SSC type of co-operation is present in the region: an open lodge network is functioning in certain settlements of the Zala Thermal Valley Rural Development Association and so called vital points were established also in the competence area of the Vital Balaton Highlands Rural Development Association. These latter serve as a location to take over those products which are qualified by the trademark "A Vidék Minősége – Éltető Balaton-felvidék" (The Quality of the Rural Areas – Vital Balaton Highlands). The similar SSC initiations of the Pearls of Central Zala Rural Development Association wasted away.

Summing up, the present regional market place infrastructural developments cannot be realised from the sources of the LAGs in the present period, because there was no actual demand for them. The demand of the local producers is realised on the level of own crop processing, profile expansion and product development.

Conclusion

Development sources make possible the solving of numerous conflicts such as the renewal of public spaces, rehabilitation of settlement districts or the direct local economy development. Out of the sources of the EU, the essence of the

community initiatives based on LEADER should be found in the improvement of population retention and the support of the rural development objectives.

Out of the present Hungarian tender sources the central calls of the SSDP and the RDP guarantee an opportunity to improve the *infrastructural circumstances* of the market places. Out of them the market places of the sample area are such multifunctional investments that are capable of serving other events as well where the financial return is a long process since they basically produce no significant profit for the investor and the operator. The examples of the producers' markets are steady from the point of view of social expedience. Nevertheless, we have to see that besides the façade of the buildings it would be worth keeping in mind that the constructions should be more protective from weather conditions. The degree of the *capacity utilisation rate* refers to the moderate volume of the number of the local producers and to the supplier activity or the emergence of other distribution channels connected to the touristic utilisation of the region (e.g. restaurants, shop(chain)s). This is confirmed by the answers of managers and the colleagues of the LAG organisations. The expenses/revenues ratio refers to the long term financial return, depending on the own contribution of the local government and the support intensity as well. The support of infrastructural investments was reasonable since creating the necessary conditions for accessing the markets cannot really be expected from the for-profit organisations. The *usefulness* of investments can be summarised on one hand in the speeding of the local economy contributing to the improvement of the local investor and labour force conditions. On the other hand the local communities based on producers' salesmanship promote the strengthening of the local civil society and social network. Reviewing the *regulatory framework* and its re-evaluation from the point of view of the producer and the consumer would be suggested which would promote the access of the local producers to the market besides upholding legislative rigour.

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Financial subsidies and the location decision of solar power plants in Hungary: An empirical investigation

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Recent years have witnessed a significant increase in the number of solar power plants worldwide, including in the European Union. In Hungary, solar capacities have increased tenfold in the past three years, primarily due to the lower cost of solar technology and the favourable investment environment. The integration of these weather-dependent power plants into the electricity system, hitherto, has not been a problem in Hungary. However the expected increase in capacity over the next decade may cause grid problems, implying that the decision about the location of solar power plants is not a secondary issue. Hence, this study examines the factors that impact investors' choice of the optimal installation site and the extent to which financial assistance, primarily operating support, influence this installation decision. This type of research has not yet been undertaken in the Hungarian context. Therefore, our research – based on a questionnaire survey conducted in March 2018 – fills an important gap. In contrast to the conclusions of the extant literature covering other countries, in the case of solar power plants in Hungary the installation location is not based on natural factors (e.g. irradiation) but on the marketability and price of electricity – classified in the financial support category – as well as the network connection options. Additionally, operating support may influence the location of solar power plant installation, which can be used as valuable information for regulation in the course of further expansion of the domestic photovoltaic power generation.

Keywords:
installation factors, location factors, operational support, financial support, solar power plants, renewable investments, renewable policies, renewable subsidies

Introduction

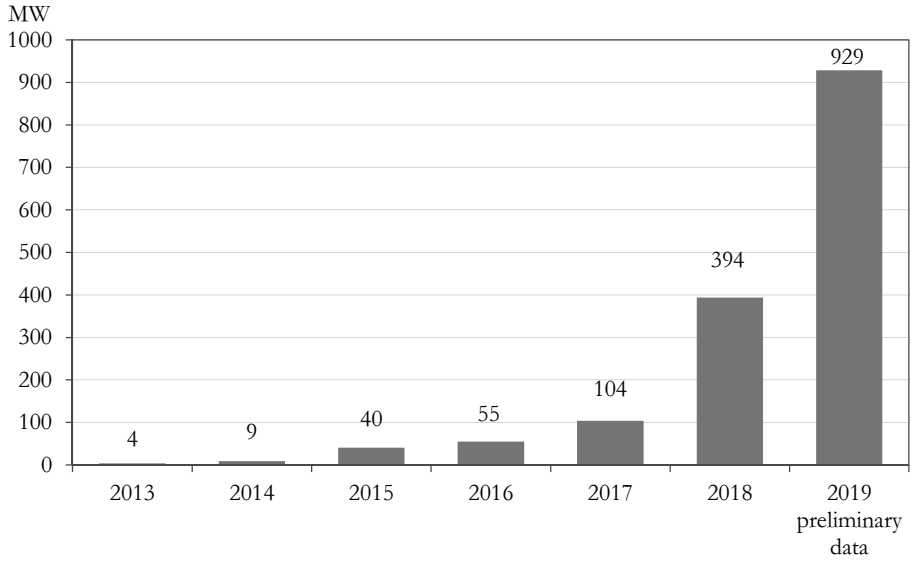
Current international trends show that solar panels are the most widely distributed renewable technologies globally, mainly due to technological cost reductions (Müller-Frączek 2019). In 2018, at 24%, the growth in solar capacity was the highest among all renewable technologies (IRENA[1] 2019). This trend is also evident in the European Union with solar capacity increasing by 61% in 2018 (Agora Energiewende 2019).

In Hungary, expansion in solar power is a recent phenomenon with the installed capacity approaching 1000 MW by the end of 2019 (Figure 1). This increase has primarily been due to three reasons: the fall in the LCOE[2] costs below the subsidised price level, favourable financing environment (low loan interest rate), and the abolition of the previous feed-in-tariff system, which increased the support applications by the solar power plants to obtain favourable subsidy conditions.

Based on the new energy strategy, domestic installed solar capacity is expected to exceed 6,000 MW by 2030 and to be close to 12,000 MW by 2040.[3]

Figure 1

Changes in the built-in capacity* of solar power plants in Hungary



* Data for household sized power plants (<50 kW built-in power capacity) is not included.
Source: Authors' elaboration based on data from the Hungarian Energy and Public Utility Regulatory Authority.

The spread of primarily decentralised solar power plants can be considered positive from climate protection, local job creation, and rural development points of

[1] International Renewable Energy Agency.
[2] Levelized Cost of Electricity.
[3] Magyarország Kormánya (2020).

view. However, it is a major challenge for the basically centralised electricity systems to integrate them into the electricity networks and regulate the weather-dependent solar power generation (in the absence of adequate storage capacity). The question worth examining is whether support systems, especially operating support systems, could influence the location decisions for investment in solar power, and if so, to what extent.

In order to investigate this question, we conducted a questionnaire survey in March 2018 on renewable power plants in operation at that time, including solar power plants. Our objective was to identify the factors considered important by domestic solar power plant investors when making the installation decision, and the extent to which the presence of financial support (mainly operational support) changed their priorities.

Overview of renewable and solar power plant installation factors

In case of renewable power plants (biomass, biogas, solar, wind, hydro, and geothermal), the following groups of factors are generally considered decisive for the installation decision (they have different weights for different renewable technologies)[4]:

- natural factors (e.g. meteorological factors, resource availability);
- infrastructure factors (e.g. network connection);
- economic factors (e.g. payback time, internal rate of return [IRR]);
- legal/regulatory/administrative factors (e.g. licensing circumstances);
- environmental factors (e.g. environmental impacts, land use); and
- social factors (e.g. social acceptance of the power plant, job creation).

According to the international literature, summarising case studies and practical experiences, eight sub-criteria can be defined within four criteria groups (climatological, topographical, localisation, and hydrological) for the selection of solar power plant sites.

In the case of photovoltaic solar power plants, the two main climatic factors that influence the performance of the modules are the irradiation level and temperature (Liu et al. 2017, Lee et al. 2017). The higher the level of irradiation, the more electricity is generated by photovoltaic installations (Al Garni et al. 2017, Ayag 2015). Furthermore, the capacity of the modules is significantly affected by temperature, as temperatures above 30 degrees Celsius reduce the amount of electricity generated, and in the long-run reduce the life and durability of the modules.

The topography of a given site should also be examined, which implies the elevation of the surface in the case of solar power plants. For photovoltaic

[4] For more information see Kyriakarakos et al. (2014).

installations, a maximum surface elevation of 3%–5% is generally accepted, and thus, flat terrain is generally preferred. A higher surface elevation jeopardises the feasibility and increases the investment costs (Carrión et al. 2008).

An important group of criteria are the so-called locational factors, where the following conditions need to be examined: in the first place the proximity of existing road networks to ensure optimal transport conditions and maintenance of the modules and associated equipment (Sánchez-Lozano et al. 2015); secondly, the distance from populated areas in order to reduce network losses and the distance from electricity networks to minimise network connection costs (Uyan 2013); and thirdly, the factor closely related to the fourth set of criteria, namely the distance from the water bases. (Azevedo et al. 2017).

The fourth set of criteria are the hydrological factors, particularly important in areas with sparse vegetation. For instance, in Morocco: being close to the Sahara desert, and where the water demand for cleaning off the sand from solar panels is significant. Thus the proximity to rivers, dams, and groundwater bases may be a determining installation factor (Merrouni et al. 2018).

The above analyses, summarising practical experiences, generally do not consider the impact of subsidies on installation decisions, while other international studies (mainly those conducted by German researchers) have revealed a link between the location of renewable power plants and subsidies for the renewable electricity generation (*Annex 2*). Some of these are comprehensive analyses covering all renewable technologies (e.g. Polzin et al. 2015, Jägemann 2014), while others are specific to solar plants (Lüthi 2010; *Annex 1*) or focus on wind farms (Hitaj et al. 2014; Schmidt et al. 2013, Pechan 2017, Obermüller 2017, Hiroux–Saguan 2010).

In a comprehensive study, *Polzin et al. (2015)* examined the impact of certain renewable policies (e.g. fiscal and financial incentives, market incentives, and regulatory and political environment) on investments in renewable electricity generation capacities in case of institutional investors (e.g. investment and pension funds, banks, and insurance companies). The data included in the study were analysed for the Organisation for Economic Co-operation and Development (OECD) countries over a 12-year period (2000–2011), broken down by sectors: wind, solar, and biomass, and aggregated renewable capacity data, in a panel regression analysis. The dependent variable in the model was the aggregated newly installed renewable capacity (MW) in a given country, year, and sector, while the independent variable was the number of each type of renewable energy policy in a given country in a given year.

Certain control variables were also included in the model, which may also have influenced the development of renewable capacities. These included the country's gross domestic product, carbon dioxide intensity, electricity consumption, long-term interest rates, and stock indices.

As the impact of individual renewable policies is delayed in some cases, a longitudinal analysis has also examined the impact of policies on the development of renewable capacities with some time lag. Thus, a measure introduced up to three years ago has also been considered to have resulted in a renewable capacity surplus in the given year.

Summarising the results of the regression analysis, it can be said that *out of the fiscal–financial incentives, feed-in-tariff support has the maximum positive impact on renewable capacity investment* in the case of aggregated renewable data, wind, and above all, solar sectors. Among the countries examined, this effect was the most significant in Germany and Italy. The strong positive correlation is primarily due to *feed-in-tariff schemes providing a guaranteed return over time, thereby reducing the risk of renewable energy investments.*

The analysis concluded that *technology-specific policies are favourable for renewable energy investments, considering the current state of the renewable market and the maturity of the technology.* Investors prefer financial incentives that are predictable in the long term (e.g. feed-in-tariff system) rather than support schemes that depend on political periods and the budget (e.g. tax breaks, favourable loans). However, it should be noted that investment subsidies and favourable loans play a very important role in diffusing the technology during its early stages. *The introduction of market incentives can only be beneficial for more mature renewable technologies.*

Lüthi (2010) examined the German, Spanish, and Greek markets with an empirical analysis for photovoltaic solar power plants, investigating why Mediterranean countries with better irradiation exposure did not develop more solar capacity than Germany, which has lower irradiation levels. It was concluded that *above a certain level of return, revenue-oriented installation factors* (such as the amount of the feed-in-tariff) *no longer influence the investment decision, rather risk factors* (such as stability of the support system or administrative barriers) *become important determinants of investment decisions.*

The solar market in each country was examined based on *revenue-oriented* (e.g. tariff rate, duration of support, and solar energy potential) and *risk factors* (e.g. support policy stability, support limit, and administrative processes), based on expert interviews.

The empirical analysis concluded that all three countries, especially Spain and Greece, perform well in terms of revenue-oriented factors. Therefore, if we examine only these factors, the Spanish and Greek solar markets should be at least as advanced as the German market. However, political risks (e.g. administrative obstacles, difficulties in network connection, and risk of sudden political changes) has greatly influenced the development of the solar market.

In Germany, the Renewable Energy Sources Act has created a stable investment environment, the administrative processes are relatively fast and transparent, and the network connection process is well regulated. This has led to a multiplication of the

installed solar capacity in the country, especially since the introduction of the feed-in-tariff system, despite the less favourable irradiation conditions than in the Mediterranean countries.

Based on the reviewed international literature, it can be concluded that renewable policies, including renewable support schemes (e.g. feed-in-tariff and premium), have a significant impact on the geographical location of renewable technology investments. These policies directly influence the producer's revenue and indirectly impact the investment environment by stabilising the support systems, administrative processes, and other political factors, which indirectly influence the installation decision (see Polzin et al. 2015, Lüthi 2010). This is the reason for countries with less favourable natural conditions but more constructive renewable energy policies (e.g. Germany) being able to build higher renewable capacities than regions with better potential (see e.g. Lüthi's analysis of photovoltaic solar power plants).

As mentioned earlier, the international literature we have reviewed also examined the impact of subsidies on the installation decision in the case of wind farms. In our opinion, these results can also provide useful information on the location of solar power plants. Therefore, we briefly summarise the key points below.

According to empirical studies (e.g. Hitaj et al. 2014), the feed-in-tariff system had a significant positive impact on the development of wind power capacity in Germany. Some authors (see also Hitaj et al. 2014) opine that the spatial location of wind farms was affected by the location-specific feed-in-tariff support system in a manner that if it had not been introduced (i.e. a location-neutral tariff had been applied), then much more wind farms would have been built in the North German provinces. In contrast, there are models (see Jägemann 2014) that argue for technology and location-neutral forms of support.

In the case of a premium system, spatial location affects wind farms' revenues, as many studies (e.g. Schmidt et al. 2013, Pechan 2017) have supported the so-called merit order effect, according to which increasing wind power production will lower market prices. According to Schmidt, this means that wind farms will be more spatially differentiated, although he did not consider the impact of network congestions in the analysis. In contrast, Pechan (2017), Obermüller (2017), and Hiroux–Saguan (2010) included the cost of network integration into the analysis. They concluded that premium support would only lead to system-wide spatial optimisation of renewable energy sources, including wind farms, if nodal pricing is used. This implies that in addition to marginal production costs, network costs are also reflected in market prices.

Questionnaire description and research methodology in the Hungarian context

In March 2018 we conducted a questionnaire survey among domestic renewable electricity producers, including solar power plants, in order to identify their installation criteria. The questionnaire was sent to the operational domestic renewable power plants on 10 March 2018, which totalled 305 power plant sites with a combined installed power capacity of 861 MW. In terms of the number of units, solar power plants accounted for the largest number (151 units) with an installed capacity of 111 MW.

The response rate was 38% based on the number of organisations and 39% based on the built-in capacity. This response rate can be considered representative based on the research performed.

In terms of the number of respondents and their installed capacity, solar power plants had the highest response rate (over 50%), with 86 responses out of the 151 solar power plants surveyed. In terms of energy source, solar power plants have the highest representation: this is where the best correlation can be found between the distribution of those questioned and those responding.

The distribution of respondents was also examined according to different relevant categories (company size, power plant size, experience in the energy sector, and company type).

The answers to the questions were evaluated using Excel, R, and SPSS statistical programmes, based on the built-in statistical functions (frequency, average, and expected value calculation).

The *Mann-Whitney test* was used to determine if the difference between the scores given by the two respondent groups (yes/no and below or above 250 persons) was significant, as the values to be examined were not normally distributed. In cases where the frequency of occurrence was also an important criterion, and when normality and the standard deviation was not equal, we used the *Z-test*.

