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Types of planning systems and effects on construction material volumes: An explanatory analysis in Europe

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ABSTRACT

The management of material stock is central for reducing emissions and for optimizing natural resource use. Construction materials are particularly the key because of their role in emission, resource use, and waste management concerns. However, the role of governance and spatial planning in the management of construction minerals is unclear. Based on a panel dataset of 35 European countries for 1995–2017, this study assesses the effect of governance and spatial planning factors, as well as of core socio-economic indicators (namely, GDP per capita, urbanization, and economic structure) at the national level According to the results, the types of spatial governance and planning systems significantly shape the effects on construction material use. Such effects range from − 67–215% relative to the most widespread system, i.e., the conformative system. Economic structure and urbanization have a positive feedback effect on the accumulation process at any level of development. In addition, the ability to resist excess material accumulation encoded by urbanization and economic transition is determined by spatial governance and planning systems. Additionally, a specific planning culture employing a moderate amount of construction material compared to other spatial governance and planning systems, i.e., the neo-performative system, is identified as a promising means to reduce significantly resource demand both in market- and state-led planning contexts.

1. Introduction

Material stock consists of the fixed infrastructure of the manufacturing and service providing companies, households, and governments, like machinery, roads, railways, and durable goods. Material stock accumulation has become a significant driver of natural resource use since the industrial revolution. The dynamics of this very process have shaped the environment significantly throughout modern history. The share of stock building materials used in the extraction of natural resources increased from 20% to 58% globally between 1900 and 2010 (Krausmann et al., 2017). The dominant part of the stock building materials is construction minerals (e.g., sand, gravel, aggregates, cement, stone), with a share above 95% of all non-metallic minerals extracted annually (UN IRP).

Material stock accumulation in the form of dwellings and other infrastructures supporting production and consumption processes (e.g., roads, vehicles, and productive capital) determines environmental impacts together with societal flow-type resource use (Berill et al., 2019). Furthermore, material stock accumulation is strongly correlated with GHG emissions (Lin et al., 2017). Buildings and other infrastructures constitute the dominant proportion of energy consumption and carbon emissions, as 55% of all GHG emissions are related to buildings, transportation, and energy systems (Ellen MacArthur Foundation, 2019). Buildings alone are responsible for one-third of global energy consumption and carbon emissions; however, they may double when embodied carbon emissions are accounted for (Resch et al., 2020).

Consequently, the material stock provides valuable services to society (dwellings, mobility, production, and consumption) on the one hand. It yet acts as a key driver of resource use, technological lock-in, raw material scarcity, and challenging waste management problems on the other. Carmona et al. (2020) argue that the quality of services delivered to society is frequently dependent on the material stock rather than flows alone. Material stock accumulation is regarded, therefore, as a central process of future emissions, and resource use (Haberl et al., 2017, 2019; Weisz et al., 2015), and it is fueled mainly by extractions and processing of construction minerals.

Besides the relevance of the material stock in the environmental impacts, affluence, economic structures, and (urban) populations have

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already been recognized as major drivers of stock accumulation (Fishman et al., 2015; Han et al., 2018; Zhang et al., 2019). Furthermore, Shao et al. (2017) found significant effects of international trade and technology on the use of mineral resources under conditions of shallow economic growth and recession.

Major land use changes, i.e., urbanization, industrialization, tropical deforestation, desertification, and agricultural intensification, accompany various inter-connected effects on human well-being, economic performance and ecosystem functions occurring at different scales, from local to global (Chhabra et al., 2006). Determination of the land use changes are observed by Pincetl (1999) and Reid et al. (2006), for instance, even by policies aiming not to alter the land use per se (e.g., production subsidies, transportation development). Multiple adverse environmental impacts of land use changes on the ecosystem have been recognized decades ago; as biodiversity loss, soil degradation, changes in carbon and water cycle were highlighted in the literature, among other concerns after the mid-'70s (Lambin et al., 2006). Several forms of the land use change introduced above are associated with intensive material stock accumulation inevitably. Therefore, Todes (2012), for instance, advocates involving infrastructure development in strategic spatial planning more intensively.

The assessment of the role of economic and natural conditions and settlement types or land use patterns has a long tradition in analyses on energy demand, socioe-conomic metabolism, and GHG emissions (Minx et al., 2013; Jones and Kammen, 2013; Seto et al., 2014; Heeren and Hellweg, 2018). Nevertheless, the examination of interactions between land use policies and several adverse effects of economic development has only been launched recently through assessments of land use changes (Hersperger et al., 2018) and GHG emissions (Kuang et al., 2016; Leibowicz, 2017) in environmental and ecological economics-related fields. Land use and spatial planning are suspected of lying at the heart of material stock accumulation (Augiseau and Barles, 2017; Lanau et al., 2019; Wiedenhofer et al., 2015). As Chester et al. (2014) highlight, while 'hard infrastructure' (buildings, dams, machinery, etc.) performs as the environmental stressor itself, it is formed by 'soft infrastructure.' This soft infrastructure is built up by institutions such as policies, culture, spatial planning, and economic signals. Multiple actors influence, thus, the soft infrastructure, as politicians, professionals, users, and industries intend to translate their power into particular strategies, plans, investments; furthermore, the economic signals (prices, taxes, fees) depend on the same stakeholders.

