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Article

Sustainable Spatial and Temporal Development of Land Prices: A Case Study of Czech Cities

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Abstract: Only a limited number of studies have examined land price issues based on official land price maps. A very unique timeline of official land price maps (2006–2019) allowed research to be conducted on four Czech cities (Prague, Olomouc, Ostrava, and Zlín). The main aim of the research was to describe the links between land price, land use types, and macroeconomic indicators, and to compare temporal changes of these links in four cities of different size, type, and structure by using spatial data processing and regression analysis. The results showed that the key statistically significant variable in all cities was population size. The effect of this variable was mostly positive, except for Ostrava, as an example of a developing city. The second statistically significant variable affecting land prices in each city was discount rate. The effect of other variables differed according to the city, its characteristics, and stage of economic development. We concluded that the development of land prices over time was slightly different between the studied cities and partially dependent on local spatial factors. Nevertheless, stagnation in 2010–2011, probably as a consequence of the global economic crisis in 2009, was observed in each city. Changes in the monitored cities could be seen from a spatial point of view in similar land price patterns. The ratio of land area with rising prices was very similar in each city (85%–92%). The highest land prices were typically in urban centers, but prices rose only gradually. A much more significant increase in prices occurred in each city in their peripheral residential areas. The results of this study can improve understanding of urban development and the economic and spatial aspects of sustainability in land price changes.

Keywords: land price map; land use development; geographic information system; spatiotemporal changes; sustainability; Czechia

1. Introduction

Regarding land price sustainability in cities, price maps play an undeniable role in providing essential price information about real estate for quick decision-making. Price information can therefore be used not only for private purposes but also at the policy-making level [1]. Land price and land price sustainability are important aspects in guiding land resource allocation during urban planning and development, particularly in large cities in fast developing countries where infrastructure and populations change frequently [2].

Many authors have addressed land price sustainability issues for these reasons. The research is broad and covers issues associated with inflation [3], land price volatility [4,5], changes [6–8], and structure [9,10]. The specific research field explores predictive models [11,12] and implementation of GIS (Geographic Information System) software [13,14].

Several researchers have studied the factors which affect land price (e.g., [2,15–17]). An estimation of the effect of environmental factors on real estate prices caused by environmental change was analyzed in research by Del Giudice and Massimo [18,19]. Studies where countries experience rapid change and development (such as China) tend to focus on land price changes and the driving factors behind these changes (e.g., [20–24]).

According to economic theory, the land supply and demand determines its price. Focusing on land demand, it is mainly affected by market factors, location conditions, and supporting facilities [21]. Land price is supposed to be determined by many driving factors. Driving factors include any variable that affects human behavior, such as environmental situations, local culture, economic and financial subjects, land policy, and also interactions between these variables [25]. Some of them can be related to a local situation within the city (e.g., migration [26], gentrification [27], tourism [25]), whereas others are connected with more general market factors.

Regarding land price drivers connected with the local situation, Qu et al. [28] identify three categories of factors: location factors, environmental amenities, and land attributes. The location factors involve also the quality of public service provided by the infrastructure around a specific piece of land. A good living location may reduce the money and time costs of traveling from home to the workplace or other public service elements. In this case, people are then willing to pay more to obtain better residential locations. Focusing on market price drivers and economic factors, Yang et al. [21] point out that the higher the economic growth rate of an area is, the greater its potential for economic development will be. The market mainly plays a role through economic development and population increases, which is connected with GDP development [21], the income of inhabitants [29], unemployment rate [30], discount rate [31], the population in the city and its structure [21,25,29], or housing construction [32].

Land price sustainability has been a significant topic studied by Czech researchers since the Velvet Revolution in 1989. After 40 years of communism, land ownership was gradually returned in restitution processes to the original owners (or their descendants), and prices began to rise rapidly [1]. Czech studies have examined general price issues at the regional or state level regarding housing [28–30,33], farmland prices [33], the segregation aspect [34], and price bubbles [35].

Land price map analysis in Czechia has only been done by a few authors [32–40]. Researchers have compared the price maps of selected European Union (EU) countries [40] and the technological processes for automating and improving efficiency in processing land price maps [41,42]. Šindelářová [43] and Kovaříková [44] analyzed price maps and described their changes and practical use for the cities of Brno and Olomouc. A land price map in relation to rental prices was discussed in a PhD thesis [45].

Two sources of land price are available for Czechia: official land price maps and unofficial land price maps. An official land price map (land price map of building plots) is defined in accordance with the law [46,47] and created and updated by its respective municipality. An official map displays the prices of building plots and is created according to the prices in purchase contracts (managed by the regional cadastral offices) and modified according to the type of land and its other characteristics (managed by the respective municipality).

The land price map is updated at the end of each year (in some municipalities, mid-year) by adding new prices of land parcels. After the price map is processed, the municipality is obliged to submit a proposal to the Ministry of Finance of Czechia, which subsequently publishes it in the Price Bulletin. The map is valid for a year, and if prices are stable, the validity may be prolonged. Price maps are published on the web pages of municipalities (as pdf maps or web applications) and are accessible to anyone. Official land price maps serve as the basis for evaluating issues addressed by court experts, banks, and government officials.

Under Act No. 151/1997 Coll. [47], a land price map is described as a graphical representation of land price and building plots in a municipal territory, with a scale of 1:5000 or a greater level of detail. A detailed description of map creation is given by [1]: “Building parcels on price maps are valued according to the negotiated prices contained in purchase contracts (base price), although not all parcels can be valued." In some cases, determining an actual price is not possible, and price is instead determined according to the prices of comparable parcels in the municipality or a similar municipality [48]. Quoting from [1]: "The final price of a building parcel is calculated as a multiple of the base price of the group of land to which it belongs and its total area in square meters. The price of the parcel is then increased according to the price of the building(s) located on the parcel and the price of green areas. The price map does not include the prices of agricultural or forested land or water areas. Information about the parcel is taken from the Land Register of Czechia."

Land price maps have been created in Czechia since 1991 for 54 municipalities, but most municipalities have ceased this activity because of fluctuating prices and the need for frequent updates. Most municipalities in Czechia have created only a few maps (3–5), while only eight municipalities have created over ten price maps. Most of these were published for Ostrava (20), Prague (24), and Olomouc (23). Currently (March 2020), price maps are valid in only five municipalities in Czechia (Olomouc, Ostrava, Zlín, Praha, Most) [49].

Besides price maps governed by law, unofficial price maps (e.g., [50–52]) are also available. These are generally created by real estate agencies, which process them very individually. These maps are used more often, although the data sources and content vary between authors. Data sources are often recorded by real estate agencies from achieved sales or rentals [52], or only selected prices or price estimations are shown [51].

Two private land price maps indicating prices from real contracts also exist [53,54], but access to these maps requires payment, and the data are not available for downloading. The methodology of the data processing is often unknown or unclear, and historical data are not available. Finally, the validity of these maps is not guaranteed by law and depends only on the quality of processing [47].

As published in our previous study [1], only a few authors have performed a detailed analysis of land price at a local level (municipality) [43,53]. For this reason, the authors decided to perform an in-depth analysis of land prices of the city of Olomouc. Under this study, official land price maps from 1993 to 2016 were used to describe temporal and spatial relationships and the changes in land prices in Olomouc. The changes were analyzed from three aspects of sustainability: economic, environmental, and social.

The results showed that some macroeconomic indicators had a significant effect on changes in land prices. The changes in land prices were affected by a mixture of economic, demographic, and social indicators. The present authors also concluded that residential and commercial areas in the historical center had significantly higher land prices than other parts of the city. Overall price was dominated by the city's historical core, and no significant growth in the commercial categories of land use was evident. The land prices for brownfields even showed decreases. Absolute price in residential areas, especially those located in the historical centers, were the highest in the long term. The analysis [1] also confirmed that land price and its change over time varied according to different spatial aspects. The smallest effect was reflected in the economic aspect. However, price was significantly affected by land quality and its location within or beyond protected urban conservation areas.

Because the conclusions only concerned an analysis of one city, the present authors extended the previous research to three other cities. The main aim of this new research was to describe the links between land price, land use types, and macroeconomic indicators, and to compare temporal changes of these links in four cities of different size, type, and structure. The main research question addressed whether the conclusions from the previous study were also valid for other cities in Czechia and whether the present authors' conclusions were valid for cities of different size.

2. Data and Methods

2.1. Study Area

For the present study, the authors selected four Czech cities representing cities of different size, history, economy, and structure. These cities currently have a valid land price map and long timeline of map updates. The city of Prague is the capital of Czechia; the city of Ostrava is the center of heavy industry with a long tradition of coal mining; the city of Olomouc is a mid-sized city with a preserved historical center and economy oriented towards services, education, and culture; the city of Zlín is a smaller city with light industry oriented towards shoe, leather, and rubber goods production. Each of the selected cities is a regional capital and represents a logical center for its region, being equipped with cinemas, theatres, shopping centers, universities, libraries, and other public services. Each city has a well-developed public transportation network. These cities also have a long history of land price maps, which allows a spatial and statistical analysis of its changes to be made. The locations of the selected cities are shown in Figure 1.

