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Is innovation (increasingly) concentrated in large cities? An international comparison

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ABSTRACT

There is a widely held belief that agglomeration economies encourage significantly more successful and productive innovation activities. Based on this belief some scholars even suggest that policies designed to stimulate innovation in non-urban areas are ineffective and a waste of resources. Investigating the geographic concentration of patented inventions in 14 developed countries, we find that in most countries patenting is geographically dispersed with considerable shares of patented inventions in areas other than large cities. South Korea and the US are two extreme outliers where patenting is highly concentrated in some large cities. Also, there is no general tendency that inventors in large cities are more productive, in terms of filing patents, when compared to inventors in rural areas. We conclude that while the agglomeration economies found in large cities may offer advantages for innovation activities, the extent of these advantages is not significant, and popular theories overemphasize the importance of large cities for innovation activities.

1. Introduction: Large cities and innovation¹

Large cities appear to have many advantages over rural areas, one such advantage is commonly known as agglomeration economies (Duranton and Puga 2004; Glaeser 2011; Jacobs 1969). Based on claims about the effectiveness of agglomeration economies, many scholars argue that large cities are ‘innovation machines’ and that agglomeration economies are a requirement for successful innovation activity (Carlino and Kerr 2015; Florida, Adler and Mellander 2017). Some scholars go so far as to take this widespread belief that innovation activities are considerably more successful and productive in large cities to suggest that policy attempts to stimulate innovation in non-urban areas are ineffective and a waste of resources (see, for example, Glaeser and Hausman 2019).

This paper investigates and compares the geographic concentration of patents in a number of developed market economies. We find a wide spectrum of the share of patenting in large metropolitan areas among the countries of our sample. While South Korea and the US are two ‘outliers’ with an extremely high concentration of patents in some large metropolitan areas, this type of concentration is much less pronounced in the other countries of our sample. We confirm that this pattern also applies

to high-quality patents. Another important finding is that inventors in large metropolitan areas do not have more patents than inventors located in non-urban areas. We also find that there is no general trend of an increase in the geographic concentration of patents over the 2000–2015 period. In fact, there are more countries where the concentration of patents in large metropolitan areas is decreasing than countries where this type of concentration is increasing.

Our results challenge the belief that innovative activity occurs primarily in large cities (Florida, Adler and Mellander 2017). We argue that generalizations based on evidence from a single country, such as the US, may not be valid for other countries. Such generalizations may ignore country-specific economic realities and other important factors that we discuss in this paper (Section 2). Based on the results of our research, we conclude that agglomeration economies are much less important for innovation activities than is suggested by some popular theories.

The paper is structured as follows. The next section (Section 2) provides an overview of the arguments for the claim that large cities are a prerequisite for successful innovation activity. Section 3 introduces the data employed in our research, and our definition of spatial categories based on population size and population density. We then compare the shares of patents in different spatial categories (Section 4.1 and 4.2) and

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analyze the link of patenting with regional size and density (Section 4.3). We also examine the geographic concentration of patents in general (Section 4.4). The distribution of high quality patents and inventions with a high degree of radicalness and originality in different spatial categories is analyzed in Section 4.5. Section 5 contextualizes our analysis in the framework of recent debates on urban scaling. Finally, we summarize our findings and discuss implications for theory development and policy, as well as outline some important avenues for further research (Section 6).

2. Why successful innovation activity might occur mostly in large cities

Empirical research suggests that innovation activity is concentrated in large cities even more than population or the general production of goods and services (Feldman and Kogler 2010; Bettencourt, Lobo and Strumsky 2007; Carlino and Kerr 2015). The common interpretation of this result is that large cities have a locational advantage over less densely populated areas with regard to innovation activity (Glaeser 2011; Glaeser and Hausman 2019). It is argued that these advantages lead to a higher number of innovations per population and attract more productive R&D personnel (Bettencourt and Lobo 2016). The argument is extended to suggest that innovations generated in large cities are more radical, tend to be technological breakthroughs and have higher economic value (Berkes and Gaetani, 2020; Duranton and Puga, 2011).

A common explanation for higher levels of innovative activity in large cities builds on the effects of agglomeration economies. Literature mentions four reasons why large cities may be favorable places for innovative activity (see Duranton and Puga 2004; Puga 2010; Carlino and Kerr 2015), especially when compared to rural or peripheral regions.

- *First*, large cities tend to have a rich endowment of R&D facilities (such as universities and/or public research institutes), and innovative private sector firms ('sharing').
- *Second*, large cities have abundant input markets that stimulate R&D and provide a better and more productive match of inputs ('matching') (Helsley and Strange 2002, 2011).
- *Third*, the rich endowment of R&D facilities found in large cities provide more knowledge spillovers due to the spatial proximity and cooperation of R&D actors ('learning').²
- *Fourth*, large cities may be highly attractive places for creative people (Florida 2002; Florida, Adler and Mellander 2017). In this way, large cities benefit from inflows of talent and new knowledge from other areas that strengthen the quality of the regional workforce. This redistribution of talent comes at the expense of nonmetropolitan areas.

Although these general advantages of large cities (Bettencourt 2013) are undisputed, cities are also affected by diseconomies, such as high levels of crime, pollution, traffic congestion, etc.³ Moreover, the relatively easy flow of knowledge that occurs within cities may be considered a disadvantage for firms that want to keep their knowledge secret.

What is still rather unclear is how the disadvantages and other potentially negative factors of agglomerations impact its assets. While some scholars assume that the advantages of agglomeration economies

dominate the disadvantages,⁴ others are more cautious in this respect (e. g., Boschma 2005). One important objection to the simple 'innovation requires large cities' argument is that cities rarely exist in spatial isolation, but rather as part of a spatial system defined by a set of locations. In other words, large cities spatially exist and interact with smaller cities and less populated areas, and the geographic distances of the spatial system introduce important idiosyncrasies (Crescenzi, Rodriguez-Posé and Storper 2007; Bettencourt and Lobo 2016). If distances between cities are relatively small, as is the case in many parts of Europe, division of innovative labor between cities and inter-agglomeration spillovers may be much more pronounced than in a constellation where geographic distances between the main agglomerations are rather large, as is the case in the US.