Since the majority of material stock consists of buildings (residential and non-residential) and transportation infrastructure, how society manages space available for the hard infrastructure is crucial regarding the evolution of the built environment. It raises the question, thus, how the legal system, strategic planning, and investment decisions, among others, influence the volume of built-in material for society. Spatial planning practices like zoning, building codes, road network development, or nature conservation decisions determine the amount of the demanded construction materials fundamentally. However, examinations of this very relationship have been rather infrequent and based on local case studies, probably due to the challenging conceptualization of spatial planning in relation to material stock. Göswein et al. (2017) assessed the effects of different policy scenarios on residential housing-related GHG emissions in Johannesburg, South Africa. The promotion of denser, apartment-based housing was forecasted to reduce emissions by up to one-third of the BAU scenario by 2040. Han and Xiang (2013) estimated regional disparities of material stock accumulation in China. The authors found that the enhancement of local government administration performance significantly reduces the regional disparity of accumulation. Schandl et al. (2020) analyzed material stock accumulated in a suburban area of Canberra, Australia, in line with socio-economic changes from a historical perspective. Gao et al. (2020) identify the substantial role of a specific land use policy intervention (rural-urban land transition zones) in stock accumulation from a case study of Shanghai.

To the best of our knowledge, the current study constitutes the first attempt to quantify the relation between spatial planning and material stock accumulation at the macroscale by investigating temporal changes in construction minerals. As presented above, the interaction between land use or spatial processes and the socio-economic system is highly complex. Therefore, an operative approach was employed to extract the political, economic, and legislative determinants of spatial processes, namely the concept of spatial governance and planning by Rivolin (2012) and Berisha et al. (2020) introduced in Section 2.1. The study aims to assess the effect of spatial governance and planning on the utilization of construction minerals based on a panel dataset of 35 European countries from 1995–2017. The analysis considers drivers already analyzed as well, including GDP per capita, urbanization, and economic structure.

2. Methods and data

If one intends to define spatial planning as a factor of material stock accumulation, applying suitable variables is essential concerning the complexities of territorial governance. Therefore, this section first introduces the explanatory variable for spatial planning (2.1.), followed by a brief introduction of other variables (2.2.) These variables are frequently applied in the literature. Section 2.3 then specifies the model and describes the estimation procedure used.

2.1. Explanatory variables – spatial planning

Spatial planning refers to a broad range of legislative, political, and other actions and practices with the aim of a balanced distribution of resources supporting development, environmental protection, and other social goods and targets (e.g., rural development and regional equality) through an active influence on the allocation of available space (European Commission (EC), 1997). Describing and analyzing spatial planning is challenging concerning multiple grounds. For example, Faludi (2012) raises attention to the ambiguity of the multi-level governance of space or territory; in addition, as Reimer et al. (2014) report, spatial planning is an interdisciplinary arena of distinct actors with economic, environmental, industrial, social, and political motivations. Furthermore, organizational forms of planning vary among countries remarkably. Since this study aims to assess the relationship between the management of available space and material stock accumulation, an indicator or proxy for different spatial planning schemes is required, which will inevitably schematize this very notion to some extent.

In the literature, several measures have been proposed. Monkkonen and Ronkoni (2016) used the Doing Business indicator created by the World Bank to examine land use policies adopted in more than 600 cities of 150 developing countries. The indicator set records the duration and number of legislative actions required by a warehouse investment. Although data collection measures involved are comprehensive, these indicators are rather ill-suited to the present analysis, as bribery involved in permitting and conscious planning decisions cannot be handled separately, as they may manifest in longer approval processes. Attardi et al. (2018) established a composite indicator to assess the policy aspects of land use changes occurring in Italy. Their subindices address the dynamics of land use change, housing, and urban form. Peiffer-Smadja and Torre (2018) interpreted the ratio of accepted retail floorspace to the submitted value (approval rate) with a French case study. The ratio was used to indicate the suitability of national land use policies for controlling regional retail development. Their work presents a comprehensive overview of distinct conflicts of interest that occur along with governance levels. In a study by Han and Xiang (2013), the authors found that local government administration performance enhancement significantly reduces the regional disparity of accumulation. Nevertheless, governmental performance was measured as the average administration expense per employee, which may strongly correlate with the operative efficiency of a governance system.

However, the determination of the quality of spatial planning is unlikely.

For the current study, spatial governance serves as a suitable concept, as it may support a macroscale comparison of policies. In every state around the globe, spatial planning has been codified to some extent to guarantee public control over spatial processes. To this end, legal devices, administrative bodies, and cultures have been merged into an institutional technology connecting the public authority and the social use of space to ensure the allocation of rights and improvement of the physical environment (Rivolin, 2012). This institutional technology has been framed as the 'spatial governance and planning system' (SGPS) (Berisha et al., 2020).

