Are cities drivers of pandemics?

Analysing the progression of Austrian COVID-19 cases according to the urban-rural typology

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1 Introduction

The resilience of cities has become a central issue in urban policy debates in recent years (cf. Coaffee & Lee, 2016; Desouza & Flanery, 2013; Eraydin & Tasan-Kok, 2013). The robustness of infrastructures and the adaptability and flexibility of infrastructural systems has received the attention of urban scholars from multiple disciplines (Acuto, 2020; Sharifi & Khavarian-Garmsir, 2020; Zecca et al., 2020; Guida & Caglioni 2020). The current health crisis has made its own mark on this debate. Exposing latent systemic vulnerabilities of e.g., services of general interest (Gray, 2020; Brown & Rocha, 2020; Tanrıvermiş, 2020; Lai et al., 2020), the tourism sector (Škare, Soriano, & Porada-Rochoń, 2020; Kreiner & Ram, 2020; Rogerson & Rogerson, 2020; Ntounis et al., 2020; Jaipuria, Parida, & Ray, 2021), and public health (Cruz et al., 2020; Biscayart et al., 2020; Paakkari & Okan, 2020; Brouard, Vasilopoulos & Becher, 2020), the pandemic has called the resilience of cities into question.

Some sections of the media have fueled this debate by repeatedly assuming cities to be drivers of the COVID-pandemic (Florida, 2020; AFP, 2021; NZ Herald, 2021). In Austria, too, public discourse suggested that a causal relation exists between densely populated areas with multi-scalar functional ties plus high levels of social interaction and the spread of COVID-19 cases. This resulted in the implementation of questionable measures, such as the temporary closing of key recreational urban public spaces such as parks and squares (Krutzler, 2020).

This was immediately criticised by public figures from the political and scientific sphere, since neither these restrictions, nor the statements justifying it, were underpinned by reliable data (Fang & Wahba, 2020; Teller, 2021). Yet while many urbanists and epidemiologists have jumped in to dispel such simplistic assumptions from a normative standpoint, there is still a significant lack of evidence to counter such claims.

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While the discussion about cities as drivers of the pandemic has meanwhile subsided as the situation has changed for the better, public debates have called some of the fundamental qualities of urban agglomerations – density, diversity, and unplanned encounters – into question. Hence, in this paper, we aim to explore whether any evidence exists to back the claim of more densely populated areas being drivers of the pandemic. To that end, we look into epidemiological data for municipalities in Austria, intersecting it with the Austrian spatial typology to distinguish urban settlement configurations from more rural ones, and investigate whether the development of the pandemic was significantly spurred by cities in Austria.

We begin with an overview of studies that have aimed to unveil the links between the spread of the health crisis and population density in Section 2, pointing to the existing knowledge in this research area and some of the shortcomings so far. In Section 3, we set forth our own approach, introducing the Austrian Urban-Rural Typology and discussing the advantages of employing a multi-dimensional spatial typology to study the spatial spread of COVID-19. In Section 4, we present the results of our analysis for Austrian municipalities. In Section 5, we discuss to what extent the 'level of urbanity' actually played a role in the spread of COVID-19 cases in Austria and reflect on some of the limitations of our own study. In Section 6, we conclude by suggesting further research avenues to better understand how cities impact and are impacted by the current and future health crises.

2 COVID-19 and population density: A literature review

New studies on the evolution of the COVID-19 pandemic are being published on a near-daily basis. They provide important evidence to support policy decisions addressing the health crisis (Lancet, 2020; Acuto, 2020) and help to better understand pandemics and the crisis resilience of society as a whole (Bryce et al., 2020; Fransen et al., 2021). However, studies on the geography of COVID-19 that deal with the influence of distinct spatial configurations on the spread of the virus are only now emerging in greater number. Many scrutinise the influence of cities or urban agglomerations on the spread of the virus. The following section provides a brief overview of these studies.

Carteni et al. (2020) analyse 20 Italian regions and find a positive correlation between the provincial capital's population density and the number of COVID-cases in that region. The authors also consider the number of tests and changes in travel behaviour as well as environmental conditions within a panel regression framework (ibid.). Boterman (2020), on the other hand, finds that there is no clear link between the COVID-19 geography of Dutch municipalities and the share of people living in densely populated areas, controlling for age and public health factors. A similar result is recorded by Rodriguez-Villamizar et al. (2020), who study 772 Colombian municipalities and show that there is no significant correlation between population density and COVID-19 mortality rates.