A common argument promoting large cities is their higher productivity (Ciccone and Hall 1996; Ciccone 2000) that is reflected in higher wages, the so-called 'urban wage premium'.⁵ This is, however, of limited relevance for innovation activity, because higher productivity is a static phenomenon while innovation is an inherently dynamic process. Hence, for successful innovation it is particularly important that places are able to manage and adapt to change. We are not aware of any study that provides robust empirical evidence of higher productivity of innovative activity in larger cities.⁶ There are, however, quite a number of examples of economic success occurring in larger cities that did not persist when the given products and technologies mature and are replaced by new and more relevant fields of knowledge (Storper 2018).⁷

It is quite remarkable that many studies examining the relationship between innovation and city-size disregard rural areas and, therefore, cannot make comparisons between cities and non-agglomerated areas. Despite this, there are a few studies that focus on successfully innovating firms in rural and peripheral areas.⁸

Research on the influences of regional innovative activity has identified a number of relevant factors other than city size and settlement structure. These other influences include: institutional conditions, the population's age structure, the sectoral composition of the local economy and knowledge base, the quantity and quality of available human and social capital, as well as regional and national cultures (Asheim, Isaksen and Trippl 2019; Crescenzi and Rodriguez-Posé 2013; Fritsch and Slavtchev 2011). There is also an emerging body of research indicating that peripheral regions can be quite innovative. It appears that certain company-related factors, like a high absorptive capacity or efficient internal organization of knowledge processing, compensate for the lack of agglomeration benefits (for a review, see Eder 2019). Historical factors may also play a significant role in explaining the geography of innovation activities. In an in-depth study of the geographic distribution of innovative activities in Germany, Fritsch and Wyrwich (2021) identify three key factors arising from a history of political fragmentation and cultural realities that influence innovative activity: political-administrative structures, the location of knowledge sources (i. e., universities) and the financial system. It is becoming increasingly clear that any investigation of what influences highly productive innovative activity must take into account an extremely complex set of factors that goes well beyond the simple advantages and disadvantages of

⁴ For example, Florida, Adler, and Mellander (2017, 93) state that "...innovation and entrepreneurship do not simply take place in but *require* cities."

⁵ Carlino and Kerr (2015), Faberman and Freedman (2016), Glaeser and Maré (2001), Puga (2010), Neffke (2017).

⁶ Moretti (2019), in a recent analysis for the USA, distinguishes a number of technological fields and finds that the number of patents per inventor in a certain field increases with the size of the cluster (not city size) measured as the number of regional inventors that have patents in the respective field.

⁷ Well-known examples are old industrialized areas, such as the German Ruhr area, Detroit in the US, or Glasgow in Scotland.

⁸ E.g., Fritsch and Wyrwich (2021), Graffenberger et al. (2019), Grillitsch and Nilsson (2015).

² Bettencourt, Lobo and Strumsky (2007), Breschi and Lenzi (2006). The importance of geographic proximity for R&D cooperation is, however, rather unclear; see Boschma (2005) and Fitjar and Rodriguez-Posé (2017).

³ Faggio, Silva and Strange (2015, 2020) show that the effect of agglomeration on labor pooling, input sharing and knowledge spillovers varies considerably across industries.

agglomeration economies.

3. Data and definitions

3.1. Patents as an indicator for innovation activities

Patents is the only available indicator that allow us to compare the geographic structure of innovation activity across a larger number of countries. Using patents as an indicator of innovation has a number of advantages and disadvantages (for an overview see [Griliches 1990](#), and [Nagaoka, Motohashi and Goto 2010](#)). A main advantage of patents is that obtaining a patent requires a certain level of ‘newness’ that secures comparability across countries and regions. Patent data include considerable information, such as: the technological field according to the International Patent Classification, the date of application, the name(s) and address(es) of the applicant(s) as well as name and address of each of the inventors. One disadvantage of patents is the fact that they represent only the first stage of an innovation process. Another critical issue is that not all firms or inventors use patents as a way to protect their intellectual property ([Cohen, Nelson and Walsh 2000](#); [Blind et al. 2006](#)). Hence, not all inventions are patented. Moreover, some inventors obtain a number of related patents for basically the same invention in order to block follow-up patents by rivals. Another shortcoming of using patents as a measure of innovation activity is that a patent represents an invention and not its application in a new process or product. Hence, one does not know if, when or how the invention will become a marketable novelty ([Feldman and Kogler 2010](#)). There is also a clear indication that the economic value of patents significantly varies, indicating that their economic impact is unpredictable.⁹

Patents are taken from the OECD regional patent database (RegPat) and are assigned to the region in which the inventor claims his or her residence. If a patent has more than one inventor, the count is divided by the number of inventors and each inventor is assigned his or her share of that patent.¹⁰ All patents in the RegPat database are registered internationally under either the EPO or PCT system. Hence, all included patents are accorded the same regulations. Since the data excludes patents that are only registered in a single country, we largely rule out that country-specific regulations and cultures of patenting will impact our results. Given that patent fees for international applications are rather high, the patents in our database should have a certain minimum quality because applicants will only register after careful consideration of the expected value of the patent. We control for quality, such as the expected value of patents, in a number of robustness checks (see [Section 4.5](#)).

3.2. Sample

For an international comparison of the spatial concentration of patenting activity across countries, we not only include the G7 countries,¹¹ but also consider some other highly developed countries, namely: Sweden, South Korea, Switzerland, and Spain. The Czech Republic, Poland, and Hungary are also included as examples of post-socialist transition countries. We assume that Sweden and South Korea will reveal a pronounced geographic concentration of innovative activities

due to the high share of the population of these two countries in and around their capital cities, Stockholm and Seoul. The same is to be expected, although to a somewhat lesser degree, for the United Kingdom (Greater London), France (Paris/Ile-de-France), Hungary (Budapest), and Japan, where population is concentrated mainly in the metropolitan areas of Tokyo and Osaka. Germany, Italy, Spain, and Switzerland are characterized by more decentralized political and economic structures caused by historical developments.

The US and Canada are geographically much larger and have the lowest population densities when compared to the other countries in our sample. The populations of both countries is highly concentrated in large cities, and the distances between metropolitan areas tend to be much greater relative to the rest of our sample. Accordingly, innovative activity in the US and Canada may be strongly clustered in some regions as well. The great distance between large metropolitan areas may work as an impediment to an inter-regional division of innovative labor ([Crescenzi, Rodriguez-Posé and Storper 2007](#)).

There are considerable differences with regard to the number of patents per 10,000 population between the countries of our sample (Table A1). Switzerland, Sweden, Japan, Germany and South Korea have the highest ratios of patents per population, followed with some distance by the US. The lowest ratios are found for the three former socialist countries of Eastern Europe: Poland, Hungary and the Czech Republic.

3.3. Regional categories

Our analysis follows the OECD definition of functional urban areas ([OECD 2012](#)). These areas are geographic units characterized by one or more cities (the core) and a commuting zone that is interconnected with the city. A city is a local administrative unit where at least 50% of its population live in an urban center. An urban center is defined as an area with a density of at least 1,500 population per km², and an overall population of at least 50,000. The commuting zone is defined by local administrative units for which at least 15% of the workforce commute to the city. Commuting zones of the functional areas are identified based on commuting data (travel from home-to-work). In the assessment, we distinguish between large metropolitan areas (population >1.5 million), metropolitan areas (population = 250,000 to 1.5 million), non-metropolitan areas (population <250,000), and regions that are not part of a functional urban area.¹²

The official OECD definition of functional urban areas does not exactly conform to the borders defined by official statistical areas (TL3 regions) for which our patent data are available. Therefore, we include TL3 regions (NUTS3 regions in European Union countries) as part of functional urban areas if the bulk share of the TL3 region is part of the commuting zone of the urban center. Since it might be the case that NUTS3 regions host a metropolitan area and some smaller parts of non-metropolitan space, we may slightly overestimate the patent share of (large) metropolitan areas. TL3 regions are also used in our regression analysis of urban scaling patterns ([Section 4.4](#)), where we apply the same logic. Table A2 in the Online Appendix displays the number of regions in the different spatial categories for each country in our sample.¹³

⁹ The distribution of the economic value of patents appears to be highly skewed. While a few patents are extremely valuable, most patents are not worth much ([Harhoff, Narin, Scherer and Vopel 1999](#); [Harhoff, Scherer and Vopel 2003](#)).