More than 40 installation factors were identified in the questionnaire. Therefore, *cluster creation* was a reasonable choice – to reduce dimension number, facilitate analysis, and increase transparency.

Given that we received a sufficient number of responses only in the case of solar power plants, clusters based on statistical calculations were also developed here. The groupings thus formed were applied to the other types of renewable power plants.

Installation factors have been grouped into the following categories:
- *Natural factors* (e.g. meteorology and topographic factors);
- *Location-specific factors* (e.g. transport, energy infrastructure, proximity to consumers, and power plants);
- *Economic factors* (e.g. costs and revenues, payback time, and IRR);
- *Financial support* (e.g. level of support and predictability of support system);
- *Environmental, social factors* (e.g. administrative procedures, relationships, environmental impacts, and social acceptance).

Absolute (average of respondents' ratings per question) and *relative order* have been used to evaluate the answers. In the latter case, the five most important installation factors of the surveyed renewable power plants were selected and ranked. In such a case, it is not only important which aspect is ranked among the top five but also where its position lies. This was accomplished by assigning weights to the criteria in each rank: in the first place, five weights per respondent were ordered to the selected aspect; in the second place, four weights per respondent were ordered to the selected aspect, and so on. In the end, we summed up the weights for each question and sorted the questions in order.

It should be noted that due to respondents' errors and the structure of the questionnaire, some respondents selected the main category of installation factors instead of a concrete installation factor. Even in the case of non-financial support, some respondents mentioned an installation factor belonging to the financial support main category. *These respondent errors were filtered by excluding incorrect answers from the analysis.* This method was used for all renewable technologies.

Results for solar power plants

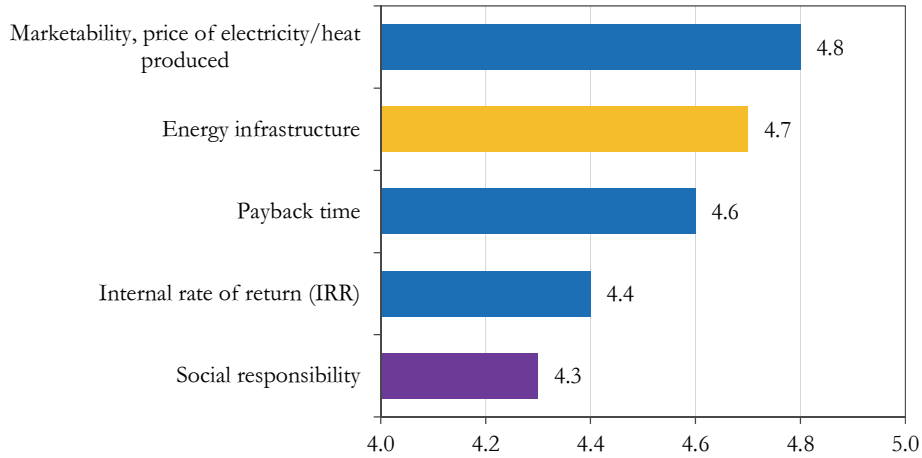
As mentioned earlier, solar power plants had the highest response rate: more than half (57%) of the respondents filled out the questionnaire. Out of the 86 responding solar power plants, only 7 had an installed capacity of more than 0.5 MW, indicating that most were small power plants with no licensing obligation. Most of the responding solar power plants (79%) were micro-enterprises with less than 250 employees. The vast majority (99%) did not belong to consolidated groups of companies. Generally, these solar power plants did not have previous energy experience (72%).

In absolute order, economic factors were predominant among the five most important installation factors (Figure 2). However, a location-specific factor (energy infrastructure) was also included (second place). *According to the respondents, the most important factor was the marketability and price of the electricity/heat produced.* Payback time and IRR were also relevant. Interestingly, an environmental/social factor (social responsibility) was the fifth most important installation factor. Solar power plant

investors with previous experience in the energy sector tended to focus more on economic factors.

Figure 2

The five most important factors considered by solar power plants in the course of installation (absolute order, average of respondent ratings)



Notes: Colour coding: yellow – location-specific factors; blue – economic factors; purple – environmental and social factors.

Source: Based on own survey (March 2018).

Solar power plant operators considered natural and location-specific factors less important than expected (on average 2.5 points for both groups of factors). Among the location-specific factors, only energy infrastructure and land availability were considered to be of significant importance. The cost of renting land received only 1.99 points on average; however, when split based on installation capacities above and below 0.5 MW, the former received 4.29 points and the latter only 1.99 points. This difference is due to the relatively large space requirements of solar power plants.

Within natural factors, meteorological factors and available energy sources are hardly considered important. This can be explained by the geographical size of Hungary, where the meteorological characteristics (e.g. number of sunshine hours) of each region are similar.

Economic factors received an average rating of 2.6. The most important economic factors were marketability/price of the electricity/heat produced, payback period, and IRR. The cost of network connection received a slightly higher than average rating. Due to the need for technological seed capital, investment-related costs and return on investment opportunities were considered important in cases where *the marketability and price of the electricity/heat produced were extremely critical.*

Within the financial support category, respondents emphasised the predictability and long-term sustainability of the financial support system (evaluated on average at 4.2). The availability

and amount of (soft) loans, credit costs, and financial subsidies received a higher than average (3.7) rating. More important than the amount of financial support was the predictability of the system in the hope of a solid return on investment.

On average, environmental and social factors were rated at 2.7. The most important environmental and social factor was *social responsibility*. The relationship with local governments, as well as the duration and complexity of administrative procedures and licensing were rated higher than average.

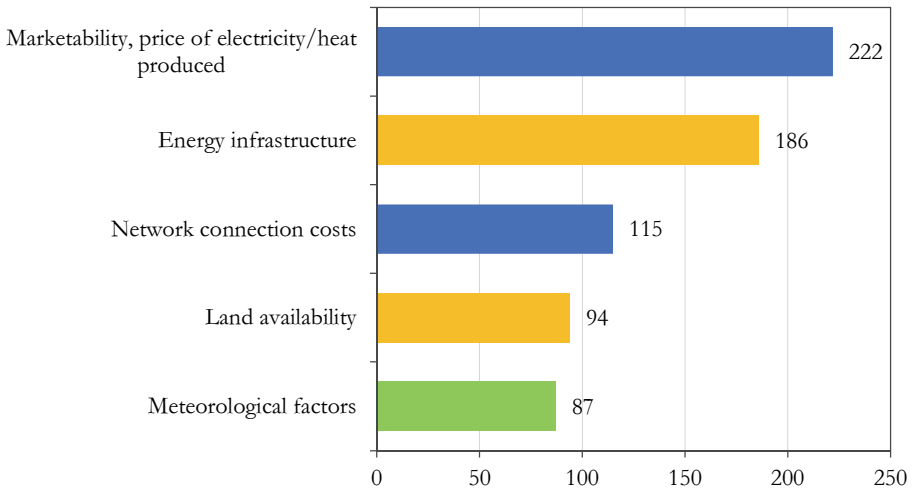
Other installation factors included the avoidance of shading effects and the special nature of the installation area (archaeological site, high gold crown value, especially suitable, e.g. re-cultivated slurry pond). One respondent mentioned that his place of birth also determined his decision, that is, personal motivation also appeared as a factor influencing the location of the installation (Dusek 2013).

Out of 86 responding solar power plant operators, 14 tested nationwide for installation. There is a much higher proportion among those who had already been engaged in energy activities before the given venture (50%). Nevertheless, the majority of respondents examined the middle regional level for implementing the investment.

For solar power plants, the five most important installation factors are shown in Figure 3, based on the *relative (weighted) order* of the installation factors.

Figure 3

Relative order of installation factors for solar power plants (sum of weights)



Notes: Colour coding: green – natural factors; yellow – location-specific factors; blue – economic factors.
Source: Based on own survey (March 2018).

Compared to the absolute order, there is no difference in the order of aspects in the first two places: not only the main category of installation factors but also the specific installation factors are the same. The third-place has a cost factor, although here it is the cost of network connection instead of payback time in absolute order. Instead of the IRR as an economic factor, a location-specific aspect – the availability of land – was at the fourth place (as mentioned earlier, the installation of solar power plants requires space). The fifth-place had a natural factor, namely the meteorological aspects (e.g. irradiation).

For companies with prior experience in the energy sector, network connection cost was the most important installation factor, while for inexperienced companies, the marketability and price of the electricity produced were of primary concern. In the case of experienced companies, meteorological factors were ranked second, while in the case of inexperienced companies, this factor did not even rank among the top five. Another highlighted factor is the energy infrastructure, which ranked only 5th for experienced companies, while it ranked second for companies with no previous energy experience. While the cost of network connection was one of the five most important installation factors for solar power plants with an installed capacity below 0.5 MW, for power plants above 0.5 MW capacity, this factor was not included in the top five. The relative order of energy infrastructure, availability of land, and meteorological factors are similar within the two groups. For capacities above 0.5 MW, the second most important factor was the IRR, and for those below 0.5 MW, it only had an average weight. For larger solar power plants, the marketability and price of the electricity produced was the primary installation factor, while for smaller solar power plants it was the availability of energy infrastructure.

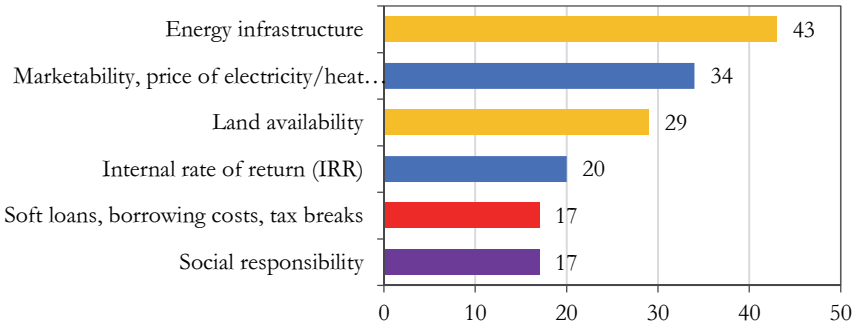
As the financial support category was the most important installation factor group for the solar power plants surveyed, it is worth *examining the impact of financial subsidies on the order of importance of the installation factors.* It should be noted that those solar power plants that responded to the questionnaire usually received operating support and soft loans.

A total of 47 solar power plants provided the relative order of factors in case of no financial support. Figure 4 illustrates the deviations from the relative order with financial support by the frequency of mentions. *Without financial support, social responsibility would have been less important and would not have been among the top five installation factors.* Energy infrastructure and marketability/price of the electricity produced were the two most important factors in both cases, although the ranking would have been reversed had the responding solar power plants not received financial support. Furthermore, *without financial support, meteorological factors would have been more important, and placed among the top five installation factors.*

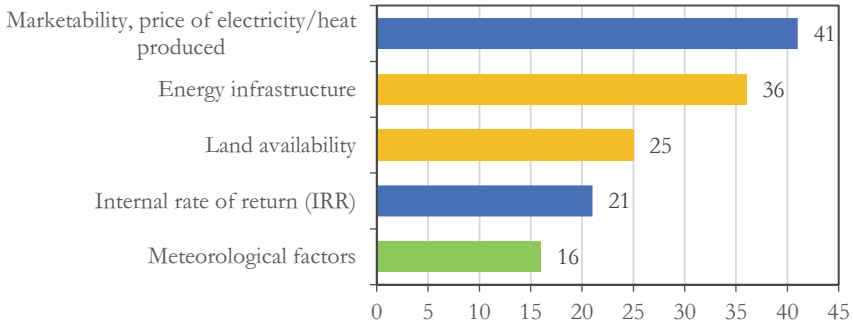
Figure 4

Relative order of installation factors for solar power plants with and without financial support (frequency of mentions)

With financial support



Without financial support



Notes: Colour coding: green – natural factors; yellow – location-specific factors; blue – economic factors; red – financial support; purple – environmental and social factors.

Source: Based on own survey (March 2018).

In the case of aspects where the greatest differences were observed with and without financial support regarding the frequency of mentions, *Z-test*[5] was performed to confirm the significance of the difference.

Statistically justifiable differences:

- In the absence of financial support, meteorological factors are more important than with financial support.
- Without financial support, energy infrastructure and environmental standards are less important than with financial support.

[5] https://www.socscistatistics.com/tests/ztest/Default2.aspx

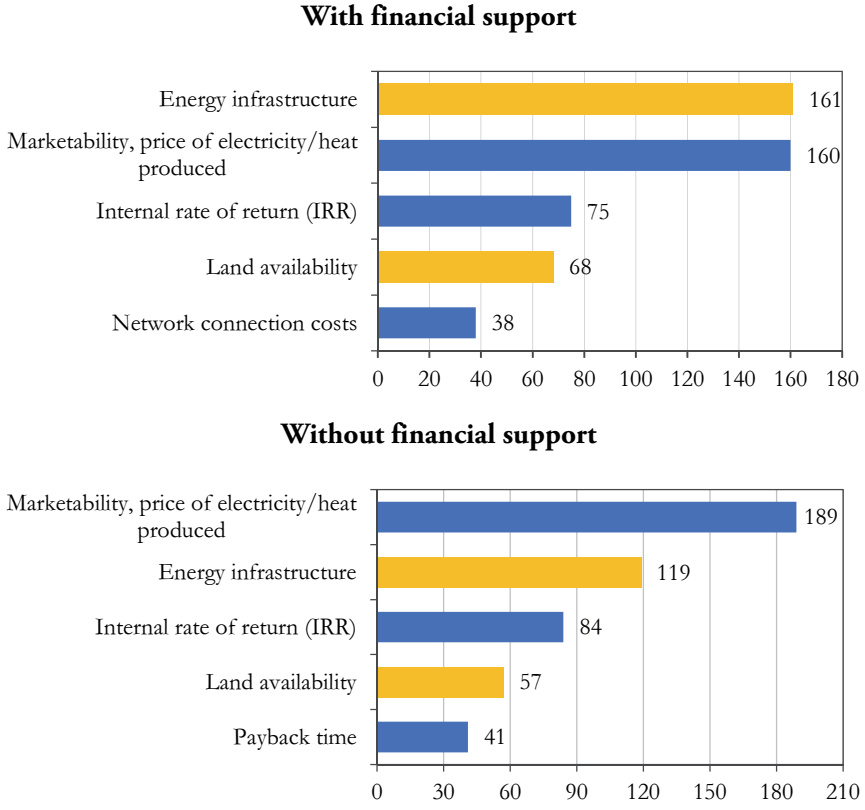
Statistically non-justifiable difference:

– There is no statistically significant difference in the importance of the availability of land with and without financial support.

An examination of the impact on the weighted ranking of installation factors reveals that *in the absence of financial support, marketability and price of electricity produced is more important than energy infrastructure*. The cost of network connection would not even appear in the top five rankings without financial support and would be replaced by the payback period (Figure 5).

Figure 5

Relative order (weighted ranking) of installation factors for solar power plants with and without financial support (sum of weights)



Notes: Colour coding: yellow – location-specific factors; blue – economic factors.
Source: Based on own survey (March 2018).

Conclusions

Our research objective was to identify the installation factors that domestic renewable power plants, especially solar power plants, consider important when making an investment decision, and how this investment decision is influenced by the existence of financial support. From a domestic perspective, the topic of the study can be considered as novel in relation to the spatial aspects of financial subsidies to renewable electricity generation. To date, no similar study has been conducted for Hungary, presumably because no major disturbances in the electricity system have occurred hitherto in connection with renewable electricity production.

On the one hand, our results show that interestingly, *the most important factors influencing the installation of solar power plants are not natural factors (e.g. irradiation) but marketability, price, and network connection (energy infrastructure) of the produced electricity, both in terms of absolute and relative order*. This may be due to the small geographical size of Hungary, where the meteorological characteristics (e.g. number of hours of sunshine) of each region are similar. In addition, *the predictability of the financial support system and the amount of financial support is critical for solar power plant investment decisions*.

As most solar power plants are included in the feed-in-tariff system, marketability of the electricity produced (that is, guaranteed acceptance by the transmission system operator) and its price (that is, the feed-in-tariff) can be considered, in our opinion, as installation factors in the financial support category. Therefore, it can be stated that *the existence of operating support was the most important installation factor in the case of solar power plant investments*.