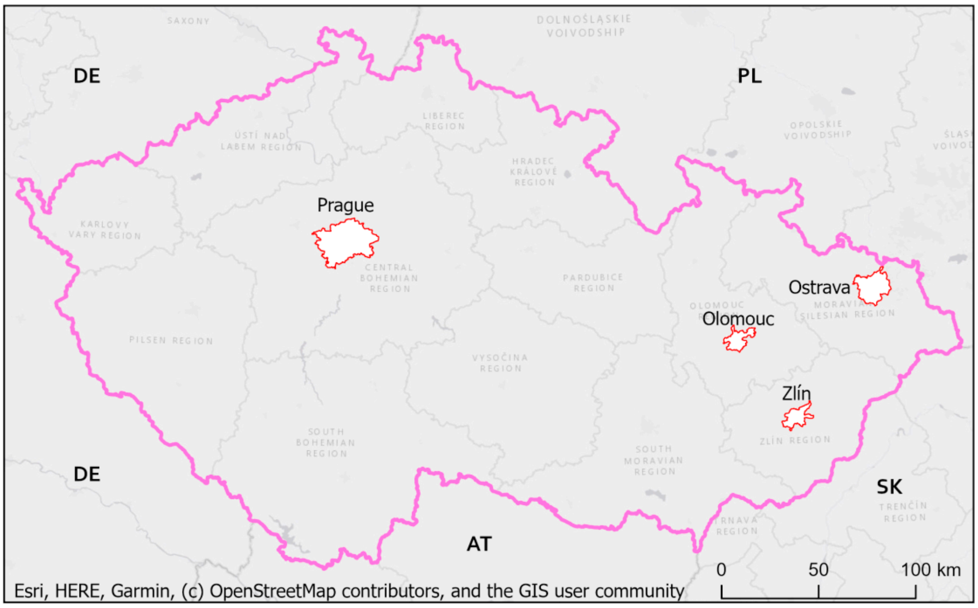

Figure 1. Study area—four selected cities within Czechia.

The city of Prague (population 1,308,632 in 2019 [54], area 496.21 km^2) is the capital of Czechia. According to [55], the city's core, with its historical buildings, bridges, and museums, is a major center of employment and traffic congestion. Around the core is a mixed zone of industrial and residential areas, containing about half the city's population and nearly half its jobs. Surrounding this area is the city's outer development zone, and beyond this is yet another zone of development containing new industrial areas, parks, recreation areas, and sports facilities. At the outer edge is a belt of agricultural land and open countryside.

Prague is the major economic and cultural center of Czechia. The city has a rich architectural heritage supplemented by post-1945 planning which preserved the old core of the city as a major monument and supervised all modern construction. In 1992, the historical city center was added to UNESCO's World Heritage List.

The city of Ostrava (population 289,128 in 2019 [54], area 214.22 km^2), is the second largest city in Czechia. According to [55], Ostrava is surrounded by a rich black-coal basin that transformed it into a center of heavy industry, with a long tradition dating from 1830, when the first blast furnace was built at the Vítkovice ironworks. Some of the coal pits extend into the city limits, and their derricks are common features of the skyline.

The conurbation of Greater Ostrava receives a steady influx of workers, and many housing estates and new towns, such as Poruba and Havířov, were built in its vicinity. Most of the planned development is east of the Ostravice River, in Slezská ("Silesian") Ostrava. Settlements west of the Ostravice are in Moravská ("Moravian") Ostrava. The population of the region is employed predominantly in mining and metalworking.

The city of Olomouc (population 100,523 in 2019 [54], area 103.33 km^2), is the sixth largest city in Czechia and the capital of the Olomouc Region. Until the mid-nineteenth century, the presence of baroque fortifications influenced development of the city [56]. Another important factor is the city's transportation system, which has a railway that divides the city into a predominantly industrial eastern section and western residential section. Olomouc is close to a monocentric city model with a centripetal transportation network. The historical center of Olomouc is a pedestrian zone and surrounded by parks. Olomouc is considered the cultural center of Moravia (UNESCO heritage, second oldest university in Czechia, a quiet city, high standard of living), which is, however, in contrast with average regional salaries (third lowest in Czechia; [57]).

The city of Zlín (population 74,997 in 2019 [54], area 102.82 km^2) for a long time had been very small and without much regional importance. A major turning point in its development came when the Bat'a shoe company settled in Zlín after the First World War. As a consequence of shoe production, the city grew in both population and area, and became an industrial center of national importance. According to [55], the planning and design of its new sections were, in part, the work of Le Corbusier, a Swiss–French architect. Zlín is a typical linear city with specific transportation needs. After the Second World War, the Bat'a company was nationalized and its importance gradually decreased. The city's activities slowly transformed from industry to services. A decline in shoe production led to extensive brownfields remaining in the city.

2.2. Data Sources

Spatial data representing the land price maps of Ostrava, Praha, and Zlín were obtained in vector format from Open Data Catalogues [58–60] for the present research. The land price maps of Olomouc were obtained from the Magistrate of the City of Olomouc (Department of Research and Development) and required more advanced processing, which is described in detail in previous research [1]. All maps are at a scale of 1:5000 and cover the city's entire area. To perform GIS processing, data were imported into a single geodatabase. Only older maps (created only in printed version) were available for Olomouc, therefore only the maps available in vector format (2006–2019) from the long timeline of existing land price maps (1993–2019) were selected. Maps for Olomouc, Ostrava, and Prague were available for one-year periods, while maps for Zlín were created (and therefore valid) for longer periods (2006–2008, 2009–2013, 2014–2019).

To study the price differences between distinct land use categories, data from the Urban Atlas were used. The Urban Atlas is a pan-European land cover dataset for Functional Urban Areas provided by the Copernicus Land Monitoring Service [61]. These data can be freely accessed in shapefile format; its most recent reference year being 2012. Following the findings from [1], only several land use categories were extracted from the Urban Atlas dataset for further examination. These categories were industrial, commercial, public, military, and private units (Urban Atlas category number 12100); construction sites (13300); urban fabric (11100–11240); and green urban areas (14100). All of these are typical land use categories also defined in urban planning processes [62], and mostly contain land price maps with valued land parcels. They were therefore selected for a more in-depth review. The present authors also considered the use of more detailed datasets (e.g., Open Street Map) or local data sources, but the data quality was too low.

One of the research questions explored the possible dependencies between economic, social, and demographic indicators, and the average prices of land. In the authors' previous study, several variables were selected for further processing. Details of the variables are as follows: Land Price—in the city of Prague/Ostrava/Olomouc in CZK per square meter, calculated as a median of all prices of all land in Prague/Ostrava/Olomouc over selected periods; GDP—per capita in CZK per year, Prague/Ostrava/Olomouc region; Income—total net income per capita in CZK per year in municipalities with a population of 100,000 and greater; Unemployment—unemployment rate in the Prague/Ostrava/Olomouc region; Discount—average discount rate per year in Czechia; Population—number of inhabitants, Prague/Ostrava/Olomouc city; Flats Started—number of started flats, city of Prague/Ostrava/Olomouc; Flats Finished—number of finished flats, city of Prague/Ostrava/Olomouc; Economic Subjects—registered economic entities (31 December), city of Prague/Ostrava/Olomouc; Year—the period 2000–2018 for Prague, the period 2003–2018 for Ostrava, and the period 2006–2018 for Olomouc. For statistical analysis, the following data sources were used: Czech Statistical Office—Statistical Yearbook of the Olomoucký Region [63], Statistics on Income and Living Conditions [57], and Czech National Bank—CNB official discount rates [64].

2.3. Data Processing

Since price per square meter is expressed in absolute CZK, its comparability across the monitored time period is significantly biased by price inflation. The inflation rate is a quantitative measure of the rate at which the average price levels rise over a period of time. The geometric mean of the annual inflation rate in Czechia between 2006 and 2019 was 1.58%, and its impact on price therefore had to be considered. The inflation rate is usually measured through several indexes, for example, the consumer price index or product price index. These indexes are calculated according to a basket of selected goods and the services in the economy; the Czech Statistical Office provides the calculation [65]. To take into account the impact of inflation on real price, the effect of inflation was incorporated into the analyzed price values. All prices in the monitored time period were then adjusted according to the average annual price level index. The most recent year of the monitored time period (2019) was selected as the reference year, and all other years for all dates were recalculated to produce a time series of comparable values.

As mentioned above, land price maps and land cover data were available in vector format. All the price map layers were imported into a GIS environment (spatial geodatabase) for further processing and spatial visualization. Basic GIS tools (such as overlay operation, clipping, and selection) were used for data processing.

The layers from 2006 to 2019 were processed with a GIS overlay tool to show spatial differences in price development. Only those parcels where the price was available for both years were kept. Number of unpriced parcels varies in each city: in Olomouc, there was 40% unpriced in 2006 and 25% in 2019; in Zlín, 14% unpriced in 2006 and 12% in 2019; in Ostrava, 33% was unpriced in 2006 and 29% in 2019; and in case of Prague, 39% was unpriced in 2006 and 29% in 2019. The change in price was subsequently expressed as a percentage, the values adjusted according to logic: 0%—the price did not change, 100%—the price increased by 100% (i.e., twice the original value), etc. During the overlay operation, a number of small size fragments were created as a result of the geometric inaccuracies in the input data, often resulting in extreme price development values. Any values less than 5 m^2 were automatically removed. Fragments with extreme values and representing a small area (less than 100 m^2) were also checked and manually attached to adjacent parcels.

2.4. Methods of Data Analysis

2.4.1. Regression Analysis

To analyze the possible dependencies between economic, social, and demographic indicators, correlation and regression analysis methods were used. Pilot analysis was performed in the authors' previous research [1] on the City of Olomouc for the period 2006–2016. Because the yielded results were so interesting, other major cities in Czechia were analyzed, the results were compared, and the similarities/differences between them were examined.

Based on current scientific literature, various variables were selected for the analysis. Table 1 shows an overview of selected variables, their description, expected impact on land price, and references.

Table 1. Land price drivers—expected effects of variables.

Variable	Units	Expected Effect	References
GDP	per capita in CZK/year	Positive	[21]
Income	total net income per capita in CZK/year for municipalities with a population of 100,000+	Positive	[29]
Unemployment	Unemployment rate/year %	Negative	[30]
Discount Rate	Average discount rate/year %	Negative	[31]
Population	Number of inhabitants/year	Positive	[21,25,29]
Started/Finished Flats	Number of started and finished flats/year	Unclear	[32]
Economic Subjects	Number of registered economic entities/year	Unclear	[32]

Since the regression analysis is primarily focused on socioeconomic factors/indicators and their impacts on land price, the key macroeconomic indicators were selected: GDP, income of households, unemployment rate, and discount rate. This set of indicators was added to by the number of inhabitants, number of started flats, finished flats, and registered economic entities in selected cities.

Suitable data were available for each city, but not the same time periods. Zlín was eliminated from the regression analysis because data were missing for all of the observed years.