¹⁰ We also run the analysis at the level of applicants ([Section 4.5](#)). This method of assigning patents to regions leads to an urban bias, because there is a strong tendency of headquarters being located in urban centers, while the research may take place somewhere else.

¹¹ The G7 countries are Canada, France, Germany, the United Kingdom, Italy, Japan, and the US.

¹² In their analysis, [Paunov et al. \(2019\)](#) define all functional urban areas as cities, while our focus is on functional urban areas that the OECD defines as metropolitan areas or large metropolitan areas.

¹³ It should be noted that the size and number of TL3 regions differs across countries. Hence, in countries where TL3 regions are relatively large, metropolitan areas can comprise larger parts of the surrounding area than in countries where TL3 regions are smaller, making the definition less precise. As a consequence, our data has a slight tendency of assigning more patents to metropolitan areas in countries with larger TL3 regions.

4. The spatial structure of innovative activity across countries

4.1. Metropolitan and non-metropolitan areas

We first investigate the contribution of a country's large metropolitan areas to the national share of patents (Table 1).¹⁴ The motivation for taking this approach is that the 'innovation requires large cities' argument suggests that across developed countries there is a general trend of innovation activities being concentrated in the largest cities. Comparable data on patenting is only available for the period 2000 to 2015.

The highest patent share of large metropolitan areas in 2015 is found in South Korea (94.7%), followed by the US (82.7%). In Germany, the patent share of large metropolitan areas is only about 36%. The value of 32.3% for the United Kingdom is surprisingly low, given the dominant role of the London area in terms of population.¹⁵ The lowest patent share of metropolitan areas (22%) is found in Italy. Focusing on the European countries in our sample, only Spain and the Czech Republic have a majority of patents in large metropolitan areas.

It is rather remarkable that in eight out of the 13 countries included in Table 1, the patent share of large metropolitan areas decreased by more than 5% from 2000 to 2015. In France, Italy and the UK the patent share of large metropolitan areas dropped by more than 10% between 2000 and 2015. In Poland the decrease was even higher (24%). Sweden is the only European country showing an increase of more than 5%, while the change of the patent share of other large metropolitan areas in the European countries included in our sample remained within the -5% to +5% range. Overall, the data show that there is no general tendency of an increasing concentration of innovative activity in large metropolitan areas in the early 21st century.

In order to understand whether the national share of innovative activity is higher than the national share of population in the largest metropolitan areas, we benchmark the concentration of innovative activities against the concentration of population. If large metropolitan areas have a patent/population ratio higher than 1, then this indicates an "urban premium" for innovative activity as suggested by the 'innovation requires large cities' argument. Large metropolitan areas might have a higher patent/population ratio because of the concentration of universities and other research facilities, and the on average higher share of R&D employees in these regions.¹⁶

We do indeed find such an urban premium in all of the countries in our sample. The exceptions are Italy in the year 2015, and the United Kingdom in all four years, where large metropolitan areas have lower patent/population ratios. The urban premium in the year 2015 is largest for the Czech Republic (2.18), Spain (1.71) and France (1.59). The values of the patent/population ratios for South Korea (1.15) and for the US (1.32), countries with exceptional high shares of patents in large metropolitan areas, are in the mid-range. It is interesting to note that the urban premium is declining over time in most of the countries, with a 2% increase being revealed in the US.

¹⁴ Switzerland has to be excluded from this analysis because the country does not have any metropolitan areas according to the OECD definition (see Section 3.3). For results on innovative activity in small and medium-sized metropolitan areas (population=250,000 to 1.5 million) across selected OECD countries, see Table A17 in the Online Appendix.

¹⁵ The patent share of London in 2015 is about 24.9%. Other regions with high national shares of patents are Cambridgeshire (8%), Oxfordshire (3.8%) and Coventry (3.7%). None of these regions are regarded as large metropolitan areas based on the OECD definition. Furthermore, for Cambridgeshire the patent/population ratio achieves a remarkable value of 8, which means that the national patent share of the region is about 8 times larger than its population share.

¹⁶ Due to the higher share of R&D activities, a value of the patents/population ratio larger than 1 does not indicate higher productivity of R&D activities in large agglomerations. A measure for productivity of regional research could be the number of patents per inventor (see Section 5).

Table 1

Shares of patents and population (in %) in large metropolitan areas (population >1.5 million) across selected OECD countries.

Country	Variable	2000	2005	2010	2015	Change 2015/2000
Canada	Patents	44.36	39.33	35.66	40.23	0.91
	Population	31.36	32.15	32.72	33.36	1.06
	Patents/ population ratio	1.41	1.22	1.09	1.21	0.85
Czech Republic	Patents	33.33	42.77	34.14	35.67	1.07
	Population	22.35	22.60	23.66	24.43	1.09
	Patents/ population ratio	1.49	1.89	1.44	1.46	0.98
France	Patents	48.19	44.20	43.96	42.00	0.87
	Population	26.10	26.23	26.28	26.39	1.01
	Patents/ population ratio	1.85	1.68	1.67	1.59	0.86
Germany	Patents	38.70	35.47	35.10	35.90	0.93
	Population	29.50	29.72	30.19	30.67	1.04
	Patents/ population ratio	1.31	1.19	1.16	1.17	0.89
Hungary	Patents	75.42	68.71	66.40	66.10	0.88
	Population	27.93	28.14	29.47	30.27	1.08
	Patents/ population ratio	2.70	2.44	2.25	2.18	0.81
Italy	Patents	28.24	27.27	24.66	21.96	0.78
	Population	22.56	22.48	22.45	23.10	1.02
	Patents/ population ratio	1.25	1.21	1.10	0.95	0.76
Japan	Patents	70.22	70.94	74.81	72.67	1.03
	Population	44.63	45.36	46.32	47.11	1.06
	Patents/ population ratio	1.57	1.56	1.62	1.54	0.98
Poland	Patents	30.58	19.86	22.62	23.24	0.76
	Population	15.78	15.75	15.76	15.95	1.01
	Patents/ population ratio	1.94	1.26	1.43	1.46	0.75
South Korea	Patents	94.83	96.48	94.42	94.72	1.00
	Population	82.18	82.73	82.78	82.37	1.00
	Patents/ population ratio	1.15	1.17	1.14	1.15	1.00
Spain	Patents	54.05	53.53	52.96	55.45	1.03
	Population	31.80	32.40	32.55	32.48	1.02
	Patents/ population ratio	1.70	1.65	1.63	1.71	1.00
Sweden	Patents	32.21	28.19	34.48	35.04	1.09
	Population	20.35	20.78	21.62	22.55	1.11
	Patents/ population ratio	1.58	1.36	1.60	1.55	0.98
United Kingdom	Patents	36.28	36.80	34.38	32.33	0.89
	Population	38.43	38.47	38.81	39.22	1.02
	Patents/ population ratio	0.94	0.96	0.89	0.82	0.87
USA	Patents	80.24	80.03	81.14	82.73	1.03
	Population	61.88	62.19	62.37	62.81	1.02
	Patents/ population ratio	1.30	1.29	1.30	1.32	1.02

Notes: OECD database. Patents is the regional number of patent applications over the national total in %. Population is the regional number of people over the national total in %. The patents/population ratio is the quotient of these two shares.

