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Testing the Environmental Kuznets Curve hypothesis on land use: The case of Romania

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ABSTRACT

The aim of the present study is to test empirically the Environmental Kuznets Curve (EKC) hypothesis for 42 Romanian counties over the 2000-2014 period. Specifically, we investigate the existence of an inverted U-shaped curve relationship between residential built-up land and economic development in a low-income EU country undergoing rapid and profound transition. We do so by making innovative use of spatial panel econometric techniques. Contrary to our expectations, the results indicate an inverted EKC, implying that higher levels of residential built-up area occur for higher levels of wealth. Moreover, we find that the built-up land in Romania mainly reflects processes of urban expansion, such as sprawl or suburbanization, that may have harmful environmental and social consequences. Spatial spill-overs in terms of built-up land arise and spread, albeit to a limited extent, to neighbouring locations. These findings are of potential significance for policy makers, because they highlight the need for coordination among neighbours. Furthermore, strengthening the institutional framework and local tax management, and planning urban regeneration better could curb and even reverse the extensive built-up land expansion and real estate speculation.

1. Introduction

Within the European Union (EU), the urban dimension is a priority on the EU Cohesion Policy agenda. Indeed, in the 2014-2020 programming period, more than EUR 100 billion have been committed to supporting sustainable urban development (EC, 2017). Recently, in 2016, the Pact of Amsterdam (EC, 2016) introduced the Urban Agenda, and among the 12 action areas established, the Sustainable Use of Land and Nature-based Solutions was intended “to ensure that the changes in Urban Areas (growing, shrinking and regeneration) are respectful of the environment, improving quality of life” (EC, 2016: iv). Moreover, the EU Urban Partnership has an international dimension, being linked with the New Urban Agenda (Habitat III) and the Sustainable Development Goals (SDGs) (UN, 2015). Among the SDGs, the 11th promotes measures ensuring sustainable urban development and enhancing inclusive urbanization by reducing “the adverse per capita environmental impact of cities (…)” (SDG 11.6), by strengthening national and regional development planning (SDG 11.a), and by implementing integrated policies for resource efficiency (SDG 11.b).

In our paper, the Environmental Kuznets Curve (EKC) in terms of a relationship between income and land use,[2] as proxied by the residential built-up area, is conceived as an indicator of environmental sensitivity for urban planning policy.[3] Land use responds inevitably to national regulatory frameworks and to their convergence and harmonization with European and international criteria like those mentioned above. In this regard, we consider the case of Romania as distinctive for the following reason. Being in 2017, according to Eurostat data, the second poorest European country, it experiences an interplay between the general improvement of the economic conditions that cause an increase in demand for housing and for real-estate investment, and the need to comply with SDG 11 and European priorities of the New Urban Agenda. Among the less developed EU countries, the highest rates of

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[1] The scientific output expressed does not imply a policy position of the European Commission. Neither the European Commission nor any person acting on behalf of the Commission is responsible for the use which might be made of this paper.

[2] In this paper, the term ‘land use’ is adopted interchangeably with the residential built-up land use as approximated by it.

[3] Urbanization phenomena, such as sprawl or suburbanization, can be indirectly observed and investigated through the EKC. Their assessment, as conducted in this study, is based on the interpretation of the empirical results of the EKC in light of the literature on urban land use.

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agricultural land conversion to residential uses are observed in Poland, Slovakia and Romania (Ustaoglu and Brendan, 2017). Moreover, in 2015 Romania ranked sixth, preceded in descending order by Slovenia, Estonia, Bulgaria, Sweden and Finland, among the European countries with a percentage of built-up area equal to 0.9, below the EU average of 1.3 (source: Eurostat). Although the population is decreasing as a consequence of massive migration to western EU countries, large amounts of remittances have been invested in real estate. According to the World Bank, Romanians living abroad sent home around USD 23 billion during the 2008-2017 period, equivalent to around 10 percent of GDP in 2017, making Romania the first recipient in the EU. Remittances are used not only for subsistence expenditure, but also for investments, especially in real estate and education (Haller et al., 2018). Thus, a growth of built-up land is occurring as Romania is developing, but the extent to which this will occur in a sustainable manner is doubtful.[4]

The urban planning process in Romania underwent profound changes in the transition period from a communist to a democratic regime. These changes consisted of (i) shifts in the property regime of land from predominantly public to private; and (ii) contradictory policies that led to the funding of built-up development on agricultural areas (Grigorescu et al., 2012a; Stanilov, 2007) with the expansion of built-up areas (Sýkora and Čermák, 1998). Romania, indeed, is characterized by heterogeneous stages of development across its counties, with a steadily increasing divergence between lagging and more developed areas in constant and relative terms, but with a high external convergence relative to the EU average (Ionescu-Heroiu et al., 2014). The authors show that the contribution of Bucharest to the national economy grew from 15% to 25% between 1995 and 2009, while most other counties became less prominent.

Our objective in this paper is to empirically verify the existence of the EKC with respect to residential built-up areas across 42 Romanian counties over the 2000-2014 period. The purpose is therefore to determine whether and how the consequences of economic development coexist in a country undergoing profound and rapid transition. In the EU, this argument has been recently addressed by Bimonte and Stabile (2017a; 2017b) for Italy, but relating economic development to building permits.[5] Romania is a distinctive case because it is subject to a set of rules which are common to other EU countries as a consequence of the 2007 accession, but it is still far from the average European stage of development. Romania has been only recently analysed by Shahbaz et al. (2013), who, by adopting a standard time series technique, empirically tested the relationship among economic growth, energy consumption and pollutants over the 1980-2010 period. They validated the environmental Kuznets curve, i.e. a concave relationship between real per capita GDP and energy emissions. The result was confirmed in both the short and long run.

In our analysis, we use spatial panel econometric tools, which enable us to identify the sign and magnitude of spatial spill-overs due to interactions in space among neighbouring locations with similar characteristics. A similar approach has been adopted by Pontarollo and Mendieta Muñoz (2020) for Ecuador who, however, similarly to Bimonte and Stabile (2017a; 2017b), concentrate on building permits.[6]

[4] Sustainable residential built-up land is defined according to SDG 11.3.1, i.e. the ratio of land use should be lower than population growth rates. The preliminary evidence in Appendix A displays at least an excessive amount of residential built-up land and, possibly, speculation.

[5] The rationale for considering residential built-up land instead of the building permits is because we can potentially control for abusive building phenomena. Furthermore, to better understand whether land use reflects processes of built-up densification and urban expansion, we also investigate the relation between the city size and the GDP per capita.

[6] The rationale for considering the residential built-up land instead of building permits is that we can potentially control for unlicensed building works. Furthermore, to better understand whether land use reflects processes of built-up densification and urban expansion, we also investigate the relation between the city size and the GDP per capita.

Land conversion due to urban expansion, according to IPBES (2018), contributes to the biodiversity decline that, in turn, has an effect on reducing nature's contributions to people´s quality of life (IPBES, 2018). Soil has a slow regeneration process and, consequently, is considered a non-renewable resource (Pimentel et al., 2010, Gardi et al., 2015). Accordingly, spatial planning has to regulate its access and to limit overuse for the common welfare.

Environmental impacts related to urban fragmentation, happening in Romania mainly because informal settlements (Suditu and Vâlceanu, 2013) and land speculation in peri-urban areas (Grigorescu et al., 2012b) cause habitat fragmentation (Swenson and Franklin, 2000; Scolozzi and Geneletti, 2012; Li et al., 2010). This produces fragmentation of socio-ecological systems and habitat loss, directly affecting biodiversity and ecological processes (Haddad et al., 2015; Wilson et al., 2016) and undermining the quality and functionality of natural ecosystems (see Alberti, 2005). This is particularly relevant to Romania, a country with an important biodiversity (EEA, 2011).

The results of the application of the EKC to land use may be useful for urban policy strategies in terms of orienting their targets and financial resources to the proper territorial level so as to generate higher benefits in terms of sustainable urban development. Moreover, if spatial spill-overs are explicitly modelled, and statistically significant, strengthening the coordination among neighbouring counties is a condition to maximize the policy objectives.

The study is organized as follows: in the second section we conduct a literature review focused on links most relevant to our approach; in the third we present an exploratory analysis, the empirical methodology and the data; in the fourth we set out the empirical results. In the fifth section we discuss the results, and in the last section we conclude.