Whereas a global assessment seems unrealistic due to the current lack of available evaluations of SGPSs, there has been an ongoing effort in Europe to classify different systems within the framework of an applied research program, namely, the European Spatial Planning Observation Network (ESPON). The ESPON supports the formulation of territorial development policies in Europe. The scope of its work is to reveal which model of institutional technology ensures planners' effective action towards an optimized allocation of space and resources.[2]

In Europe, a wide variety of SGPSs are observable (Dallhammer et al., 2018) for historical reasons and due to the relatively large number of independent states in the region (Rivolin, 2017). Based on a tradition of the evaluation of spatial planning models applied in ESPON projects, Berisha et al. (2020) clustered the countries of Europe into SGPSs. From a comprehensive set of case studies and qualitative assessments, 39 European countries were found to be characterized by the two aspects of spatial governance and planning, i.e., whether a system is market or state-led (spatial development model) and positioning with regard to the scale representing conformative/performative models of planning[3] (Fig. 1). While the former aspect addresses power relations between the market and state, the latter dimension addresses whether a decision on an investment is an object of predefined land use regulation such as zoning (conformative planning) or an object of individual evaluation and judgment (performative planning). A conformative spatial planning system dedicates all land use and development rights through generally applicable binding plans. In contrast, a performative one applies a case-by-case evaluation on the ground of a spatial development strategy. The neo-performative system operates with the conformative allocation of rights for land use and development at the local scale; however, binding plans are highly context-dependent and objects of inclusive negotiation with the actors (Rivolin, 2017). These country-related characteristics were applied as time-constant proxies for the institutional technology of spatial planning in the panel regression.

According to the first ESPON report analyzing spatial planning styles adopted in Europe, the styles are dynamic, as they tend to evolve over time. The report shows several countries shift their planning styles from the first 'EU compendium of spatial planning systems and policies' of 1997 to the report's publication in 2006. The classification developed by Berisha et al. (2020) used in this study, however, provides a static assessment of current systems, though it represents a basis of clustering using materials other than former reports. Reforms of spatial planning are observed in several periods; for instance, a turn to neo-performative systems occurred in the 1980 s in Sweden and 2000 in Denmark (Rivolin, 2017). Therefore, a modified model estimation was applied to a subpanel of data after the year 2000. The estimation results of this subpanel are similar to the results generated by the complete database (Table SI2). At the same time, the overall explanatory power of the model is decreased. In the absence of an assessment adopting a historical perspective, clusters of SGPSs incorporate a set of institutional traditions of the studied countries, which are assumed to be stable over the long run.

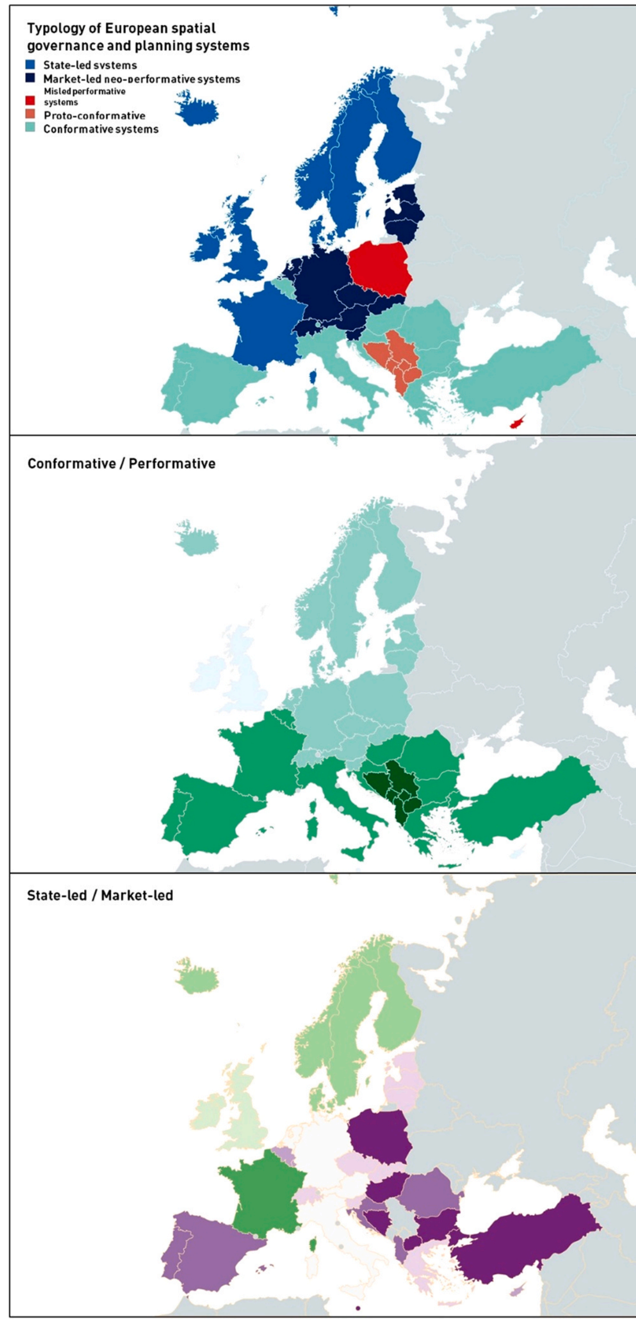

Fig. 1. Spatial governance and planning systems of European countries by Berisha et al. (2020). Figure legend: conformative (dark green) to performative (light green) systems are shown in the middle figure while dark colors indicate extreme values on the market-led (purple) and state-led (green) scale in the bottom figure.

