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The uneven benefits of conservation: A spatial analysis of how different protection regimes influence local development in Polish municipalities

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ABSTRACT

The balance between environmental protection and socioeconomic development remains a critical policy challenge. Conservation efforts may constrain local development but can also generate benefits beyond nature protection itself, with effects varying across protection regimes and spatial scales. Poland provides a compelling case for examining this trade-off, given its rapid economic growth alongside the significant expansion of protected areas (PAs) in recent decades. This study assesses the relationship between nature protection regimes and local development across Polish municipalities between 2009 and 2022. Using spatial econometric modelling (Spatial Durbin Error Model), we estimate the direct and indirect effects of national parks, nature reserves, and Natura 2000 sites on three dimensions of local development: economic, social, and infrastructural. The most consistent positive effects are observed for economic development in municipalities with a high share of national parks and Natura 2000 sites. Infrastructure-related effects are limited: only Natura 2000 areas show a positive direct effect, while negative indirect effects suggest regional competition for investment. Social impacts are predominantly negative, particularly for stricter protection regimes, and extend beyond administrative boundaries, likely reflecting integrated labour markets. These findings challenge the notion that conservation uniformly constrains economic development. Instead, they indicate that outcomes vary by protection regime and that benefits are unevenly distributed, supporting local economic growth while reinforcing social exclusion. The study underscores the need for policies that mitigate social costs and promote more equitable and territorially integrated development under expanding conservation efforts.

1. Introduction

Protected areas (PAs) represent a dominant and well-established instrument of nature conservation in Europe and worldwide. Nonetheless, both their functioning and the designation of new areas remain contested, largely due to the diverse socioeconomic impacts associated with area-based conservation (Maxwell et al., 2020; Gurney et al., 2023). A substantial body of critical scholarship, particularly within political ecology, examines such tensions through the lens of environmental justice, focusing on how environmental benefits and burdens are distributed, whose knowledge is recognized, and who participates in decision-making processes (Bontempi et al., 2023; Strzelecka et al., 2021). Much of this literature concentrates on the Global South, where the establishment of PAs has at times involved forced displacement and human rights violations disproportionately affecting marginalized groups (Brockington and Igoe, 2006; Busscher et al., 2018).

In this article, however, we focus not on the environmental justice tradition, but on a different body of literature, concerned with quantifying the trade-off between nature protection and local development, particularly in the context of the Global North. In such settings, conservation often imposes restrictions on land use, raising concerns regarding employment, income, and investment opportunities for local communities. At the same time, it may enable alternative development pathways, especially in tourism and recreation, rendering the net impact on local development context-dependent and institutionally mediated (Kauano et al., 2020; Hjerpe et al., 2022; Auliz-Ortiz et al., 2023; Mouillot et al., 2024). Among the relevant mediating factors, the protection regime itself plays a central role. For instance, according to the authors of an extensive meta-analysis on this topic, (…) *socioeconomic benefits were more likely to arise when PAs were managed to promote sustainable resource use rather than enforcing stricter protection of biological resources* (Oldekop et al., 2015). Our study aligns with the institutional

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fit literature, which emphasizes the alignment between environmental governance arrangements and the ecological and socioeconomic systems they seek to manage (Folke et al., 2007; Siltanen et al., 2022). From this perspective, the developmental consequences of nature protection depend not only on spatial scale but also on the extent to which conservation instruments are adapted to local capacities and trajectories.

Trade-offs between conservation and socioeconomic development are also heterogeneous across development dimensions and social groups. Changes in aggregate output or income may mask distributional effects, underscoring the need to consider indicators beyond economic growth alone, such as employment, entrepreneurship, poverty, and access to public services. This broader perspective resonates with contemporary debates on conservation and well-being (Díaz et al., 2015).

In the transition economies of Central and Eastern Europe, the past decades have witnessed both rapid economic transformation and the expansion of protected area networks, particularly following the implementation of the EU-wide Natura 2000 network. These processes have not always been mutually reinforcing and have occasionally generated social tensions. Evidence suggests that the Europeanization of conservation, combined with uneven regional development, has contributed to environmental conflicts and the marginalization of rural communities (Kluvankova-Oravska et al., 2009; Petrova, 2016; Yakusheva, 2019; Farkas and Kovács, 2021; Strzelecka et al., 2021).

Poland offers a particularly instructive case for examining these dynamics. The country has experienced one of the fastest economic growth trajectories in the region while simultaneously developing a large Natura 2000 network (Głogowska et al., 2013; Warchalska-Troll, 2019). Policy debates have recently intensified following the adoption of the EU Nature Restoration Law (European Union, 2024) and the introduction of new fiscal transfers to municipalities hosting protected areas (Polish Press Agency, 2024). Against this backdrop, we investigate whether municipalities containing PAs have lagged behind in socioeconomic terms, or rather the existence of these areas enabled them to pursue an alternative path of development.

To address this question, we analyse the relationship between protected areas and local development dynamics across 2476 Polish municipalities over the period 2009–2022. We model changes in three aggregate indices, each representing a different dimension of local development: economic, social, and infrastructural. We investigate the role of three diverse protection regimes, measuring the share of national parks, nature reserves and Natura 2000 'Birds' (SPA) areas in the total land area of municipalities. Finally, we apply spatial econometric techniques to account for spatial dependence and spillover effects.

The remainder of the article proceeds as follows. Section 2 reviews the literature on the relationship between nature protection and local development, with particular emphasis on institutional variation across protection regimes. Section 3 describes the study area and methodological approach. Section 4 presents the empirical results, Section 5 discusses the findings, Section 6 outlines the study's limitations and future research directions, and Section 7 concludes.