2. Setting the context: The Environmental Kuznets Curve

The existence of an inverted U-shape curve was first verified by Kuznets in 1955 to test the relationship between per capita GDP and income inequality. Specifically, if the per capita GDP increases, then the income inequality initially increases, reaches its maximum, labelled 'turning point', and then declines. Inspired by the theory in its original version, a large body of literature investigating the existence of a nonlinear relationship between per capita GDP and alternative environmental measures, namely EKC, started with the pioneering studies of Grossman and Krueger (1991; 1995). The present paper is related to two specific research strands within the broader EKC literature that explores the dynamics between income level and urban development. First, we refer to those papers that analyse the wealth/land use relationship, still little investigated, at a territorial level lower than the national one. Among them, Bimonte and Stabile (2017a; 2017b) explore this issue by adopting building permits as a proxy for land consumption. Using standard panel econometric techniques, with a focus on Italian regions, they conclude that an inverted EKC is occurring. Kumar and Aggarwal (2003), with a similar approach, test the EKC for changing patterns of land use other than the residential, with respect to the 19 major states of a low-income country like India. They find that the hypothesis of a concave relation with the local development stages holds. Second, we are indebted to authors who have applied spatial econometrics to assess the EKC hypothesis. Among them, we first consider Maddison (2006) who investigated the relation between income and air pollution for 135 countries, finding evidence of an inverted EKC and spatial spill-overs. Recently, Wang et al. (2013) have extended application of the spatial econometric technique to estimate the EKC for ecological footprints of 150 countries, confirming the theoretical expectations of a U-shaped relation and the dependence of the

(*footnote continued*)
between the city size and the GDP per capita.

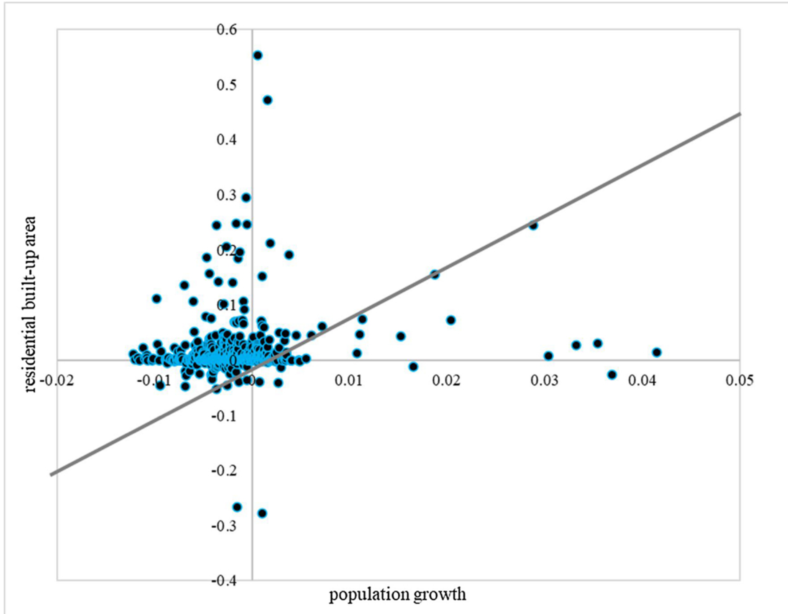

Fig. 1. Expansion of residential built-up area and population growth in Romania.

domestic environmental performance in terms of the ecological footprint of consumption (or production) on the characteristics of neighbouring countries. Finally, Liu and Guo (2015) prove the existence of an EKC and spatial spill-overs for land conversion in a panel of Chinese provinces. Pontarollo and Mendieta Muñoz (2020) focused on land consumption as proxied by building permits, for 221 Ecuadorian cantons. Using a Bayesian comparison approach applied to a spatial panel, they demonstrate that an inverted EKC and limited spill-overs hold.

3. Methods and Data

3.1. Exploratory analysis

We perform a preliminary exploratory analysis to provide a first overview of the Romanian context. The main objectives are to test if residential built-up land (i) grows at a lower rate than the population, fulfilling SDG 11.3.1, or vice-versa; (ii) is persistently concentrated in certain counties, and (iii) is both spatially polarized and clustered in space, i.e. “clustered by nature”.

To illustrate the relation between residential built-up land in Romania and population, Fig. 1 shows in x-axis the annual population growth in Romanian counties, and in the y-axis the annual residential built-up area expansion over the 2000-2014 period. If the points were along the diagonal (in grey), then the built-up land would be sustainable because it is proportional to population growth. If most points were up to the diagonal, this would mean an excessive built-up land use, compared with the population, and the reverse. In the Romanian case, we observe that the majority of points are above the diagonal and that, while built-up land grows year by year, the annual population growth is negative. This preliminary evidence displays at least an excessive built-up land use and, possibly, speculation.

To check for spatial concentration of residential built-up land and the existence of “clusterization by nature”, we rely on Fig. 2, which shows Moran’s I[7] on the left-y axis and the variance on the right-y axis. The positive and statistically significant Moran’s I highlights that areas with similar shares of residential built-up land are likely to be located close to each other. The share of residential built-up land, which is increasing over the period under analysis, means that a growing clusterization, located in particular in the South-East where the capital city Bucharest is located and north-western parts of the country (see Fig. A1), is occurring over time. Moreover, the variance of built-up land, which, in this context provides a measure of the spatial inequality, is increasing together with Moran’s I, confirming a “polarization by nature”.

3.2. Methods

We borrow our empirical model from Bimonte and Stabile (2017a; 2017b) and we extend it in order to take account of the spatial dimension as follows:

$$y_{i,t} = \rho \mathbf{W}_t \boldsymbol{y}_t + \psi log\left(\frac{GDP}{pop}\right)_{i,t} + \gamma \left[log\left(\frac{GDP}{pop}\right)_{i,t}\right]^2 + \theta \boldsymbol{x}_t + \boldsymbol{\mu}_i + \varepsilon \quad (1)$$

where i is the i$^{\text{th}}$ Romanian county of which there are n, and t is the year of which there are T. $\mathbf{W_t}$ is a squared spatio-temporal spatial contiguity weight matrix defined as the Kronecker product between the row standardized spatial weight matrix $\mathbf{W}$ of size $n \times n$, and the identity matrix $\boldsymbol{I}_T$ of size T, formally, $\mathbf{W_t} = \mathbf{I}_T \otimes \mathbf{W}$. $\mathbf{W}$ is based on a Queen contiguity scheme, where counties are considered neighbours if they share at least one point of their borders. The parameter ρ is the spatial autoregressive coefficient comprised between -1 and 1; $\boldsymbol{\mu_i}$ is the vector of spatial fixed effect (which embodies the unexplained time invariant characteristics); ε_t is the idiosyncratic error term.

The term $\boldsymbol{y}_t$ represents the log of residential built-up area in county i at time t, while the vector $\boldsymbol{x}_t$ comprises control variables representing population density, the share of green areas, the number of buses over area, as a proxy for public transport, and the net migration.

In accordance with the hypothesis of Kuznets (1955), the GDP per

[7] Moran’s I varies between the minimum and maximum eigenvector extracted from $\mathbf{W}$ (roughly -1 and +1). A positive (negative) value indicates positive (negative) spatial autocorrelation, i.e. locations with similar (dissimilar) values of the variable analysed are located close to each other. Moran’s I is based on a spatial weight matrix $\mathbf{W}$. Formally, the spatial weights matrix is an $n \times n$ positive matrix, where n is the number of regions. In each row i, a non-zero element w_{ij} defines region j as being a neighbour of region i. By convention, the diagonal elements are zero ($w_{ii} = 0$). $\mathbf{W}$ is based on a contiguity Queen matrix.