A correlation analysis was first performed on all cities as a means to reveal the possible relationships between certain variables or whether a statistically significant positive or negative relationship existed. A nonparametric Spearman correlation coefficient was used, which has no assumption about the distribution of the data.

The second step required a more sophisticated approach in analyzing the relationships between data. Several regression models were designed to include all possible variables simultaneously and to detect any variable(s) in the model which may have been significant in increasing land price in the selected cities. Based on this key idea and the results obtained from the correlation analysis, different regression models were tested.

At the beginning, a "General" regression model, including all of the variables described above, was created for each city (Prague, Ostrava, Olomouc). From the results of this General regression model and the results of the correlation analysis, various regression models were then tested on different cities. Certain models differed in their independent variables, but the dependent variable was the same in each model tested.

The following regression models represent the rules for General model, Income model, Population model, Flats model, and Economic model.

General Model

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \beta 5X5 + \beta 6X6 + \beta 7X7 + \beta 8X8 + \beta 9X9 + u \quad (1)$$

where β0–β8 represent the regression coefficients that reveal the effect of independent variables on a dependent variable. Dependent variable Y represents land price in the city of Prague/Ostrava/Olomouc in CZK per square meter, calculated as a median of all land prices in Prague/Ostrava/Olomouc over the selected time period. Variable u is a dummy variable. The General model is based on all studies mentioned in Table 1 and the following independent variables:

- X1—population/number of inhabitants, Prague/Ostrava/Olomouc city (Inhab);
- X2—unemployment rate, Prague/Ostrava/Olomouc city (Unem);
- X3—registrations of economic subjects (Econs);
- X4—number of flats started, Prague/Ostrava/Olomouc city (Flatst);

- X5—number of flats finished, Prague/Ostrava/Olomouc city (Flatfi);
- X6—average discount rate per year, Czechia (Disc);
- X7—total net income per capita, CZK per year, municipalities with a population of 100,000 and greater (Inc);
- X8—time/years 2000–2018 for Prague, 2003–2018 for Ostrava, and 2006–2018 for Olomouc (Time);
- X9—GDP per capita per year, Prague/Ostrava/Olomouc region (GDP).

Income Model

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + u \quad (2)$$

where β0–β2 represent the regression coefficients that reveal the effect of independent variables on a dependent variable. Dependent variable Y represents land price in the city of Prague/Ostrava/Olomouc in CZK per square meter, calculated as a median of all land prices in Prague/Ostrava/Olomouc over the selected time period. Variable u is a dummy variable. This model is based on studies [29,30] and the following independent variables:

- X1—unemployment rate, Prague/Ostrava/Olomouc city (Unem);
- X2—total net income per capita, CZK per year, municipalities with a population of 100,000 and greater (Inc).

Population Model

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + u \quad (3)$$

where β0–β3 represent the regression coefficients which reveal the effect of independent variables on a dependent variable. Dependent variable Y represents land price in the city of Prague/Ostrava/Olomouc in CZK per square meter, calculated as a median of all land prices in Prague/Ostrava/Olomouc over the selected time period. Variable u is a dummy variable. This model is based on studies [21,29,31,33] and the following independent variables:

- X1—population/number of inhabitants, Prague/Ostrava/Olomouc city (Inhab);
- X2—average discount rate per year, Czechia (Disc);
- X3—number of flats started, Prague/Ostrava/Olomouc city (Flatst).

Flats Model

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + u \quad (4)$$

where β0–β2 represent the regression coefficients which reveal the effect of independent variables on a dependent variable. Dependent variable Y represents land price in the city of Prague/Ostrava/Olomouc in CZK per square meter, calculated as a median of all land prices in Prague/Ostrava/Olomouc over the selected time period. Variable u is a dummy variable. This model is based on study [32] and on the following independent variables:

- X1—population/number of inhabitants, Prague/Ostrava/Olomouc city (Inhab);
- X2—number of flats finished, Prague/Ostrava/Olomouc city (Flatfi).

Economic Model

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + u \quad (5)$$

where β0–β2 represent the regression coefficients which reveal the effect of independent variables on a dependent variable. Dependent variable Y represents land price in the city of Prague/Ostrava/Olomouc in CZK per square meter, calculated as a median of all land prices in Prague/Ostrava/Olomouc over the selected time period. Variable u is a dummy variable. This model is based on studies [21,30] and on the following independent variables:

- X1—average discount rate per year, Czechia (Disc);
- X2—GDP per capita per year, Prague/Ostrava/Olomouc region (GDP).

2.4.2. Comparison of Different Factors

The nonparametric Kruskal–Wallis test was applied to statistically confirm the differences between categories (city and land use). This alternative to the analysis of variance (ANOVA) is useful in situations where the basic assumptions of ANOVA, such as normal distribution of probability, are violated. The test does not consider the match of specific parameters, but the match of distribution functions of the compared files. Subsequent processing of Kruskal–Wallis test results was solved with Dunn's Multiple Comparisons. The null hypothesis for each pairwise comparison is that the probability of observing a randomly selected value from the first group that is larger than a randomly selected value from the second group equals one half [66].

3. Spatial and Temporal Development of Land Prices

3.1. Temporal Development of Land Prices

In the first part of the analysis, the prices from the price maps of all four cities were aggregated and studied using basic visualization tools and statistics. Many of the parcels in view were unvalued, therefore the missing prices were first quantified. A significant proportion of unvalued parcels existed, but this ratio has decreased over time in each city. The highest proportion of unvalued parcels in Olomouc in 2006 was 40.4%, which had decreased to 25.5% by 2019. The same trend was present in other cities: Prague, 39.6% to 29.1%; Ostrava, 33.4% to 29.8%; and Zlín, 25.1% to 12.7%. The total number also varied according to city and time. Of course, the number of parcels also depended on the city's area: Prague had a total of 9611 parcels in 2006 and 9420 parcels in 2019. The lowest numbers were counted in Zlín (1878 and 726).

The basic characteristics of central tendencies represented by mean and median were calculated to discover the trend in land price development. Using only inflation-adjusted values, the values for each city are plotted in Figure 2. For the observed period, prices increased in Prague, Ostrava, and Olomouc. An especially rapid increase in prices was observed between 2006 and 2010: in Prague, the difference was most distinct between 2008 and 2009, when both the mean and median price rose by approximately 1000 CZK; in Olomouc and Ostrava, growth only reached hundreds of CZK. Zlín's development was different, the mean price increasing only very slowly, although continuously. The city's median price, however, decreased in the first part of the monitored time period (the median price decreased between 2006 and 2013 by 140 CZK). In the case of Zlín, estimating the trend was unfortunately unreliable due to the different ways that was used in releasing price maps (one map is valid for 3–4 years).

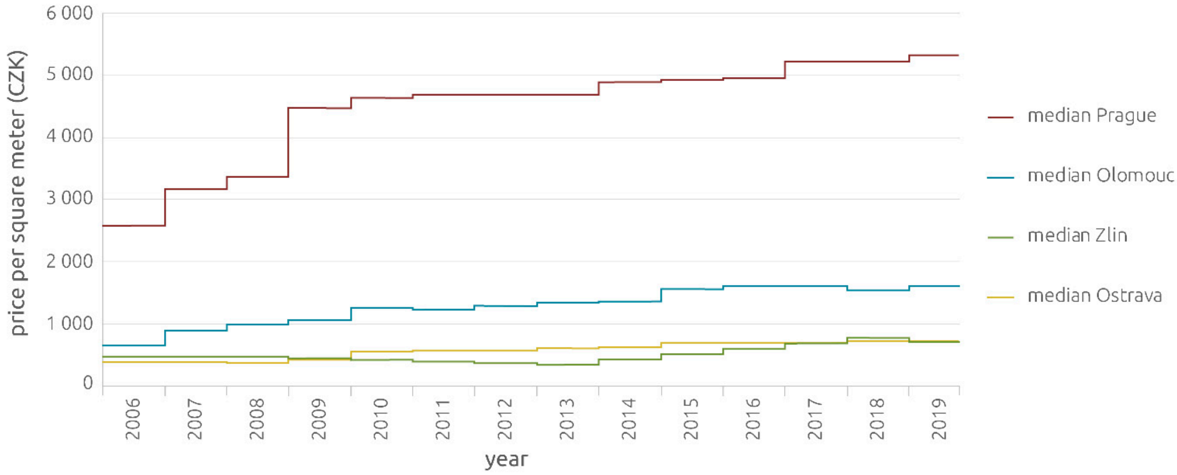

Figure 2. Land price median value development.

In each city, median price was invariably less than the mean price. This suggests that some extreme values may have distorted the mean value. The range of prices was extreme, especially in Prague, where the maximum price reached CZK 70,310 in 2019. Data therefore had to be plotted on a logarithmic Y axis to cover the entire price range and to keep detail in the low and medium prices (see Figure 3 with boxplots of all parcel prices in the monitored cities). In the same graph, Zlín obviously indicates deviating data, the lower quartile of the boxplot being noticeably larger than in other cities and suggesting a considerable variance in the medium and lower valued parcels.