2.2. Other variables

The natural logarithm of the domestic material consumption (DMC)

[2] Governance of Territorial and Urban Policies from EU to the local level (ESPON 2.3.2.), ESPON 2006; Territorial Approaches for New Governance (TANGO), ESPON 2013; Regional strategies for sustainable and inclusive territorial development – Regional interplay and EU dialogue (ReSSI), ESPON 2017; https://www.espon.eu/programme/espon/espon-2020-cooperation-programme

[3] The conformative and performative model of spatial planning introduced here does not correspond to the 'conformance' and 'performance' concepts, which are widely applied frameworks for plan implementation assessment (see for instance Mastop and Faludi, 1997; Lyles et al., 2016)

of construction minerals was defined as the dependent variable in the panel regression. The DMC covers all the raw materials extracted inland plus the net physical trade balance of that particular material category in mass. For the purposes of the current research, the UN Environment International Resource Panel's (UN IRP) Global Material Flows Database was used with disaggregation of material groups into 13 categories, as it is freely available and separates construction minerals.

As introduced above, population, affluence, economic structure, and urbanization are widely recognized as factors that influence material stock accumulation. In this regard, the World Bank's World Development Indicators dataset was used as the source data. Affluence was measured as the natural logarithm of GDP per capita in constant 2010 USD. The economic structure was measured from the share of services in value added while urbanization was measured as the ratio of urban citizens in the total population. Both ratios are represented in percentages. In a few cases, data shortages were observable for the beginning of the covered period, so empty data points were estimated based on the linear trend of the following ten-year period.

Hence the total population shows no correlations with the construction material use per capita for our sample of 35 European countries for 1995–2017 (see the complete list of countries considered in the Supporting Information, Table SI1). Thus it was excluded during the panel regression analysis. This is probably due to the downward demographic trends of European countries; their stock accumulation supports other societal needs, which are likely driven by emerging wealth. Kasanko et al. (2006) found that urbanization trends in EU-15 were somewhat independent of population dynamics but affected by geographic, historical, and land use policy factors. Pu et al. (2020) emphasize in their study on Chinese cities that spatial planning has a significantly more substantial impact on carbon emission than population growth, as altered consumption patterns and productivity of urban citizens due to urbanization outweigh the demographic effects. Collier and Venables (2017) also revealed public policies' primacy aimed at coordination, investments, and proper allocation on other development factors.

2.3. Panel regression

The country-specific characteristics of SGPSs are explanatory variables of primary interest. These variables were adopted from the study by Berisha et al. (2020) directly. Hence, these variables are time constant, and the random effects model is advised, given the aims of this work. Random effects estimation assumes that individual characteristics are exogenous, i.e., all regressors are independent. However, the Hausman test results report inconsistency of the estimated model due to the endogeneity of one or more regressors, namely, at least one regressor's actual value is a result of others' performance. At the same time, the F test for individual and time effects shows significant fixed effects, i.e., there are individual differences between the elements in the panel. Consequently, a pooled ordinary least squares (OLS) estimation delivers no robust results, and the fixed effects model eliminates time-constant variables (spatial planning). In contrast, the random effects model is inconsistent due to endogenous individual random effects. This problem was solved by applying the Hausman and Taylor model (Wooldridge, 2001).

The Hausman test for endogeneity reports that the categorical variable of SGPS type is endogenous, as the null hypothesis of independent error terms was rejected. Thus, its two dimensions, i.e., values on scales of spatial planning (conformative/performative) and the spatial development model (market led/state led), were used as instrumental variables in the model. Weak instrument and Sergan tests results indicate that the instruments are valid since no covariance is detected between the error term and the instruments.

Additionally, several interactions were detected between the instrumental and other variables (Fig. 3). After including these interaction terms, the explanatory power of the model improved. The specification of the model is given by

$$\ln(DMC_{min}) = \beta_0 + \quad \beta S + \quad \beta U + \quad \beta \ln(GDP) + \beta Spat + \beta(S * \ln(GDP)) + \quad \beta(S * U) + \quad \beta(U * \ln(GDP)) + \quad \beta(S * U * \ln(GDP))$$

where DMC_{min} is the per capita domestic material consumption of construction minerals, S is the share of services in gross value added, U is the share of the urban population, GDP is gross domestic product per capita, and Spat is the spatial planning factor based, on external instrumental variables of the spatial development model (state-led/market-led) and model of planning (conformative/performative).

Marginal effects of variables (Table 2) with interaction terms were calculated by applying different levels of the given variable, ceteris paribus. The results were estimated using the plm package of open source software program R. The data and R code were published for public access in a scientific data repository (SI3).

3. Results and discussion

3.1. Estimation results

The estimation results of the model are presented in Table 1. The type of SGPS employed has a remarkable effect on construction material use. Except for the effects of 'market-led neo-performative systems,' these effects are statistically significant. In the random effects model, all of the SGPSs indicate significant effects at the 5% significance interval with similar effect directions as those of the results gained by the Hausman-Taylor estimator in Table 1. The category 'conformative systems' was defined as the reference. Therefore, the panel regression results concerning SGPSs report the predicted effect of SGPS conversion to another type on the logarithm of construction minerals DMC.

3.2. The role of spatial governance and planning in resource demand

The link between SGPSs and socio-economic factors (GDP and DMC) is introduced in Fig. 2. Compared to the spatial development model

Table 1
Model estimations (Hausman-Taylor estimator).