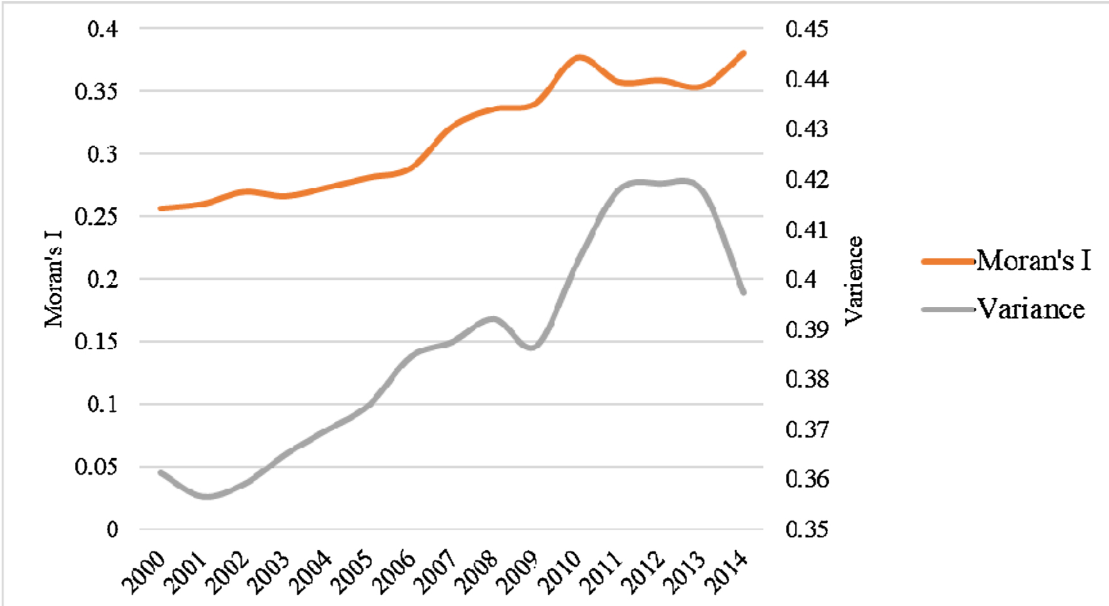

Fig. 2. Gini and Moran's I of the residential built-up land.

capita is included non-linearly. According to his theory, GDP per capita should be concave and significantly different from zero, implying that once a certain stage of development has been reached, land use starts shrinking (Skonhoft and Solem, 2001; Culas, 2007; Liu and Guo, 2015).

Equation (1) is a Spatial Lag Panel Model with spatial fixed effects (see, for instance, Elhorst, 2014). Because the model cannot be estimated through an Ordinary Least Squares (OLS) method, it is here estimated with a maximum likelihood approach (ML) (Anselin, 1988a). In a standard regression model $\rho = 0$, i.e., $\mathbf{W}_t\boldsymbol{y}_t = 0$, so the marginal effect of a change in a variable belonging to vector $\boldsymbol{x}$, say $\boldsymbol{x}_i$, would be equal to θ_i. In the Spatial Lag Panel Model, the marginal impact of a change in a regressor on the dependent variable is related not only to θ_i but also to the spatial lag coefficient ρ, given that it is associated with the spatial autoregressive parameter $\mathbf{W}_t\boldsymbol{y}_t$. The spatial lag coefficient ρ associated with the spatial autoregressive parameter generates spill-overs due to the spatial multiplier $1/(1\text{-}\rho)$, whose matricial form is $(\mathbf{I}\text{-}\rho\mathbf{W})^{-1}$ and that can be expressed as a geometric series: $\mathbf{I}+\ \rho\mathbf{W}+\rho^2\mathbf{W}^2+\ldots+\rho^n\mathbf{W}^n$. Loosely speaking, this means that the total impact of a change in a variable $\boldsymbol{x}_i$ on land use is the result of the interaction among other neighbouring counties. Indeed, following LeSage and Page (2009) the total effect of a change in $\boldsymbol{x}_i$ is disentangled into two components: i) the direct effect, which is the result of a marginal change of a variable in a certain spatial unit *i* on the dependent variable of the same unit *i*,[8] and ii) the indirect effect, which corresponds to the impact that changes in the explanatory variable in a neighbour county *j* exert in county *i* due to spatial spill-overs; or, alternatively, how a shock hitting a county *i*, which has also an impact on the neighbour counties *j*, is reflected back to county *i*. Formally, the total impact of a change in a variable θ_i (its marginal effect), is equal to the average of the values of the matrix $(\mathbf{I}\text{-}\rho\mathbf{W})^{-1}\theta_i$, the direct effects to the average of the diagonal elements of $(\mathbf{I}\text{-}\rho\mathbf{W})^{-1}\theta_i$, and the indirect effects to the average of the off- diagonal elements of $(\mathbf{I}\text{-}\rho\mathbf{W})^{-1}\theta_i$.

Our selection of the Spatial Lag Panel Model is due not only to the idea that built-up land in a specific location is positively related to its use in neighbouring locations, but also to a set of statistical tests. The Hausman test is used on standard and Spatial Lag Panel Model to determine if fixed or random effect has to be chosen. The selection of the Spatial Lag Panel Model is based on a Lagrange Multiplier (LM) (Anselin, 1988b; Anselin et al., 1996). LM test for spatial error dependence (LM_{err}) and LM test for spatial lag dependence (LM_{lag}) are carried out on the residuals of the standard (not spatial) regression. The model is selected according to the most significant test. If both are not statistically significant, a non-spatial model has to be chosen. Otherwise, if both are significant, the spatial lag or spatial error model is chosen according to the most significant robust version of the two LM tests mentioned above. We additionally test for the presence of spatial autocorrelation on the residuals of the standard and spatial models via a randomized Moran test based on 1,000 permutations. Furthermore, for each model, we check for heteroskedasticity using the Breush-Pagan test and for model misspecification through the RESET test. Finally, multicollinearity issues are checked by means of the Variance Inflation Factor (VIF).

3.3. Data

All the variables employed in the analysis are constructed using annual data over the 2000-2014 time-period from the TEMPO dataset issued by the Romanian National Institute of Statistics. Data are disaggregated at NUTS3 level accounting for the 41 Romanian counties plus the capital city Bucharest. The built-up land use, i.e. our dependent variable, is expressed as the log of the share of hectares of residential built-up land in the total number of hectares of each county. The only monetary variable employed in the analysis, namely the log of per capita GDP, is reported at 2005 Lei constant prices. The GDP deflator was taken from the World Bank.

To deal with potential misspecification problems, we also consider possible control variables that enter the model specification as explanatory (descriptive statistics are provided in Table B1 in Appendix B). They are defined as follows:

- *Population density* is the ratio between the population and the area in hectares of a certain county. It is a proxy for agglomeration, which is linked to geographical concentration of economic activities and raising productivity which, in turn, increases wages (Duranton and Puga, 2003; Charlot and Duranton, 2004). On the other hand, population concentration, since it is expected to increase the

[8] The direct effect accounts also for the feedback effects that, in general, are sizable. According to LeSage and Pace (2009: 36), "These arise because region *i* is considered a neighbour to its neighbour, so that impacts passing through neighbouring regions will exert a feedback influence on region *i* itself."

residential land consumption, may impose high pressure on the housing market, increasing prices and potentially off-setting the rising wages. Both processes can modify peoples' location choices (World Bank, 2013).

- *Share of green areas* is expressed as the percentage of hectares of land devoted to public parks and green spaces over the total number of hectares of each county. This is a proxy for the presence of natural and environmental amenities in an area (Borgoni et al., 2018; Schaeffer and Dissart, 2018). Previous studies on Romania highlight that the access to public open spaces and parks can be associated with sustainable urban planning strategy (Badiu et al., 2016);
- *Number of buses over area* (in hectares) is considered a proxy for the public transport system because the bus is by far the most used public means of transport. Indeed, according to Eurostat data, between 2000 and 2014 passengers using buses increased from 12.2% to 16.9% while, over the same period, train transport decreased from 16.3% to 4.6%.[9] The presence of public transport has a positive effect on house prices because people are disposed to pay more for being close to the service (Des Rosiers et al., 2010; Wang et al., 2015). This, in turn, may be an incentive to increase the urbanised area, or to convert low density areas into higher density places, as shown, for example, by Cervero and Kang (2011). Heavy reliance on public transport and better connectivity are more likely to be observed in higher urban densities areas like compact and dense cities (Lehmann, 2008, Newman and Kenworthy, 1989);
- *Net migration over population* is the balance between immigration and emigration flows with respect to the total population. Inbound (outbound) migration flows can increase (decrease) the housing demand (Bell et al., 2010) and leave space for speculation due to the rising rent prices (Saiz, 2003, 2007). Out-migration, on the other hand, can determine inflows of remittances that can be used for consumption or investment (Yang, 2011). Although there is empirical evidence that remittances are used mainly for consumption and only secondarily for investment (see, among others, Chami et al., 2003), we cannot exclude that they have a significant effect on real estate. However, unfortunately, we cannot empirically control the effect of remittances on residential built-up land because the Romanian National Institute of Statistics does not provide data on remittances at county level.