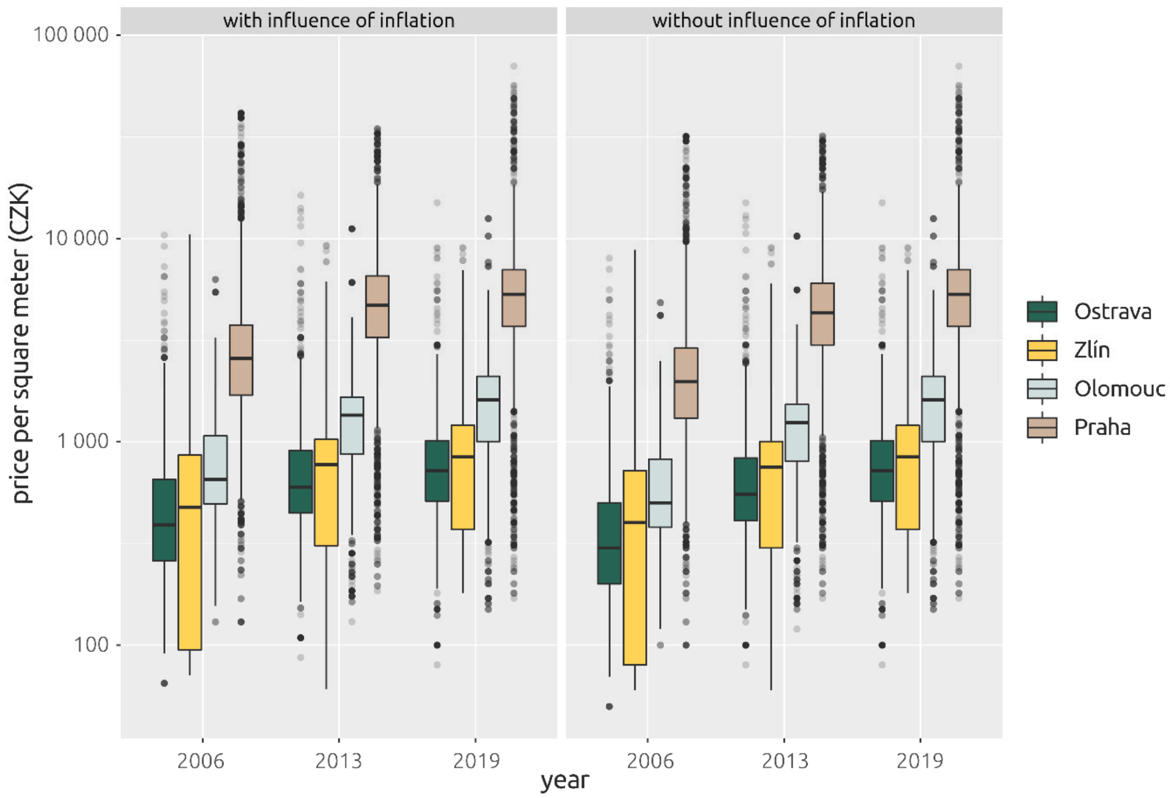

Figure 3. Parcel price changes in the monitored cities between 2006 and 2019.

Finally, the change between the first and the final time point was evaluated (Table 2). The number of land parcels with increasing prices prevailed significantly, most rapidly in Olomouc, where prices increased in 92.6% of all valued land parcels. The average mean of change was also highest in Olomouc, at 165.4%.

Table 2. Development in land parcels between 2006 and 2019.

City	Number of Parcels	Increasing (%)	Mean Increase (%)
Ostrava	3706	85.5	135.8
Olomouc	1383	92.6	165.4
Prague	8171	89.0	144.1
Zlín	1266	88.6	114.4

3.2. Temporal Dependencies

3.2.1. City of Prague

The present research first studied Prague as the capital of Czechia, beginning with a correlation analysis of the evaluation of temporal dependencies between economic, social, and demographic indicators. Figure 4 shows the results of the correlation analysis and indicates possible relationships between the following variables: Land Price, Inhabitants, Unemployment Rate, Registered Economic Subjects, Started Flats, Finished Flats, Discount Rate, Household Income, Time, and GDP.

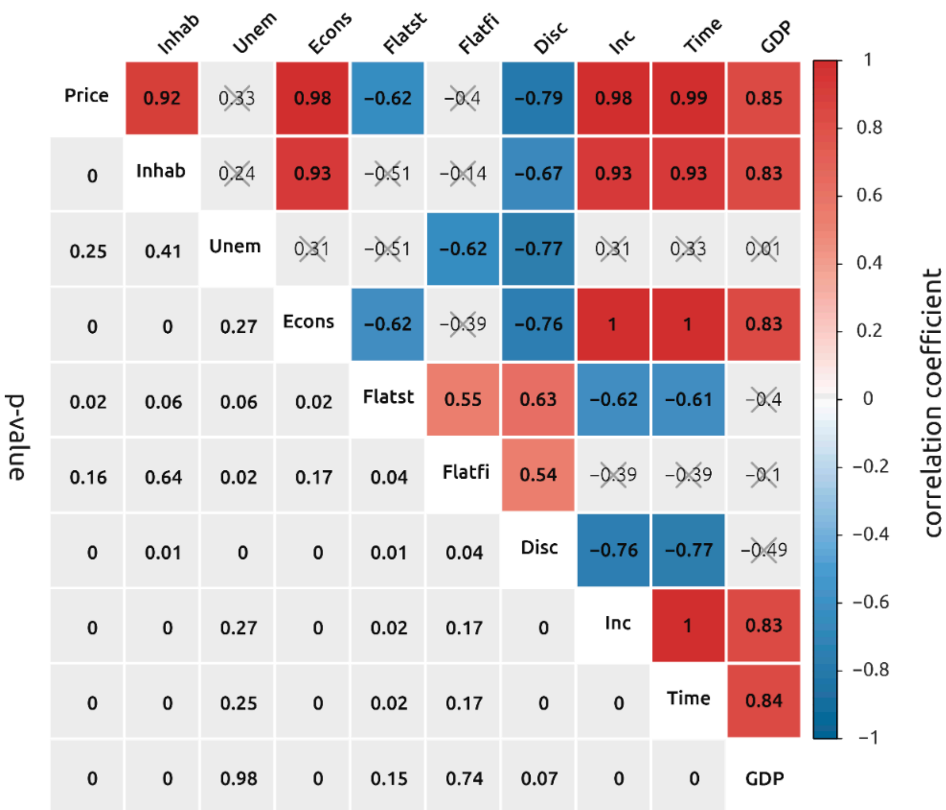

Figure 4. Correlation matrix for the city of Prague. Used abbreviations: Price—Land Price, Inhab—Inhabitants, Unem—Unemployment Rate, Econs—Registered Economic Subjects, Flatst—Started Flats, Flatfi—Finished Flats, Disc—Discount Rate, Inc—Household Income, Time—year, GDP—GDP.

A statistically significant positive correlation between Price and Inhabitants, Economic Subjects, Income, Time, and GDP was observed in the key variable, Land price. By contrast, a statistically significant negative correlation was seen between Price and Started Flats and Discount Rate. The other possible relationships between Price and Unemployment Rate and Flats Finished were not statistically significant.

In the second step, various regression models were tested, applying all the variables used in the correlation analysis. Detailed characteristics of selected regression models, including the results of a Durbin–Watson test (autocorrelations test) and the variance inflation factor VIF (multicollinearity test), are described in Table 3.

Table 3. Regression analysis for Prague.

Variables	General Model			Income Model			Population Model		
	Sig.	Coef.	VIF	Sig.	Coef.	VIF	Sig.	Coef.	VIF
X1—Inhab	0.904	−0.001	122.530	x	x	x	0.000	0.016	2.419
X2—Unem	0.165	175.706	11.070	0.010	121.673	1.148	x	x	x
X3—Econs	0.751	0.004	546.894	x	x	x	x	x	x
X4—Flatst	0.804	−0.012	7.946	x	x	x	0.000	−0.161	1.334
X5—Flatfi	0.801	0.012	3.690	x	x	x	x	x	x
X6—Disc	0.274	−156.834	7.339	x	x	x	0.003	−153.156	1.982
X7—Inc	0.122	0.036	230.391	0.000	0.030	1.148	x	x	x
X8—Time	0.308	−202.164	422.726	x	x	x	x	x	x
X9—GDP	0.239	0.004	51.819	x	x	x	x	x	x
Constant	0.303	399883		0.000	-1808		0.000	−14945	
Observ.	14			14			19		
R2	0.995			0.989			0.998		
Signif.	0.000			0.000			0.000		
DW	2.763			1.575			1.977		

Used abbreviations: Inhab—Inhabitants, Unem—Unemployment Rate, Econs—Registered Economic Subjects, Flatst—Started Flats, Flatfi—Finished Flats, Disc—Discount Rate, Inc—Household Income, Time—Years, GDP—GDP, Constant—Constant, Observ.—Observations, R2—Coefficient of Determination, Signif./Sig.—Significance, DW—Durbin-Watson test, Coef.—Coefficient, VIF—Variance Inflation Factor, x—this variable is not covered in the model.

In fact, all models work with the same dependent variable Y, which represents land price in Prague in CZK per square meter, calculated as a median of all land prices in Prague in certain years in the period 2000–2018. Nevertheless, the entire period is analyzed only in the Population model. Some of the variables were not available for the entire period. The General model and Income model were therefore applied to the shorter period 2005–2018.

The General model represents the results for all of the selected variables; however, the variables in the model were not statistically significant. The Durbin–Watson test (DW) and VIF coefficients showed insufficient values. A Durbin–Watson test did not provide clear results regarding autocorrelation (the value fell between the boundaries); moreover, the VIF coefficients were extremely high and showed multicollinearity between variables.

The Income model is based on Household Income and Unemployment Rate. Both the model and variables were statistically significant; the VIF indicators had sufficient volume, and the model demonstrated no autocorrelation. The results for the 0.01 significance level indicate that Household Income together with Unemployment Rate affected land price in Prague rather positively.

The Population model represents the effect of number of inhabitants and is calculated using the number of Inhabitants, Discount Rate, and additional variable, Started Flats. The model and variables were statistically significant; the VIF indicators had sufficient volume and the model had no autocorrelation. The results for the 0.01 significance level indicate that the number of Inhabitants affected land price in Prague rather positively, the number for Discount Rate and Started Flats rather negatively.

3.2.2. City of Ostrava

The research also examined Ostrava as a typical industrial city in Czechia. A correlation analysis was performed first, using the same variables as with Prague. Figure 5 shows the results of the correlation analysis.