Secondly, *without financial subsidies* (mainly operating support for solar power plants), *investors would strive to maximise revenues* (that is, selling electricity at higher prices or making better use of environmental factors) *and minimise losses* (e.g. choosing the network connection point as close as possible or searching for cheap land). *Thus, operating support influences other aspects of the site selection process, their order of importance, and through this, the site selection process itself. Therefore, operating support can influence the location of the renewable power plant installation*, which can be used as valuable information by the regulator in case of further expansion of domestic renewable capacities, especially the intermittent solar power generation in Hungary.

Our research should be pursued and widened in two directions: on the one hand, by repeating the questionnaire survey among (producing) solar power plants already operating at a given time, as this would provide more information on the site selection criteria (given that there were more than 1,400 solar power plant producers by the end of 2019[6]). This survey could also explore possible installation effects of the premium scheme introduced in 2017. The other direction of research could be the examination of location-specific subsidies.

[6] *Source:* Hungarian Energy and Public Utility Regulatory Authority.

Annexes

Annex 1

The most important installation factors for solar power plants

Author	Grouping aspect	Installation factor
Liu et al. (2017)	Geographical features	Irradiation
		Altitude
		Temperature
	Economic factors	Investment costs
		Operational costs
		Revenues
		Outage costs
	Environmental factor	Carbon dioxide emission avoidance rate
Lee et al. (2017)	Costs	Land purchase/lease costs
		Module costs
		Maintenance and repair costs
	Biological environment	Land use
		Population density
	Physical environment	Soil quality
		Weather
	Economic development	Impact on agriculture
		Future capacity expansion opportunities
Azevedo et al. (2017)	Climatic factor	Direct normal irradiation
	Topographic factor	Surface elevation
	Environmental factor	Land use
	Location factors	Distance from electricity networks
		Distance from water bases
		Distance from major routes
		Distance from populated areas
Al Garni et al. (2017)	Environmental factors	Land use
		Agrological capacity
	Location factors	Distance from populated areas
		Distance from electricity substations
		Population density
		Distance from major road networks
		Distance from electricity networks
		Distance from sites of historical importance
		Distance from nature reserves
	Economic factors	Land price
		Construction costs
	Climatic factors	Irradiation
		Average temperature
	Topographic factors	Surface elevation
		Orientation
Sánchez-Lozano et al. (2015)	Environmental factor	Agrological capacity
	Topographic factors	Surface elevation
		Orientation
		Surface features of the site
	Location factors	Distance from major routes
		Distance from electricity networks
		Distance from cities
		Distance from electricity substations

The most important installation factors for solar power plants (continued)

Author	Grouping aspect	Installation factor
Ayag (2015)	Geographical factors	Cost of earthworks
		Number of hours of sunshine
		Irradiation
		Wind force
		Air pollution
		Precipitation amount
	Economic factors	Energy cost
		Government support
		Land price
	Social factors	Workforce availability
		Safety
		Social acceptance
		Contribution to the economic development of the region
Uyan (2013)	Environmental factors	Distance from populated areas
		Land use
	Economic factors	Distance from roads
		Surface elevation
		Distance from electricity transmission networks
Carrión et al. (2008)	Environmental factors	Land use
		Visual impact
	Topographic factors	Surface elevation
		Orientation
	Location factors	Distance from major routes
		Distance from electricity substations
		Distance from populated areas
	Climatic factors	Global radiation
		Diffuse radiation
		Number of hours of sunshine
		Average temperature

Source: Edited by Tóth (2019)

Annex 2

A summary of international literature on the effects of renewable subsidies on the location of renewable power plants

Author	Level of analysis	Locational factors examined	Renewable technologies included in the study	Analysis/model type	Main conclusion
Polzin et al. (2015)	Global (OECD countries)	Renewable policies (financial, market, regulatory incentives)	All renewable technologies	Panel regression analysis	Feed-in-tariff systems have the greatest impact on renewable investments.
Lüthi (2010)	Regional (German, Greek, Spanish)	Income-oriented factors risk factors	Solar power plants	Empirical analysis based on historical data	Risk factors are more important than revenue-oriented factors.
Hitaj et al. (2014)	Local (Germany, county level)	Feed-in-tariff support	Wind farms	Econometric model	Feed-in-tariff support has a significant positive and timely impact on the development of wind power capacity.
Jägemann (2014)	National level (Germany and Austria)	Marginal cost, limit value, net marginal cost (marginal cost minus limit value) of certain renewable technologies	All renewable technologies	Electricity optimisation model	Technology and region-neutral renewable subsidies lead to a socially cost-effective renewable power plant location.
Schmidt et al. (2013)		Feed-in-tariff and premium support	Wind farms	NPV[a)]-optimisation model, regression model	Premium systems encourage site diversification of wind farms.
Pechan (2017)		Feed-in-tariff, premium or network congestions (single vs. nodal pricing)		General Algebraic Modelling System	Only nodal priced premium systems promote the site diversification of wind farms.
Obermüller (2017)		Feed-in-tariff, premium or network congestions (single vs. nodal pricing)		Electricity optimisation model	Nodal pricing and regionally differentiated feed-in-tariffs promote the site diversification of wind farms.
Hiroux–Saguan (2010)		Market signals (e.g. nodal, zonal pricing, intraday/ day-ahead trading)		Empirical analysis	Enabling intraday and day-ahead trading, as well as nodal and zonal pricing, affect the location of wind farms.

Source: Tóth (2019).
a) Net Present Value.

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Separation effects in a microregion: traffic volume estimation between the settlements of Lake Velence

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Keywords:
separation effect, gravity modelling, spatial statistics, transportation geography

In an analysis of separation effects, borders are usually taken into consideration. However, in addition to country borders, borders within a microregion that are experiencing resistance, for example, county borders, may also exhibit separation effects. In this article the focus is on such borders; a separation effect has been proven in the microregion of Lake Velence and its surroundings (in Hungary). The novelty of the analysis is that the effect of the order of settlements is taken into consideration as proof of its usability. In doing so, a more accurate gravitational model can be built for modelling the number of commuters in the microregion, which, in turn, can be used to predict traffic demand.

Introduction

In transportation sciences the effect of spatial separation on transportation is researched occasionally and usually focuses on national borders. However, county and district borders also exhibit a separation effect. This can be analysed through changes in the transport demand. However, there are several aspects to the demand for transportation (work, school, leisure). This article only considers daily commuting or commuter travel demand. It should be noted that although recreational travel is also significant, here it is outside the scope of the investigation.

It is widely acknowledged that the strictness of borders influences traffic volumes. For instance, free trade agreements between Indonesia and Malaysia, which include facilitating border crossing, can significantly improve the quality of road freight transport between the two countries (Opasanon–Kitthamkesorn 2016). Numerous studies analyse the relationship between the United States and Canada. Authors (Avetisyan et al. 2015) show how the use of one additional border guard affects the development of a given border crossing and bilateral relations. However, several authors (Bradbury 2013, Brown–Anderson 2015, Burt 2009, Maoh et al. 2016, Park et al. 2014) estimate traffic volume and bilateral relations based on

economic performance and the strictness (resistance) of border surveillance. The effects have been demonstrated in the European region (Miltiadou et al. 2017), and the results discussed the impact of cross-border isolation in the rest of the European Union (EU) on Greece. A situation similar to that of Hungary is presented in an article (Niebuhr 2008) on how reducing the cost of cross-border movement influences the condition of individual border regions. The relationship between cross-border traffic and the micro-environment of border crossing points has also been described (Szabó et al. 2017, Szabó–Török 2018a, b). The findings indicate that resistance to cross-border traffic (such as the Schengen Convention or EU membership) has a significant impact on traffic volume.

In Hungary, numerous transport features were surveyed during the 2011 census. For example, daily commuters were asked about their origin and destination according to the different transportation modes (KSH 2011). As the publication of low values would violate privacy in many cases, only an excerpt of this survey is publicly available, which shows the extent of commuting to district centres by any means of transportation. Based upon these data, using spatial statistic tools, in particular the gravity model, it is possible to produce the origin-destination (OD) matrix for describing traffic flows between the settlements (Dusek–Kotosz 2016).

The gravity model is often used in numerous fields of science (e.g. Márkus 2018) as well as in transport sciences in order to determine the estimated traffic demand between two points in space. It was first used for transportation research by John Q. Stewart (1948) in a article; however, in the case of railways the usefulness of the gravity model usage in 1846 is proven (Odlyzko 2015). Efforts have been made to analyse the impact of geographical features on international trade (Limão–Venables 2001). The relationship and the volume of transport between countries can be examined based on the similar properties of the neighbours (e.g. similar language, closeness or whether is there a border between them) using a gravity model (Hummels 1999).

The purpose of this paper is to refine gravity models by considering other spatial effects. Our goal is to illustrate the order of settlements through theoretical models, and the separation effects – based upon (McCallum 1995) – through a practical example, and to estimate current traffic demand. To this end, in the second section, we present the methodology, including the characteristics of the area and the explanatory variables. In the third section, the results of each model are presented, while the fourth section shows an evaluation of the main parameters.

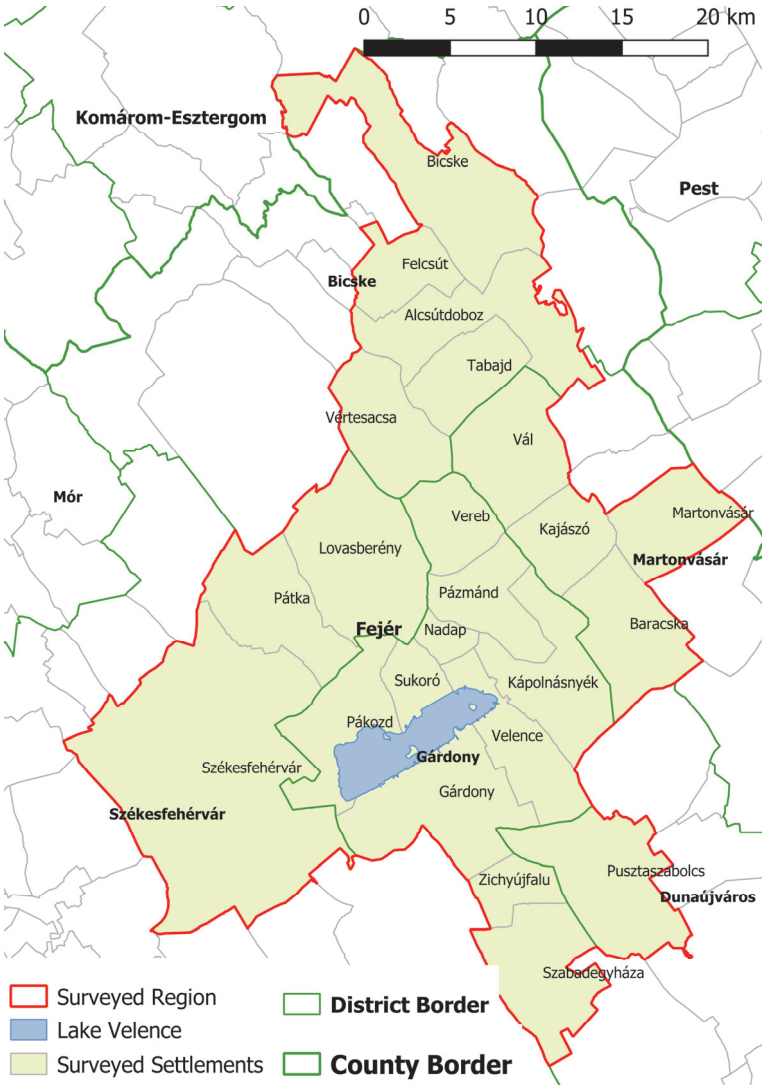
Methodology

During the analysis, the wider environment of Lake Velence in Hungary was taken into consideration. The test site included the Gárdony District and parts of the related districts of Bicske, Martonvásár, Dunaújváros, Székesfehérvár, and the national capital (Rechnitzer et al. 2019, Varga et al. 2020). The site was chosen because it satisfies multiple criteria: first, the area has recently been experiencing a demand to upgrade the transportation network. The next criterion was the existence of a quasi-closed bus network – a compact network comprising a few main lines and some connecting lines, thus minimising the number of lines leading out of the network. Furthermore, the separation effect can be observed, and during the reform of the LAU-1 level of administration in Hungary, the borders were changed, so change in transportation flows can be observed.

In terms of the regional bus network, there are three main routes from Székesfehérvár toward the chosen region, specifically, in the direction of Bicske (via Lovasberény on road nr. 811), Kápolnásnyék (via Sukoró on road nr. 8116), and Martonvásár (via Gárdony on road nr. 7). The most important bus links use these three routes. There are also some lines connecting the three main routes, for example, Bicske–Martonvásár (via Vál on road nr. 8111) and Lovasberény–Velence (via Vereb on road nr. 8117). There are two joined lines between Velence–Pusztaszabolcs and Gárdony–Zichyújfalu–Szabadegyháza. These links create a compact network with connection points on three railway lines in Bicske, Székesfehérvár, Kápolnásnyék, and Pusztaszabolcs, and important bus routes in Szabadegyháza and Bicske. There are only three bus lines that connect unmentioned settlements and create fulfill outside the region (Bicske–Etyek, Etyek–Tabajd, and Besnyő–Pusztaszabolcs–Adony); however, there is only one bus service per day. A map of the region is presented in Figure 1.

Figure 1

Map of the area, 2018



In this case the gravity model will serve to estimate the amount of traffic demand between two settlements. To this end, first the 2011 parameter values are estimated from the available data (using the 2011 data) and then, assuming they are independent of time, these are applied to the 2018 data set. Baseline data is the commuter traffic that can be extracted from the 2011 official census data (Table 1). The columns show the departure settlements, while the destination cities are reported in the rows.

Table 1

The available data for commuting (commuters per day) in the analysed area, 2011

From \ To	Budapest	Székesfehérvár	Bicske	Gárdony	Martonvásár
Budapest	–	624	200	32	64
Székesfehérvár	1 893	–	33	156	38
Alcsútdoboz	78	11	91	1	1
Baracska	358	45	77	27	6
Bicske	830	30	–	1	2
Felcsút	114	11	146	1	1
Gárdony	515	925	1	–	28
Kajászó	136	19	9	4	13
Kápolnásnyék	280	198	1	56	15
Lovasberény	31	494	33	9	2
Martonvásár	716	72	8	8	–
Nadap	45	37	1	9	1
Pákozd	58	728	1	14	1
Pátka	18	466	2	1	1
Pázmánd	168	83	2	20	14
Pusztaszabolcs	517	186	1	13	4
Sukoró	90	172	1	8	2
Szabadegyháza	14	336	1	7	1
Tabajd	40	5	88	0	2
Vál	259	19	69	1	29
Velence	409	310	2	94	10
Vereb	34	51	2	8	2
Vértesacsa	30	162	58	0	1
Zichyújfalu	8	148	2	46	3

Source: authors based on the KSH (2011) survey.

The gravity model is based on Newton's law of universal gravitation (1).

$$F=-\gamma\frac{m_1 m_2}{\mathrm{r}^3}r \tag{1}$$

where: F: is the gravitational force acting between two objects; m_1, m_2: are the masses of the objects; r: is the distance vector between the centres of their masses (r is the scalar value); γ is the gravitational constant.

Note that the exponent of the r is 3 instead of 2, owing to the vectorial form. The scalar form of Eq. 1 can be transformed to calculate the transportation demand (denoted by U) between two settlements (Eq. 2).

$$U = \gamma\frac{m_1 m_2}{r^2} = \gamma m_1 m_2 r^{-2} \tag{2}$$

To accomplish the analysis, it is necessary to estimate the parameters of the gravity model. There are two possible methods for setting the model parameters. One is when the exponent of the distance is considered to be constant and known, so only γ needs to be estimated (Jung et al. 2008). In this case, simple linear regression can be applied without a constant term. However, this analysis uses another approach wherein, besides γ, the exponent of the distance and the exponent of the settlement populations are also estimated (Okubo 2004). While using the power function on population is not the most effective in terms of the model's reality, there are many examples of weighting the population by some factor to better estimate mobility propensity (Dusek–Kotosz 2016). Thus, a linear regression model is used that contains logarithmic dependent and explanatory variables.

The explanatory variables of the models can be divided into two groups. One is a group of variables derived from the classical gravity model (CGM), which includes the population of the settlements (KSH 2018) and the distance between settlements. In terms of population, two models can be set up. In one case, the explanatory variable is going to be the product of the population of the two settlements, while in the other the weighting of the population is done separately.