4. Results

In our empirical estimation we proceed as follows. The first phase is estimation of a standard fixed effect panel regression model, which is chosen according to the Hausman test; in the second phase we control for the presence of spatial autocorrelation in the residuals and, if present, an appropriate spatial model (spatial lag or spatial error) is selected; the last step consists in estimation of the appropriate spatial model. Eq. (1) is estimated keeping our core variables, GDP per capita and its square, and then adding step by step one at a time the control variables. This enables us (i) to check for the robustness of the coefficients associated with GDP per capita and its square to the inclusion of additional controls, and (ii) to identify if the latter additional controls have a significant impact too on land use. Finally, as mentioned in Section 3.2, a set of tests are carried out on the estimates to check for their goodness and for the properties of the residuals.

The estimates of the standard fixed effects panel regression model are set out in Table 1 and show a clear convex relation between GDP per capita and residential built-up area, even when controlling for additional regressors. Nevertheless, the Breush-Pagan test reveals heteroskedasticity of residuals and the RESET test model misspecification. On the other hand, VIF does not show multicollinearity issues. The randomized Moran test, based on 1,000 permutations, on the residuals of standard fixed effects panel regression model is statistically significant, pointing to the presence of spatial autocorrelation. Furthermore, the LM test for spatial error dependence and the LM test for spatial lag dependence are both significant, and their robust versions point to spatial lag, since the Robust LM test for spatial lag dependence is more significant than the Robust LM test for spatial error dependence.

Results obtained from the fixed effect Spatial Lag Panel Model are reported in Table 2. Tests on residuals show a strong improvement of the fit in terms of the Akaike Information Criterion (AIC) and residuals' properties. Indeed, the difference between the AIC of the corresponding standard and spatial models, in Tables 1 and 2, respectively, is almost always greater than around 10 or more, pointing to a "strong" preference for spatial models, following the rule of thumb of Burnham and Anderson (2004). Furthermore, in addition to the absence of spatial autocorrelation (The Moran's I test is not significantly different from zero), also heteroskedasticity is absent, while the RESET test indicates possible non-linearities due mainly to population density.

Given these results and the considerations listed above, we focus on the estimates obtained through the fixed effect Spatial Lag Panel Model in commenting on the regression results.

The relation between GDP per capita and residential built-up land is convex ($\psi < 0$; $\gamma > 0$), and not concave as expected from the theory, implying that higher levels of land use occur for higher levels of wealth; i.e. the turning point where greater wealth implies decreasing built-up land is not reached.[10] This is clearly shown in Fig. 3, where the log of GDP per capita and the log of the share of built-up area are distributed along the x-axis and y-axis, respectively. The dots represent the counties and the black line the fitted (quadratic) regression line. The grey areas around the black line are the five percent confidence intervals. We can observe that the curve is relatively flat for very low values of (log) GDP per capita and then it starts growing exponentially. The 45-degree red (dashed) line can be taken as a reference for understanding at which point the elasticity of built-up land is equal to one, i.e. a 1% increase in GDP per capita implies a 1% increase in land use. We see that this happens for comparatively high levels of GDP per capita. Furthermore, it is worth mentioning that we checked for the existence of further turning points adding the third power of log(GDP/pop), finding a non-significant coefficient.

In our case, differently from the last studies listed above, as mentioned, four additional control variables were considered to deal with misspecification issues that might arise.

The convex relation between residential built-up land and per capita GDP is confirmed when additional explanatory variables are included.

The strongest and most statistically significant relationship of built-up land is with population density and natural amenities, both of which have a positive impact. Overcrowding phenomena tend to foster urbanization, but at a decreasing rate, while the proximity of public green parks, which in principle can be associated with sustainable urbanization, has also the effect of attracting speculation. The proxy for public transport is positive and marginally statistically significant, and the proxy for net migration is positive but not statistically significant. The effect of the latter, in particular, can be explained by the evidence that despite persistently heavy outflows in Romania during the period under analysis (Eurostat, 2011),[11] residential built-up land was still very

[9] Since, according to the Global Competitiveness Report 2018 (Schwab, 2018), railroad efficiency is very low in Romania, ranking the country in 2018 24th out of 26 EU countries for which data were available, we consider the bus transport a valid proxy.

[10] These findings, as happens in the literature, are based on an empirical regularity drawn from existing data that provide a snapshot of the present situation. In our study, indeed, we are not able and we do not aim to forecast if, in the future, further turning points in terms of GDP could be reached, which is reasonable in a developing country like Romania.

[11] During the period from 2001 to 2010, people left Romania to work abroad and became the group of non-nationals living in the EU with the largest increase (almost seven-fold from 0.3 million in 2001 to 2.1 million by 2010).

Table 1
Panel Estimates for residential built-up area.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log(GDP/pop)	−1.776 ***	−1.3925 ***	−0.8146 ***	−1.7895 ***	−1.7864 ***	−1.7809 ***	−1.5274 ***	−1.0132 ***
	(0.2912)	(0.2813)	(0.2770)	(0.2849)	(0.2870)	(0.2905)	(0.2966)	(0.2907)
Log(GDP/pop)^2	0.1099 ***	0.0884 ***	0.0567 ***	0.1106 ***	0.1104 ***	0.1100 ***	0.0960 ***	0.0679 ***
	(0.0162)	(0.0156)	(0.0154)	(0.0159) ***	(0.0160)	(0.0162)	(0.0165)	(0.0162)
Pop. density		0.2949 ***	1.0201 ***				0.3112 ***	0.9904 ***
		(0.0603)	(0.1074)				(0.0058)	(0.1085)
Pop. density^2			−0.0056 ***					−0.0055 ***
			(0.0007)					(0.0007)
Green areas				3.7883 **			4.9200 **	3.0883 *
				(1.7395)			(1.7445)	(1.6541)
Buses/area					7.2968 *		−0.2945	4.9035
					(3.9956)		(4.1219)	(4.0759)
Net migr./pop.						6.0668 *	4.5501	1.9518
						(3.3768)	(3.3018)	(3.0745)
Turning point	3229	2634	1317	3262	3264	3278	2850	1739
Observations	630	630	630	630	630	630	630	630
R squared	0.3196	0.3667	0.4290	0.3462	0.3446	0.3233	0.3777	0.4593
(adj.)	(0.3174)	(0.3191)	(0.3850)	(0.2970)	(0.2953)	(0.3200)	(0.3275)	(0.4532)
AIC	−1308.98	−1332.21	−1401.51	−1312.07	−1310.56	−1310.53	−1337.25	−1395.51
Moran's I	0.04779 **	0.0590 **	0.0990 ***	0.0365 *	0.0576 **	0.0387 *	0.0385 *	0.0856 ***
LM spatial lag	10.2674 ***	11.0095 ***	15.7604 ***	9.8322 ***	12.4014 ***	9.1203 ***	9.3583 ***	17.1145 ***
LM spatial error	3.2333	4.9324 **	13.8667 ***	1.8322	4.6930 **	2.1203	2.1042	10.3680 ***
Robust LM spatial lag	20.1480 ***	11.7751 ***	2.4670	29.8307 ***	18.3984 ***	23.1812 ***	21.1327 ***	7.0379 ***
Robust LM spatial error	13.1139 ***	5.6981 **	0.5733	21.8871 ***	10.6900 ***	16.2492 ***	13.8786 ***	0.2913
Hausman test	2.6973	18.621 ***	18.621 ***	20.282 ***	39.944 ***	2.7251	19.53 ***	65.463 ***
Reset test	6.06	21.04	4.49	3.73	3.614	5.36	16.67	1.51
	(p-val = 0.01)	(p-val < 0.01)	(p-val = 0.03)	(p-val = 0.05)	(p-val = 0.06)	(p-val = 0.021)	(p-val < 0.01)	(p-val = 0.21)
Breusch-Pagan test	172.23	21.75	2.57	23.49	23.49	181.6	25.69	8.43
	(p-val < 0.01)	(p-val < 0.01)	(p-val = 0.63)	(p-val < 0.01)	(p-val < 0.01)	(p-val < 0.01)	(p-val < 0.01)	(p-val = 0.30)
VIF	1.517	1.579	1.7514	1.529	1.529	1.526	1.607	1.7683

Note: *p ≤ 0.05; **p ≤ 0.01; ***p ≤ 0.001. Std. errors in parenthesis. Turning point is calculated as the exponential of the coefficient of Log(GDP/pop) over two times the coefficient of Log(GDP/pop)^2. Prices are expressed at 2005 Lei constant prices.