In a study concerned with US metropolitan areas, Hamidi et al. (2020) conclude that larger metropolitan areas measured by total population have significantly higher infection rates and mortality rates. At the same time, population density within the county is not significantly related to infection rates once controlled for the total metropolitan population, while death rates are even negatively related (ibid.). Another study by Zhang & Schwartz (2020) detects a significant positive relation between population density and confirmed cases by analysing the average data of urban, suburban, and rural counties. In contrast, the provincial level and prefecture-level data from China show that there is no linear relation between population density and the spread of COVID-19 (Lin et al., 2020; Fang & Wahba, 2020; McFarlane, 2021).

Hence, the debate on the impact of urban agglomerations on the spread of COVID-19 is still very inconclusive. What these studies have in common is that they use population density as a proxy to account for a certain level of urbanity. However, as Teller (2021) points out, such aggregate statistical models in most cases fail to show the possible interactions between different factors (ibid.: 158). Analyses based on disaggregated and individual-level data are thus necessary for drawing more precise conclusions. Hence, we combine micro-level epidemiological data from Austrian municipalities with our own more complex, multi-dimensional spatial typology, that is, the Austrian Urban-Rural-Typology.

3 Methodology

In their most elementary form, spatial typologies depend on total population per spatial unit, population density and land use patterns and characterise physical settlements based on methodologies of varying complexity (Bibby, 2013). Adding a degree of complexity, some also incorporate functional inter-dependencies of urban areas and their surroundings to delineate urban-rural functional units (Zasada et al., 2013). Aiming at a swift analysis, we were looking to employ a typology that already existed for our area of interest, i.e. the Austrian national territory, while incorporating both physical and functional settlement characteristics.

A review of existing methodological approaches aiming to typify urban-rural patterns, however, reveals three problem areas with respect to a pragmatic application in our case: firstly, most (European) typologies refer to either NUTS 2 or NUTS 3 levels, which is too aggregated to allow for micro-level analyses or conclusions on the spread of COVID-19 (cf. for instance Bengs & Schmidt-Thome, 2004). Secondly, many typologies have been developed with a clear thematic focus, thus aiming to either soundly represent urban or rural areas of a certain region or national territory, making the respective other a residual category that is less well typified (cf. for instance Copus et al., 2008 focusing on rural areas). Thirdly, a number of typologies that are methodologically sophisticated are not feasible for the Austrian case study since the corresponding database is not available in the necessary form (cf. Lepicier et al., 2006).

Hence, only three spatial typologies meet our requirements and are thus worth considering, namely, the EU Urban-Rural Typology (Eurostat, 2018), the EU Degree of Urbanisation classification (ibid.), and Statistik Austria's Urban-Rural Typology (Statistik Austria, 2021a).

Figure 1: The Comparison between the EU Urban-Rural Typology (1a) Degree of urbanisation classification (1b), and the Austrian Urban-Rural Typology shows different levels of Detail (1c). (Source: Eurostat, Statistik Austria, 2021a).
Note: Bright areas represent rural areas, dark areas represent urban areas.

While both the EU Urban-Rural Typology and the EU Degree of Urbanisation classification are based on a 1x1 kilometre grid and the same datasets, their focus is different. The EU Urban-Rural Typology identifies rural and urban clusters on the level of NUTS 3 regions, using the share of population living in rural grid cells and urban clusters it ultimately provides three types of regions: (i) predominantly urban regions, (ii) intermediate regions, and (iii) predominantly rural regions (Eurostat, 2018). The EU Degree of Urbanisation classification is more detailed. It transfers cell-based results into local administrative units (LAU) and identifies three types: (i) cities (i.e., densely populated areas), (ii) towns and suburbs (i.e., intermediate density areas), and (iii) rural areas (i.e., thinly populated areas) (Eurostat, 2018).

The EU Urban-Rural Typology does not distinguish sufficiently in terms of coherent spatial units. It builds on NUTS 3, which consists of groups of Austrian districts that are highly heterogeneous. Our study, however, seeks a delineation along the fault lines and transition areas between spatial types that are as homogeneous as possible and independent of the administrative delineation by districts or NUTS units.

The Degree of Urbanisation classification meets our requirements regarding adequate spatial resolution. However, with only three classes, it does not distinguish well enough between relevant spatial types. In particular, functional criteria are not considered. Thus, the differentiation of areas with similar characteristics regarding land-use patterns and population density with respect to their inter-dependencies with urban agglomerations and centres is lacking.