In all cases the distance is the time needed for commuting (assuming an arrival time no later than 8:30 am), based on the timetable data (Saif et al. 2018). The reason behind this is that the public transportation network holds a significant role in case of daily commuting (Lakatos et al. 2020, Lakatos–Mándoki 2020, Pupavac et al. 2019). In the case of distance calculating there is a debate about methods that can or cannot be used (Dusek 2011, Nagy 2011), however the timetable data seems to be acceptable. The transportation network or infrastructure distance is widely used in different researches, for example (Pálóczi 2016, Pálóczi et al. 2016, Kincses et al. 2016, Varga et al. 2016, Guzik et al. 2017, Kiss–Szalkai 2018, Tagai et al. 2018, Mátyás et al. 2019).

Examining the previous table and summarising the number of commuters reveals that on one hand, traffic demands are not symmetrical (since more people commute from the smaller settlements to the populated ones) (Konecka-Szydłowska et al. 2019, Novotný–Pregi 2019, Alpek–Tésits 2019, Molnár et al. 2018), and traffic operates on two levels (regional, national). Therefore, the introduction of additional explanatory variables for the extended gravity models (EGM), which belong to the other group of variables is recommended. The first is the rate of the orders, denoted by C_B. The order is a number between 0 and 5 assigned to each settlement based on the European Union's NUTS (Nomenclature des Unités Territoriales Statistiques – Nomenclature of Territorial Units for Statistics) (Brandmueller et al. 2017). C_B compares the order of the two settlements between which commuting occurs (Szabó et al. 2019). In the case of Hungary, Budapest's order is 0, as it is the capital. The NUTS-1 and NUTS-2 levels are only statistical, so no settlement is assigned to this level. The county towns (for example,

Székesfehérvár) are denoted by 3, while district seats (for example, Gárdony) are denoted by 4. The remaining settlements are in order 5. Based on these values, a ratio can be calculated for the settlement pairs as follows (Eq. 3).

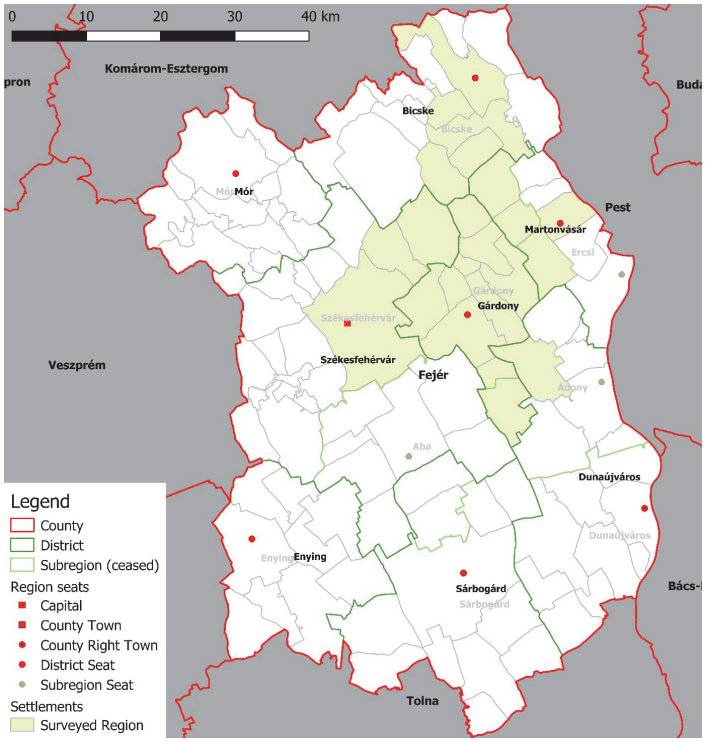
$$c_B = \frac{c_{from\_settlement}}{c_{to\_settlement}} \tag{3}$$

where C is always the actual order of the settlement.

However, it is worth noting that some modifications in the definition of the order were needed here, since the logarithm of the coefficients needs to be determined later, and consequently, none of the coefficients can be 0. Therefore, the order of Budapest is set to 1 in further calculations. Another change to the previously introduced rules is that due to the characteristics of the micro-region, it is worth considering Agárd and Dinnyés as separate settlements. However, these are officially part of the town of Gárdony, so their order will be 6.

Figure 2

The differences in the borders in Fejér County, 2018



Two additional explanatory variables were introduced to model the difference between regional and national traffic. *j* indicates the number of the districts affected, while *h* indicates the number of counties concerned. It must be noted that in 2013

there was a reform of the LAU-1 administration level in Hungary. Before 2013, and in 2011, the districts were called *kistérség* - 'subregion' in Hungarian. After 2013, the LAU-1 units were renamed *járás* in Hungarian, for which the *district* will be used. It was not only a change in terminology; the borders were modified as well, so this should be taken into consideration at different levels of modelling. Thus, when the parameters are estimated for the models, *j* stands for the pre-2013 administration; and when the OD matrix is estimated, the post-2013 system will be taken into consideration. The difference is shown in the map of Figure 2.

Based on the introduction of the variables, two extended models could be set up, which will be compared to CGM. In the first model population data are treated together, so they are multiplied before the modelling (extended gravity model-multiplied before modelling or EGM-MBM). In the second model (based on Okubo (2004)), the two population variables are multiplied after parameter estimation (Extended gravity model-multiplied after modelling or EGM-MAM). Therefore, the following linear regression model EGM-MBM can be constructed by treating the product of the settlement population as a unit.

$$\ln U = \alpha + \beta_1 \ln(m_1 m_2) + \beta_2 \ln r + \beta_3 \ln c_B + \beta_4 \ln j + \beta_5 \ln h \tag{4}$$

where: U: number of commuters for a given pair of settlements in a given direction; α: constant; β_i: estimated parameter of the explanatory variables; m_1, m_2: population of the settlements; r: the distance between settlements; C_B: the ratio of the orders defined by the settlement relationships; j: number of districts; h: number of counties.

If the exponentiation of Eq. 4 is taken, a formula similar to Eq. 2 arises (Eq. 5).

$$U = e^{\alpha} (m_1 m_2)^{\beta_1} r^{\beta_2} c_B^{\beta_3} j^{\beta_4} h^{\beta_5} \tag{5}$$

In this case, the γ from Eq. 2., originally the gravitational constant, is described by Eq. 6.

$$\gamma = e^{\alpha} c_B^{\beta_3} j^{\beta_4} h^{\beta_5} \tag{6}$$

As previously mentioned, two models could be set up, the first is described by Eq. 4, while the second (EGM-MAM) is described by Eq. 7.

$$\ln U = \alpha + \beta_1 \ln m_1 + \beta_2 \ln m_2 + \beta_3 \ln r + \beta_4 \ln c_B + \beta_5 \ln j + \beta_6 \ln h \tag{7}$$

Based on the aforementioned models, two main steps in the analysis can be defined. The first is to determine the β coefficients for each model. This proves that county boundaries and district boundaries exercise a separation effect, which is an obstacle for daily commuting. The second is to determine the traffic demand between settlements using 2018 data, assuming the constancy of coefficients. In this way, it can be seen how the dynamic change of the population (as we can talk about the suburbs of Budapest) and the change in the LAU-1 administration influenced traffic volumes; however, this falls outside the scope of this article. In addition, the full OD matrix can be estimated, instead of commuting only to district centres, which can be used in further analysis.

Results

CGM

The results for the linear regression of the CGM are shown in Table 2. Hybrid, Fisher, and Newton-Raphson methods (Ketskeméty et al. 2011) were used alternately in parameter estimation. The number of iterations was usually set to 200, and the convergence criterion for the iterations was linked to a minimum change of 1E-006 in the parameter estimates. In each case, Type III model effect analysis was used, as it is the default, choosing Wald Chi-square statistics and confidence intervals. The confidence interval was set to 95%. The rows in the table include the coefficient for each variable and the associated *t*-value (in square brackets). The significance level of the *t*-values is denoted alongside: if $p < 0.1$,* if $p < 0.05$, ** if $p < 0.01$, and *** if $p < 0.001$.

Table 2

Parameters of the linear regression model, 2011

Intercept	2.3328
	[2.0698]*
ln m_1	0.3855
	[6.2518]***
ln m_2	0.7801
	[16.4673]***
ln r	–2.6212
	[–11.2459]***
R^2	0.7667
Standard Error	1.0320
F-statistics	[121.5896]***

Based on the results, it can be seen that in case of CGM, the R^2 value is smaller than in the case of extended models. The other difference is the greater exponent (note that only in absolute value) of the distance parameter. These results can be compared to the two extended models below.

EGM-MBM

In the case of EGM-MBM, as aforementioned, the multiplication of the population parameters is made before the parameter estimation, so these are treated jointly. The results of the parameter estimation are in Table 3. The legend is the same as for Table 2.

Table 3

Parameters of the linear regression model, 2011

Intercept	3.9847
	[2.4811]*
ln m_1 m_2	0.8598
	[12.8762]***
ln r	1.9787
	[8.0645]***
ln c	0.9401
	[5.6546]***
ln j	–1.3894
	[–3.9133]***
ln b	–1.9247
	[–3.0264]**
R^2	0.8079
Standard Error	0.9449
F-statistics	[91.7085]***

According to the Gauss-Markov theorem, an estimate can be considered as the best linear unbiased estimate (BLUE) if the conditions of the classical linear model are met, among which the condition that distribution of the error terms must be normal (Bolla–Krámli 2005). For this, we used the Kolmogorov–Smirnov test (Massey 1951), applying a distance from a theoretical normal distribution at both ends of the interval. The value of the test statistic can be determined by Eq. 8 (Ketskeméty et al. 2011):

$$D_n = \sqrt{n} \sup_{x \in R} |F_n(x) - F_0(x)| \tag{8}$$

where: Dn: the value of the test statistics; n: sample size; $F_0(x)$: theoretical cumulative distribution function; $F_n(x)$: sample cumulative distribution function. If Dn < Ks, then the null hypothesis, which is that the distribution of the sample is the same as the theoretical distribution, is accepted. The critical values for the test statistics are listed in Table 4 (Ketskeméty et al. 2011).

Table 4

The critical values for the test statistics

ε	$K(\varepsilon)$
0.9	1.23
0.95	1.36
0.99	1.63
0.999	1.96

Source: authors, based on Ketskeméty et al. (2011).

Since in this case the value of the test statistic (D_n=1.1609) is less than the critical value $K(\varepsilon)$ of 0.9, the null hypothesis that the error vector is normally distributed is acceptable. Based on these factors, the traffic demand between individual settlements can be estimated (Table 5).

Table 5

Travel demand (commuters per day) between individual settlements in the micro-region, 2018

From \ To	Agárd	Alcsútdoboz	Baracska	Bicske	Budapest	Dinnyés	Felcsút	Gárdony	Kajászó	Kápolnásnyék	Lovasberény	Martonvásár	Nadap	Pákozd	Pátka	Pázmánd	Pusztaszabolcs	Sukoró	Szabadegyháza	Székesfehérvár	Tabajd	Vál	Velence	Vereb	Vértesacsa	Zichyújfalu	Total
Agárd		0	2	5	264	12	0	193	1	21	2	10	2	12	1	8	4	4	2	184	0	1	34	3	1	8	775
Alcsútdoboz	0		1	27	91	0	33	1	1	1	2	5	0	0	0	0	0	0	0	13	19	5	1	0	13	0	215
Baracska	5	3		24	255	1	1	11	8	18	0	64	1	4	0	3	3	2	0	41	1	10	11	1	0	1	469
Bicske	3	19	10		1 907	1	38	6	6	4	4	26	0	2	1	2	3	1	1	43	8	25	5	1	9	1	2 126
Budapest	9	6	8	155		4	8	22	4	15	2	53	2	4	1	7	10	2	2	184	3	6	12	3	5	2	529
Dinnyés	22	0	1	2	82		0	111	0	8	1	3	1	5	0	2	3	2	1	93	0	1	13	1	0	1	352
Felcsút	0	33	1	66	92	0		1	1	1	1	4	0	0	0	0	0	0	0	13	9	4	1	0	9	0	237
Gárdony	81	0	2	5	241	18	0		1	31	1	13	2	9	1	7	11	5	2	423	0	2	56	3	0	16	932
Kajászó	1	2	9	13	131	0	1	3		3	0	45	0	0	0	1	1	0	0	20	2	19	2	0	0	0	256
Kápolnásnyék	14	0	2	5	234	5	0	44	1		7	13	3	32	1	66	6	17	2	145	0	1	108	16	0	3	725
Lovasberény	1	3	0	7	66	0	3	2	0	1		1	0	1	3	7	1	1	1	218	1	1	2	14	8	0	341
Martonvásár	6	3	33	23	688	2	2	14	22	8	1		1	5	0	4	4	3	1	78	3	23	13	1	0	1	937
Nadap	5	0	0	1	26	1	0	5	0	25	0	1		3	0	3	1	2	0	25	0	0	19	1	0	1	120
Pákozd	10	0	1	3	71	7	0	20	0	30	2	3	4		1	4	2	17	3	198	0	0	30	1	0	1	410
Pátka	1	0	0	1	25	0	0	1	0	1	3	0	0	1		0	0	0	0	83	0	0	1	0	1	0	122
Pázmánd	5	0	2	2	101	1	0	9	0	75	7	4	1	3	0		2	2	1	45	0	0	17	20	0	1	298
Pusztaszabolcs	10	0	3	7	237	3	0	20	0	9	1	4	1	1	0	4		1	19	56	0	1	12	1	0	5	396
Sukoró	4	0	0	1	40	1	0	6	0	22	1	2	4	22	0	3	2		1	62	0	0	21	1	0	1	194
Szabadegyháza	3	0	0	2	60	1	0	5	0	2	0	1	0	3	0	1	18	1		71	0	0	3	0	0	1	173
Székesfehérvár	59	9	14	35	1 339	47	5	289	7	64	87	61	7	55	58	20	32	17	27		4	6	94	7	15	9	2 368
Tabajd	0	19	1	11	76	0	9	1	1	1	0	5	0	0	0	0	0	0	0	11		8	1	0	1	0	145
Vál	2	5	11	37	202	0	4	4	17	3	0	42	0	1	0	2	2	0	0	30	8		3	1	1	0	376
Velence	17	0	2	5	265	6	0	48	1	98	2	12	6	30	1	16	11	21	2	180	0	2		5	0	4	735
Vereb	1	0	1	1	41	0	0	3	0	19	14	1	0	1	0	20	1	1	0	25	0	0	6		0	0	136
Vértesacsa	0	15	1	14	75	0	9	1	0	0	5	2	0	1	0	0	0	0	0	17	3	2	1	0		0	147
Zichyújfalu	5	0	0	1	31	1	0	16	0	2	0	1	0	2	0	1	5	1	1	24	0	0	3	0	0		98
Total	267	120	106	452	6 640	112	118	835	74	460	143	375	35	200	72	181	122	101	69	2 281	62	118	465	80	66	56	13 610

EGM-MAM

As mentioned in the other model, the population of the settlements is weighted separately according to whether it is an origin or a destination. The parameter table of the linear regression model is illustrated in Table 6. The legend is the same as for Table 2.

Table 6

Parameters of the linear regression model, 2011

Intercept	5.1249
	[–3.2970]*
ln m_1	0.5372
	[4.9362]***
ln m_2	1.2872
	[9.6573]***
ln r	–2.0220
	[–8.6816]***
ln c	–0.5910
	[–1.3170]
ln j	–1.3588
	[–4.0356]***
ln b	–1.8762
	[–3.1112]**
R^2	0.8290
Standard Error	0.8958
F-statistics	[87.2461]***

The Kolmogorov–Smirnov Test statistics (D_n=1.0486) is still lower than the critical value $K(\varepsilon)$ of 0.9, so the null hypothesis is also acceptable in this case (Ketskeméty et al. 2011). On this basis, the estimated commuter travel demand between different settlements can be determined (Table 7).