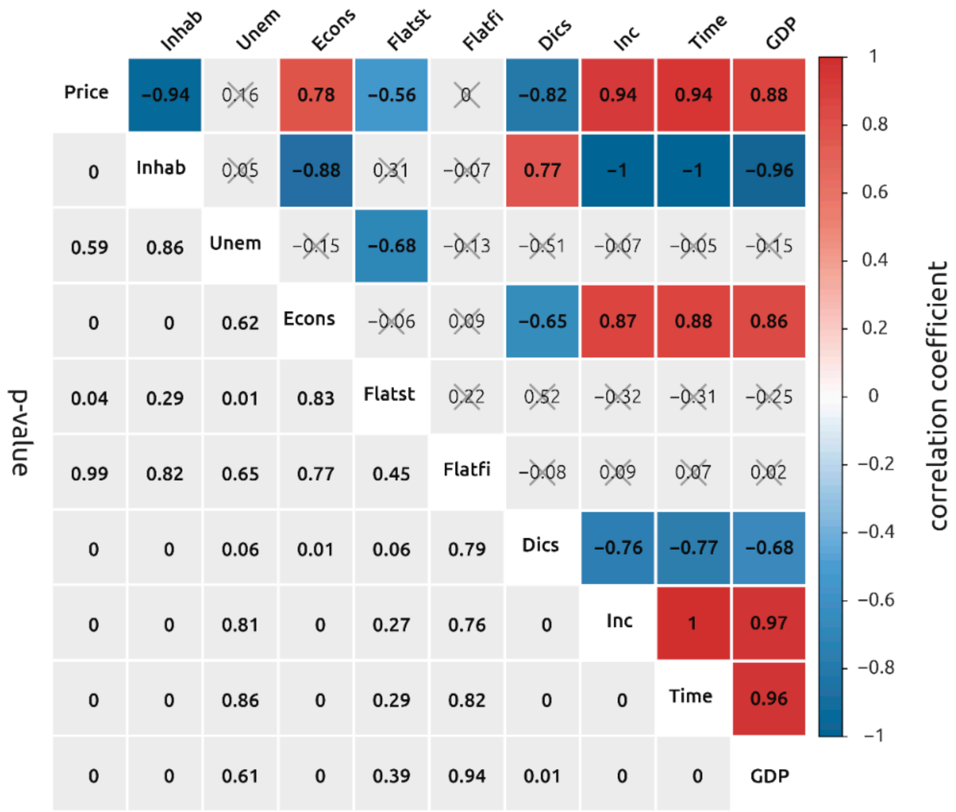

Figure 5. Correlation matrix for the city of Ostrava.

Each model used the same dependent variable Y, which represents land price in Ostrava in CZK per square meter, calculated as a median of all land prices in Ostrava in certain years in the period 2003–2018.

Examining the models in more detail (see Table 4), the General model represents a statistically significant model, and a Durbin–Watson test simultaneously confirmed no autocorrelation. Not all of the variables included were statistically significant, however. The VIF coefficients were extremely high and indicated multicollinearity between the variables.

Table 4. Regression analysis for Ostrava.

Variables	General Model			Economic Model			Population Model		
	Sig.	**Coef.**	**VIF**	**Sig.**	**Coef.**	**VIF**	**Sig.**	**Coef.**	**VIF**
X1—Inhab	0.558	0.017	679.362	x	x	x	0.000	−0.016	2.555
X2—Unem	0.102	63.978	67.241	x	x	x	x	x	x
X3—Econs	0.655	0.010	98.193	x	x	x	x	x	x
X4—Flatst	0.173	0.158	9.604	x	x	x	x	x	x
X5—Flatfi	0.207	0.134	4.036	x	x	x	x	x	x
X6—Disc	0.050	−161.313	36.185	0.000	−98.210	534.4	0.026	−41.669	2.555
X7—Inc	0.148	−0.006	17.621	x	x	x	x	x	x
X8—Time	0.462	−25.028	41.096	x	x	x	x	x	x
X9—GDP	0.081	0.011	97.297	0.000	0,001	0,000	x	x	x
Constant	0.561	41677.02		0.053	194.727		0.000	5738.655	
Observ.	14			16			16		
R2	0.996			0.898			0.976		
Signif.	0.005			0.000			0.000		
DW	3.110			1.381			1.895		

The Economic model was calculated using the variables GDP and Discount Rate. According to the 0.01 significance level, GDP affected land price in Ostrava rather positively, the Discount Rate rather negatively. The Economic model contained no autocorrelation, but the VIF coefficient of the discount rate was high, which is representative of a problem with multicollinearity.

The Population model represents the effect of Number of Inhabitants and Discount Rate; it appears to be the most suitable model statistically. The Population model was statistically significant, the VIF indicators showed sufficient levels, and the model had no autocorrelation. Regarding the 0.01 significance level, both the number of Inhabitants and Discount Rate affected land price in Ostrava rather negatively.

3.2.3. City of Olomouc

The third city selected for temporal dependencies evaluation was Olomouc. Olomouc represents a typical academic city in Czechia. As with Prague and Ostrava, a correlation analysis was performed as the first step in a complex analysis. Figure 6 shows the results of the correlation analysis.

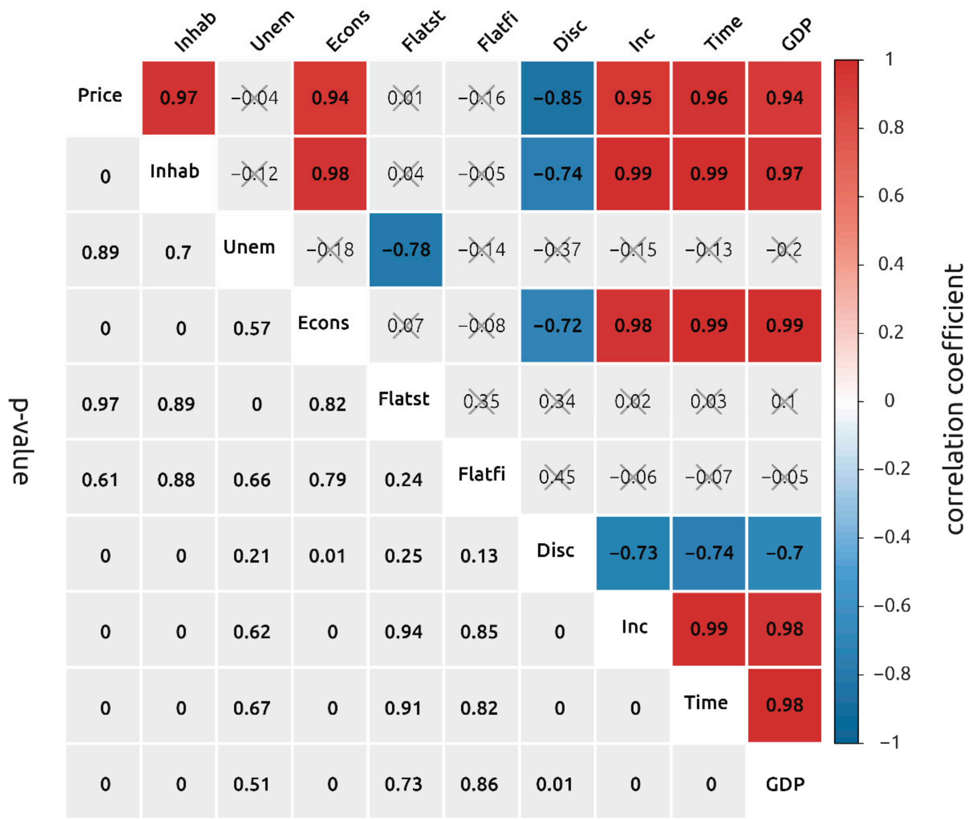

Figure 6. Correlation matrix for the city of Olomouc.

Similar results to the correlation analysis of Prague were obtained. In the key variable, Land Price, a statistically significant positive correlation between Price and Inhabitants, Economic Subjects, Income, Time, and GDP was observed. A statistically significant negative correlation was seen between Price and Discount Rate. The other possible relationships between Price and Unemployment Rate, Flats Started, and Flats Finished were not statistically significant.

Various regression models were then tested, applying all the variables used in the correlation analysis. Detailed characteristics of selected regression models, including the results of a Durbin–Watson test (autocorrelations test) and variance inflation factor VIF (multicollinearity test), are listed in Table 5.

Table 5. Regression analysis for Olomouc.

Variables	General Model			Flats Model			Population Model		
	Sig.	Coef.	VIF	Sig.	Coef.	VIF	Sig.	Coef.	VIF
X1—Inhab	0.889	−25.269	360.188	0.000	177.97	1.003	0.000	150.68	1.861
X2—Unem	0.376	−27.684	15.829	x	x	x	x	x	x
X3—Econs	0.510	0.047	193.948	x	x	x	x	x	x
X4—Flatst	0.160	0.388	24.793	x	x	x	x	x	x
X5—Flatfi	0.059	−0.457	3.719	0.006	−0.318	1.003	x	x	x
X6—Disc	0.274	202.45	70.910	x	x	x	0.047	−76.570	1.861
X7—Inc	0.196	0.027	895.805	x	x	x	x	x	x
X8—Time	0.237	135.24	626.356	x	x	x	x	x	x
X9—GDP	0.140	−0.021	1143.960	x	x	x	x	x	x
Constant	0.181	−266295		0.000	−39867		0.000	−33724	
Observ.	13			13			13		
R2	0.996			0.985			0.978		
Signif.	0.004			0.000			0.000		
DW	2.319			1.358			1.874		

The General model represents the results for all selected variables in the period 2006–2018. As with Prague and Ostrava, the variables were not statistically significant. The DW and VIF coefficients showed insufficient values. A Durbin–Watson test indicated no autocorrelation; however, the VIF coefficients were extremely high and showed multicollinearity between the variables (space in the table does not permit the VIF coefficients to be included).

From the other results of testing the models, two statistically significant models were selected. The Flats model was calculated using Inhabitants and Flats Finished. Both the model and variables were statistically significant. The VIF indicators had sufficient volume, and the model had no autocorrelation. According to the results for the 0.01 significance level, Inhabitants affected land price in Olomouc rather positively, Flats Finished rather negatively.