In Table 2, we focus on the innovative activities found in the three metropolitan areas with the largest populations across the selected OECD countries. It should be noted that the proportion of a country's population in the three largest metropolitan areas differs across countries, partly because of different country sizes. Therefore, the results are particularly informative when comparing groups of countries where this proportion is relatively similar such as the US, Germany, and Italy.

The focus on the three largest metropolitan areas reveals some remarkable differences when compared to the analysis that includes all metropolitan areas. For the US, the patent share in the year 2015 drops to only 16.29% while the population share of these areas is 17.08%, suggesting that no urban premium exists for the three largest agglomerations in the US. This clearly indicates that it is not the largest metropolitan areas in the US that have most of the patents. It is also remarkable that the patent share of the three largest metropolitan areas is decreasing over time. In Germany, the patent share of the three largest metropolitan areas is about 11.3% while the population share is slightly above 16%. The respective patent/population ratio (0.69 in 2015) is the lowest in the sample of countries, and is relatively stable over time. For Italy, the urban premium seen in the years 2000 and 2005 disappears in 2010 and 2015. The urban premium also disappears for the United Kingdom. Even in a sparsely populated country like Canada, where metropolitan areas play a particularly important role, there is a significant decline of the urban premium, from 1.47 to 1.25. Only one of the nine country in our sample (Germany) shows an increase of the patent/population ratio.

Altogether, the rather pronounced heterogeneity across countries suggests that the largest metropolitan areas do not necessarily host a more than proportional share of innovative activity, and that the largest agglomerations did not increase in importance over the 2000 to 2015 period. Rather, the urban premium for the three largest metropolitan areas is relatively stable or declining in all countries with the exception of Germany. These results suggest that the largest metropolitan areas of a country do not necessarily provide the most conducive framework conditions for, nor are specialized in innovation activity.

4.2. Non-metropolitan areas

To shed more light on the role of non-metropolitan areas (functional regions with a population of less than 250 000), we calculate the national share of patents registered in these areas (Table 3). These calculations identify two clear outliers, South Korea and the US, where the share of patents in non-metropolitan areas in the year 2015 is extremely low (0.65% in South Korea and 2.39% in the US). While the patent share of non-metropolitan areas is also relatively low in Japan (between 4.4% and 5.93%), it is much higher in all other countries. The highest values are found for Switzerland (50.16–52.75%) and Italy (43.38–49.01%), two countries with a pronounced historically grown federal tradition. For most of the other countries, the national share of patents registered in non-metropolitan areas varies between around 13% and 35%. The development of the patent share of non-urban areas in the 2000 to 2015 period is rather stable in most of the countries in our sample. The patent share of non-metropolitan areas increased by more than 5% in six countries and decreased by more than 5% in five countries of our sample. Hence, the data show no general trend of a concentration of patenting in non-metropolitan areas.

In nearly all countries and years (exceptions are Switzerland and the UK) the patents/population ratio for the non-metropolitan areas is below 1, indicating that for most of these regions specializing in innovative activities is below the national average. Table 3 shows, however, some rather pronounced heterogeneity in this respect. While South

Table 2

Patents and population in the three largest metropolitan areas across selected OECD countries.

Country	Variable	2000	2005	2010	2015	Change 2015/2000
Canada	Patents	41.25	37.28	32.47	36.76	0.89
	Population	28.15	28.80	29.11	29.45	1.05
	Patents/ population ratio	1.47	1.29	1.12	1.25	0.85
France	Patents	48.19	44.20	43.96	42.00	0.87
	Population	26.10	26.23	26.28	26.39	1.01
	Patents/ population ratio	1.85	1.68	1.67	1.59	0.86
Germany	Patents	9.95	10.42	10.34	11.25	1.13
	Population	16.27	16.25	16.38	16.41	1.01
	Patents/ population ratio	0.61	0.64	0.63	0.69	1.12
Italy	Patents	21.82	19.34	18.53	15.73	0.72
	Population	18.74	18.69	18.66	19.33	1.03
	Patents/ population ratio	1.16	1.04	0.99	0.81	0.70
Japan	Patents	62.27	61.56	64.06	63.31	1.02
	Population	33.27	33.89	34.74	35.37	1.06
	Patents/ population ratio	1.87	1.82	1.84	1.79	0.96
South Korea	Patents	82.00	84.56	82.03	81.30	0.99
	Population	66.04	67.33	67.81	67.62	1.02
	Patents/ population ratio	1.24	1.26	1.21	1.20	0.97
Spain	Patents	54.05	53.53	52.96	55.45	1.03
	Population	31.80	32.40	32.55	32.48	1.02
	Patents/ population ratio	1.70	1.65	1.63	1.71	1.00
United Kingdom	Patents	31.33	32.40	29.91	28.44	0.91
	Population	30.55	30.65	31.08	31.59	1.03
	Patents/ population ratio	1.03	1.06	0.96	0.90	0.88
USA	Patents	19.44	19.34	17.89	16.29	0.84
	Population	17.89	17.65	17.29	17.08	0.96
	Patents/ population ratio	1.09	1.10	1.03	0.95	0.88

Notes: OECD database. Only countries from Table 1 with at least three large metropolitan areas are considered. For the definition of variables see Table 1.

Korea and the US have the lowest values of (0.29 and 0.24 in 2015, respectively), rather high values can be found for Italy, Switzerland and the UK. The patents/population ratio decreased by more than 5% in four countries of the sample, remained relatively constant in four countries and increased by more than 5% in six countries. Hence, there is also no general trend towards an increased specialization of innovative activities in non-metropolitan areas.

4.3. Regional size, density, and innovation intensity

Most proponents of the 'innovation requires large cities' argument relate their hypotheses to population size or level of economic activity, rather than density (e.g., Bettencourt, Lobo and Strumsky 2007; Bettencourt 2013; Gomez-Lievano, Patterson-Lomba and Hausmann 2016),

Table 3

Patents and population in non-metropolitan areas (less than 250,000 population) across selected OECD countries.