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Table 7

Travel demand (commuters per day) between the different settlements in the micro-region, 2018

From \ To	Agárd	Alcsútdoboz	Baracska	Bicske	Budapest	Dinnyés	Felcsút	Gárdony	Kajászó	Kápolnásnyék	Lovasberény	Martonvásár	Nadap	Pákozd	Pátka	Pázmánd	Pusztaszabolcs	Sukoró	Szabadegyháza	Székesfehérvár	Tabajd	Vál	Velence	Vereb	Vértesacsa	Zichyújfalu	Total
Agárd		0	1	3	147	4	0	71	0	9	1	4	0	5	0	3	2	1	1	155	0	1	18	1	0	2	430
Alcsútdoboz	1		1	29	97	0	22	1	1	1	1	3	0	0	0	0	0	0	0	21	10	4	1	0	9	0	203
Baracska	5	2		20	225	1	1	6	3	13	0	39	0	3	0	2	2	1	0	55	0	6	10	0	0	0	396
Bicske	3	8	6		1 494	1	19	3	2	2	2	13	0	1	0	1	2	0	0	50	3	13	4	0	4	0	1 632
Budapest	15	4	7	204		3	7	20	2	16	1	49	1	4	1	6	13	2	1	376	2	5	15	1	4	1	763
Dinnyés	24	0	0	1	71		0	65	0	6	0	2	0	3	0	1	2	1	1	123	0	0	11	0	0	0	315
Felcsút	1	18	1	67	92	0		1	0	1	1	3	0	0	0	0	0	0	0	19	4	3	1	0	5	0	217
Gárdony	103	0	2	5	251	13	0		1	26	1	9	1	7	0	5	11	3	2	679	0	1	57	1	0	7	1 186
Kajászó	2	1	8	14	158	0	1	3		3	0	38	0	0	0	1	1	0	0	37	1	16	2	0	0	0	288
Kápolnásnyék	13	0	1	3	189	3	0	23	0		4	7	1	19	0	35	4	8	1	177	0	1	87	5	0	1	585
Lovasberény	1	2	0	6	59	0	1	1	0	1		1	0	1	2	4	1	0	0	290	0	0	1	5	5	0	383
Martonvásár	7	1	24	21	687	1	1	9	10	6	0		0	4	0	3	3	2	0	117	1	15	13	1	0	0	929
Nadap	8	0	0	1	37	1	0	5	0	30	0	1		3	0	2	2	2	0	55	0	0	27	0	0	0	176
Pákozd	10	0	0	2	59	4	0	11	0	20	1	2	1		1	2	2	8	2	257	0	0	25	1	0	0	409
Pátka	1	0	0	1	26	0	0	1	0	1	2	0	0	1		0	0	0	0	125	0	0	1	0	0	0	160
Pázmánd	5	0	1	2	96	1	0	5	0	60	4	3	0	2	0		2	1	0	65	0	0	15	8	0	0	273
Pusztaszabolcs	9	0	2	5	164	1	0	9	0	5	0	2	0	1	0	2		0	9	58	0	0	8	0	0	2	276
Sukoró	5	0	0	1	42	1	0	4	0	19	1	1	2	18	0	2	2		1	101	0	0	22	0	0	0	222
Szabadegyháza	3	0	0	2	58	1	0	3	0	2	0	1	0	2	0	0	18	1		104	0	0	2	0	0	0	197
Székesfehérvár	44	3	6	20	823	19	2	118	2	32	36	26	2	26	20	8	19	6	11		1	3	57	2	5	2	1 292
Tabajd	1	13	1	13	93	0	7	1	1	1	0	4	0	0	0	0	0	0	0	20		7	1	0	1	0	164
Vál	2	3	7	32	186	0	2	3	8	3	0	27	0	1	0	1	1	0	0	42	3		3	0	0	0	324
Velence	14	0	1	3	185	3	0	21	0	56	1	6	2	16	0	7	8	8	1	189	0	1		1	0	1	525
Vereb	2	0	1	1	54	0	0	3	0	21	13	1	0	1	0	18	1	0	0	49	0	0	7		0	0	174
Vértesacsa	1	8	0	14	75	0	6	0	0	0	4	1	0	0	0	0	0	0	0	26	1	1	1	0		0	139
Zichyújfalu	8	0	0	1	39	1	0	13	0	2	0	1	0	2	0	1	7	1	1	45	0	0	4	0	0		127
Total	287	65	71	472	5 406	57	70	398	33	335	77	244	11	121	28	104	106	45	32	3 234	28	78	392	30	36	21	11 783

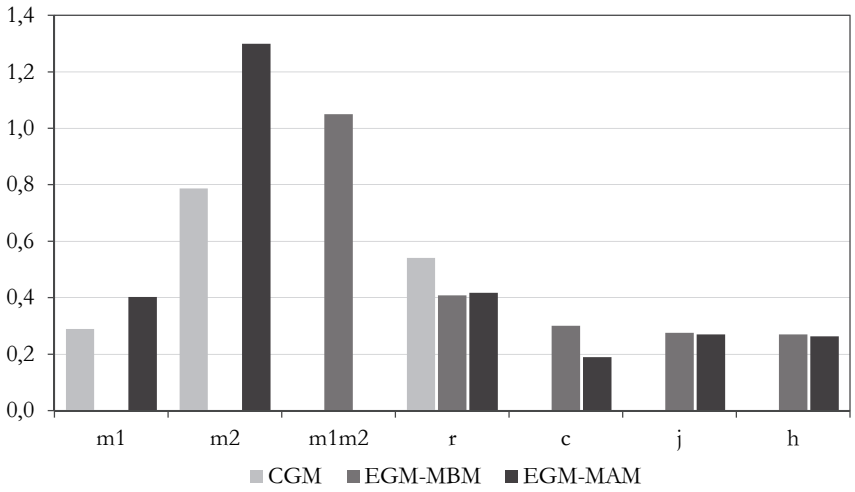
A comparison of the two matrices shows that the models estimate different demands in many relations. It is worth examining the individual coefficients to determine the causes of these effects. Beta coefficient is often used in statistics to compare the explanatory power of parameters. Calculation is possible with the formula of Eq. 9, while the explanatory strengths thus obtained are illustrated in the diagram of Figure 3 (Ketskeméty et al. 2011).

$$BETA_i = b_i \frac{\sigma_{x_i}}{\sigma_y} \forall i \in [1..n] \tag{9}$$

where: $BETA_i$: is the beta coefficient for the i^{th} explanatory variable; b_i: is the estimated parameter for the i^{th} explanatory variable; σ_{xi}: is the variance of the i^{th} explanatory variable; σ_y: is the variance of the dependent variable; n: is the number of explanatory variables.

Figure 3

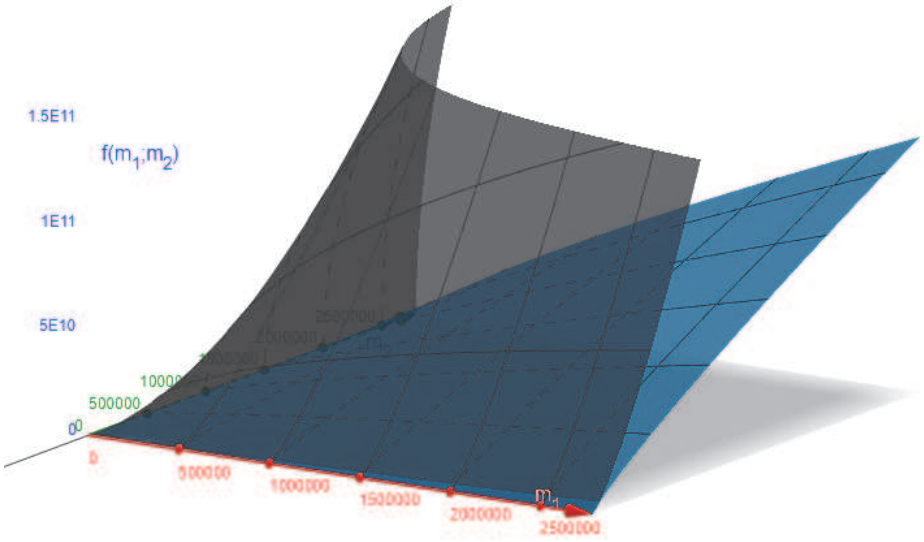
Beta coefficients for each model and explanatory variables, 2011



If the beta coefficients are analysed for the models (Figure 3), it can be seen that in the case of CGM, the revelation of the population data is lower than the extended models, while the revelation of the distance is higher. For both extended models, population data are most influential on the outcomes of the calculations. Consequently it is worth examining how population numbers influence model output. This is illustrated in Figure 4, where the two horizontal axes represent the two population numbers, while the vertical axis represents the value of the calculated subtotals.

Figure 4

The effect of population data, 2018



As shown in Figure 4, in the case of settlements with a small population (practically all, except Székesfehérvár and Budapest), differences in the population do not matter, so the other parameters influence model estimates.

If comparing the models is desirable according to which model is better, Table 8 can be taken into consideration. This contains the Omnibus Test and the information criteria associated with the likelihood function. The Omnibus Test is very similar to the *F*-test, the only difference being that here the null hypothesis that the parameters of the explanatory variables do not have all-zero value is tested by the x^2 test. As seen from the table, both models are suitable based on this approach. The different information criteria calculations (Akaike (*AIC*, *AICC*), Bayes (*BIC*), and Consistent Akaike (*CAIC*)) are based on Cameron and Trivedi (2005).

Table 8

Parameters for comparing the models, 2011

	CGM	EGM–MBM	EGM–MAM
Omnibus	167.731***	189.746***	203.082***
Log Likelihood	–164.769	–153.581	–146.913
AIC	339.537	321.162	309.827
AICC	340.088	322.209	311.185
BIC	353.262	340.377	331.786
CAIC	358.262	347.377	339.786

In terms of information criteria, the lower they are, the better the model. Table 8 shows that the second model can be considered to be better according to each information criterion. It can thus be concluded that although the order is suitable for modelling commuting relationships, using population figures provides a better model in all respects. Therefore, the use of order is negligible, because its effect is not significant.

Evaluation

The aim of this study is to present the hypothetical separation effect and the effects of the order of settlements through a practical model. Our analysis proved that in both models the sign and the magnitude of the coefficients of separation effects are adequate. On one hand, it was a pre-requisite for the coefficients to be negative, and on the other, for the county borders to be more significant than the district borders. The results show that both criteria are met. This suggests that administrative borders also have a distorting effect on transport volumes.

As for the county border's separation effect, the only settlement out of Fejér County in the analysed area is Budapest, which could mean that the measured separation effect is due to the special properties of Budapest, the capital of Hungary. However, in gravity modelling, most of its special properties (such as higher distance or population) are separated from the county border effect. Therefore, the hypothesis of the county borders' separation effect could be accepted. This is untrue in the case of districts because more district seats (Bicske, Gárdony, Martonvásár, and Székesfehérvár) were taken into consideration.

In the case of the quotient of orders, the basic idea was that the ratio would be higher when travelling from a smaller settlement to a larger one. As this direction is more significant than the opposite one in our basic hypothesis, the expected sign of the coefficient is positive. In EGM-MBM, the sign of the coefficient was the expected one, however, in EGM-MAM the parameter was no longer significant. This is due to the fact that the role of order ratio here has been taken over by the ratio of population numbers, so the order has become insignificant.

Conclusion

In this model the travel needs (OD matrix) of the larger area of Lake Velence were determined. To this end, we used a gravity model to which we added the effects of orders and district borders. The first step was based on the known commuting numbers, and as a result, the parameters of the gravity model were estimated. The second step was that assuming the robustness of the parameters, an OD matrix was set up for all the settlements in the surveyed region. For this, two extended gravity models were used and compared to the classic gravity model. It is given that the

extended models seem to outperform the classic model based on the information criteria. In the case of the extended models two important independent variables were analysed.

In all, the separation effect is significant in both models and has the appropriate sign, while the effect of rank numbers is significant only in the EGM-MBM. This is because in the second model separately managed populations reduce the explanatory value of order.

In this article, we built a gravity model where the accuracy of commuter travel demand prediction has been improved, and a more accurate OD matrix has been set up. The increase in efficiency is due to the fact that many new explanatory variables have been taken into account in model building. On one hand, we have demonstrated that the county border and the district border have a significant effect on commuter travel demand, and on the other, the possibility to use the orders is also proven. This can be used to further refine the existing traffic generation models.

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Regional inequalities in front-office services

Focus shift in e-government front offices and their regional projections in Hungary

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In developed countries, administrative front offices are becoming increasingly more sophisticated, with e-government facilities and applications. Public administrations are finding ever-improving interfaces to serve customers while optimising their operations. They are also discovering the increasing functionality that can be achieved through popular social media platforms. At the same time Hungary is responding to these phenomena with a significant phase delay, and regional inequality has been observed. Although public administration should show a uniform level of development and service portfolio in each part of the country, Hungary is experiencing very large extremes, which do not always stem from the existing framework, disadvantages, settlement size, and ethnic backgrounds. A great deal is at stake if uniform development is not ensured: some areas will become invisible not only in cyberspace and in Hungary's thematic maps, but at the same time will not be able to provide basic administrative services to those who live there. These areas are currently referred to as 'administratively disadvantaged' districts. This situation worsens the livelihood of the affected population and on the long-term the survival chances of these settlements as well. In this paper, we shed some light on the factors responsible for the regional inequalities in the infocommunication technologies (ICT) facilities of Hungarian local governments. Similar trends have been observed in Slovenia, Slovakia, and the Czech Republic, too.

Keywords:
e-administration facilities, regional inequalities of front-office services, Web 2.0 and social media impact on e-government, administratively disadvantaged municipalities

Introduction

The patterns in education, standard of living, taxation capacity, health status and life expectancy determine the territorial differences in e-government services. The government's centralisation efforts precisely aim to eliminate these territorial disparities. The focus of this study, organised by the Municipal Coordination Office of the Ministry of the Interior is the e-government front office, and particularly, the analysis of office websites and community spaces. We assume that in areas where the economic performance and potential of the settlements are lower, e-government interfaces are also in a more rudimentary state. In the course of our analysis, we would like to indicate that the existence of an IT strategy, the condition of computers, the status of websites, the use of social media, and the management and patterns of announcements exhibit a correlation with the position and development of a settlement. We also attempt to detect and map the geographical distribution of the development of municipal informatics. Similar studies have been conducted in other Central- and Eastern European countries (CEE countries), concluding that the development of ICT-based smart cities is decelerating due to human factors related to informatics (Klimovský et al. 2016). The administrative services provided in the front office as well as in health care should, in principle, exhibit the same standard throughout the country. With regard to modernisation, data on the presence or absence of information-communication and computer tools is measurable and may be used to indicate the regional differences in the level of development of administrative modernisation.

Methodology

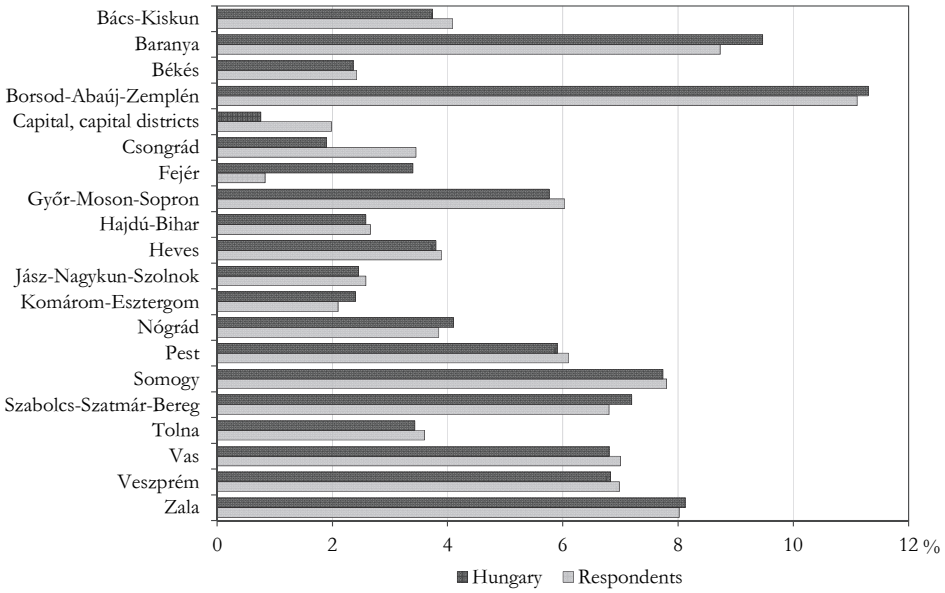
When establishing our methodology for surveying the ICT facilities of Hungarian local municipalities, we considered the methods used abroad, too. Hungary's neighbour in the Central European region that could serve as an example to follow in the field of e-government is Slovenia, which ranks higher than Hungary in the E-Government Readiness Index list, and has the best rankings in this respect together with Estonia among former socialist countries. Pinterič (2010) describes a method used in a Slovenian survey on citizens regarding e-communications by public administrations. It is based on sending e-mails with relevant questions to the general e-mail addresses of the most important public administration and government institutions. Based on the results it could be argued that even in Slovenia considerable progress has been made in providing quality public services in terms of the quality of correspondence with citizens. Slovenian municipalities usually have the necessary human and technical resources but their employees have to be additionally educated in 'electronic literacy' as well as in understanding that public administration has to be changed from a self-sufficient organisation to public service, enabling people to deal with things beyond bureaucratic matters.