Table 2
Spatial Panel Estimates for residential built-up area.

	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Log(GDP/pop)	−1.4827 ***	−1.1977 ***	−0.5521 **	−1.5987 ***	−1.5983 ***	−1.4981 ***	−1.3724 ***	−0.7658 ***
	(0.2687)	(0.2489)	(0.2631)	(0.2725)	(0.2738)	(0.2681)	(0.2828)	(0.2750)
Log(GDP/pop)^2	0.0917 ***	0.0759 ***	0.0400 ***	0.0984 ***	0.0981 ***	0.0926 ***	0.0859 ***	0.0520 ***
	(0.0149)	(0.0149)	(0.0146)	(0.0152)	(0.0152)	(0.0149)	(0.0158)	(0.01531)
Pop. density		0.2955 ***	1.0448 ***				0.3026 ***	1.0182 ***
		(0.0577)	(0.0102)				(0.0621)	(0.1026)
Pop. density^2			−0.0058 ***					−0.0059 ***
			(0.0007)					(0.0007)
Green areas				3.6307 **			4.7613 ***	2.7584 *
				(1.6638)			(1.6367)	(1.5647)
Buses/area					8.9540 **		1.4414	7.6421 **
					(3.8131)		(4.0189)	(3.8557)
Net migr./pop.						5.1510 *	3.6565	5.4664
						(3.1149)	(3.0557)	(2.9084)
Turning point	3244	2670	993	3373	3451	3259	2946	1577
Rho	0.1305 ***	0.1329 ***	0.1602 ***	0.1272 ***	0.1462 ***	0.1234	0.1260 ***	0.1767 ***
	(0.0470)	(0.0465)	(0.0454)	(0.0470)	(0.0473)	(0.0473)	(0.0469)	(0.0454)
Observations	630	630	630	630	630	630	630	630
AIC	−1318.50	−1342.22	−1410.92	−1321.24	−1321.88	−1319.20	−1346.27	−1412.21
Moran's I	−0.0438	−0.0336	0.0076	−0.0511	−0.0424	−0.0462	−0.0439	0.0069
Hausman test	41.765 ***	37.519 ***	110.27 ***	92.841 ***	39.358 ***	41.929 ***	55.837 ***	82.246 ***
Reset test	0.44	22.03	1.64	0.87	2.44	1.74	14.01	3.619
	(p-val. = 0.64)	(p-val < 0.01)	(p-val = 0.16)	(p-val = 0.45)	(p-val = 0.06)	(p-val = 0.16)	(p-val < 0.01)	(p-val < 0.01)
Breusch-Pagan test	5.39	0.22	4.42	5.30	4.58	5.80	5.66	3.8819
	(p-val = 1)	(p-val = 0.97)	(p-val = 0.1)	(p-val = 1)	(p-val = 1)	(p-val = 1)	(p-val = 1)	(p-val = 1)
VIF	1.517	1.579	1.7514	1.529	1.526	1.526	1.607	1.7683

Note: *p ≤ 0.05; **p ≤ 0.01; ***p ≤ 0.001. Std. errors in parenthesis. Turning point is calculated as the exponential of the coefficient of Log(GDP/pop) over two times the coefficient of Log(GDP/pop)^2. Prices are expressed at 2005 Lei constant prices.

intense, as shown also in Fig. 1.

Inspection of Tables 1 and 2 shows that the values of the regression coefficients estimated with standard panel models are bigger in size than the ones estimated with the Spatial Lag Panel Model because spatial dependence is not correctly modelled. This happens because, as in an a-spatial regression $\rho = 0$, spatial dependence is implicitly embedded in the dependent variable, causing upward biased regression coefficients. The Spatial Lag Panel Model, compared with the standard

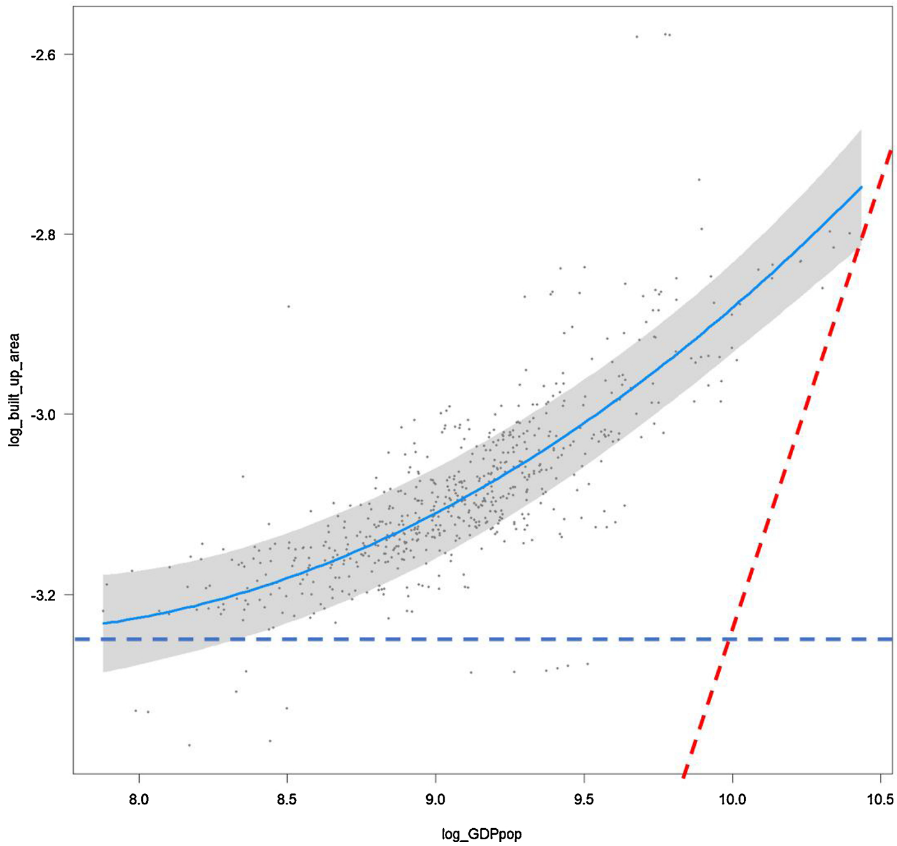

Fig. 3. Marginal effect of GDP per capita over residential built-up land based on model (16).

panels, enables us to estimate also the direct, indirect and total effects due to the spatial multiplier. The direct, indirect and total effects based on the Spatial Lag Panel Model are reported in Table 3 and refer to model (16) in Table 2.

The values of the direct effects are in line with the coefficient estimates, while the total effects are around 21% larger because they incorporate the indirect effects due to the spatial multiplier, obtained as $1/(1-\rho)$. In the case of model (16) in Table 2, it is equal to $1/(1-0.177) = 1.21$. Residential built-up land in a certain county *i* is determined jointly by the stage of development of the county in which it is located and the surrounding counties. This phenomenon, namely spatial spill-over, can be explained by the fact that, as wealth increases in these neighbourhoods, people may decide to invest not only where they live, but also in the neighbouring counties, thus increasing their built-up land. Analogously, a shock hitting the available income in one county has repercussions in the real estate market of the neighbouring counties, and back to the first one through the spatial multiplier.

Finally, mention should be made of LeSage and Pace's study (2009), which introduced a partitioning technique that can be used to compute the coefficient estimates by different orders of neighbours, determining their relative importance in explaining residential built-up land. The results of this analysis, available upon request, show that spatial spillovers are confined to the immediate neighbour. This is reasonable given our units of observation, and demonstrates not only that what happens in a county is not independent from what happens in neighbouring counties, but also that the phenomenon of polarization and of "clusterization in nature" observed in Fig. 2 and Fig. A1 in Appendix A holds also when we control the built-up land dimension. This has major policy implications that will be discussed in the following section.