The Population model was calculated using Inhabitants and Discount Rate. The Population model was statistically significant, the VIF indicators showed sufficient levels, and the model had no autocorrelation. According to the 0.01 and 0.05 significance levels, Inhabitants affected land price in Olomouc rather positively, Discount Rate rather negatively.

3.2.4. Comparison of Prague, Ostrava, and Olomouc

The key question at the beginning of the present research was whether changes in economic indicators affected land price. An analysis of the selected cities and various models suggest that the answer is yes, although not every economic indicator affected land price.

Comparing the most suitable models for Prague, Ostrava, and Olomouc (Table 6), some economic indicators were identified as independent variables with either a positive or negative effect on land price in each city. In fact, Discount Rate had a rather negative impact in each city, while Unemployment Rate and the Household Income both had a positive impact in Prague.

Table 6. Comparison of Prague, Ostrava, and Olomouc.

	Prague	Prague	Ostrava	Olomouc	Olomouc
Variables	**Income Model**	**Population Model**	**Population Model**	**Flats Model**	**Population Model**
X1—Inhab	-	positive	negative	positive	positive
X2—Unem	positive	-	-	-	-
X3—Econs	-	-	-	-	-
X4—Flatst	-	negative	-	-	-
X5—Flatfi	-	-	-	negative	-
X6—Disc	-	negative	negative	-	negative
X7—Inc	positive	-	-	-	-
X8—Time	-	-	-	-	-
X9—GDP	-	-	-	-	-

3.3. Spatial Development of Land Prices

The research also evaluated the relative price development between 2006 and 2019 in the cities from a spatial point of view. The spatial visualizations (Figures 7 and 8) clearly show that areas whose prices had risen strongly dominated, as already revealed by the results in Table 1. Although it is difficult to describe any spatial trend in the changes, each city demonstrates some findings.

In Olomouc (Figure S1), the most dramatic development occurred in the peripheral urban areas (Slavonín, Nemilany, and Nedvězí in the south, Neředín and Topolany in the west, and Holice in the southeast). These areas were typified by increasing residential construction activities, and although the prices in these areas rose due to demand, they were still not as high as in the historical center. Prices in the historical city center remained continuously high and increased more slowly.

In Zlín (Figure S2), price development behavior was untypical. Several land parcels with decreasing prices were observed both in the city center and residential areas. Parcels with decreasing prices were still the most expensive, especially in the city center. This indicates the overpricing already evident at the beginning of the monitored period (2006), which may have reduced appeal in the real estate market and caused a gradual decline in prices. This contrasts the trend observed for the center of Olomouc. The highest increases were found mainly in peripheral areas (Jaroslavice, Kudlov, and Příluky). These parcels are typically small, distant from built-up areas, and dedicated to individual housing.

As with Zlín, some areas in Ostrava (Figure S3) with high land prices saw a decreasing trend in development. This price behavior related to Moravská Ostrava, which may be considered the city's center. The second area with significant price decreases was in Třebonice ve Slezsku, where parcels with two shopping malls fell in price by 60% and 30%, respectively. Rising prices were concentrated in two main areas: the industrial areas of Vítkovice and Zábřeh and the residential areas of Hrabůvka, Dubina, and Zábřeh nad Odrou.

In Prague (Figure S4), evaluation was complicated because of the city's size and spatial arrangement (especially distant suburbia and rapidly sprawling districts on the outskirts). As with Olomouc, price did not strongly increase in the city's center, but saw increases in peripheral areas, specifically in the satellites Čakovice, Kbely, Satalice, and Vinoř. In terms of absolute price, however, these areas still had low to medium prices. Absolute price was still highest in the city's center, but its rise had slowed. Unfortunately, land prices for the historical sections were not available, though land prices here probably achieved the most extreme values.

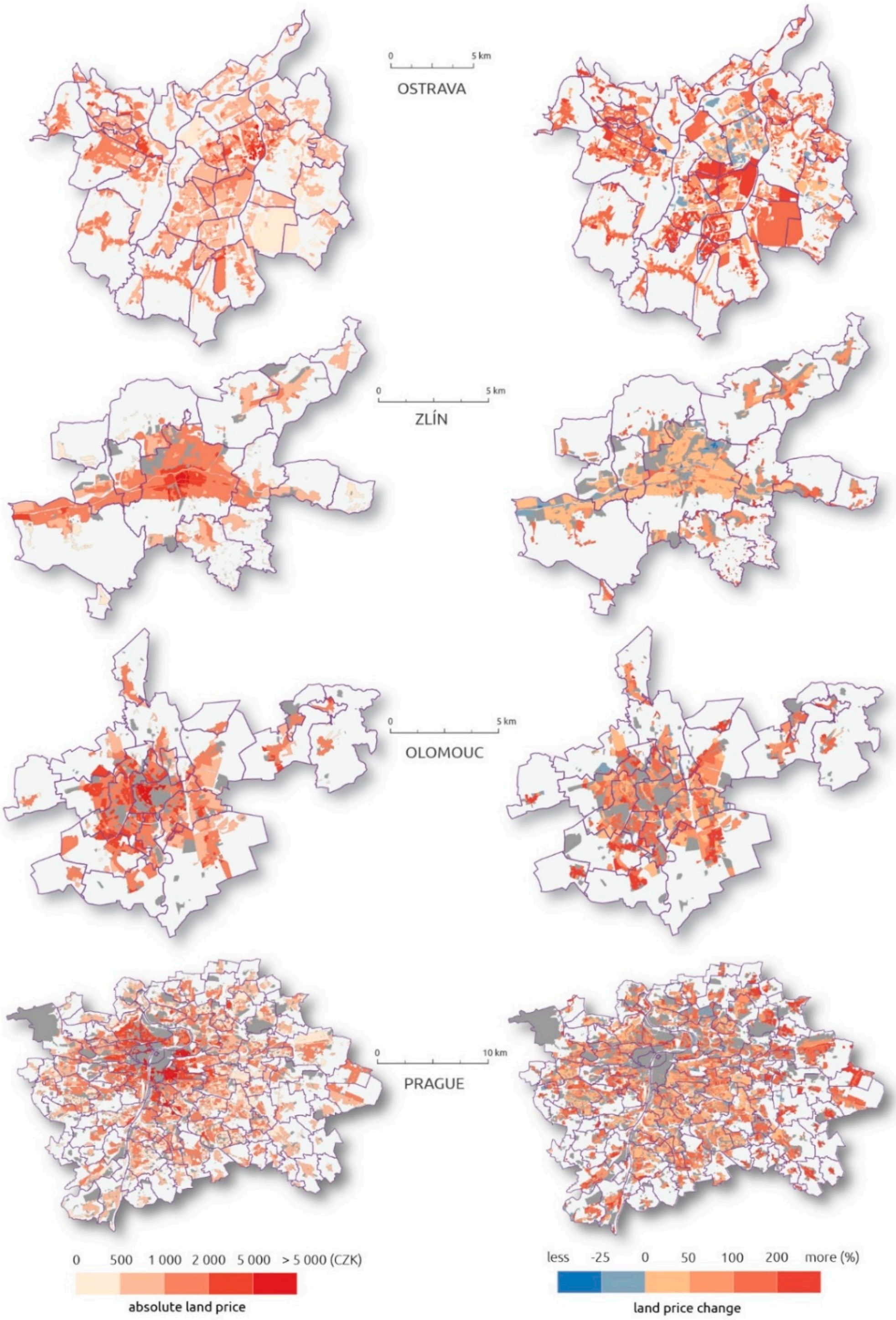

Figure 7. Absolute land prices in 2006 and relative land prices changes between 2006 and 2019 (a different scale was used for absolute values in Prague, as follows: 0–3000–6000–9000–15,000 and over).

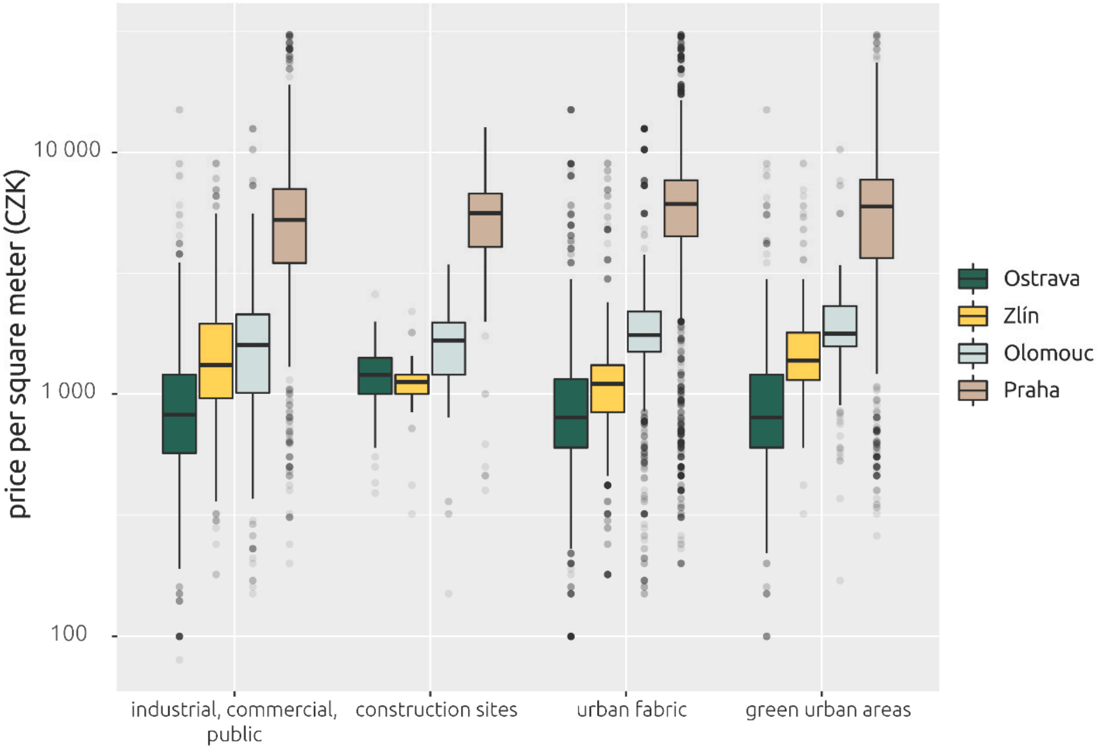

Figure 8. Land price related to selected land use types.