Thus, we decided to use a similar method, based on an extended online questionnaire accompanied by personal interviews. The online questionnaire survey was conducted between 17 February and 3 March 2017. The questionnaire consisted of 34 questions, which asked about the information management and capabilities of the local governments of the settlements. The questionnaire was received by all Hungarian municipalities (through the Integriertes Lern-, Informations- und Arbeitskooperations-System [German for "Integrated Learning, Information and Work Cooperation System" – ILIAS] system of the Ministry of the Interior), and it was completed and returned by almost four-fifth of settlements. This response rate constitutes a remarkably high value in the category of online surveys.[1] A total of 4,100 respondents from 2,520 out of a total of 3,200 municipalities participated in the survey; usually a clerk or the mayor answered the questions. (At least one response was received from nearly 2,700 settlements. When processing the data, we also took into account questionnaires with partial responses, which were technically not fully complete; thus we obtained data from 2,645 settlements.) SPSS 22 and MapInfo 12, a GIS mapping application were used to process the data. The sample size we selected can be considered representative in the following three respects based on the fit test:

[1] A first version of the questionnaire was tested in 40 settlements between 16 and 24 January 2017, in the framework of personal interviews involving 40 main research organisers. The results of the testing were presented by the research organisers on 27.01.2017, within the framework of the Research Support Workshop. The meeting was attended by research leaders, colleagues performing operational tasks, and methodological and system design experts, namely Gábor Csanádi and Miklós Illéssy. The results of the questionnaire testing were recorded, the experts compiled their professional suggestions, and the research leaders finalised their questions. The final remaining questionnaire issues were prioritised by the two methodological and systems design experts.

Figure 1

Respondents of the online questionnaires by Hungarian counties

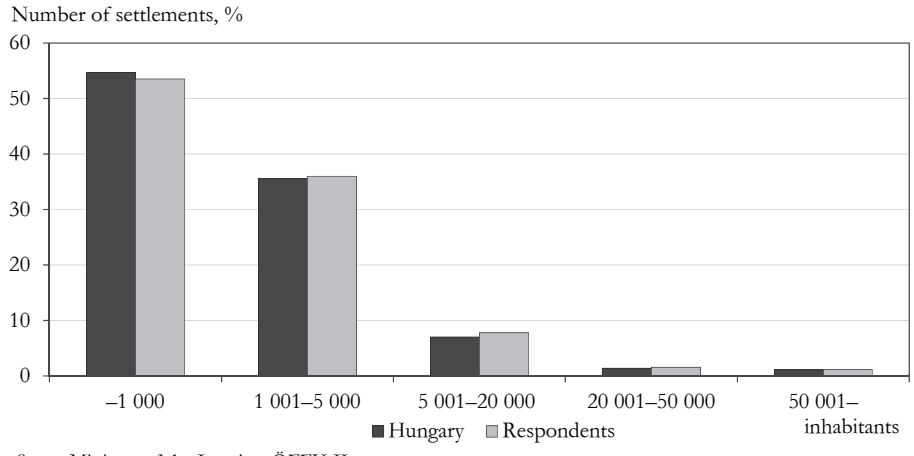


Source: Ministry of the Interior, Önkormányzati Fejlesztések figyelemmel Kísérése II. (Hungarian for Monitoring of Development Projects of Local Governments II. – ÖFFK II.).

Based on the fit test, the responses can be considered representative (Chi-square=5.74, df=19, p=0.999) because the municipalities' answers were of the same distribution as the national average.

Figure 2

Respondents to the online survey based on the population of the settlements

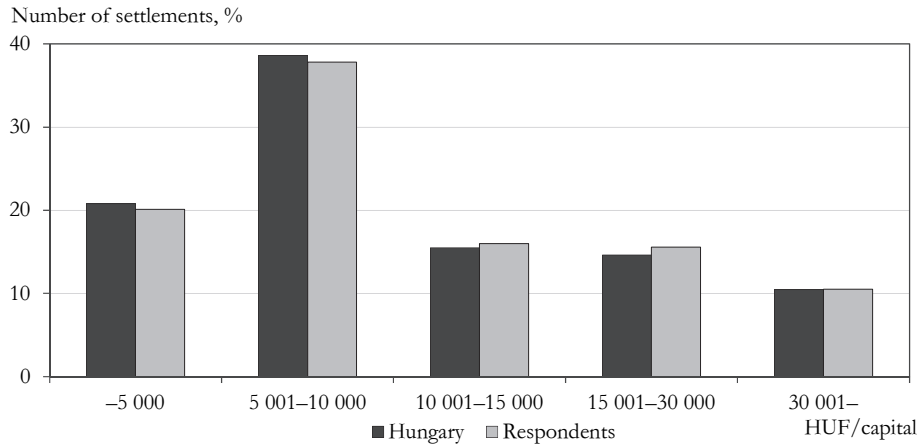


Source: Ministry of the Interior, ÖFFK II.

Based on the fit test, the survey can be considered representative (Chi-square=3.00, df=4, p=0.558) according to the number of inhabitants per settlement among the respondents.

Figure 3

Respondents to the online survey based on the settlements' tax capacity



Source: Ministry of the Interior, ÖFFK II.

Based on the fit test, this test dimension can also be considered representative (Chi-square=2.82, df=4, p=0.588).

Hereinafter the research results are presented in detail.

Theoretical background and literature review

Despite the real or perceived balancing role of the use of Internet-based ICT tools, there are currently significant economic and social inequalities. This digital divide is fundamentally caused by differences in ICT access among different social groups (Mészáros–Jakobi 2013). Factors limiting ICT access include economic ones, such as cost; infrastructural ones such as networking; social ones, such as a low level of education; and cultural ones, such as a lack of exemplary groups to follow (Szarvák 2004). It is clear that an adequate level of modern administrative services is also influenced by the factors above, and lower quality of service is expected where these factors become unfavourable. In Hungary this occurs on the peripheries where, for historical reasons, there is no large city along the state border, as Pécs, Szeged, and Debrecen (Tagai et al. 2018). The extent to which Internet service depends on physical, geographical space is well-illustrated by Jakobi (2017) who analysed the connections of one of the Internet social networks. It was revealed that the majority of cyberspace connections followed the public road network pattern existing in physical reality, for example, around mountains and lakes.

The most complex manifestation of social factors affecting the quality of services, including public administration, is creativity. Its spatial distribution in principle also determines the quality of electronic services. According to a complex study, NE-Hungary, SW-Transdanubia, SE-Great Plain, that is, the peripheries are in the most unfavourable position at the district level in terms of creative professionals and enterprises (Jeney–Varga 2016). Another social aspect is the extreme manifestation of deviance, namely, the spatial distribution of the number of suicides, where the areas of low creativity in the peripheries exhibit the highest proportions of suicide (Bálint–Elekes 2016). After such geographical considerations, let us examine the theoretical foundations of a specific municipal-level ICT survey.

The multi-threaded megatrends (e.g. globalisation, digitalisation, big data, networking mobilisation, the growing role of online communities, and the blurring of generational boundaries) are fundamentally changing more and more areas. The development of these trends significantly impacts public administration. The advent of the Internet in the mid-1990s in the field of government and administration made the use of electronic channels increasingly widespread. Front-office interfaces in the e-government approach offer a wide range of services, on a growing number of platforms. In addition, the concept of government can now be linked not only to state governments and government actors, but also to external actors, for example, economic and civil society actors, and citizens themselves (Betz–Kübler 2013).

Web 2.0 technologies[2] and social media offer an opportunity to advertise the intentions of individuals and traditional and emerging interest groups, to manage affairs, to handle ordinary or extraordinary events, and to initiate community actions. In the 2020s, open government discourse intensified, and these technologies became the focus of public and economic policies. With the spreading of mobile devices, these technologies are offering an ever-widening availability for users. At the same time, communication in virtual space is also becoming an ideal tool for public administration and government actors.[3] Social community media help in making targeted communication and (public) policy materials more understandable and to filter individual opinions for strategic purposes. Public administration can provide in this way a good-quality, customer-friendly, interactive and innovative public service.

[2] Web 2.0 technologies constitute a group of technologies optimised for community use, which facilitate information sharing, networking, and community building in the virtual cyberspace.

[3] Social media is a collective name for interfaces based on mobile and web technologies that enable interactive, multimedia, and multimodal, and one-to-one, one-to-many, or many-to-many communication in real time, regardless of location. Social media content is shared by users and often generated by them (or shared from other media interfaces). It can be, for example, collaborative projects (like Wikipedia), blogs (like blog.hu), content communities (such as Filckr and YouTube), social sites (such as Facebook, LinkedIn, and Myspace), virtual game worlds (such as Farmville), virtual social worlds (such as VirtualPlanet 3D administration). There are also regionally popular spaces like Naver apps in Korea, QZone and Weibo–leading in China, Orkut in Brazil, or v Kontakte in Russia.

When, for what purpose and how should we use the functionalities available in public spaces? Should we share information of public interest through them, such as in first-generation websites, or should we communicate with institutions with their help? Should we perhaps promote public services, increase customer-side (retail and entrepreneurial) participation, and consider them as a tool for crisis communication? Experience to date shows that most Organisation for Economic Co-operation and Development (OECD) countries view community spaces as extra channels of communication (Mickoleit 2014). In many cases, we can witness the late response of the government and state administration in these platforms.[4]

Individuals' online petitions, community-developed mobile apps, crowdfunding[5], and other community actions are common and they can move political events from virtual space to real space; for example, a call made in social media can turn into an actual demonstration in only a few hours.[6]

The Hungarian public administration is adapting to the mass use of the Internet with a significant time lag. In the current situation, the majority of local governments cannot perform their obligations of statutory information and access to information. They are only exposed to the knowledge of their own ICT institutions or to that of their ICT partners. Legislation provides the right to information, self-determination and the freedom of information in Act CXII of 2011. The Act, however, has not yet been adapted to the new channels either; for example, most of the offices still use the Web 1.0 system.

The government and administration are facing an ongoing learning process. The demand, which needs to be tailored to customer needs, imposes additional tasks on the administration. It is essential to know and follow the megatrends, and consciously plan, design, and develop systems so that the quality of services can adapt to the citizens' growing expectations. This requires a marked change in approach, the central elements of which should be adaptation, the development of the capacities needed to perform new functions, and the creation of new communication strategies in administration.

[4] Out of the 25 OECD countries surveyed, only 7 had a social media strategy in 2013. Although the governments of all these countries studied used some kind of community solution, only 10 of the 25 countries applied community media apps in their internal communication processes. In addition, only 5 countries measured the success of their strategies and the impact of social media.

[5] Crowdfunding is a form of community funding in which think tanks generate the money needed to launch a product or service on their own site or on a site specifically dedicated to fundraising (e.g. kickstarter.com and indigogo.com). The success of such campaigns crucially depends on the presence (number of appearances and shares) on related social sites. The concept originally covered business initiatives but now administrative or civil initiatives are not uncommon either (e.g. crowdrise.com and justgiving.com).

[6] The Internet is starting to replace the employer–employee matching function of employment centres, and these institutions are increasingly trying to open the door to training. In Germany, local employment centres have collaborated with a community portal named Xing, which includes job searches and job offers.

The alternative nature of community space

The use of traditional websites, mainly for one-way communication, is dominant in most parts of Europe. Community spaces provide easy, fast, and direct access to reduce digital inequalities. They also play a significant role in interactivity and therefore, they are important for public administration. The benefits of community spaces are seen in the strong interactions, user-centricity, easy interface and service management, and great added value for users (Wirtz et al. 2010). Yet, in most government strategies, even if they include the use of a community space, its aim is only the alternative dissemination of information, the improvement of communication, and not an increase in public consultation and active participation of the inhabitants.

In the Nordic countries as well as in Germany and Austria, there is no correlation between the use of social media and an individual's education. In Spain, the United Kingdom, Poland, Portugal, Turkey, and Greece however the use of social media is much more common among those with higher education (Mickoleit 2014). In Hungary, according to the Eurostat 2017 report, 83% of the population aged 16-74 use social media applications. This is the highest value among EU countries. Among regular users women, people with lower education and those under 30 are overrepresented in the population.

The age groups with the highest use of community spaces show very low activity in public and political affairs. (This behaviour can be seen in their willingness to participate in elections as well.) At the same time, it is also an important indication that the young generations (the Z and Alpha generations) already prefer communication through social media even in instant messaging to traditional channels of communication such as e-mail (Howard 2013).

In Central Europe, there are two of the Visegrád Group, Visegrád Four, or V4, is a cultural and political alliance of four Central European countries: the Czech Republic, Hungary, Poland and Slovakia (V4 countries) that face similar problems in public administration due to their similar historic development: the Czech Republic and Slovakia. There, investigations found territorial inequalities in the quality of municipal services. They concluded that the largest problem is the lack of the application of the theory of economies of scale. Consequently, the smaller a local government, the lower its efficiency is. Matějová et al. (2017) analysed the effects of economies of scale on the administration at the local level, regarding the local government offices' amalgamation in the South Moravian region in the Czech Republic. They showed that the existence of municipalities that are too small results in inefficiencies in the services provided. One can conclude that the economies of scale in small municipalities are not very good but the Applications Service Providing (ASP)-like maintenance of the IT infrastructure could improve them, thus allowing a stronger focus on local services and their customisation. Again, that was

one of the reasons we focused our research on the IT facilities of local governments.

Some very well-established studies have been conducted in order to solve the problem of territorial fragmentation of administration in the Czech Republic. In addition to finding that economies of scale are an indicator of a reshaping of the office size in local governments, they discovered that municipal expenditures on selected public services determined a municipality's optimal office size for the services analysed (Nemec et al. 2016). Finding the right size for territorial consolidation of administration has long been a serious problem but because of fears of violating self-governments' autonomy, this has been a sensitive issue since the establishment of municipalities. The solution may be that without violating autonomy, it is necessary to reconsider what tasks the local government should undertake and which tasks should be delegated to higher, micro-regional, regional, or central levels. We believe that IT-supported services could be run in an ASP system on some regional level to obtain improved economies of scale. This was another reason we investigated municipal IT access and facilities. This opinion is further strengthened by the findings of another study from the Czech Republic: a significant fragmentation of regions, and municipalities in particular, is associated with the fact that small municipalities face financial difficulties in their development, to which their mayors respond by cumulating mandates and forming micro-regional interest associations (Jüptner–Kruntorádová 2015).

The basic assumption we relied on in this study includes the regional distribution of unemployment (Alpek et al. 2018, 2019a, b, Demeter 2020). We assumed that the distribution of the worst e-government facilities would coincide with the districts showing the lowest values in the proportion of individuals with higher education in the population (Kanó et al. 2017). This assumption is to be verified through a strong correlation. There is another social aspect, the impact of which may also influence the regional inequalities in the facilities of electronic front office services: the crime rate. This is also significantly higher in the settlements that we assume as administratively disadvantaged in terms of e-government facilities. This may be because a continuous police presence is missing in these small settlements since they have no police stations or guardhouses. Mátyás et al. (2019) showed that the average number of crimes in settlements with no police station or guardhouses was higher in the districts where we expected poor e-government front office services.

Finally, it should not be overlooked that the factors affecting the success of online public services in new media[7] include quality and user-friendliness. The greatest social satisfaction can be achieved if in addition to digital information and services, certain analogue services continue to be available; personal contact and

[7] New media is the overarching name of the type of media created through digital network communications (internet, interactive digital television, cellular data transmission, etc.), characterised by interactivity among and the actions of consumers (or consumer communities) shaping the content.

direct communication remain important in cases of more complex issues and topics (Federal Office for Building and Regional Planning – Bundesinstitut für Bau-, Stadt- und Raumforschung 2017). However, the existence of offline services is also justified by generational differences.

Research results

The fact that the citizens of the state must be served on equal terms and conditions across the entire country was already stated in the Public Administration Procedure Act (Act IV of 1957), and since then, all procedural codes have declared it. However, as time passes and development advances, digital inequality can be traced in public administration as well. Therefore, the portfolios of public services are becoming completely different in different parts of the country.

By mapping our research data, we observed particular regional patterns in the distribution of the quality of administration that are very clear. These were compared with the patterns in economic performance factors (such as tax capacity and purchasing power and its change), urbanisation types, the population, the distribution of the most disadvantaged urban areas, the number of segregations and the presence of Roma ethnic groups (as the most disadvantaged regions from the aspect of digital equality). Then we examined the overlaps of these regional patterns. In order to study the relationships among the most disadvantaged economic regions (the most disadvantaged economic regions – DER) and the ethnic regions, we used the research methods in Kadét–Varró (2010) and Lukács (2017).