To better understand the residential built-up land dynamics, the estimates are replicated by considering as dependent variable the city size as proxied by the share of hectares of urban area on the total number of hectares of each county.[12] The results, set out in Tables C1 and C2 in Appendix C, are close to those in Tables 1 and 2, indicating not only that built-up area and city growth are closely related (the correlation between them is 0.85) but also that, specifically, these

Table 3
Direct, Indirect and Total Effects Estimates.

	direct		indirect		total	
Log(GDP/pop)	−0.7711	***	−0.1590	**	−0.9302	***
	(-2.7300)		(-2.1042)		(-2.7118)	
$Log(GDP/pop)^2$	0.0523	***	0.0108	**	0.0631	***
	(3.3427)		(2.3484)		(8.7259)	
Population density	1.0253	***	0.2114	***	1.2367	***
	(10.1004)		(3.0602)		(8.7259)	
Population $density^2$	−0.0059	***	−0.0012	***	0.0071	***
	(-8.9614)		(-2.9681)		(-7.8249)	
Share of green areas	2.7777	*	0.5728		3.3503	*
	(1.8011)		(1.5655)		(1.8061)	
Number of buses over area	7.6951	*	1.5870	*	9..2820	*
	(1.9295)		(1.6771)		(1.9371)	
Net migration over pop.	0.5504		0.1135		0.6639	
	(0.2848)		(0.2567)		(0.2819)	

Note: $^*p \leq 0.05$; $^{**}p \leq 0.01$; $^{***}p \leq 0.001$. Z-values based on 1000 permutations in parenthesis for the direct, indirect and total effects in parenthesis. Estimates are based on model (16) in Table 2.

[12] According to the indicator "GOS102A - Inside town area of municipalities and towns by counties and localities", of the TEMPO database, "The built-up area (ha) represents the territorial area comprised in the buildable perimeter of municipalities and towns, including the localities belonging to municipalities and towns, according to the systematisation plan approved for that locality. The area of villages which belong to the municipality (the town) is not included."

findings confirm what Iaţu and Eva (2016) found, i.e. that in Romania the increase of built-up areas coincides with city expansion and its suburbanization. In this regard, Ionescu-Heroiu et al. (2014: 40) show that the development patterns of new housing units from 1990 to 2011 confirm that the Romanian population is concentrating around key economic centres, including suburban areas that may offer better living standards at a more affordable price. Suburbs around major cities gained around 300,000 inhabitants between the 1990 and 2011 Censuses, while the country's total population decreased by 4 million people. The suburbanization process, according to Sýkora and Ouředníček (2007), affects the spatial distribution of the population and increases inequalities (Petrovici, 2012). Indeed, contrary to the traditional socio-spatial patterns of the socialist cities, suburban zones are now characterized by élite persons with high incomes (Ouředníček, 2007), causing social tensions and residential segregation (Soós and Ignits, 2003) in territories traditionally populated by the working class and inhabitants of the former rural settlements.

Finally, it is worth mentioning that, as a robustness check, we estimated both models (standard and spatial) by means of random effects, and the results hold.

5. Discussion

In light of the main results of the analysis, we discuss the potential causes behind land use dynamics in Romania and identify a role for policy interventions. Our first main finding demonstrates that there is a convex relation between economic development and residential built-up land, which contrasts with the classic inverted U-shape predicted by the EKC. This outcome, despite its contrast with some recent empirical analyses conducted on the relation between income and environmental variables (see, among others, Skonhoft and Solem, 2001; Culas, 2007; Liu and Guo, 2015), is not an isolated case in Europe, because it has been found by Bimonte and Stabile (2017a; 2017b) for Italy. Differently from previous studies, however, we extend the classic EKC framework to include spatial effects explicitly, which yield useful information that enables us to draw additional policy implications.

In the Romanian case, the increasing marginal effects of GDP per capita on residential built-up land and thus on city expansion can be explained by various alternative factors.

One of them is the weak institutional framework and the lack of transparency of the public administration (data from Worldwide Governance Indicators) and contradictory policies that have made land speculation possible (Niţă et al., 2015). Tudor et al. (2015), indeed, show that the land-use regulation has been not properly implemented in recent years, leading to an increased likelihood of distressed situations (Iojă et al., 2014; Tudor et al., 2013). According to BTI (2018: 26), "the central government has used various mechanisms and legal loopholes to prevent local government from actually increasing its leeway or making autonomous decisions in a large number of policy fields. On the other hand, many local decisions, taken in the previous climate of loose budget constraints, were clientelistic or simply wasteful". Local authorities took advantage of urban sprawl as a way to increase their budgets through new taxation areas (Suditu, 2012). The resulting spatial pattern, as observed by Sýkora and Ourednek (2007) contrasts with the compact built-up areas developed during the communist period. This increased land speculation leads to urban fragmentation (Hirt, 2013). Furthermore, agricultural land abandonment, which characterised Romania after the transition (Kuemmerle et al., 2009), has been proved to be a precursor of built-up development at the sprawling peripheries (Grădinaru et al., 2015a) that compromise the sustainable development of the urban landscape as long as urban planning is not under control and the collaboration among authority levels is rather weak (Grădinaru et al., 2015b).

Another interpretation of our results is that the transition in the past two decades from a centrally planned structure to a decentralised one, and the EU accession in 2007, have resulted in a complex regulatory framework. During this process, several land laws[13] have been promulgated to discipline decollectivisation and privatisation of the previous state-owned land since the first law No 18/1991 also known as "The Land Law", and the national land policy has been harmonized with the Common Agricultural Policy (CAP) prescriptions. As a consequence of both the switch from the state to a private regime and the convergence on EU criteria, local governments have experienced an even greater knowledge lag about the quality of individual properties, including the property rights, thus facing huge urban planning and management challenges. Information asymmetry may arise between economic agents with local administrations that may find it convenient to grant additional building permits to maximise their revenues at the expense of an excessive and unsustainable urban development (Suditu, 2012). Furthermore, the positive and significant spatial lag, which accounts for the second main result of the analysis, can be interpreted as evidence of policy mimicking among neighbours, as found for example by Revelli (2001) in the UK context. This implies that, with the aim of not leaving all the advantages of additional revenues from granting building permits to the neighbouring governments, local governments of a certain county may grant higher "urbanistic freedom" in response to the neighbours' behaviour. Private agents, on the other hand, might find it preferable to behave like their counterparts in the neighbouring counties so as not to leave them all the advantages of the rising real estate prices. These results extend the win-win game observed for Italy by Bimonte and Stabile (2017a; 2017b), where public and private interests, together with institutional and political elements, interact in a spatial context.

An additional result of the analysis is the robustness of the existence of a convex relation between residential built-up land and per capita GDP to the inclusion of additional explanatory variables, namely population density, natural amenities, public transport and net migration. Therefore, in what follows, the discussion will focus upon those factors and their different roles in affecting the residential built-up pattern.

Regarding the effect of population density, a possible interpretation of the mechanisms responsible in Romania for its positive relation with the extensive built-up land use can be, as documented by the World Bank (2013), the fact that population distribution in major cities follows what is known as a 'camel-back' pattern, i.e. a city's periphery has a higher population density than the central business district. This is related to the post-communist suburban residential preferences that led to the increasing urbanization of suburban municipalities adjacent to major cities (Ionescu-Heroiu et al., 2014) due to the inability to reconfigure the fixed capital stock of central cities, driving a very rapid rate of expansion of major Romanian cities (World Bank, 2013). Furthermore, the lack of policy vision and planning of the local public administration has contributed to generating chaotic and unsustainable sprawl, prioritizing private financial profits rather than public interest (Nae et al. 2019). This process has been due to the mass privatization (Buckley and Mathema, 2017) supported by the financial sector. In Romania, indeed, monthly mortgage payments are equal to, or even lower than, monthly rental payments, pushing up the homeownership rate contributing to suburbanization (Grigorescu et al., 2012b; Iaţu and Eva, 2016).[14] Romanian banks offer a special credit that is guaranteed by the Government, which in 2009 launched the First Home program to restart mortgage lending and support the construction sector in the aftermath of the financial crisis (Government Urgency Ordinance no.

[13] Among several laws (No 15/1990, No 31/1990, No 169/1997, No 1/2000) that influenced the land changes, the more recent No 198/1999 and No. 46/2000 were legislated to reorganize the state-owned farms into private trading companies.

[14] According to Eurostat, Romania has the highest homeownership rate in Europe in 2016. About 96% of Romanians own their residential properties. Moreover in 2016 the highest rate of people living in overcrowded dwellings among the Member States was registered in Romania (48.4%), followed by Latvia and Bulgaria.