3.4. Spatial Dependencies on Land Use Category

The final part of the spatial data processing also looked at the differences in land prices between the cities according to the different land use categories. For this analysis, land use data were obtained from the Urban Atlas, as described in Section 2.1. Only the final year 2019 was examined. In each city, the highest average prices were found in different land use categories (Ostrava, construction sites; Zlín, green urban areas; Olomouc, green urban areas; Prague, urban fabric). These categories were difficult to compare because of the different numbers of representative land parcels, but offered an approximation of how the land use categories were valued. An examination of simple boxplot visualization (Figure 8) surprisingly revealed no dramatic differences between the categories in the case of Prague and Olomouc. More differences between the categories were visible for Zlín and Ostrava.

To support the graphical visualizations (Figure 7 and Figures S1–S4), a statistical test such as a two-way ANOVA should have been computed. Unfortunately, some assumptions of ANOVA would have been violated, for example, the normal distribution of values within the groups or the same sample size of each group. Since no two-way nonparametric alternative was available, the data were modified into a one-factor structure in which each category was a combination of city affiliation and the land use category. After this transformation, a Kruskal–Wallis test was applied, which revealed significant differences between several factors. These factors were the city, land use, and a combined factor of the city and land use. Significant differences were found between these categories and the city, except for the combinational factors of construction sites, industrial, commercial plus public areas, and construction sites plus green urban space. A multiple pairwise comparison using Dunn's multiple comparison procedure was then applied to identify which pairs of groups of combinational factors differed significantly. Finally, all the possible combinations of the city and land use were tested, 62% of the combination proving a statistically significant difference in price. Although no differences were apparent from the boxplot visualization, for example, in the case of land use categories in Prague, the statistical test confirmed a similarity in the combinational factor of green urban areas and industrial, commercial, and public areas, and in the pair green urban areas and construction sites. However, no confirmed differences in Ostrava's land use categories were observed. The results of a pairwise comparison (Appendix A) showed differences that were not apparent from a simple visualization. Supplementing these visualizations with an appropriate statistical test was therefore necessary.

To compare the cities in each category, the cities were ordered in terms of average price as follows: Ostrava, Zlín, Olomouc, Prague, except for construction sites, in which Zlín achieved the lowest average land price. Since the land use category data were from 2012 and the price map data from 2019, these constructions may have already been completed and their land prices may not necessarily reflect the overall trend of price differences between the monitored cities.

4. Discussion

Land maps have an important role in determining the allocation of land resources for spatial planning and development, especially in large and rapidly developing cities where changes in population and infrastructure occur frequently. In recent years, the real estate market in Czechia has fluctuated wildly, therefore studies examining price maps are topical and beneficial.

A key input aspect in meaningful analysis is the quality of the processed data. As spatial data processing demonstrated, the geometric delimitation of priced land parcels was inaccurate over specific time intervals. As a result, parcels often overlapped in the time–space evaluation. For this reason, many small parcels could not be clearly defined as to whether they were newly delimited and priced parcels or whether they were areas created by geometric inaccuracy. By overlapping layers where some of the parcels were not priced, these missing values were passed onto the output layers and increased the amount of missing data. This fact may have also contributed to the insufficient capture of real trends when the price maps were created. It is therefore necessary to take into account a degree of uncertainty and the quality of the data, which, however, cannot be verified in any way.

The present study demonstrates the importance of price map analyses which focus on the spatial component of data, and also highlights the usefulness of GIS tools. Even simple visualizations of the current state or development in a monitored interval can reveal interesting information and patterns that remain hidden with nonspatial techniques. The authors see the potential for future research in this area by deploying more sophisticated spatial methods in spatial statistics. For example, analyzing spatial autocorrelation and areas of concentration of high or low prices supported by statistical significance could be more precisely defined.

Concerning the spatial data, the research could also benefit from a dataset of selected socioeconomic indicators at a very detailed administrative level, such as basic settlement units. A very detailed spatial analysis of dependencies between land price and a set of socioeconomic indicators could then be performed using, for example, geographically weighted regression [67]. This technique can model spatial heterogeneity and describe the variation in relationships obtained from the global model in Section 3.2 in relation to different locations, i.e., different parts of the cities.

A significant benefit of the present study over the original study [1] is extension of the area of interest, which now covers four cities and allows the validity of results from different types of cities to be verified. In the same manner as Yang [17], who monitored the variability of the impact of macroeconomic indicators on land prices in Chinese cities, the present research compared the original results of the study on the city of Olomouc with other selected cities. By extending the original study to four selected cities, the authors also encountered problems in comparing the achieved results to the final, inferenced synthetic information, since the monitored cities had very different characters. This difference was most evident for the capital city of Prague, which strongly deviated from others in prices and development. More comparable and generalized results could be achieved by analyzing cities of similar character, size, historical development, and especially spatial structure. However, it should be considered that a comprehensive set of price maps is hardly ever available, and therefore limiting the range of cities that could be potentially analyzed.

Concerning the temporal development of land prices, in long term period, the price increased in all observed cities. A conclusion from the main statistical and visualization findings is that Prague is clearly the most expensive city regarding land prices. This is unsurprising since it is the capital, and in all terms, it is always fluctuating. More unexpected are the results of a comparison of the other cities, the average prices being lower in Ostrava. Since Ostrava is the third largest city in Czechia in terms of population, higher prices would be expected. However, average salaries in this region are not high, and the unemployment rate is higher than the national average. In case of Zlín, deviating data can be observed due to a significant number of very cheap parcels that distort the static characteristics. The Zlín data are also aggregated over several years and may therefore be more difficult to compare to other data. Looking at the price variance, Olomouc appears to be the most compact, especially in 2006 and other years, and has only several price outliers. Regarding the temporal differences, the monitored time period can be divided into two stages, which have a similar pattern in each city: the first stage (approximately 2006–2010) was characterized by a more rapid price increase. Olomouc has experienced massive growth in real estate prices, along with increased construction of new residential facilities. These conditions are clearly reflected in the city's land price data. The second stage (approximately 2010–2019) was typified by a stable but less dramatic increase, which may indicate some stabilization in the real estate market. From the economic perspective, the present study and its economic models can illuminate key periods in the economic development of a city. The results showed the differences in a developing city (currently industrial city transforming or rebuilding its center), an academic city, a commercial city, and finally, a capital city. The relationships between economic indicators and land prices differed according to the development stage of each city. From the results, it can be concluded that the number of inhabitants had a positive impact on land prices in Prague and Olomouc. By contrast, Ostrava revealed a different scenario, which may be a consequence of Ostrava's different character as an industrial city and with industrial buildings located directly in the city's center. For the observed period, the number of inhabitants decreased, despite new construction of flats. The city therefore appears to be in the process of transformation. Prague as the capital is the richest city in Czechia, which suggests that economic indicators have a greater effect on land price development. Olomouc had the greatest positive effect on land prices from an increasing number of inhabitants. The results of this study proved the results of the previous study [1], which examined a shorter period.

Concerning the spatial dependencies, we observed no significant differences between the categories in the case of Prague and Olomouc. This may be explained by the vast number of Prague's land parcels, which demonstrated strong variability in each category and smoothed any differences. An explanation for Olomouc may be the extremely high demand for building parcels over last decade, leading to price equalization in all land use categories.

Future research could explore the economic and income structure of the population in these cities, the temporal changes in this structure, and various economic entities/agents and their behavior [68], which can influence land price development. Land price can be influenced by several driving factors [25], including any variable that affects human behavior, such as environmental situations, migration [26], tourism, gentrification [27], local culture, economic and financial subjects, land policy, and also interactions between these variables. Economic entities/agents are supposed to be not only inhabitants of cities, but also tourists, investors, hospitals, universities, etc., as described in other scientific studies analyzing land price or land use changes [21,25,28].

Additionally, there are more aspects of land price changes that can be elaborated. In our previous study [1], we elaborated several environmental factors (like soil quality or floods [69]), but the data processing for four cities is quite demanding and opens a new challenge for further research. As one of the most important factors affecting the quality of urban land, location conditions have an impact on the urban land price through traffic location and convenience of supporting facilities. The density of the road network in the area and the convenience of traffic nodes, such as main bus stations and rail transits, can affect the urban land price [21].

5. Conclusions

Land price sustainability is a key aspect that affects city development. The authors of the present research studied four Czech cities (Prague, Ostrava, Olomouc, and Zlín), exploring their spatial and temporal development in relation to dependencies in land price. These maps are very significant documents which contribute to and monitor the real estate market in the larger cities of Czechia. According to our objectives, the authors analyzed the relations between land price and selected macroeconomic indicators, and compared temporal changes. Concerning the question of the relationship between macroeconomic indicators and land prices, the authors' previous study [1] concluded that the correct answer was partially affirmative. Some macroeconomic indicators had a significant impact on the changes in land prices in Olomouc in the period 2006–2016, but not in the case of all the observed macroeconomic indicators. The changes in land prices were affected by a mix of economic, demographic, and social indicators. From all the analyzed variables, the most statistically significant were the number of inhabitants (in a positive manner), the number of flats finished (in a negative manner). By comparing the previous results with the results of the current regression analysis and the regression models for Prague, Ostrava, and Olomouc, more general conclusions can be stated. First, the statistically significant variable in each city and model was the number of inhabitants. The effect of this variable was positive, except for Ostrava as an example of a developing city. Discount rate was the second statistically significant variable, and in this case, the effect was negative in each city and model. The group of variables relating to the number of flats finished/started was significant in Prague and Olomouc, with a rather negative effect. The effect and statistical significance of other economic variables varied according to each city, its characteristics, and stage of economic development. These general results supported the results of the authors' previous case study [1].