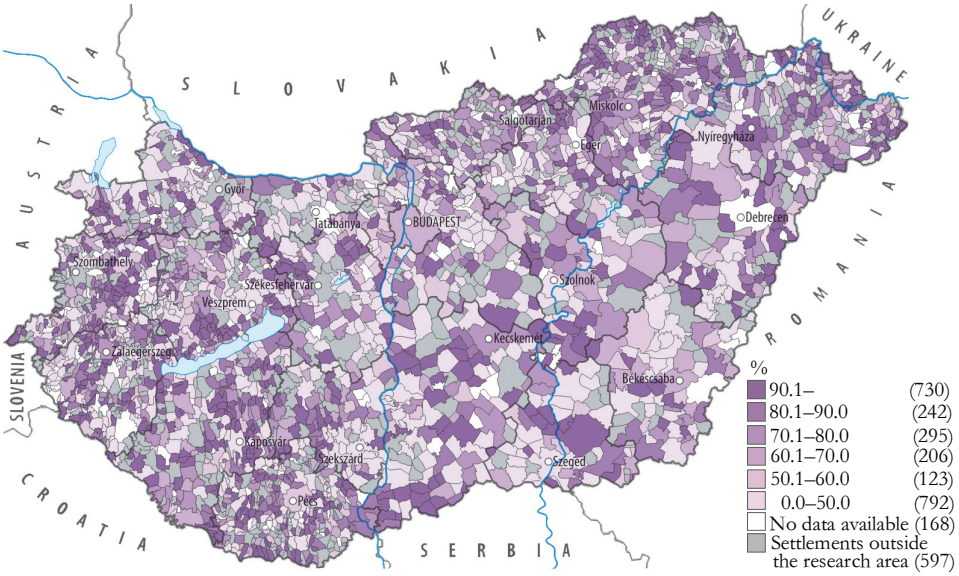
1) We observed significantly worse results in regions with small settlements than in regions with isolated farms or rural areas although all these types of regions have a low urbanisation level. Naturally, urban settlements with a relatively high urbanisation level exhibited the opposite results. Cserehát (in North Hungary) and Ormánság (in South Transdanubia) showed extremely poor results.
2) The DER – in line with our preliminary expectations – showed significantly weaker values than those of settlements with good or increasing purchasing power and tax capacity.
3) The presence of the Roma ethnic group in the population and the number and location of their settlements also coincided with our expectations for the results in all research dimensions. However, these characteristics did not always reveal the worst performers. In general, public administration front offices operate poorly in settlements with weak economic performances (although, as mentioned above, public administration is supposed to operate at the same level of development, regardless of location.) Pénzes et al. (2018) found that the Roma population increased by more than 20% in the Bátonyterenye, Encs, Heves, Ózd, and Sellye districts and this agrees with

our findings: these districts are the worst performers in terms of e-government facilities.

In the following, we present five dimensions of the study, from which the backlog degree of an administrative front office compared to the national average can be derived for several administrative districts.

Figure 4

Estimated proportion of computers older than three years in each municipality



Source: Data of the Ministry of the Interior based on ÖFFK II. 2018. Analysis by the authors.

Based on the age of computers we can infer directly the state of the IT service infrastructure, the innovation potential, and the development of the resulting service portfolio. Three years is considered the limit because this is the time it takes to write down the book value of computers to 0, and after three years the machine requires replacement. In the municipalities where the proportion of computers older than three years is high, obsolescence of the machines, limitations to the obligatory local government tasks and a low innovation potential can be assumed. As a consequence, these local governments have to prefer the traditional (offline) way of contacting customers. (Therefore, in most cases, the first question determines the answers to the following questions.)

As expected, based on the economic data, the urbanisation structure and the number of settlements, we see poor values in the DER, mostly in the NE regions of the Borsod county districts (e.g. Szikszó district: 85.1%; Putnok district: 88.6%), in the Szabolcs-Szatmár-Bereg county district (e.g. Vásárosnamény district: 76.7%; Csengeri district: 90%), several in the Baranya county district (e.g. Hegyháti district:

70.8%; Sellye district: 71.7%). In North Hungary, poor values are also observed in the Nógrád county districts (e.g. Salgótarján district: 75.3%; Szécsény district: 73.3%), and in Southern Transdanubia, in the Somogy county districts (e.g. Barcs district: 84%; Nagyatád district: 80.8%). However, we were surprised by the poor results in some districts in the Balaton Uplands outside the DER (e.g. Fonyód district: 77.4%) and some of the Zala county districts (e.g. Letenye district: 76%). While the national average is 52.1% for settlements with less than 1,000 inhabitants, the proportion of computers older than 3 years is even higher than 70% in the above listed areas. Thus, in all the listed districts there are at least three broken-down or over-used computers out of four that are prone to failure, endangering the continuity of office work. If we consider the population, geographical position, proportion of the Roma population and purchasing power in the listed settlements, we observe that the population and geographical position are the most decisive factors, resulting in low purchasing power as well. A geographical location along the borders, only accompanied with a low population, creates a disadvantaged position, which may be exacerbated by a higher-than-average proportion of the Roma population and the population over 65 years old (though the latter two aspects have the exact opposite effects). This is how the 'administratively disadvantaged regions' are being formed (hereinafter referred to as Administratively Disadvantaged Regions [ADR]), where the ability to receive customers is limited (either due to the poor facilities of the office or a large number of customers). We can see a variety of such ADR, in terms of their composition. The worst eight districts in terms of infrastructural facilities are presented in Table 1 below.

Table 1

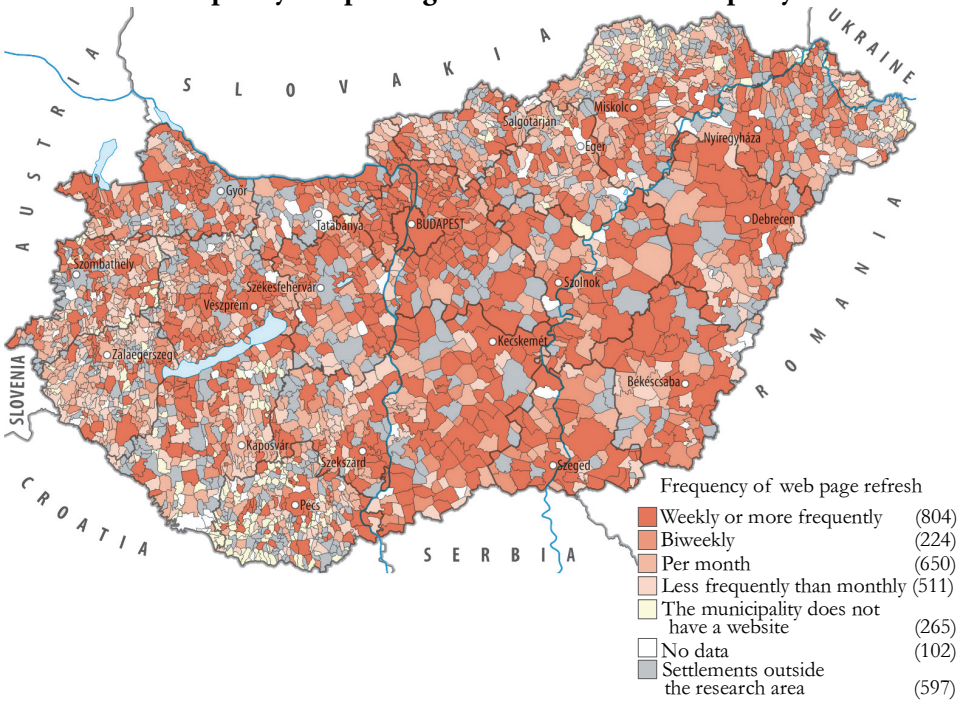
Proportion of computers older than three years, settlement population, Roma population, and purchasing power in the worst eight districts in Hungary

District	Population, capita	Roma population, %	Purchasing power, EUR	Computers older than 3 years, %
Nagyatád	833	18.7	2,970	80.8
Siklós	765	6.2	3,511	81.9
Edelény	740	15	3,637	82.0
Záhony	1,772	10.9	3,253	82.0
Barcs	938	14.3	3,000	84.0
Szikszó	804	16.9	3,101	85.1
Putnok	709	9.4	3,589	88.6
Csenger	1,428	10.3	3,078	90.0

Source: Data of the Ministry of the Interior based on ÖFFK II. 2018 and KSH data 2018. Analysis by the authors.

Figure 5

Frequency of updating websites in each municipality



Source: Data of the Ministry of the Interior based on OFFK II. 2018. Analysis by the authors.

The frequency of website updating shows how many resources the municipality devotes to informing customers properly. Minor settlements with only a few dozen inhabitants would be expected to update their website news at least once every two weeks as this shows that the municipality is active. Monthly or less frequent updates (or ad absurdum, the lack of websites) imply that customers are not properly informed and cannot use electronic public services based on the websites. On average, 14.1% of the settlements with fewer than 1,000 inhabitants update their online information at least weekly, 7.7% of them do it every two weeks, and 28.6% of them do it monthly (i.e. almost 50% of them update the information less frequently). For settlements with a population between 1,000 and 5,000 people these proportions are 44.7%, 11.8%, 25%, and 18.6%, respectively. Thus, small-village areas are likely to either be invisible online or have websites with outdated information.

This is reflected in Figure 3, which shows the municipalities. Many of the minor ones mostly located along the borders exhibit worse values than those of municipalities with monthly updates. The settlements along the River Drava and the Croatian and Slovenian borders; in Southern Transdanubia, in Somogy and Zala counties; in NE Hungary close to the Ukrainian and Romanian borders; and in

Northern Hungary, in Borsod county along the Slovakian border are barely visible in the digital space. The smaller a municipality is, the fewer resources it can devote to functions outside the mandatory tasks, especially if it cannot be financed by any external sources (e.g. if its tax capacity is low) or if it does not have the necessary human resources.

Table 2

Frequency of updating websites in the districts exhibiting the worst situation

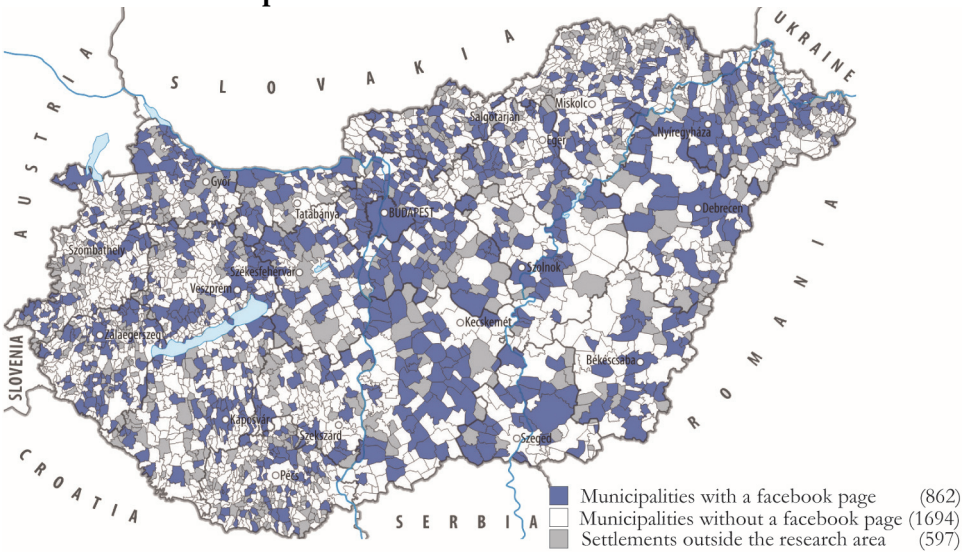
District	Population, capita	Roma population, %	Purchasing power, EUR	Average website refresh rate
Hegyhát	465	14.6	3,197	Less frequently than every three months
Sellye	383	24.5	2,986	Less frequently than every three months
Szentlőrinc	795	11.9	3,565	Less frequently than every three months
Siklós	765	6.2	3,511	Less frequently than every three months
Barcs	938	14.3	3,000	Less frequently than every three months
Putnok	709	9.4	3,589	Less frequently than every three months
Szigetvár	574	10.6	3,038	Every three months
Letenye	585	12.6	3,320	Every three months

Source: Data of the Ministry of the Interior based on ÖFFK II. 2018. Authors' calculations.

All of the worst eight districts have small villages, with a significantly higher-than-average proportion of Roma population and settlements, and the lowest purchasing power (merely over two-thirds of the national average).

Figure 6

Municipalities with and without Facebook accounts



Source: Data of the Ministry of the Interior based on OFFK II. 2018. Analysis by the authors.

When examining online community spaces, we observed a negligible number of cases where Twitter and Instagram were being used. The few dozen applications of these two platforms (36 for Twitter and 51 for Instagram) deserve no further explanation. Overall, the great majority of Hungarian municipalities have not yet recognised the advantages and real functionalities of these channels in public administration. However, one out of three responders is already an active Facebook user. Out of the settlements with fewer than 1,000 inhabitants 30.9% use Facebook; of those with 1,000–5,000 inhabitants, 44.8% use Facebook. In addition, the pattern in municipalities with a Facebook account differs from the previous ones in several aspects. It is not the presence of rich and developed urban areas that is unusual but that of settlements that stand out because they have had a poor performance in the previous surveys, as shown in Figures 4 and 5. Therefore, it seems that these municipalities are trying to overcome their unfavourable endowments by seeking an interface to communicate with customers. However, it is surprising that the developed parts of NW Transdanubia (Kisalföld, excluding the vicinities of Győr and Esztergom) do not have online community spaces yet, similarly to the settlements in the vicinity of Debrecen (the Nagykunság region).

Table 3

Proportion of Facebook accounts in the eight districts with the worst results

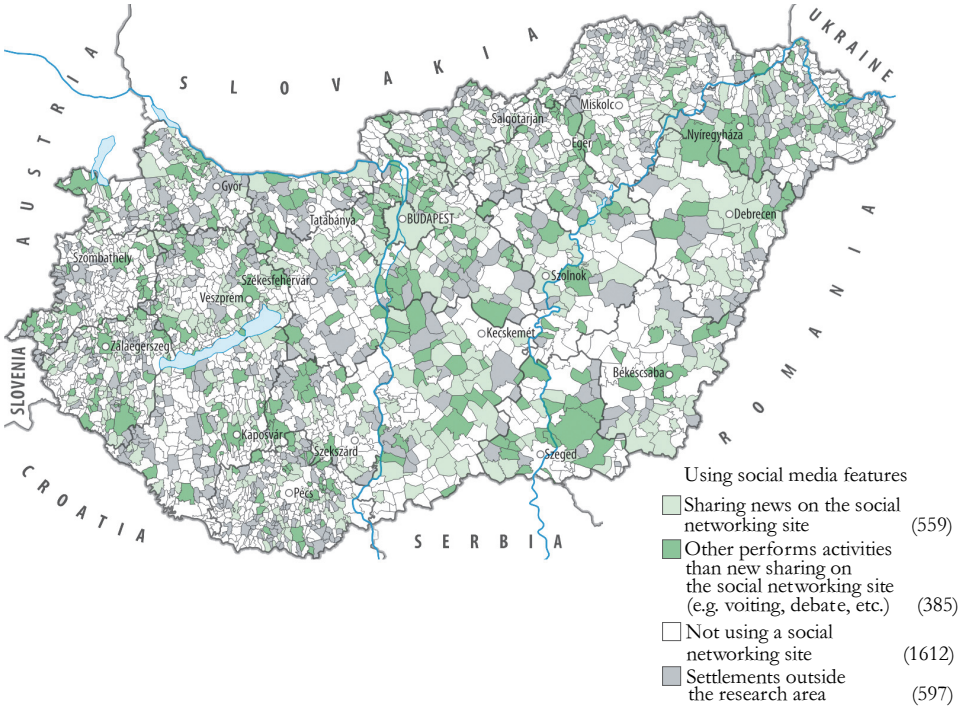
District	Population, capita	Roma population, %	Purchasing power, EUR	Proportion of Facebook accounts, %	Average website refresh rate
Nagyatád	833	18.7	2,970	0.0	Every three months
Csenger	1,428	10.3	3,078	10.0	Every three months
Marcali	976	11.2	3,689	12.9	Monthly
Edelény	740	15.0	3,637	15.4	Every three months
Sellye	383	24.5	2,986	17.9	Less frequently than every three months
Szikszó	804	16.9	3,101	18.8	Every three months
Devecser	503	7.2	3,595	20.0	Monthly
Nyírbátor	2,413	12.2	3,294	21.4	Monthly

Source: Data of the Ministry of the Interior, ÖFFK II. 2018. Authors' calculations.