60/2009 and Government Decision no. 717/2009).

The positive and statistically significant coefficient associated with the intrinsic value of natural and environmental amenities may be associated with their scarcity (Suditu et al., 2004) due to the transition process that came at the expense of the conversion of green and agrarian landscapes into built-up land with industrial and residential uses. This is demonstrated by the fact that, in light of their importance, and given that in Romania environmental changes are the catalyst for land-use conflicts (Ianos et al., 2012), as a consequence of the EU accession, a sustainable urban policy process has been framed. Indeed, currently, to comply with the EU Policy on urban environment as stated by the 7th Environmental Action Programme (7EAP) under the Priority Objective 8 on Sustainable Cities, in 2006 the Romanian government promulgated law no. 265/2006 for the environmental protection of soil through adequate interventions of management and conservation.

Regarding the positive effects of the variable that proxies public transport, to be noted is that, according to the World Bank (2013), public transport provision is crucial in Romania given that uncontrolled urban expansion due to planning fragmentation has increased pressures on transport infrastructure and utilities. However, public transport provision, because people are disposed to pay more for housing located near easily accessible services, may push up the residential built-up land use and urban expansion (see Cervero and Kang, 2011).Towards the end of the 1990s, Romania started to receive support to strengthen its public transport system from the European Bank for Reconstruction and Development and international donors. Thereafter, from 2007, the EU structural funds contributed to subsidising the process. The policy objective to create an integrated transport network, given that the private car is the prevalent means of transport in the country (Iordache, 2009 and Eurostat data), is now even more urgent as urban sprawl is likely to increase (Ianţu et al., 2011). However, since public transport plays an important role in city expansion, fares should be kept at market level because, if artificially low, they could lead to unsustainable (sub)urban development patterns that incentivize, for example, commuting from the suburbs instead of living closer to the city centre (World Bank, 2013).

Finally, the coefficient of net migration is found not to be significant. Considering that Romania is losing population, the net outflows may impact indirectly on the residential built-up land use through the role of remittances for real estate purposes. Indeed, as observed by Mehedintu et al. (2020), in Romania, people's decreasing intention to engage in productive activities, relying on remittances, and the rise of inflationary pressure due to the excessive demand for land and houses caused by the artificial increase of their prices may be listed among the possible negative effects of remittances. In our study, however, the unavailability of data on remittances prevents us from investigating further the lack of significance of our variable, which might be due to the fact that (i) it does not proxy remittances well, or that (ii) remittances do not have the foreseen impact.

In view of the SDGs on socially sustainable spatial planning and of the EU Urban Partnership and the New Urban Agenda, the empirical evidence presented in this paper suggests various possible policy interventions. A first concern consists not only in the need to strengthen the institutional framework, to design an accessible and transparent cadastral system, and close the housing legislation lag, but also to rethink the main channel through which local governments collect their revenues, lowering the importance of property taxes. Another option, aimed at limiting real estate speculation, is to improve the legal rent control with more severe protection measures for the parties and to provide incentives for restructuring houses rather than building new ones. This last point, framed in a wider context of urban regeneration, would improve living standards in cities and suburbs, mitigating the rise of house prices in order to respect habitat preservation. A more flexible approach to land-use planning recommended by the OECD (2017) requires co-ordination across all levels of government as well as across policy domains, to be timelier and adaptable to new challenges. Accordingly, horizontal policies like transport policy, environmental and building code regulations, spatial framework plans and population mobility have to be integrated with each other and, as demonstrated in our paper, coordinated among neighbours to avoid freeriding behaviour and to promote sustainable development.

6. Conclusions

In this paper, we have analysed the relationship between GDP per capita and residential built-up land among Romanian NUTS3 regions.

Romania is an interesting case study not only *per se*, as it is little explored in the literature, but also because it is one of the poorest EU member states, that could be taken as a reference to analyse similar contexts. Besides the convex relation between residential built-up land and economic development, the relation between city size and economic development has also been considered, leading to the conclusion that the mass residential built-up land expansion in Romania mainly reflects the process of city expansion and urbanization phenomena such as sprawl or suburbanization. Generally speaking, however, although the EKC, even with the explicit inclusion of spatial spill-overs, is a tool easily applicable and understandable, it is not always possible to model the factors affecting the land use conversion because they differ among countries, among regions, and over time even within a single country. In the context of the EKC for residential built-up land, our study, like similar studies in the literature, has relied on a relatively short time span, due to data limitation. However, to assess the general validity of the EKC for residential built-up land, an extension using longer time series is required in the future. Furthermore, our approach to the EKC reveals its limitation, because prescriptions in terms of the environmental impact of excessive land use cannot be drawn directly from its analysis *per se*; rather, they require a literature overview that indirectly allows one to infer the negative implications for the environment of the suburbanization process and sprawling phenomena. In our context, the geography of inequalities, the role of migration flows and remittances, which contribute to explaining how population distributed in the urban space in the post-socialism period, their causal relation with the built-up land consumption and the social and environmental consequences deserve further attention. Finally, another aspect that warrants investigation in the future is the effect of the state-to-private regime switch and its consequences in terms of intensive spatial urban/suburban development among the Central and South-Eastern European states.

Authors statement

The authors contributed equally to this work.

Acknowledgements

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Appendix A

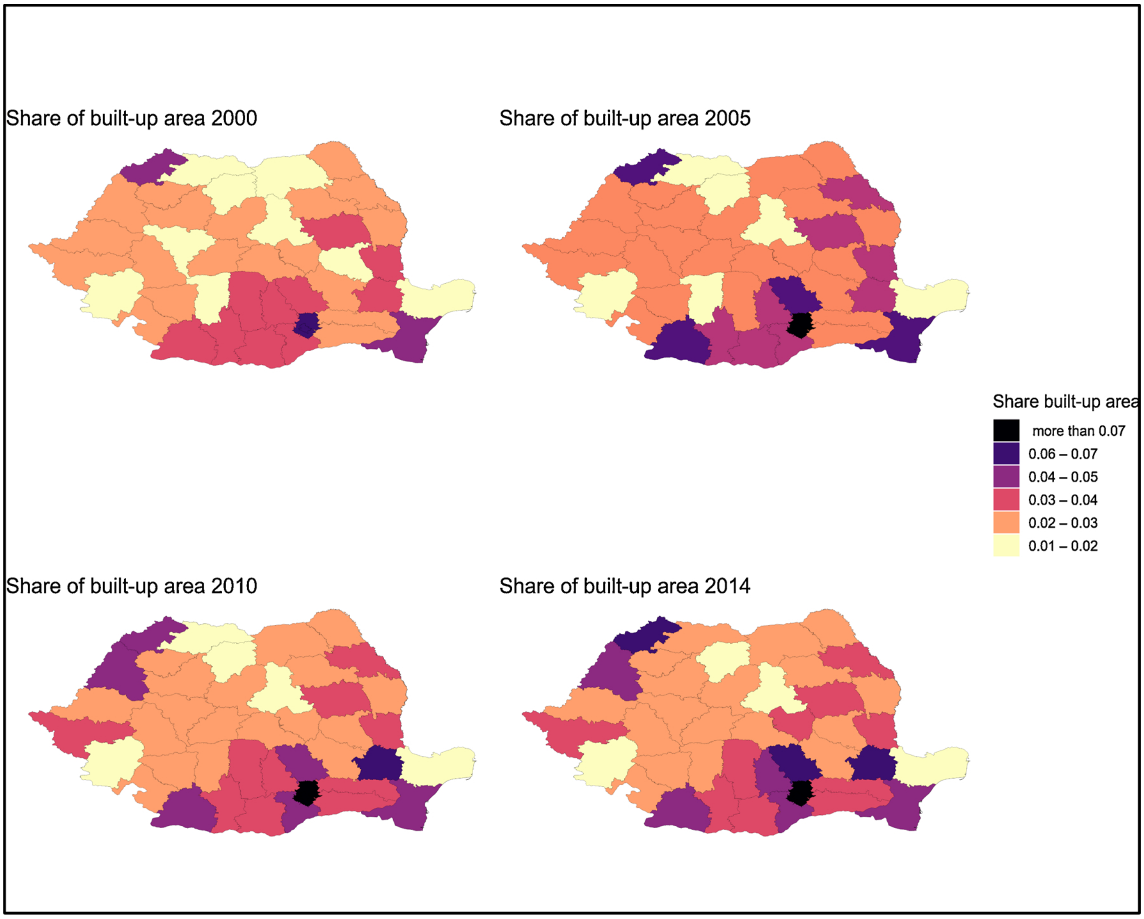

Fig. A1. Residential built-up land over the 2000-2014 period by NUTS3.