	Estimate	Std. Error	p-value
Intercept	-3.3145e+ 01	4.8223e+ 00	6.271e-12***
SGPS			
Market-led neo-performative systems	*-2.2408e-01*	*5.3313e-01*	*6.733e-01*
Misled performative systems	*1.1400e+ 00*	*6.2214e-01*	*6.690e-02.*
Proto-conformative systems	*1.1530e+ 00*	*6.4982e-01*	*7.600e-02.*
State-led systems	*-1.1022e+ 00*	*3.9067e-01*	*4.783e-03***
Share of services (%)	6.7149e-01	9.3871e-02	8.473e-13***
Urban population (%)	3.1506e-01	8.1073e-02	1.019e-4***
ln(GDP per cap)	3.2054e+ 00	5.3839e-01	2.620e-09***
Services*ln(GDP per cap)	-5.7765e-02	9.7710e-03	3.382e-09***
Services*Urban population	-1.0597e-02	1.5350e-03	5.081e-12***
Urban population*ln(GDP per cap)	-2.4154e-02	8.3720e-03	3.913e-04**
Services*Urban population*ln (GDP per cap)	8.7411e-04	1.4907e-04	4.543e-09***

Reference SGPS category: conformative systems
Signif. codes: 0 '*** ' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Total Sum of Squares: 121.1
Residual Sum of Squares: 802.21
R-Squared: 0.54133
Adj. R-Squared: 0.53497
Chisq: 938.134 on 11 DF, p-value: < 2.22e-16

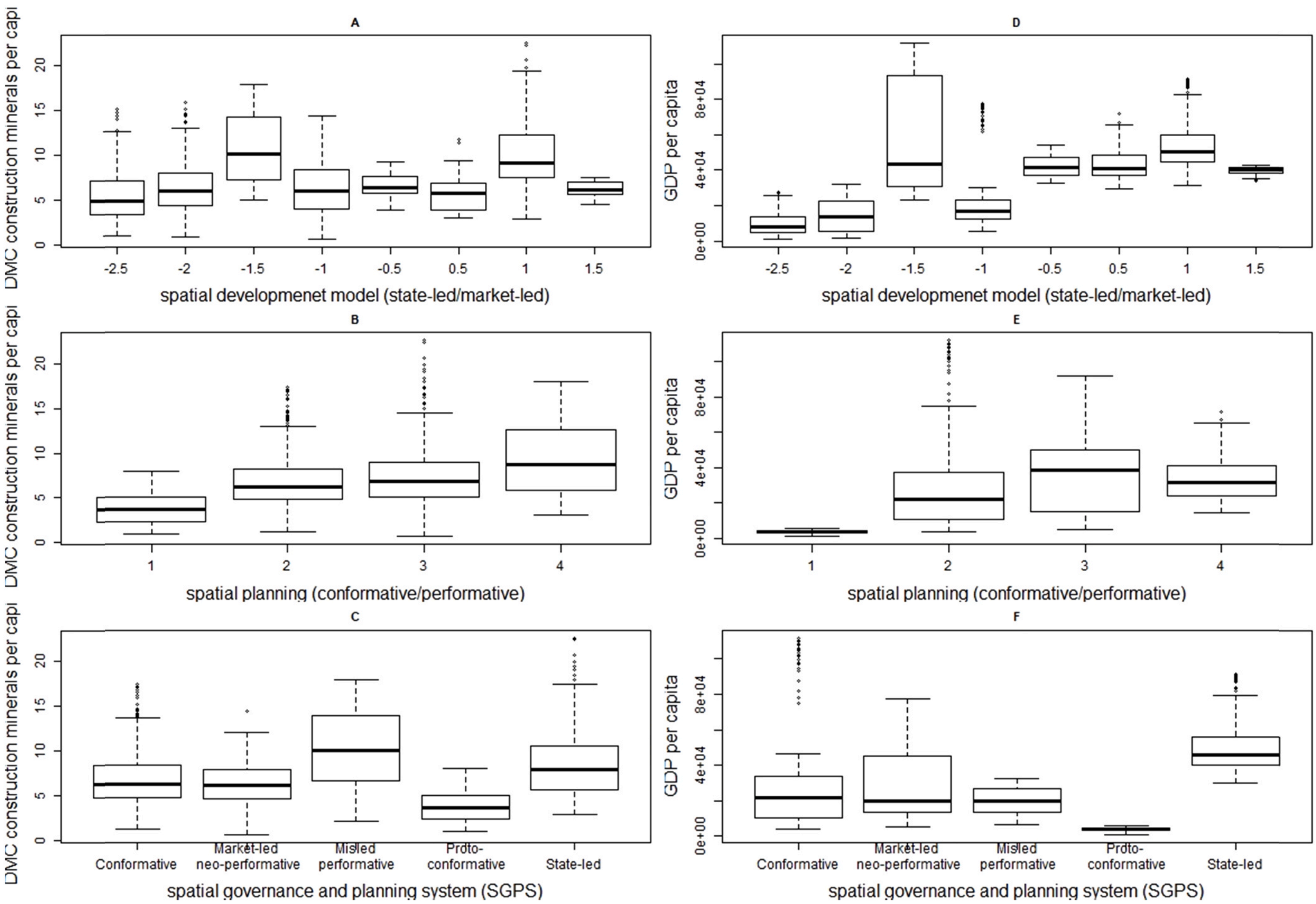

Fig. 2. Construction material use and affluence relative to the two dimensions of spatial governance and planning system (SGPS) classification. The scale on the horizontal axis refers to the original classification given in Berisha et al. (2020), i.e., values of the spatial development model increase as the model turns to state-led extremes (two panels on the top, A and D) while a zero value denotes ideal conformative spatial planning (two panels in the middle, B and E).