The Austrian Urban-Rural Typology, however, uses grid data from register-based statistics and considers the number of inhabitants as well as population density. Based on a study by Giffinger et al. (2006) on city-regions ("Stadtregionen"), different types of urban areas are defined. The key idea for the classification of urban agglomerations is based on two different levels of population density in order to identify a contiguous urban fabric with dedicated and high-density urban cores. A measure of centrality according to the functional characteristics of the urban core and a measure of agglomeration size in terms of the urban area's total population complement the structural criteria.

Table 1: Attributes of the Austrian Urban-Rural Typology.

101	Urban centres	Urban centre (large)
102		Urban centre (medium)
103		Urban centre (small)
210	Regional centers	Regional centre (central)
220		Regional centre (intermediate)
310	Rural area surrounding centres	Rural area surrounding centres (central)
320		Rural area surrounding centres (intermediate)
330		Rural area surrounding centres (peripheral)
410	Rural areas	Rural area (central)
420		Rural area (intermediate)
430		Rural area (peripheral)

Additionally, *the Austrian Urban-Rural Typology* integrates the number of jobs and infrastructure facilities, the total population of the surrounding area, commuter ratio, the area's economic focus, tourist numbers, and accessibility. Within the basic analytical steps, the process of typecasting is not related to administrative units. This allows for a higher degree of accuracy wherever a heterogeneous structure exists. Nevertheless, the resulting classification is applied on the municipality level and based on the concept of dominance of a specific type within an administrative unit. (ibid.) The result is a typology with four main classes and three levels of subclasses that distinguish more urban from more rural settlement areas (see Table 1).

Concerning epidemiological data, in this paper we use a unique panel dataset provided by the Austrian National Public Health Institute (Datenplattform COVID-19, 2021). The data contains the weekly number of newly detected COVID-19 cases for each of the 2,104 Austrian municipalities, was originally retrieved from the 'Epidemiologisches Meldesystem' (Epidemiological reporting system) and corresponds to the official COVID19 statistics used by the Austrian government. It covers a period of roughly one year, starting with the onset of the pandemic in March 2020 and ending April 07, 2021, hence allowing an analysis of the infection history before a significant share of the population was vaccinated. The Austrian population is mostly located in the urban centers (61%), while rural areas (22%), rural areas surrounding centers (12%), and regional centers (5%) all have substantially lower population shares (Statistik Austria, 2021b; Statistik Austria, 2021c). Thus, it is of course important to account for these differences by analysing the respective cases per hundred thousand inhabitants. Hence, we combine the epidemiological data not only with with information about the spatial classification (Statistik Austria, 2021c) but also with data on the resident population (Statistik Austria, 2021b) with the aim of calculating local incidence rates across municipalities, the four main regional types, as well as the eleven subtypes previously described. We track these incidence rates over time and investigate which types of municipalities accumulate more cases relative to their population size. Last but not least, we map average weekly incidence rates together with information on the spatial typology. This should act as a robustness check, as geographical distribution of urban areas across Austria could potentially lead to misleading outcomes in the aggregate.

4 Results

Firstly, we investigate the respective development of the three indicators that refer to the impacts of detected COVID-19 cases, since the beginning of 2020 across the four main regional categories described in Section 3. The left plot of Figure 2 reports newly confirmed cases for each calendar week, while the right plot shows the cases accumulated over time. Figure 2 shows quite similar developments of detected cases across the four main regional types, suggesting that there are no systematic deviating patterns. All regional categories appear to peak around the same time within the three respective waves experienced in Austria. However, at the peak of the first two waves, Urban Centers experienced lower numbers per hundred thousand inhabitants, while Rural Areas and Regional Centers were hit the hardest. Meanwhile, at the peak of the third wave in March 2021, Urban Areas were close to Rural Areas with slightly less detected cases per hundred thousand. Therefore, we do not see any evidence for Urban Centers being the drivers of the pandemic in Austria. On the contrary, they tend to perform comparatively well, especially in the arguably most critical stages during the second wave; the peak point for Urban centres was the 472 newly detected cases per hundred thousand while Rural Areas recorded a peak of 624.

Rural Areas end up with the highest number of cases, recording 7338.27 confirmed cases per hundred thousand at the end of April 2021. They are closely followed by the Regional Centers with 7101.66 confirmed cases per hundred thousand. Urban Centers were slightly lower with 6536.49 confirmed cases per hundred thousand. The lowest numbers are found in Rural Area Surrounding Centers, with 6185.04 cases per hundred thousand.