Appendix B

Table B1
Descriptive statistics.

Variable	Min.	Mean	Max.	Std. Dev.
Log(Share built-up area)	−4.6388	−3.5070	−0.4081	0.6176
Log(Share area occupied by cities)	−5.5540	−4.1760	−4.000	0.8086
Log(GDP/pop)	7.8800	9.0790	10.4360	0.4210
Population density	0.2920	3.0296	90.8860	13.6843
Share of green areas	0.00008	0.0051	0.2034	0.0286
Number of buses over area	0.000009	0.0015	0.0651	0.0085
Net migration over pop.	−0.0017	−8.954e-05	0.0153	0.0011

Appendix C

Table C1
Panel Estimates on city size.

	(1a)	(2a)	(3a)	(4a)	(5a)	(6a)	(7a)	(8a)
Log(GDP/pop)	−1.6796 ***	−1.7029 ***	−0.4096	−2.0578 ***	−1.6771 ***	−1.9155 ***	−1.4925 ***	−0.7195
	(0.4652)	(0.4661)	(0.4652)	(0.4665)	(0.4768)	(0.4817)	(0.4891)	(0.4838)
Log(GDP/pop)^2	0.1174 ***	0.1189 ***	0.0474 *	0.1389 ***	0.1172 ***	0.1309 ***	0.1073 ***	0.0650 **
	(0.0259)	(0.0259)	(0.0259)	(0.0260)	(0.0265)	(0.0268)	(0.0273)	(0.0269)
Pop. density		0.0399 ***	1.5238 ***				0.4730 ***	1.4939 ***
		(0.0045)	(0.1804)				(0.1073)	(0.1805)
Pop. density^2			−0.0091 ***					−0.0083 ***
			(0.0012)					(0.0012)
Green areas				12.3596 ***			13.8868 ***	11.1336 ***
				(2.8483)			(2.8303)	(2.7525)
Buses/area					−0.1587		−10.6507	−2.8377
					(6.6391)		(6.9496)	(6.7824)
Net migr./pop.						4.7273	3.5396	−0,3658
						(5.6027)	(5.2841)	(5.1160)
Turning point	1278	1288	–	1648	1280	1505	1048	–
Observations	630	630	630	630	630	630	630	630
R squared	0.4490	0.4848	0.5097	0.4662	0.4490	0.4298	0.4841	0.5232
(adj.)	(0.4086)	(0.4833)	(0.4719)	(0.42604)	(0.4076)	(4.7273)	(0.4792)	(0.4838)
AIC	−672.754	−684.047	−710.27	−690.712	−670.755	−671.551	−706.269	−704.269
Moran's I	0.0487 **	0.0488 **	0.1114 **	0.0912 ***	0.0486 **	0.0592 **	0.0161	0.1583 ***
LM spatial lag	7.1896 *	6.0040 **	18.6343 ***	18.5237 ***	7.1764 ***	7.0383 ***	11.8000 ***	34.8632 ***
LM spatial error	3.3558 ***	2.6471 *	17.5724 ***	11.8000 ***	3.3418 *	3.2442 *	18.5237 ***	35.4772 ***
Robust LM spatial lag	7.0323 *	6.2242 **	2.1008	8.3864 ***	7.0571 ***	7.0467 ***	1.6628	2.4774
Robust LM spatial error	7.0323 ***	2.8672 **	1.0389	1.6628	3.2225 *	3.2526 *	8.3864 ***	3.0914 *
Hausman test	7.4798 **	4.566	44.823 ***	14.458 ***	43.104 **	7.4931 *	15.64 **	50.88 ***
Reset test	6.06	24.72	5.777	67.72	1.98	1.85	0.43	14.94
	(p-val. = 0.01)	(p-val < 0.01)	(p-val = 0.01)	(p-val < 0.01)	(p-val = 0.160)	(p-val = 0.175)	(p-val = 0.51)	(p-val < 0.01)
Breusch-Pagan test	192.82	46.45	12.72	51.79	46.80	195.83	45.18	17.72
	(p-val < 0.01)	(p-val < 0.01)	(p-val = 0.01)	(p-val < 0.01)	(p-val < 0.01)	(p-val < 0.01)	(p-val < 0.01)	(p-val = 0.01)
VIF	1.815	1.854	2.039	1.873	1.815	1.817	1.938	2.097

Note: $^*p \leq 0.05$; $^{**}p \leq 0.01$; $^{***}p \leq 0.001$. Std. errors in parenthesis. Turning point is calculated as the exponential of the coefficient of Log(GDP/pop) over two times the coefficient of Log(GDP/pop)^2. Prices are expressed at 2005 Lei constant prices.

Table C2
Spatial Panel Estimates on city size.

	(9a)	(10a)	(11a)	(12a)	(13a)	(14a)	(15a)	(16a)
Log(GDP/pop)	−1.5718 ***	−1.5351 ***	0.0013	−1.9104 ***	−1.4917 ***	−1.5782 ***	−1.8780 ***	−0.3432
	(0.4617)	(0.4612)	(0.4417)	(0.4508)	(0.4573)	(0.4615)	(0.4720)	(0.4512)
Log(GDP/pop)^2	0.1089 ***	0.1075 ***	0.0202	0.1266 ***	0.1043 ***	0.1091 ***	0.1251 ***	0.0379
	(0.4617)	(0.0257)	(0.0245)	(0.0251)	(0.0255)	(0.0257)	(0.0263)	(0.0251)
Pop. density		0.0391 ***	1.6119 ***				0.0066 ***	1.6057 ***
		(0.0048)	(0.1713)				(0.0089)	(0.1683)
Pop. density^2			−0.0099 ***					−0.0095 ***
			(0.0011)					(0.0011)
Green areas				16.8302 ***			14.6951 ***	15.4915 ***
				(1.7952)			(2.7765)	(2.5671)
Buses/area					1.1075		1.4544	2.8809
					(6.3677)		(6.5602)	(6.3256)
Net migr./pop.						4.3297	4.0807	−1.9299
						(5.3639)	(5.2542)	(4.7715)
Turning point	1362	1261	–	1891	1275	1384	1819	–
Rho	0.1013 **	0.0758 *	0.1610 *	0.1627 ***	0.0959 **	0.1002 **	0.1497 ***	0.2407 ***
	(0.0448)	(0.0445)	(0.0425)	(0.0436)	(0.0442)	(0.0446)	(0.0462)	(0.0436)
Observations	630	630	630	630	630	630	630	630
AIC	−679.385	−689.898	−758.251	−707.540	−677.415	−678.082	−721.586	−784.637
Moran's I	0.2127 ***	−0.0336	−0.0396	−0.0095	−0.0272	0.2119 ***	−0.0595	−0.0313
Hausman test	4.0319	6.1865	6.1865	6.1078	28.742 ***	0.5619	13.045 *	22.772 ***
Reset test	0.10	19.47	2.84	19.47	0.37	3.08	11.30	3.76
	(p-val = 0.90)	(p-val < 0.01)	(p-val = 0.02)	(p-val < 0.01)	(p-val = 0.78)	(p-val = 0.027)	(p-val < 0.01)	(p-val < 0.01)
Breusch-Pagan test	24.27	28.61	9.21	28.61	24.61	24.01	8.70	4.91
	(p-val = 0.99)	(p-val = 0.96)	(p-val = 1)	(p-val = 0.96)	(p-val = 0.99)	(p-val = 0.99)	(p-val = 1)	(p-val = 1)
VIF	1.815	1.854	2.039	1.873	1.817	1.815	1.938	2.097

Note: $^*p \leq 0.05$; $^{**}p \leq 0.01$; $^{***}p \leq 0.001$. Std. errors in parenthesis. Turning point is calculated as the exponential of the coefficient of Log(GDP/pop) over two times the coefficient of Log(GDP/pop)^2. Prices are expressed at 2005 Lei constant prices.

Appendix D. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.landusepol.2020.104695.

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