(state-led/market-led, panels A and D), the spatial planning style (conformative/performative, panels B and E) explains the material use of construction minerals more precisely out of two dimensions of SGPS clustering, as Fig. 2 shows. The former variable is linked to economic performance as well as to the practical power relation between the state and other actors, which is biased in many cases by corruption, illegal developments, and inadequate public control over spatial development (Berisha et al., 2020).

An ideal conformative spatial planning system (zero value on the scale of spatial planning) would allocate all land use and development rights through generally applicable binding plans, while an ideal performative system would allocate on a case-by-case basis based on the spatial development strategy imposed. Most systems globally are closer to the conformative style, while performative systems have emerged since World War II, mainly in countries sharing a Commonwealth history (Rivolin, 2017). The decision-making on investments is relatively straightforward in conformative systems, while performative systems tend to ensure flexibility in spatial planning (Muñoz Gielen and Tasan-Kok, 2010).

Fig. 2 reports increasing construction minerals DMC in countries adopting systems closer to those of performative spatial planning, though affluence does not follow the same path. Nevertheless, as panel D of Fig. 3 shows, there is no interaction between spatial planning and GDP per capita. In other words, emerging GDP per capita enhances construction mineral use in any spatial planning system while it is not exclusively explained by GDP per capita. Therefore, the planning system itself determines the dynamics of resource use. In contrast, the covariance of the predicted value of construction DMC and affluence is significantly stronger in the case of market-led systems (panel E, Fig. 3); therefore, state-led systems tend to be more likely to mitigate the adverse effects of economic growth.

There is a third hybrid spatial planning culture of particular interest, namely, the neo-performative system constructed first in northwestern European countries (Knieling et al., 2016; Rivolin, 2017). In this case, the conformative allocation of rights for land use and development is applied at the local scale; however, binding plans are highly context-dependent and objects of inclusive negotiation with the actors involved, whereas public authorities control them in more detail. The results presented in Table 2 and Fig. 2 imply that neo-performative spatial planning culture accompanies relatively low levels of construction material usage; hence, 'market-led neo-performative systems' (2) and 'state-led systems' (5) are both assigned to this category. The former requires 22% less material accumulation while the latter requires 67% less construction material use, all else being equal. Note, however, that the coefficient of market-led neo-performative systems is not statistically significant if the Hausman-Taylor estimator is used; however, both the pooled OLS and random effects models report similar coefficients (−0.259 and −0.394, respectively) at the 99% confidence interval. The case of the Slovak Republic illustrates an example of the neo-performative systems' lower resource use, as the Slovakian impressive GDP growth last years witnessed half of the construction materials' consumption of Bulgaria, and approximately 60% of the Hungary and Romania (all conformative systems), despite the similar history and development path. The majority of highly developed European countries belong to neo-performative SPGS. Their construction material usage is eighter stable (e.g., Switzerland, Austria, Belgium), or