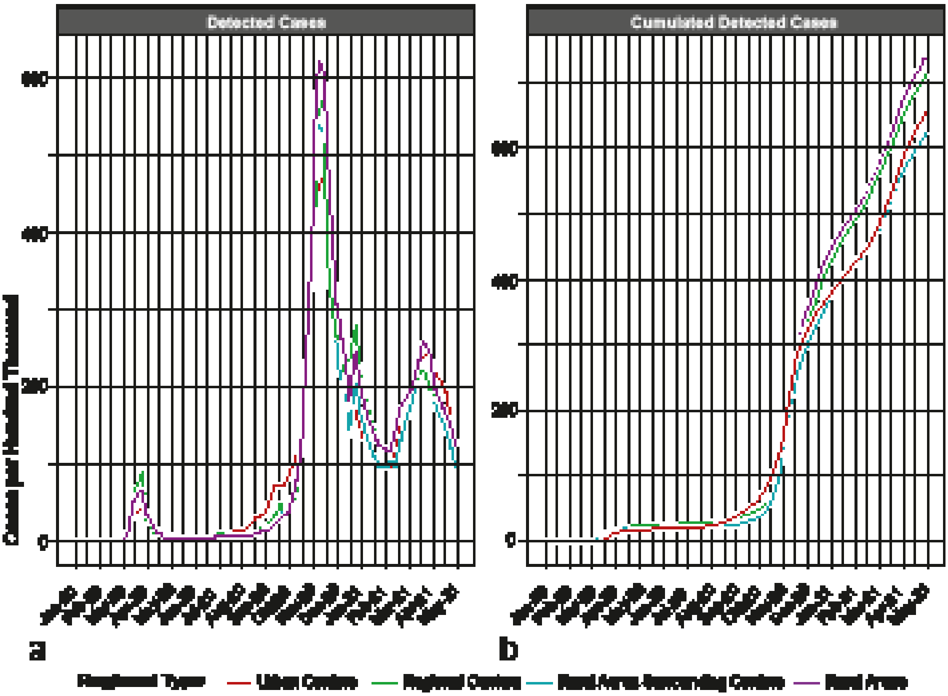


Figure 2: Case numbers per hundred thousand inhabitants by spatial type. (2a) new infections per calendar week; (2b) cumulated cases.

Thus, we have strong evidence against the driving role of Urban Centers in the spread of COVID-19 in Austria. Our four main regional categories exhibit a similar pattern of new infections over time. Relative to the number of inhabitants, Urban

Centers are, counter-intuitively, even slightly less affected by the pandemic than more rural types of municipalities.

In the next step, we aim to differentiate further between different subcategories of the regional typology used so far. Specifically, as the class of Urban Centers not only refers to larger cities but actually also contains many municipalities considered Medium Urban Centers as well as Small Urban Centers. By investigating infection trends on a more disaggregated level, we can test whether the picture obtained in the previous subsection may be driven by an outlying subsection of municipalities.