Country	Variable	2000	2005	2010	2015	Change 2015/2000
Canada	Patents	28.97	26.16	25.91	28.31	0.98
	Population	51.79	50.63	49.91	48.87	0.94
	Patents/population ratio	0.56	0.52	0.52	0.58	1.04
Czech Republic	Patents	29.73	26.42	33.33	34.80	1.17
	Population	44.52	44.47	43.78	43.27	0.97
	Patents/population ratio	0.67	0.59	0.76	0.80	1.20
France	Patents	16.70	16.22	15.23	14.89	0.89
	Population	32.92	32.71	32.63	32.26	0.98
	Patents/population ratio	0.51	0.50	0.47	0.46	0.91
Germany	Patents	23.57	26.19	27.26	26.08	1.11
	Population	33.63	33.35	32.84	32.36	0.96
	Patents/population ratio	0.70	0.79	0.83	0.81	1.15
Hungary	Patents	13.97	15.65	19.37	22.03	1.58
	Population	51.09	50.97	50.00	49.50	0.97
	Patents/population ratio	0.27	0.31	0.39	0.45	1.63
Italy	Patents	43.38	45.58	49.01	47.71	1.10
	Population	52.47	52.40	52.33	51.70	0.99
	Patents/population ratio	0.83	0.87	0.94	0.92	1.12
Japan	Patents	5.21	5.37	4.40	5.93	1.14
	Population	7.11	6.99	6.85	6.73	0.95
	Patents/population ratio	0.73	0.77	0.64	0.88	1.20
Poland	Patents	21.49	31.51	29.76	25.28	1.18
	Population	50.64	50.59	50.60	50.25	0.99
	Patents/population ratio	0.42	0.62	0.59	0.50	1.19
South Korea	Patents	0.65	0.27	0.53	0.65	1.01
	Population	2.20	2.22	2.22	2.28	1.04
	Patents/population ratio	0.29	0.12	0.24	0.29	0.97
Spain	Patents	16.93	13.63	12.38	13.33	0.79
	Population	30.37	29.99	29.96	29.74	0.98
	Patents/population ratio	0.56	0.45	0.41	0.45	0.80
Sweden	Patents	28.46	27.83	27.00	26.44	0.93
	Population	46.87	46.09	44.85	43.90	0.94
	Patents/population ratio	0.61	0.60	0.60	0.60	0.99
Switzerland	Patents	52.04	51.58	52.75	50.16	0.96
	Population	53.24	53.09	52.89	52.84	0.99
	Patents/population ratio	0.98	0.97	1.00	0.95	0.97
United Kingdom	Patents	27.85	26.75	28.38	24.32	0.87
	Population	26.58	26.63	26.50	26.25	0.99
	Patents/population ratio	1.05	1.00	1.07	0.93	0.88
USA	Patents	3.07	3.23	2.86	2.39	0.78
	Population	10.44	10.26	10.19	10.01	0.96
	Patents/population ratio	0.29	0.31	0.28	0.24	0.81

Notes: OECD database. For the definition of variables see Table 1.

while most arguments in the literature examining agglomeration economies rely on density in terms of geographic proximity to a large number of actors (e.g., [Storper and Venables 2004](#)). When we compare the relationship of these two alternative definitions of agglomeration economies with the number of patents per population (patent intensity), some important differences are revealed.

We base our assessment on average values for the entire 2000–2015 period. Taking all regions together, we find a highly significant positive relationship with patents per population for both size and density ([Fig. 1a](#)).^{17,18} The correlations coefficient is larger for population density (0.42) than for population size (0.19), but there are high levels of heterogeneity at all levels of size and density. The correlation of patents per population with size remains in about the same range for large metropolitan areas ([Fig. 1b](#)). However, the relationship between patents per population and population density is close to zero and insignificant (0.07) for the large metropolitan areas ([Fig. 1b](#)). Overall, the results suggest that the relationship between population size and patenting for

large metropolitan areas is in the same range as it is for other types of regions. The relationship between patenting and population density for large metropolitan areas is much weaker than for other areas and not statistically significant.

4.4. The general geographic concentration of patenting

In the next step of our analysis, we look at the overall geographic concentration of innovative activities. Our measure of geographic concentration is the well-known normalized Herfindahl–Hirsch Index (HHI) that assumes the value of 1 if innovative activity is completely concentrated in one region.

[Table 4](#) shows the geographic concentration of patents in our sample countries. An international comparison is somewhat hampered by the fact that the value of the index is affected by the number of regions, which considerably varies across countries. However, we are more interested in relating the concentration of patents to the concentration of population, which is more or less comparable across countries. In all countries, the number of patents in the year 2015 is more geographically concentrated than population. The value of the ratio for Japan (4.5) is exceptionally high. The three countries with a pronounced federal tradition have rather low values: Germany (1.6), Italy (1.6) and Switzerland (1.3). The value of about 2.3 for the US is similar to the values for the United Kingdom (2.1) and France (2.2). Comparing the

¹⁷ The relationship between the number of inventors, density, and patents per inventors is shown in Figure A1 in the Online Appendix.

¹⁸ The plots show the prediction for patents per population from a linear regression of this measure on population and population density respectively and the corresponding confidence intervals at the 95 percent level.

Fig. 1. Population size, density, and patents per population.

values of the index for different years clearly reveals that there is an increase in the geographic concentration of patents relative to population by more than 5% in two countries, while the concentration decreases by more than 5% in eight countries. Hence, there is also no general trend of a geographic concentration of innovative activity.

To summarize, our results reveal significant differences in the geographic concentration of innovative activity in large metropolitan areas across our sample. The highest shares of patents in large metropolitan areas are found for South Korea and the US. These are also countries (together with Japan) that have relatively low shares of patents in non-urban and rural regions. The result that the metropolitan areas in all of the countries in our sample have a higher number of patents per population (urban premium) than intermediate and non-metropolitan regions does suggest that cities have certain locational advantages for innovative activities. However, the pronounced variation of the urban premium among the different types of metropolitan areas in a specific country shows that the effect of size and density on innovative activity can considerably vary. Specifically, the largest agglomerations do not have the highest urban premium.

4.5. Further analyses: Sensitivity check

Metropolitan areas and rural regions may have differing sources of inspiration that drive inventions. Based on this presumption, firms in rural and peripheral regions may focus on different types of inventions, or have different modes of innovative activity than firms in large urban areas. It has been argued that actors in rural areas are more likely to engage in incremental innovations, while radical and unconventional innovations primarily occur in cities (Duranton and Puga 2011; Shear-mur 2011; Berkes and Gaetani 2020). For example, there is evidence that digital technologies are spurring an increase in the concentration of

innovative activities in selected cities (Paunov et al. 2019). There also seems to be a tendency that start-up activity in high-tech sectors is becoming more concentrated in cities (Florida and Hathaway 2018; Fritsch and Wyrwich 2021).