If we rank the administrative districts by the extent to which they provide information (primarily on Facebook, secondarily on their websites), we observe that districts are neglecting this aspect across the entire country but mostly in Somogy, in Szabolcs-Szatmár-Bereg, and in Borsod, Veszprém and Baranya counties. Therefore, the lack of community spaces is a national feature among Hungarian local government offices. This is a serious problem because no alternative connection with customers exists in these districts as websites do not provide meaningful information either. As a result, they are completely invisible in virtual space.

Figure 7

Use of Facebook features in Hungarian municipalities

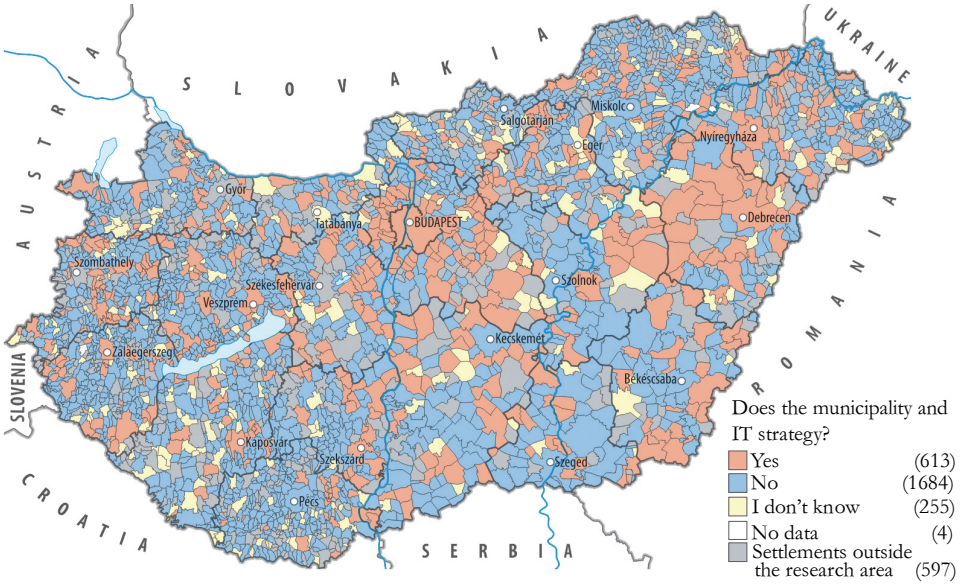


Source: Data of the Ministry of the Interior, ÖFFK II. 2018. Analysis by the authors.

Approximately one-third of the municipalities use Facebook, which can be a source of some hope for ICT development. However, we have to note that meaningful use (regarding the functionalities indicated in the introduction of this paper) occurs in one-tenth of the local government offices only. On the other hand, two-thirds of Facebook activities are limited to publishing news only. The municipalities showing substantial Facebook activities (beyond providing news) are difficult to typify: we can find good solutions almost everywhere, regardless of the financial background, development dynamics, settlement size, number of settlements and so on. It is assumed that the preparedness and attitude of the official human resources may be the decisive factors in this matter. It seems unnecessary and impossible to highlight the worst eight municipalities because dozens of them exhibiting a value of 0% are tied in the last positions.

Figure 8

Awareness of IT development in Hungarian municipalities



Source: Data of the Ministry of the Interior, ÖFFK II. 2018. Analysis by the authors.

Finally, the attitudes of Hungarian municipalities regarding ICT facilities are also worth examining. From the map in Figure 8, we can see that the number of municipalities with conscious ICT development is very small. Two out of every ten local governments have a strategy for dealing with IT issues. (The proportion of local governments with such strategies in force is 13.6% for settlements with fewer than 1,000 inhabitants and 29.6% for settlements with 1,000–5,000 inhabitants.) In other words, 80% of the municipalities do not see the communication of information as a strategic pillar but as an additional task or burden. It is seen as a utility that assists (or sometimes even hinders) the statutory performance of tasks rather than as a tool that can provide value-added services to customers. Even worse, there are several major towns without a valid IT strategy (only 54.5% of the major cities have an IT strategy).

Table 4

Proportion of valid IT strategies in the worst eight districts

District	Population, capita	Roma population, %	Purchasing power, EUR	Proportion of valid IT strategies, %
Csenger	1,428	10.3	3,078	0.0
Devecser	503	7.2	3,595	0.0
Pécs	894[a)]	8.1	4,794	0.0
Szentlőrinc	795	11.9	3,565	0.0
Sellye	383	24.5	2,986	3.6
Hegyhát	465	14.6	3,197	4.5
Szigetvár	574	10.6	3,038	5.3
Nagyatád	833	18.7	2,970	5.9

a) Excluding the city of Pécs itself.
Source: Data of the Ministry of the Interior ÖFFK II 2018 and KSH data 2018. Authors' calculations.

In addition to the aforementioned eight districts, there are dozens of districts with poor results regarding IT strategies. They do not seem to know their potential needs or the opportunities to expand their strategies. As a result, no rapid catching-up can be expected in the short and medium term. The differences between the relatively well-developed and less-developed districts will increase.

However, these settlements will probably not focus on the modernisation of their administrative front-offices until they are required to do so by law and have the necessary means to do it. As long as this is the situation in a significant part of Hungarian settlements, we can hardly see mass adoptions of the social media functions mentioned in the introduction. Therefore, compared to developed countries, Hungary lags behind in terms of the quality of administrations, and regional inequalities occur within the country (see the regional overlaps in the tables presented above). These regional inequalities are as sharp as if the municipalities at the two extremes were located in two different countries. Since 70–80% of the Roma population live in deep poverty and their capacity to assert their interests is also low, the administrative services in their regions are shrinking. This further deepens their segregation and worsens both the opportunities for those living there and the efficiency of the administration.

The government is taking unifying and at the same time centralising measures against the abovementioned dangers and inequalities; however, the costs, efficiency, and implementation rate of these measures have not yet been proven by time.

Conclusions

After the spread of the mobile internet in the 2010s, the prevailing assumption was that e-government, and as part of it, the spread and dominance of local e-government services, would face a generational issue. It was assumed that as the young generations grew up, they would naturally use mobile internet applications, and municipal services would be offered exclusively through ITC tools. This would occur in a way similar to how the typewriter naturally replaced handwriting, and then the typewriter was replaced by the computer. Researchers believed that the establishment of e-government was not primarily hampered by a lack of knowledge or technology but motivation. The tax and statistical administration services where e-government was required by law showed 100% penetration among users. Law is kind of an external, coercive motivation, but internal motivation, namely that customers demand and prefer electronic administration, has lagged. The regional data published here shows that in the late 2010s in a relatively developed Central European country such as Hungary, which is in the middle of the ranking of EU countries in terms of the e-government readiness index, is lagging in the modernisation of municipal front office customer services. As mentioned above, a very high percentage of municipalities participated in the survey. This was the largest volume of municipal surveys to date, so it gives a fairly realistic picture.

The most important of our findings is that while a wide range of online mobile applications do not appear in municipal administration, this is not a generational issue. The digital divide is reproducing itself. The reason is that outdated and cumbersome municipal services are more an economic, infrastructural, and social issue than an unresolved ICT shortage issue. In the NE, SW and SE peripheries of Hungary, where the flow of capital is small, the road network is insufficient and social segregation and deviance are a problem, web applications are not used in the operation of local governments and public administration is not being modernised in a large extent. That is why the government's efforts to raise the development level of public administration across the country, including local governments, have been unsuccessful so far, especially on the periphery and in places with social problems, poverty and low levels of education, as well as a high proportion of Roma population. Local administrative services cannot be developed and modernised without economic, infrastructural, and social funds, similar to the way that no house can be built without fundament. Widespread use of ICT occurs in large cities, including in the areas of municipal services; in underdeveloped areas, this can only be achieved if similar economic, infrastructural, and social conditions emerge. Our findings agree with those of another recent study, Faluvégi (2020): the least developed micro-regions coincide with the least developed districts in terms of e-government front office facilities.

Since our starting point of methodology was the Slovenian initiative, it would be worth noting that in Slovenia studies also tried to understand the reasons for the relatively poor implementation of electronic government tools as a principle for improving bureaucratic processes. Survey results in Slovenia showed a general lack of motivation, measured as the ignorance of technology potentials as well as that of existing threats. Their main argument was that the lack of motivation blocks most reform attempts by creating a negative human environment (Pinterič 2020). Our results prove that in addition to the lack of motivation, the totality of regional inequalities play an intensifying role in slowing down technological transfer into the ICT development of local municipalities. What is interesting from a regional development point of view is that the districts showing a relative low ICT penetration in local government offices reflect the physical location of technological and social infrastructure. This is why the lowest ICT penetration in e-government can be found in the inner and outer peripheries of Hungary. A major study on two other countries in the Central European region, with similar dimensions as Hungary, was Nemec et al. (2008). They examined the demand for benchmarking in public administration bodies in the Czech Republic and Slovakia. It was verified that benchmarking is not regularly or properly used, either in Slovakia or in the Czech Republic. Subjective barriers to its implementation, for example, the lack of accountability, the rent-seeking attitudes of elected politicians, and ineffective public services schemes, were found to be the most important issues. Further, although they found that the situation was slowly improving, the progress was limited by territorial fragmentation. The present study also verifies the need for benchmarking so that territorial differences could be reduced. Continuous monitoring, benchmarking and bench-learning help to measure and bridge the degree of digital, economic, and social inequalities influencing the effectivity of local municipal services.

In this study, out of the 34 questions in our online survey, we addressed only 5. We did this because these five questions focus on the most characteristic features from which the presence of municipalities in virtual space can be deduced. The rich research materials we obtained are also suitable for exploring further aspects, which we are going to study in the future.

Acknowledgements

This major municipal study involving 34 online questions, of which we selected 5 items, was funded by the Local Government Coordination Office of the Hungarian Ministry of Interior, grant number KÖFOP-2.3.4-VEKOP-15-2016-00002. This study was the largest-scope investigation into local self-governments in Hungary since their establishment in 1990.

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How coronavirus spread in Europe over time: national probabilities based on migration networks

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Global migration trends (Hatton−Williamson 2005, Bálint et al 2017, Farkas–Dövényi 2018) today differ from those in previous centuries in terms of both the number of people migrating (as of 2017, 272 million people live in a country other than their country of origin) as well as the geographical, economic, and cultural distance between sending regions and destination countries. The interconnection between countries is constantly growing, relationships are expanding through migration, and people's movement is increasing.

Migration shows strong territorial concentration (Winders 2014); in 2019, half of the global migrant population lived in nine countries. In international migration, there are centres (large host countries) and global migration destinations, which attract migrants over long distances. Such hubs include the USA, Canada, Australia, the UK, Germany, France and Spain.

Close migration relationships mean strong exposure and vulnerability to the spread of infectious diseases. The calculation does not assume that infection can only be caused by migration, but states that migration relationships between countries, that is, their network, well represent the spread of infections between countries.

Keywords:
international migration, migration networks, coronavirus

Methodological notes for establishing migration links

There is a close relationship between two countries when there is international migration (Wimmer−Schiller 2002, Novotný–Pregi 2018, Lados–Hegedűs 2019) between them, that is, someone moved from one (birth) place to another (current residence). Only movements above a threshold are considered by the network (Ba-

rabási 2016), as a small number of international migrants between two large countries does not necessarily represent a real migration link (Castles 2010; Castles–Miller 2013). In other words, the network connects two countries only if the number of migrants between them is relevant and asymmetric. That is,

$$q(A,B) = \frac{M[A \to B] - M[B \to A]}{N(A) + N(B)}$$

is above a fixed threshold μ. Here, M [X → Y] is the population density of country Y born in country X and N (X) is the population of country X, μ∈ {-1; +1}, μ∈R.

If q (A, B)> μ, a migration link from country A to country B is created; if not, there is no such link between the two countries. This allows different grids to be edited depending on the μ parameter.

Situation in Europe

1.2 million people born in China live in Europe (UN 2019). European countries most densely populated by Chinese people (Italy, the UK, Spain, Germany, and France) are home to 120-300,000 Chinese per country. Italy, the UK, Spain, Germany (Glorius 2018), and France are global migration centres and also the countries most infected with coronavirus.

In the following, we estimate the magnitude of the Chinese migration impact on European countries by creating scenarios for the temporal spread of the coronavirus at the national level.

Set up scenarios

Within real migration networks (Barabási 2016), their topology shows the „distance" between countries, that is how "far away" they are from China and how many countries they are connected to. There is an inverse relationship between the distance in the network and the probability of propagation.

(Figure 1 (top left) shows the most important target areas for migration from China) With a longer migration distance, the rate at which the infection appears is as follows:

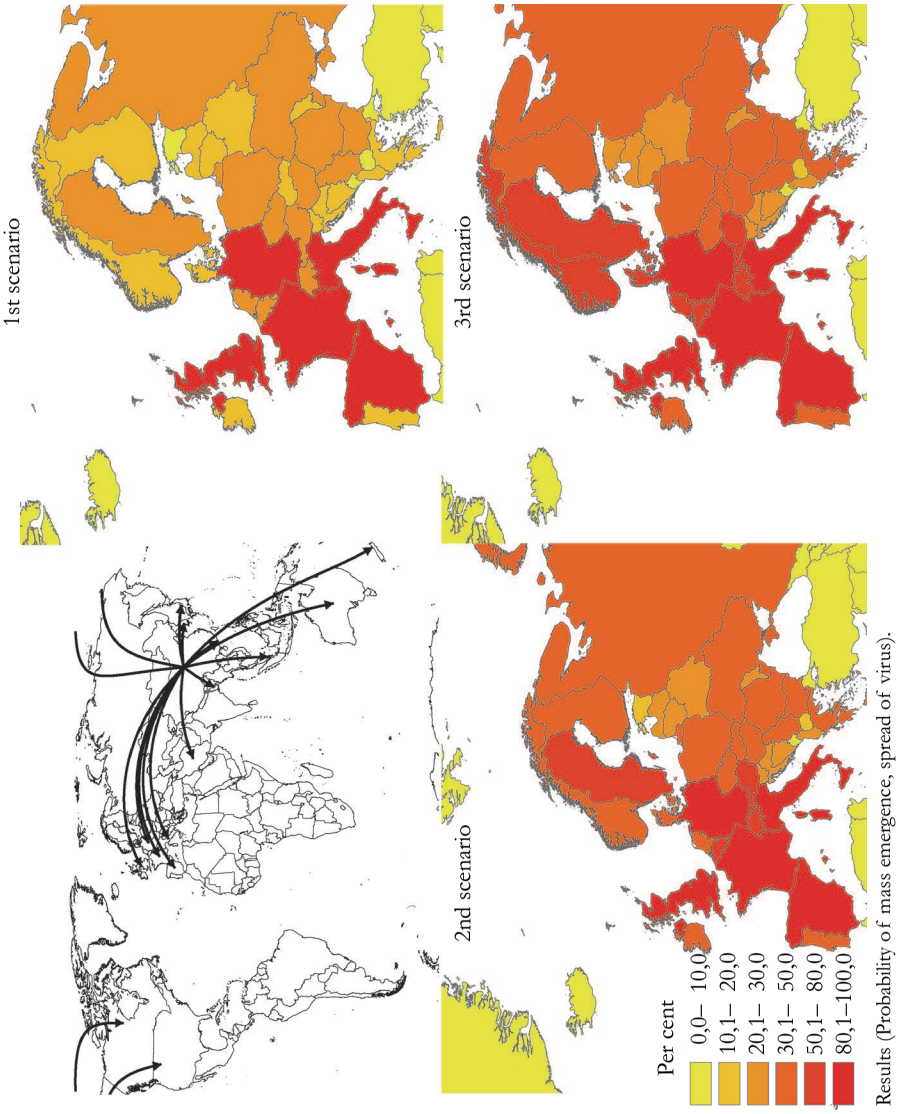
• Scenario 1: 5% (Lower values for Wuhan and surrounding regions) (top right)

• Scenario 2: 15% (Average spread for Lombardy and neighbouring regions in the case of Italy) (bottom left)

• Scenario 3: 25% (Highest penetration rate among regions of Italy) (bottom right)

Figure 1

Probability of mass emergence and spread of coronavirus over time



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