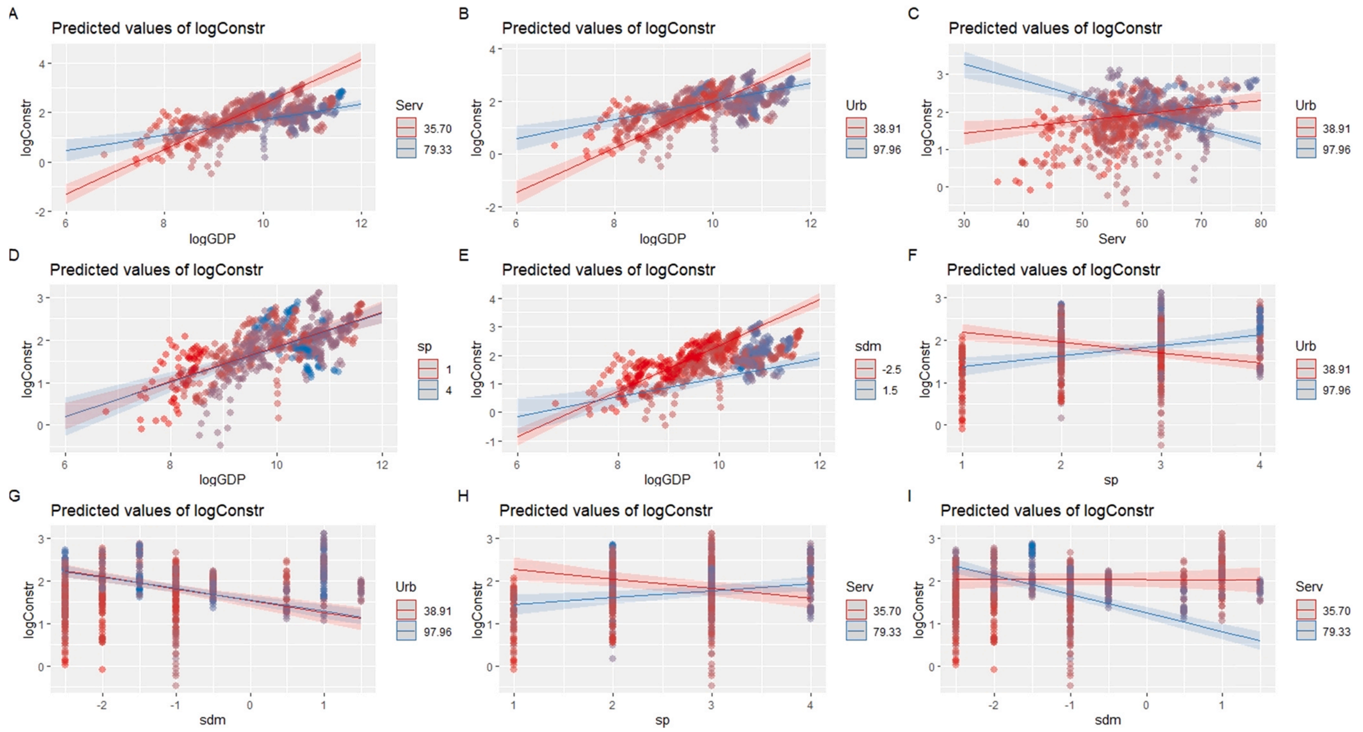

Fig. 3. Interactions between explanatory variables of the model.

Table 2
Main and marginal effects in the estimation.

	Main effect	Marginal effects											
		Share of services (%)				Urban population (%)				GDP per capita (USDk 2010)			
		40	50	60	70	40	50	60	70	15	25	35	45
State-led systems	-66.85	0.43	0.30	0.21	0.14	0.67	0.46	0.31	0.21	0.01	0.11	0.17	0.22
Market-led neo-performative systems	-21.89	1.04	0.72	0.50	0.34	1.61	1.10	0.75	0.51	0.11	0.20	0.27	0.31
Conformative systems		1.31	0.90	0.62	0.43	2.02	1.37	0.94	0.64	0.13	0.23	0.29	0.34
Misled performative systems	183.69	4.09	2.81	1.94	1.34	6.31	4.29	2.92	1.98	0.25	0.35	0.41	0.46
Proto-conformative systems	215.17	4.14	2.85	1.97	1.36	6.39	4.38	2.95	2.01	0.25	0.35	0.42	0.46

The highest coefficients are shown in dark colors (red, yellow, and brown), and the lowest coefficients are highlighted in colorless.
The highest coefficients are shown in dark colors (red, yellow, and brown), and the lowest coefficients are highlighted in colorless.

even decreased during the analyzed period (Denmark, United Kingdom). However, Baltic states perform as outliers in the market-led neo--preformative group, with remarkable ascend in the construction material consumption in line with rapid economic development, contrary to the Slovak Republic.

Neo-performative systems, therefore, involve significantly less construction material use compared to globally widespread conformative systems. In contrast, clusters of countries in the two remaining groups (misled performative systems (3) and proto-conformative systems (4)) are affected by issues that are political in nature, resulting in 184% and 215% higher levels of material accumulation than those of conformative systems, respectively. These countries (Cyprus, Malta, Poland, and countries of the Balkan region) are characterized by weak public control over spatial development, imbalanced power relations between real estate markets and the state, and corruption (Berisha et al., 2020). These malfunctions experienced during the economic transition are not directly captured by two instrumental variables used in the current panel analysis; they are, however, associated with the applied SGPSs.

3.3. Does socio-economic transition mitigate resource needs?

Recently, a trade-off between material/energy efficiency and material stock accumulation has been suspected by some authors. This is plausible both technologically (Whiting et al., 2020) and structurally in economic terms, as excess space is essential for providing several services, e.g., trade, food services, sports, and recreation (Dombi, 2019). Flow-type material efficiency improves in parallel with technological progress and higher shares of services in the economy; however, it also requires rapid growth in stock in line with the evolving complexity of infrastructure (Chester et al., 2020; Luderer et al., 2019). The long-term trend of rapid stock accumulation (Krausmann et al., 2017) further supports this hypothesis.

Although more densely populated urban areas may more efficiently provide services requiring notable material inputs (e.g., transportation, dwellings, water, and other supplies), urbanization accompanies rising resource needs globally. The notion of parallel consumption may resolve this paradox; as urban areas are coupled with reduced living space per inhabitant, space provided by several services is utilized in the form of home extension (e.g., restaurants, bars, laundries, and malls). As a result, urban citizens spend less time at home, which probably does not translate into a proportional drop in their resource use at home, such as decreased energy needs for heating. At the same time, they utilize resources in the form of services for relatively short periods (Ala-Mantila et al., 2014; Heinonen et al., 2013). Minx et al. (2013) reported on the carbon footprint unrelated to settlement type, while Jones and Kammen (2013) imply that suburbanization serves as a continuation of the process.

The evaluation of the role of economic structures, urbanization, and GDP per capita in material accumulation in this sample is not a trivial task since four interaction terms are included in the model. Nevertheless, in Table 2 their marginal effects are presented, which is further confirmed by a report on the coefficients of variables ceteris paribus considering all interaction terms.