Based on the OECD patent quality indicators, we conducted sensitivity analyses in order to assess regional differences with respect to common indicators of a patent's quality (see Squicciarini, Dernis and Criscuolo 2013). A key measure of patent quality is renewal of patent protection over a longer period of time. Since extending patent protection for a longer time period is not without cost, renewal indicates that the owner of the patent believes that the patent has a certain economic value. The number of forward citations indicates a patent's impact on further technological developments. The measure of an invention's radicalness and originality is based on backward citations. While radicalness is measured by the number of IPC classes of the patents that are cited by the focal patent (Shane 2001), originality is measured by the breadth of the distribution across these IPC classes (for a detailed definition see Squicciarini, Dernis and Criscuolo 2013).¹⁹

We replicate the overview shown in Table 1 for these subsets of patents, and the results of this exercise are summarized in Table 5. It can be seen that when we use different definitions of quality, large metropolitan areas tend to have about the same, or only slightly higher shares of patents compared to all patents. While the patents/population ratios differ considerably across countries, there is no clear pattern indicating that large metropolitan areas have higher shares of higher quality patents as compared to all patents. Detailed results on quality indicators are provided in the Online Appendix, where we also consider additional measures for patent renewal and citation patterns (Tables A3-A8).

Table A9 in the Online Appendix presents the share of patents in

¹⁹ We do not include breakthrough inventions (Ahuja and Lampert 2001). These inventions are the top 1% of patents with regard to forward citations, and there are so few of these patents that their inclusion does not lead to meaningful results in the comparison.

Table 4

Geographic concentration of patenting activity (Herfindahl-Hirsch-Index) across selected OECD countries.

Country	Variable	2000	2005	2010	2015	Change 2015/2000
Canada	Patents	0.058	0.062	0.067	0.058	0.991
	Population	0.023	0.024	0.024	0.025	1.069
	Patents/population-ratio	2.482	2.598	2.770	2.301	0.927
Czech Republic	Patents	0.148	0.132	0.116	0.114	0.766
	Population	0.084	0.084	0.084	0.085	1.016
	Patents/population-ratio	1.772	1.577	1.377	1.337	0.754
France	Patents	0.039	0.038	0.037	0.036	0.920
	Population	0.016	0.016	0.016	0.016	0.999
	Patents/population-ratio	2.363	2.337	2.230	2.175	0.920
Germany	Patents	0.009	0.008	0.008	0.009	0.996
	Population	0.006	0.006	0.006	0.006	1.055
	Patents/population-ratio	1.661	1.429	1.406	1.568	0.944
Hungary	Patents	0.398	0.323	0.284	0.252	0.633
	Population	0.074	0.073	0.075	0.077	1.046
	Patents/population-ratio	5.401	4.444	3.785	3.270	0.605
Italy	Patents	0.040	0.037	0.033	0.032	0.813
	Population	0.020	0.019	0.019	0.020	1.034
	Patents/population-ratio	2.045	1.906	1.694	1.607	0.786
Japan	Patents	0.142	0.140	0.163	0.196	1.375
	Population	0.039	0.040	0.041	0.042	1.079
	Patents/population-ratio	3.619	3.474	3.934	4.612	1.275
Poland	Patents	0.072	0.046	0.046	0.051	0.706
	Population	0.016	0.016	0.016	0.016	1.005
	Patents/population-ratio	4.527	2.916	2.889	3.181	0.703
South Korea	Patents	0.258	0.288	0.265	0.272	1.055
	Population	0.113	0.119	0.123	0.123	1.090
	Patents/population-ratio	2.282	2.416	2.162	2.209	0.968
Spain	Patents	0.149	0.147	0.132	0.146	0.978
	Population	0.052	0.053	0.054	0.054	1.039
	Patents/population-ratio	2.875	2.759	2.456	2.706	0.941
Sweden	Patents	0.170	0.167	0.186	0.193	1.133
	Population	0.101	0.103	0.107	0.110	1.091
	Patents/population-ratio	1.686	1.613	1.740	1.751	1.038
Switzerland	Patents	0.100	0.095	0.092	0.106	1.055
	Population	0.078	0.079	0.080	0.080	1.023
	Patents/population-ratio	1.279	1.199	1.160	1.319	1.032
United Kingdom	Patents	0.021	0.022	0.022	0.026	1.234
	Population	0.012	0.012	0.012	0.012	1.042
	Patents/population-ratio	1.799	1.822	1.856	2.130	1.184
USA	Patents	0.047	0.043	0.046	0.048	1.017
	Population	0.021	0.021	0.021	0.021	0.974
	Patents/population-ratio	2.202	2.033	2.188	2.299	1.044

Notes: OECD database.

large metropolitan areas when a patent is assigned to the region of the applicant that is also the headquarters of the respective organization. As mentioned in [Section 3.1](#), this method of assigning patents to regions leads to an urban bias because headquarters are frequently located in urban centers, even though the research was conducted somewhere else.²⁰ Not surprisingly, we find that this inappropriate method of determining a patent's place of origin leads to a considerably higher share of patents being assigned to large metropolitan areas.

Finally, in order to rule out that our results are driven by inventors that hold a high number of patents, we replicate the overview presented in [Table 1](#), but we distinguish between patents held by top inventors and non-top inventors. The results of this robustness check do not indicate that our main findings are driven by top inventors (Tables A10 and A11 in the Online Appendix).

5. Urban scaling in innovative activity across countries

Our analysis of urban scaling is based on [Bettencourt and Lobo \(2016\)](#), who regress the number of patents on the size of the population

²⁰ For example, although the Max Planck and Fraunhofer Society have more than 150 research institutes broadly spread across Germany, all patents are filed at their headquarters in Munich.

of a region. In contrast to these authors, we do not restrict the analysis to cities of a certain minimum size. We consider all regions in order to understand whether cities and metropolitan areas have a scaling advantage when compared to non-metropolitan areas. As a robustness check, we run the analysis for (metropolitan) regions with a population greater than 500,000 similar to [Bettencourt and Lobo \(2016\)](#) (Table A12 in Online Appendix).²¹

We regress the number of patents on the regional population level ([Table 6](#), Model I) and the number of inventors (Model II). We use the average values for the period 2000 to 2015. We interact the population

²¹ This deviates from the OECD definition of metropolitan areas that we follow in other parts of the paper. The approach by [Bettencourt and Lobo \(2016\)](#) measures the role of urban scaling conditioned on a region being a metropolitan area. This is not suited to our primary interest, which is a comparison of innovative activity between metropolitan areas and rural regions. Table A14 and Figure A2 in the Online Appendix provide more details on country-specific coefficient estimates and scatterplots of urban scaling across metropolitan regions with a population of more than 500,000. The results of the analysis for metropolitan regions with more than 500,000 population resemble the patterns of the main analysis, although the levels of statistical significance tend to be weaker because of the smaller sample size. The scaling coefficients of 1.457 and 1.481 that we estimate for the US are higher than that of 1.291 estimated by [Bettencourt, Lobo and Strumsky \(2006\)](#) for the years 1980-2001.