Certain similar patterns in temporal changes can be observed from a spatial point of view in the monitored cities. As observed in the original study of Olomouc, prices rose in most of the priced parcels. The ratio of land area with rising price was very similar in each city (85%–92%). In each city observed, the highest land prices were typically in urban centers. These areas remained the most expensive, but prices rose only gradually. A much more significant increase in prices occurred mainly in peripheral resident areas. However, no clear common pattern emerged, since all of the cities had different characters, sizes, and spatial structures.

In terms of temporal evaluation, the monitored cities experienced different developments. While the average price in the original study of Olomouc gradually increased during the observed period, this growth was not so significant in the case of Zlín and Ostrava, but rather constant and sometimes declined. Prague differed significantly since the growth rate was much faster. Each city indicated stagnation in 2010–2011, likely as a consequence of the global economic crisis in 2009.

Supplementary Materials: The following are available online at http://www.mdpi.com/2220-9964/9/6/396/s1, Figure S1: Land price–Olomouc, Figure S2: Land price–Zlín, Figure S3: Land price–Ostrava, Figure S4: Land price–Prague.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Results of the Dunn test: multiple comparison of the combination all land use categories and city affiliation. Combinations with a *p*-value greater than 0.05 cannot reject the null hypothesis that no difference exists between the groups.

z Score	*p*-Value	Combination
−1.271236	1	Olomouc_construction_Olomouc_green
−1.468196	1	Olomouc_construction_Olomouc_urban
0.8916088	1	Olomouc_construction_Ostrava_construction
2.8816906	0.1700856	Olomouc_construction_Ostrava_green
3.0345084	0.1084176	Olomouc_construction_Ostrava_industrial
3.1475032	0.07574879	Olomouc_construction_Ostrava_urban
−8.674407	2.82684×10^{-16}	Olomouc_construction_Prague_construction
−10.13592	2.94711×10^{-22}	Olomouc_construction_Prague_green
−9.755031	1.28149×10^{-20}	Olomouc_construction_Prague_industrial
−11.02944	2.23215×10^{-26}	Olomouc_construction_Prague_urban
1.1121987	1	Olomouc_construction_Zlín_construction
−0.411145	1	Olomouc_construction_Zlín_green
−0.071641	1	Olomouc_construction_Zlín_industrial
1.5135615	1	Olomouc_construction_Zlín_urban
1.876825	1	Olomouc_green_Ostrava_construction
6.5260719	3.91598×10^{-09}	Olomouc_green_Ostrava_green
6.8545974	4.29082×10^{-10}	Olomouc_green_Ostrava_industrial
7.1717833	4.58968×10^{-11}	Olomouc_green_Ostrava_urban
−9.993432	1.23761×10^{-21}	Olomouc_green_Prague_construction
−13.21063	6.47595×10^{-38}	Olomouc_green_Prague_green
−12.69522	5.27956×10^{-35}	Olomouc_green_Prague_industrial
−14.74808	2.75374×10^{-47}	Olomouc_green_Prague_urban
2.4137182	0.6316267	Olomouc_green_Zlín_construction
1.1235143	1	Olomouc_green_Zlín_green
1.9612934	1	Olomouc_green_Zlín_industrial
4.5080015	0.00033375	Olomouc_green_Zlín_urban
0.2624305	1	Olomouc_industrial_Olomouc_construction
−1.760516	1	Olomouc_industrial_Olomouc_green
−3.610408	0.01467435	Olomouc_industrial_Olomouc_urban
1.2149056	1	Olomouc_industrial_Ostrava_construction
8.7680309	1.25454×10^{-16}	Olomouc_industrial_Ostrava_green
9.8335013	6.05708×10^{-21}	Olomouc_industrial_Ostrava_industrial
11.360979	5.42883×10^{-28}	Olomouc_industrial_Ostrava_urban
−16.07402	3.57046×10^{-56}	Olomouc_industrial_Prague_construction
−30.90424	1.0687×10^{-207}	Olomouc_industrial_Prague_green
−30.97085	1.3713×10^{-208}	Olomouc_industrial_Prague_industrial
−37.0283	4.2545×10^{-298}	Olomouc_industrial_Prague_urban
1.64811	1	Olomouc_industrial_Zlín_construction
−0.307108	1	Olomouc_industrial_Zlín_green
0.4377036	1	Olomouc_industrial_Zlín_industrial
5.1060628	1.77628×10^{-5}	Olomouc_industrial_Zlín_urban
−0.029164	0.9767341	Olomouc_urban_Olomouc_green
2.0047748	1	Olomouc_urban_Ostrava_construction
14.983584	8.36675×10^{-49}	Olomouc_urban_Ostrava_green
17.41345	6.13181×10^{-66}	Olomouc_urban_Ostrava_industrial
22.229726	1.7013×10^{-107}	Olomouc_urban_Ostrava_urban
−15.07652	2.0803×10^{-49}	Olomouc_urban_Prague_construction
−36.80662	1.5189×10^{-294}	Olomouc_urban_Prague_green

Table A1. *Cont.*

z Score	*p*-Value	Combination
−38.24314	0	Olomouc_urban_Prague_industrial
−49.63981	0	Olomouc_urban_Prague_urban
2.7055483	0.2864052	Olomouc_urban_Zlín_construction
1.4996261	1	Olomouc_urban_Zlín_green
3.5997042	0.01497323	Olomouc_urban_Zlín_industrial
10.78045	3.36381×10^{-25}	Olomouc_urban_Zlín_urban
0.83239	1	Ostrava_construction_Ostrava_green
0.9708769	1	Ostrava_construction_Ostrava_urban
−6.960054	2.07487×10^{-10}	Ostrava_construction_Prague_construction
−7.610366	1.77658×10^{-12}	Ostrava_construction_Prague_green
−7.349422	1.27402×10^{-11}	Ostrava_construction_Prague_industrial
−8.152379	2.39079×10^{-14}	Ostrava_construction_Prague_urban
0.0320599	1	Ostrava_construction_Zlín_construction
−1.269571	1	Ostrava_construction_Zlín_green
−1.081667	1	Ostrava_construction_Zlín_industrial
−0.064523	1	Ostrava_construction_Zlín_urban
−22.39032	4.7443×10^{-109}	Ostrava_green_Prague_construction
−47.16052	0	Ostrava_green_Prague_green
−48.56064	0	Ostrava_green_Prague_industrial
−57.72071	0	Ostrava_green_Prague_urban
−1.045529	1	Ostrava_green_Zlín_construction
−5.033263	2.55566×10^{-5}	Ostrava_green_Zlín_green
−7.22224	3.2217×10^{-11}	Ostrava_green_Zlín_industrial
−4.433572	0.000463422	Ostrava_green_Zlín_urban
−0.917649	1	Ostrava_industrial_Ostrava_construction
−0.426327	1	Ostrava_industrial_Ostrava_green
0.3501245	1	Ostrava_industrial_Ostrava_urban
−23.31579	3.0049×10^{-118}	Ostrava_industrial_Prague_construction
−54.73768	0	Ostrava_industrial_Prague_green
−57.62324	0	Ostrava_industrial_Prague_industrial
−70.84884	0	Ostrava_industrial_Prague_urban
−1.161113	1	Ostrava_industrial_Zlín_construction
−5.330484	5.38732×10^{-06}	Ostrava_industrial_Zlín_green
−7.971203	1.0371×10^{-13}	Ostrava_industrial_Zlín_industrial
−5.369381	4.42441×10^{-06}	Ostrava_industrial_Zlín_urban
−0.796714	1	Ostrava_urban_Ostrava_green
−24.49523	1.6438×10^{-130}	Ostrava_urban_Prague_construction
−72.67429	0	Ostrava_urban_Prague_green
−82.32754	0	Ostrava_urban_Prague_industrial
−118.0432	0	Ostrava_urban_Prague_urban
−1.236074	1	Ostrava_urban_Zlín_construction
−5.602927	1.20134×10^{-06}	Ostrava_urban_Zlín_green
−8.908818	3.61058×10^{-17}	Ostrava_urban_Zlín_industrial
−6.770101	7.59288×10^{-10}	Ostrava_urban_Zlín_urban
−0.899801	1	Prague_construction_Prague_green
−2.459297	0.5707584	Prague_construction_Prague_urban
8.970989	2.08643×10^{-17}	Prague_construction_Zlín_construction
11.231578	2.33975×10^{-27}	Prague_construction_Zlín_green
15.525965	2.10662×10^{-52}	Prague_construction_Zlín_industrial
20.18187	1.34234×10^{-88}	Prague_construction_Zlín_urban
10.13854	2.90648×10^{-22}	Prague_green_Zlín_construction
14.756411	2.46204×10^{-47}	Prague_green_Zlín_green
26.723667	2.5241×10^{-155}	Prague_green_Zlín_industrial
44.684602	0	Prague_green_Zlín_urban
0.1054708	1	Prague_industrial_Prague_construction

Table A1. *Cont.*

z Score	p-Value	Combination
−2.214257	1	Prague_industrial_Prague_green
−9.119451	5.43642×10^{-18}	Prague_industrial_Prague_urban
9.8068315	7.78633×10^{-21}	Prague_industrial_Zlín_construction
14.257505	3.46232×10^{-44}	Prague_industrial_Zlín_green
26.447665	3.8815×10^{-152}	Prague_industrial_Zlín_industrial
46.212362	0	Prague_industrial_Zlín_urban
4.8226476	7.36659×10^{-05}	Prague_urban_Prague_green
10.890346	1.02522×10^{-25}	Prague_urban_Zlín_construction
16.329648	5.64825×10^{-58}	Prague_urban_Zlín_green
30.983132	9.4609×10^{-209}	Prague_urban_Zlín_industrial
56.247156	0	Prague_urban_Zlín_urban
−1.647875	1	Zlín_construction_Zlín_green
−0.137682	1	Zlín_construction_Zlín_urban
1.4641406	1	Zlín_industrial_Zlín_construction
−0.564214	1	Zlín_industrial_Zlín_green
3.9630292	0.003626231	Zlín_industrial_Zlín_urban
−3.001092	0.1183658	Zlín_urban_Zlín_green

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