The coefficients of marginal effects partially confirm the findings of the literature. Fishman et al. (2015) reported coefficients of 0.22 and 0.47 for the urban population and for the gross provincial product in Japan, respectively. In models also considering economic structures, the tertiary sector coefficients were significantly higher than those of other sectors (0.54–0.67). Zhang et al. (2019) estimated the role of GDP and services in the logarithm of material stock with coefficients of 0.57 and 0.64, respectively. Shao et al. (2017) also reported a positive contribution of the urban population to DMC; however, a negative link between the services share and DMC was also reported. When their panel was filtered for DMC minerals, however, the results became no longer statistically significant. Furthermore, only results for material used 'under recession' and 'very low growth' was provided, and the interactions between variables were not reported.

Fig. 3 presents the value of the dependent variable (natural logarithm of construction minerals' DMC) predicted by the model (vertical axis) for different levels of two explanatory variables. Red points indicate the lowest values, while blue points represent the highest values of explanatory variables. Accordingly, blue and red lines indicate the minimum and maximum values of the sample.

Both economic structure (share of services) and urbanization interact with affluence (GDP per capita), as shown in Fig. 3, panels A and B. The relationship between GDP per capita and predicted construction material use is stronger for lower urban population and service values. While holding GDP constant, the marginal effect shown in Table 2 implies that in line with the rise in the share of services and the urban population, the effect on minerals DMC decreases for each SGPS. Additionally, the shares of services and urbanization interact with each other as well (Fig. 3, panel C). It may be that a higher urban population ratio accompanies the material efficiency of services and vice versa.

In analyzing the results, the effects of economic structure and urbanization seem to be path-dependent with regard to economic growth, although they have positive feedback effects at all levels of development. Reinforced material stock accumulation with an increasing share of services and urban populations has also been formerly detected for a developing country (China; Zhang et al., 2019), transitioning country (Hungary; Dombi, 2019), and highly developed country (Japan; Fishman et al., 2015).

In addition, spatial governance and planning greatly influence the marginal effects of other variables. The ability to resist material accumulation encoded by urbanization and economic transition is determined by the SGPS as well. Detailed analyses of material stock in the literature have concluded that the mass of built infrastructure of the economy is equally significant as that of dwellings and other infrastructure (Cao et al., 2017; Lanau et al., 2019; Ortlepp et al., 2015). Therefore, investments aiming to expand housing stock, capital stock, and transportation networks are key objects of accumulation and are greatly affected by facets of spatial planning culture such as institutional technologies.

Obviously, spatial governance and planning have a considerable political aspect as well. Two SGPSs, namely, misled performative and proto-conformative tend to exaggerate the effect of economic and social transitions on resource use. As Berisha et al. (2020) describe, these systems have essentially no public control over investments; thus, market decisions translate into stock accumulation immediately and excessively. In being allowed to build anything, what wealthy countries had already built up decades ago might be an attractive target from a political point of view. For the emerging economies of Europe, conformative, misled performative, and proto-conformative systems probably deliver short-term gains in economic growth and political success. In this way, severe ecological consequences of investments supported by mild public control of spatial processes are foreseen.

4. Conclusions

This present examination aims to report the economic and social drivers of material stock accumulation at a country scale, focusing on spatial planning. Spatial processes and their planning, regulation, and research are highly complex, multi-level phenomena requiring an interdisciplinary approach when studied. This analysis presents a statistical estimation of the influence of socio-economic factors and spatial governance and planning systems on construction mineral usage in mass with the help of a quantified concept of spatial planning. As this quantification is challenging to a great extent, this concept constitutes a limitation in implementing the results. Nevertheless, this assessment presents the very relevance of the planning context concerning the material stock accumulation process at the macro level for the first time.

Results imply that economic growth, services-oriented economic structure, and urbanization reinforce material construction mineral usage; their effects, however, vary significantly between spatial governance and planning systems and development stages. Therefore, to dissolve the trend of the inevitably emerging needs for construction materials during economic transition both in the service sector and urbanization and suburbanization, a shift towards less demand for resources through effective land use will be required. The results here imply that the difference in the existing spatial planning system of a country per se explains a large amount of variety in construction mineral use.

According to the results, lower construction mineral consumption is inevitably associated with spatial planning style and is mostly independent of the market-led/state-led dimension of the development model. Neo-performative systems require a moderate volume of construction minerals compared to other spatial governance and planning systems. Furthermore, this planning culture translates GDP growth into significantly lower levels of material stock accumulation during the development process, and it also may protect against excess accumulation due to market failures.

It was found that in case a country's system is described as a neo-performative one, the construction mineral demand will perform as significantly lower in both market-led and state-led planning contexts. In order to shift a spatial governance and planning system towards a neo-performative character, the focus should be on strategic planning at higher regional levels, and more public control should be assigned at the level of individual investments or other land use changes. Considering the considerable relevance of environmental policies, the European Union should also promote neo-performative spatial governance and planning systems.

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CRediT authorship contribution statement

Mihály Dombi: Conceptualization, Methodology, Software, Data curation, Writing – original draft, Visualization, Investigation, Writing – reviewing & editing.

Declaration of Competing Interest

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

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.landusepol.2021.105682.

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