Table 5

Shares of different types of patents (in %) in large metropolitan areas (population >1.5 million) and at country level across selected OECD countries.

Country	Variable	All patents	Patent renewal	Forward citations	Radicalness	Originality
Canada	Share patents metro	39.89	37.16	33.07	38.85	35.58
	Patents/population ratio	1.23	1.16	1.03	1.20	1.10
	Share at country level	-	66.80	4.42	*	*
Czech Republic	Share patents metro	36.48	30.72	33.33	38.47	36.67
	Patents/population ratio	1.57	1.34	1.47	1.67	1.57
	Share at country level	-	58.27	0.62	*	*
France	Share patents metro	44.59	43.88	56.26	46.36	46.28
	Patents/population ratio	1.70	1.67	2.15	1.77	1.76
	Share at country level	-	68.64	1.70	*	*
Germany	Share patents metro	36.29	35.99	39.98	37.88	36.79
	Patents/population ratio	1.21	1.21	1.34	1.26	1.23
	Share at country level	-	67.99	2.39	*	*
Hungary	Share patents metro	69.16	74.73	47.22	64.02	72.31
	Patents/population ratio	2.39	2.63	1.65	2.22	2.51
	Share at country level	-	58.76	1.58	*	*
Italy	Share patents metro	25.53	28.63	25.79	28.85	27.22
	Patents/population ratio	1.13	1.27	1.15	1.27	1.20
	Share at country level	-	60.79	1.77	*	*
Japan	Share patents metro	72.16	72.05	69.60	72.93	72.51
	Patents/population ratio	1.57	1.59	1.53	1.59	1.58
	Share at country level	-	69.92	3.38	*	*
Poland	Share patents metro	24.08	30.98	11.11	32.16	22.68
	Patents/population ratio	1.52	1.97	0.70	2.03	1.43
	Share at country level	-	56.77	0.70	*	*
South Korea	Share patents metro	95.11	96.18	98.75	96.52	95.15
	Patents/population ratio	1.15	1.16	1.20	1.17	1.15
	Share at country level	-	68.03	4.12	*	*
Spain	Share patents metro	54.00	55.86	67.28	54.63	56.15
	Patents/population ratio	1.67	1.73	2.09	1.69	1.74
	Share at country level	-	52.94	2.00	*	*
Sweden	Share patents metro	32.48	32.33	44.99	37.31	31.17
	Patents/population ratio	1.52	1.54	2.14	1.75	1.46
	Share at country level	-	72.74	2.82	*	*
United Kingdom	Share patents metro	34.95	34.75	36.38	38.42	34.10
	Patents/population ratio	0.90	0.90	0.94	0.99	0.88
	Share at country level	-	62.81	3.39	*	*
USA	Share patents metro	81.03	81.03	85.97	80.90	80.08
	Patents/population ratio	1.30	1.30	1.38	1.30	1.29
	Share at country level	-	65.71	4.88	*	*

* The shares refer to the top 5% patents of this category per priority year and country (for details, see Table notes).

Notes: OECD database. *Share patents metro* is the regional number of patent applications in metropolitan areas over the national total by quality indicator in %. *Share at country level* is the total number of patent applications by quality indicator over the national total of all patents in %. The *patents/population ratio* is the quotient of *share patents metro* and the share of population living in metropolitan areas. The columns on quality indicators consider only information from patents registered for EPO because the information on quality indicators is not available for PCT-only registered patents. Patents in the column on renewals refers to EPO patents that were renewed for at least 7 years. Patents in the column on forward citations refer to the top 5% EPO patents per priority year in terms of citations up to 5 years after priority year. Patents in the column on radicalness refer to the top 5% of EPO patents with respect to the OECD radicalness indicator per priority year and country. Patents in the column on originality refer to the top 5% of EPO patents with respect to the OECD originality indicator per priority year and country. All columns show average values for the period 2000 to 2015. For patent renewal and forward citations only information until 2010 is considered to avoid the problem of truncation.

level and the number of inventors with country dummies where the US is the reference category. Significant interaction effects indicate whether urban scaling for innovative activity in the respective countries is more pronounced than in the US. We use the US as a benchmark because theories emphasizing the importance of large cities for innovative activity are mainly based on observations made for this country.

In the population-based model (Model I, Table 6), we obtain a coefficient estimate for the US of 1.457. There are significantly negative interaction effects for Canada, Germany, Switzerland, and the UK. The negative effects are particularly pronounced for Canada and Switzerland. In Switzerland, the coefficient for urban scaling is only slightly above 1 while for Canada it is even below 1, indicating urban descaling. For the UK and Germany, the overall effect is only about 1.2.

Table A13 in the Online Appendix documents the scaling coefficient estimates and the respective confidence intervals. There are several countries for which the lower bound of the confidence interval is below one, indicating that the coefficient is not significantly different from one. Figures A2 in the Online Appendix show the respective country-specific scatterplots.

To explore whether inventors located in cities are more productive,

we regress the number of patents on the number of inventors per region (Table 6, Model II). If inventors living in metropolitan areas have more patents, the coefficient estimate and the lower bound of the confidence interval should exceed the value of one.

We find hardly any urban mark-up on inventor productivity across countries (see also Tables A15 and A16, and Figure A3 in the Online Appendix). Japan, South Korea, and Italy are the only countries where, with a relatively small margin, inventors seem to be (weakly) significantly more productive in cities. While the scaling coefficient for the US is close to one, it is significantly below one in Canada, the Czech Republic, Hungary Poland, Spain, and France. This indicates that inventors in metropolitan areas of these countries are even (slightly) less productive than those in other regions.

6. Conclusions

Some prominent theories suggest that successful innovative activity is stimulated by agglomeration economies and thrives in large cities (Carlini and Kerr 2015; Glaeser and Hausman 2019; Florida, Adler and Mellander 2017). Our investigation of the geographic concentration of

Table 6

Urban scaling based on regional population and inventors across selected OECD countries.

Dep variable: Patents	I	II
	Size = Level of population	Size = Number of inventors
Country dummies	Y	Y
Size	1.457*** (0.047)	0.963*** (0.006)
(reference group: USA)		
Size X Canada	-0.592*** (0.071)	-0.112*** (0.014)
Size X Czech Republic	-0.318 (0.208)	-0.133* (0.077)
Size X France	0.034 (0.097)	-0.029** (0.014)
Size X Germany	-0.289*** (0.066)	0.003 (0.011)
Size X Hungary	0.071 (0.159)	-0.134* (0.069)
Size X Italy	-0.196 (0.132)	0.028* (0.016)
Size X Japan	0.174 (0.161)	0.062*** (0.013)
Size X Poland	0.029 (0.146)	-0.126*** (0.020)
Size X South Korea	-0.041 (0.150)	0.061* (0.035)
Size X Spain	-0.226** (0.093)	-0.111*** (0.027)
Size X Sweden	0.152 (0.110)	0.001 (0.020)
Size X Switzerland	-0.415*** (0.082)	-0.039 (0.024)
Size X United Kingdom	-0.314*** (0.065)	-0.017 (0.013)
R ²	0.845	0.993

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Observations: $N = 1,265$. Robust standard errors in parentheses. Size, inventors, and patents are log-transformed annual averages of their total number for the periods indicated in the column headings.

patents in a sample of developed countries reveals a wide variety of environments where innovative activity is prevalent. We do not find any general trend towards an increasing concentration of innovative activities in large agglomerations over the 2000–2015 period (Section 4.1). Our results clearly suggest that population density and agglomeration economies do not play a dominant role in regional innovative activity, at least in the majority of the countries in our sample. This clearly suggests that innovation does not ‘require’ large cities. Finally, we investigated the general regional concentration of population and patents. In all countries, patents are considerably more geographically concentrated than population, but there is also no general trend of an increasing concentration over time.