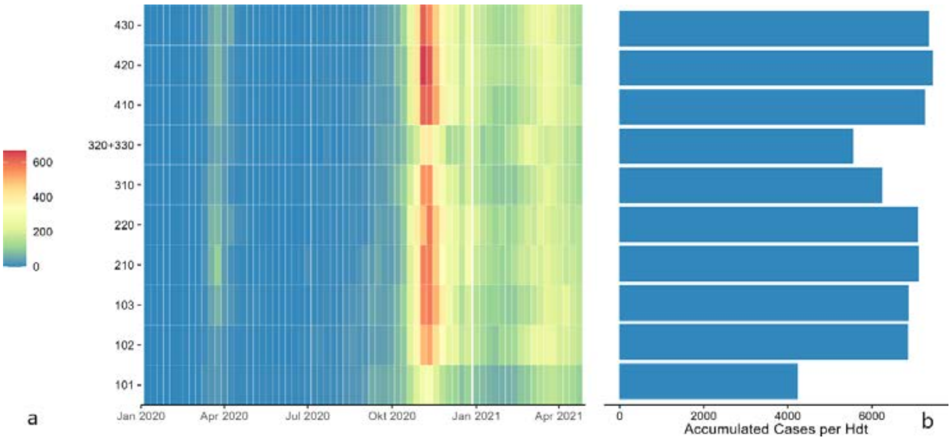


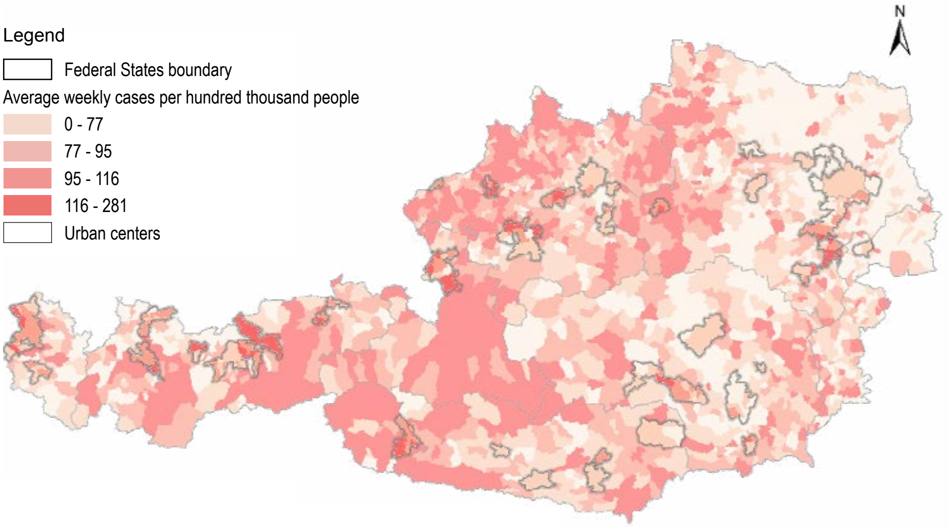
Figure 3: Case numbers per hundred thousand according to detailed spatial types. (3a) new infections per calendar week; (3b) cumulated cases.

Figure 3 shows a heatmap of new confirmed weekly COVID-19 cases per hundred thousand (3a) as well as the respective accumulated cases (3b); both are depicted across ten regional categories. The numeration of regional categories follows an ordinal interpretation. The scale goes from Peripheral Rural Areas (430) to Large Urban Centers (101).[1] While we can confirm that Rural Areas were generally hit the hardest during the second wave, Intermediary Rural Areas (420) recorded the most cases relative to their population. Peripheral and Intermediary Rural Areas Surrounding Centers (320+330) generally fared best during the second wave but in turn had an early start to the third wave, while Central Rural Areas Surrounding Centers also recorded below-average numbers of cases. Meanwhile, Central (210) as well as Intermediary (220) Regional Centers show relatively similar numbers. However, within the urban types, one can observe that, during the second wave, Large Urban Centers had much lower numbers than Medium Urban Centers, which in turn had lower numbers than Small Ur-

1 Due to very low population numbers, Peripheral Rural Areas Surrounding Centers (330) and Intermediary Rural Areas Surrounding Centers (320) were merged and are reported as one category 320+330.

ban Centers. Large Urban Centers even had the second shortest second wave across all types.

This again supports the hypothesis that Urban Centers were not at the forefront of infections and shows that even within the different urban municipalities, the larger ones fared better during the pandemic. However, considering all ten Regional Types we cannot detect any linear relationship between the degree of urbanisation and the number of cases.



Data source: Datenplatform COVID (GÖG); Statistik Austria BEV - data.gv.at
Data range: from beginning of 2020 to April 07, 2021

Figure 4: Spatial distribution of Covid-19 cases in Austria.

In the third step, we look at the geographical distribution of average weekly cases per hundred thousand inhabitants on the municipal level and investigate how the spatial pattern of infections coincides with the location of urban municipal types. The cases are classified into four levels: a high case class, high-medium case class, medium-low case class, and low case class; the average number of the four classes ranges are from 116 cases to 281 cases, 95 cases to 116 cases, 77 cases to 95 cases, and 0 case to 77 cases respectively. The results are shown in Figure 4.

Figure 4 illustrates that the high case areas do not follow a clear-cut pattern but tend to be denser in the mid-west of Austria, while the northeast shows relatively low numbers. Particularly pronounced are hotspots in those areas which were reported to be the first affected areas when the pandemic reached Austria, located in Tyrol in the west of Austria. Generally, there is a fair level of spatial autocorrelation in the average infection rates across Austria. Focusing on the highlighted urban municipalities, it becomes apparent that although having generally lower numbers, urban centres also tend to vary with the regional trends. However, they are distributed evenly enough across Austria to allow us to assume that the geographical location within hot or cold spots of COVID-19 infections is not driving the outcomes of the previous analysis.