Our analysis of the relationship between the number of patents and the size of the regional population (urban scaling) shows more patents per population in most of the countries in our sample. The obvious reason behind this result is that agglomerations tend to have higher levels of innovative activity caused by a higher share of inventors among that specific population. The scaling coefficient for the number of patents based on the number of inventors (patent productivity) is close to or below one for nearly all countries. This clearly indicates that inventors in larger agglomerations are not more productive in terms of having more patents.

It goes without saying that a good theory is a radical simplification of reality and focuses on the most relevant factors and relationships. We also recognize the role of agglomeration economies in promoting successful innovative activities. However, our results clearly indicate that the role of agglomeration economies is much less pronounced than many authors suggest (e.g., Bettencourt 2013; Carlini and Kerr 2015; Florida, Adler and Mellander 2017). Hence, the popular theory that emphasizes

and builds almost entirely on the role of agglomeration economies is much too simple to explain the regional distribution of innovative activities, and is largely inappropriate for many countries.²²

The main policy implication of our research is that innovation does not require large cities, but can also be successfully conducted in non-urban environments. If agglomeration economies are of only limited relevance for successful innovative activities, concentrating public R&D spending in large agglomerations (see, for example, Glaeser and Hausman 2019) is not necessarily the best strategy recommendation. Instead, policy programs such as the EU Smart Specialization Strategy (Foray 2014; McCann 2015; McCann and Ortega Argilés 2015) that aim at stimulating regional development of low-density and lagging regions by initiating and supporting innovation processes may be quite successful, and are not necessarily an inefficient or wasteful allocation of resources, as some scholars suggest (e.g., Glaeser and Hausman 2019).

Since our research shows that agglomeration economies are not the main factor determining the spatial structure of innovative activities in most countries, the policy recommendations promoted by popular theories to concentrate public spending on large agglomerations may be misleading and harmful. Therefore, policymakers are strongly advised to consider influences other than city size or population density.

An important avenue for further research could be to overcome the limitations of our analysis due to the weaknesses of patents as an indicator for innovative activity (Section 3.1). Hence, it would be an important step forward to develop more fine-tuned indicators for innovative activity that distinguish between different types of innovation, and are comparable across countries and regions.²³

A key question that follows from our analyses concerns the factors that determine the location of innovative activities and the region-specific determinants of their success. Why are some firms located in remote rural areas innovative and economically successful? How do these firms acquire the qualified labor that they need for their innovative activities? Is a decentralized settlement structure with a variety of easily accessible smaller and medium-sized cities (as it is found in many parts of Europe) important for innovative activities in rural areas?

The development of formal institutions in Germany provides an excellent example of the long-lasting effect historical factors have on current structures. The educational system, labor market regulations and the tax treatment of inheriting a business also seem to have an effect in the German context (for details, see Fritsch and Wyrwich 2021). The interplay of these dynamics may be suitable candidates as factors for a closer inspection of causal relationships in case studies for other countries. An important issue of such investigations could be the basic orientation of other countries’ innovation system. Is innovation activity aimed at more radical, breakthrough innovation as is the claim for the US, or is it mainly focused on developing more incremental improvements, as seems to be the case in countries such as Germany (Ergas 1984; Hall and Soskice 2001)? It could be that a specific innovation system’s geographic structure is conducive for specializing in a certain type of innovation. Another relevant distinction, particularly for industry studies, could be between an entrepreneurial or Schumpeter Mark I regime and a routinized regime (Schumpeter Mark II) where innovation

²² Our result show that even in the US it is not the largest agglomerations that have the highest shares of patents. This clearly indicates that any theory that prioritizes the role of agglomeration economies has limited relevance, even in outlier cases.

²³ One indicator that may overcome the weaknesses of patents could be the introduction of new products to the market. Another type of metric could be the foundation of innovative start-ups and the location of venture capital investment (see Florida and Hathaway 2018). The data of the Community Innovation Survey (CIS) are not suited for an analysis across regions because the innovative activities of a firm’s subsidiary locations are assigned to the firm’s headquarter, and not to the region where the R&D took place. See <https://ec.europa.eu/eurostat/web/microdata/community-innovation-survey>.

activity is mainly in well-established large firms (Audretsch 1995; Winter 1984).

Our research certainly has limitations. First of all, we acknowledge that countries differ in size and that such differences may to some degree affect the results. While following the standard OECD definition of (large) metropolitan areas allows for comparability, some inconsistencies across countries cannot be completely ruled out. It should also be noted that the geographic patterns of patenting in densely populated countries like Germany are very similar to some low-density countries such as Sweden. Although by focusing only on internationally registered patents we can largely rule out that country-specific regulations and cultures of patenting impact our results, there might be some smaller inconsistencies that remain. However, there is no firm argument why, for example, country-specific cultures of patenting (internationally) should leave an imprint on the geographic distribution of innovation activity within each respective country. It should also be noted that our results hold when assessing the quality and the degree of radicalness and originality of patents.

We also acknowledge that the OECD patent quality measures that we use in our sensitivity analyses (see Section 4.5) may not perfectly grasp patent quality, originality, and/or radicalness. Finally, due to data constraints we do not distinguish between city centers and suburbs in our assessment. Hence, our cross-country analysis does not identify possibly interesting spatial patterns of patenting activities within metropolitan areas.

Another appropriate avenue for future research is to investigate and explain the role of public policy in this respect. How can public policy affect the geographic distribution of innovative activities? To what extent does policy aimed at rural and lagging areas stimulate innovative activities? Can an appropriate time period be established in which to expect significant changes of regional innovative activities? Do differing national and local policies of OECD countries explain the existing differences in the role that metropolitan areas play in innovative activity?

Any of these analyses could focus on, or distinguish between different types of innovation, such as radical vs. incremental, high vs. low tech, science-based vs. engineering or artistic-based. Such types of empirical analyses should help to provide a more relevant basis for policy decisions than the simple “big is efficient” paradigm.

Credit Author Statement

Both authors contributed in equal shares to conceptualization of the research and writing the manuscript. Michael Wyrwich organized and analyzed the data.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

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