5 Discussion

In this paper, we looked at COVID-19 infections in Austria in the context of the rural-urban typology and showed that urban areas could not be identified as drivers of the pandemic. Statistics Austria's urban-rural typology integrates not only aspects of spatial density but also functional criteria. The infection waves are mostly similar across all spatial types – with rural areas showing the most infections at the peak of each wave. Thus, we can confirm that urban density did not lead to an intensification of the pandemic in Austria and, therefore, should not play a role in determining regionally differentiated containment measures. This resembles the findings in Boterman (2020), or Rodriguez-Villamizar et al. (2020), among other authors, which in turn, obviously does not imply that regionally specific containment measures and response policies are obsolete. However, they should rather be orientated towards local infection rates as well as developments within integrated regions.

However, while the methodology we employed builds on a more sophisticated spatial typology to analyse urban density, some limitations regarding the epidemiological data set need to be mentioned. Firstly, infections are always assigned to the infected person's place of residence – even if the person became infected at work or on vacation. This causes small-scale distortions, most probably in functionally integrated regions with an above-average mobile population. Secondly, the number of reported infections depends on the number of tests performed. Unfortunately, it was not possible to obtain an integrated data set on the number of tests performed at the municipal level. Other measures such as hospitalisations, intensive-care demand or COVID-19 related deaths would be possible indicators which do not depend on testing infrastructure or compliance of the respective citizens. However, such measures would heavily depend on geographies of age, medical preconditions and various other factors. Thirdly, various regional actions, such as regional lockdowns, occurred during the pandemic. These have caused small-scale effects that were not taken into account in the empirical analysis. Fourthly, the effect of vaccinations could also not be considered due to a lack of sufficient data. Particularly at the beginning of the vaccination campaign in early 2021, vaccinations were given in a fairly focused way to vulnerable facilities such as hospitals and senior residences. This may have led to small-scale effects. Thus, our results need to be interpreted as net outcomes.

Nonetheless, the health crisis has made it evident that we need more fine-grained spatial data to investigate how social phenomena and crises affect distinct spatial configurations of society and how these phenomena are affected by spatial factors. Also, the provision of health data on a daily basis has proven to be vital to making informed policy decisions. It can be assumed to have had an effect on the data literacy of the general population, and has therefore been one of the few positive effects during this major global crisis. However, even the latest small-scale data on COVID-19 cases or ICU-beds has not been a guarantor of well-reasoned spatially differentiated policy measures – at least in Austria. There is still a great deal of work to do in this regard.

6 Conclusion

In the early phase of the pandemic, some of the public discourse in Austria suggested a causal relation between urban agglomerations and the spread of COVID-19 cases. While many have jumped in to dispel such simplistic assumptions, there is still a significant lack of evidence to counter such claims.

In our paper, we analysed epidemiological data on COVID-19 cases in Austrian municipalities vis-á-vis a differentiated spatial typology of urban and rural settlement areas to investigate whether any evidence exists that cities can be considered drivers of the pandemic. We aimed for a robust spatial classification that goes beyond size classes according to the number of inhabitants, as these largely depend on the size of administrative units. Hence, we decided to employ a spatial typology that incorporates multiple indicators, including not just population numbers and population density, but also functional interactions that better represent the diverse characteristics of urban agglomerations, namely, our own Austrian Urban-Rural Typology.

Combining epidemiological data with the Austrian Urban-Rural Typology, we found that there is no significant relationship at any point in time between the occurrence of infections and urban settlement areas. Consequently, physical spatial patterns and population density are not relevant when it comes to predicting the regional progression and impact of pandemics or determining regionally differentiated health or virus containment measures.

In this paper, we addressed two novelties: firstly, a spatial perspective on Austria & COVID-19, by means of which we added to the growing evidence on the spatial patterns of the pandemic. And secondly, a more nuanced perspective on addressing density as a weighting measure in this and other contexts of spatial analysis.

There is, of course, more that defines cities than mere population density that is of significance for the development of health incidents. This includes functional ties, socioeconomic configurations, or an over-proportional share of critical infrastructures and SGIs that cannot be shut down during lockdown. Hence, further studies would need to investigate these aspects to make sense of the factors significantly affecting the spread of the pandemic. As shown in our paper, population density is not one of them. We thus conclude that we do not need a 'one size fits all' measure, but pointedly contextualised spatial analyses to make sense of the spread of the virus.

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