2. Literature review

2.1. Between nature protection and socioeconomic development

Traditionally, protected areas (PAs) aimed to preserve ecosystems in a near-natural state by restricting human activity within designated territories (Mose and Weixlbaumer, 2006), often triggering social conflicts (West et al., 2006). From the late twentieth century onwards, however, the role of PAs increasingly shifted towards more integrated approaches, with local stakeholders' interests incorporated into conservation objectives (Mose and Weixlbaumer, 2006; Mose, 2007; Roe, 2008; Du et al., 2015). This shift is reflected, for instance, in changes to EU member states' conservation policies in the 1990s, codified through the Habitats Directive (Gibbs et al., 2007).

Today, the question of whether integrated conservation can reconcile ecological objectives with local community needs, or whether PAs ultimately constrain local socioeconomic development, remains highly contested. While trade-offs are central to these debates, and diverging perceptions among actors have been widely documented (Stern, 2008; Warchalska-Troll, 2019), the Polish case illustrates how conflict-generating mechanisms emerged during the implementation of the Natura 2000 network (Grodzińska-Jurczak and Cent, 2011; Grodzińska-Jurczak et al., 2012; Strzelecka et al., 2021). Early studies of stakeholder perceptions reported ambivalent attitudes toward Natura 2000 areas. Two recurrent concerns were that Natura 2000 was perceived as a barrier to investment, mainly due to protracted planning procedures and administrative costs (Głogowska et al., 2013; Cieślak et al., 2015; Dziemianowicz et al., 2015; Gutowska, 2015), and as a constraint on economic opportunities, particularly for private landowners whose properties fell within protected zones (Strzelecka et al., 2021). These perceptions were reinforced by insufficient funding and information, as well as limited flexibility and public participation within a largely top-down governance process (Dziemianowicz et al., 2015). Together, these concerns underscore the need for empirical assessment of the actual impacts of PAs on local development, and for situating the Polish case within the growing body of quantitative work addressing similar dynamics in other contexts.

Several European studies report positive associations between PAs and indicators of local economic development, such as municipal income or investment spending (Cieślak et al., 2015; Zawilińska et al., 2021). At a more disaggregated level, a global meta-analysis of 30 studies finds a statistically significant positive effect of PAs on household income, particularly in the Global South, although the magnitude of this effect is generally modest (Kandel et al., 2022).

Within the social development dimension, poverty reduction remains among the most frequently examined outcomes. A correlation has been observed between PAs and higher poverty levels, which may partly reflect the non-random placement of PAs in initially poorer regions (Andam et al., 2010; Vilela et al., 2022). However, based on data from 11 countries, Mammides (2020) finds no conclusive evidence that administrative regions containing PAs experience worse poverty outcomes. Conversely, several studies identify poverty-reducing effects of PAs in parts of the Global South (Canavire-Bacarreza and Hanauer, 2013; Vilela et al., 2022), despite the comparatively lower baseline level of economic development in municipalities adjacent to such areas.

Regarding employment, the debate centres on whether tourism-driven benefits can compensate for reduced opportunities in resource extraction and processing. While some European cases report tourism development in municipalities with PAs (Zawilińska et al., 2021), such dynamics do not necessarily translate into higher tourism employment (Lundmark et al., 2010; Cremer-Schulte and Dissart, 2015). Empirical evidence remains mixed, with studies reporting positive (Sims et al., 2019), negative (D'Alberto et al., 2023), or negligible effects (Cremer-Schulte and Dissart, 2015), depending on geographical context and measurement.

The impact of PAs on public infrastructure development and access has been examined less frequently. Cieślak et al. (2015) document a steady increase in water supply and sewerage infrastructure in Polish municipalities hosting Natura 2000 sites, although this progress was insufficient to close the gap relative to the national average.

Despite growing interest, important knowledge gaps persist, particularly regarding the impact of PAs on public infrastructure as well as on economic and social development outcomes in high-income settings (Bonet-García et al., 2015). Much of the literature relies on single case studies, even though PAs show substantial variation across sites (Robalino and Villalobos, 2015). In broader national or interregional assessments, methodological approaches often remain descriptive (e.g. for Poland: Cieślak et al., 2015; Dziemianowicz et al., 2015; Zawilińska et al., 2021), rather than employing regression-based models (Sims, 2010; Kauano et al., 2020), quasi-experimental designs (Mammides, 2020; Vilela et al., 2022), or matching techniques (Auliz-Ortiz et al., 2023), which limits the scope for causal inference. Moreover, many studies do not sufficiently address the non-random placement of PAs (Sims, 2010), meaning that observed outcomes may partly reflect underlying natural amenities rather than the effects of protection measures themselves.

Finally, because much of the existing research focuses on isolated outcomes such as poverty, wages, or employment (Lundmark et al., 2010; Canavire-Bacarreza and Hanauer, 2013; Robalino and Villalobos, 2015), more integrated approaches remain needed. A key contribution of this study is the use of three outcome variables, capturing economic, social, and infrastructural development, to provide a more comprehensive assessment of local development. This integrated perspective, combined with spatial econometric analysis, facilitates the identification of potential trade-offs and complementarities.

2.2. Forms of nature protection areas and their diversified impacts

In practice, area-based conservation takes diverse forms, differing in protection strictness, permitted human activities, and spatial extent. In line with IUCN categorisations, different protection regimes pursue distinct conservation objectives, with diverse implications for local communities and socioeconomic development (Locke and Dearden, 2005; Maxwell et al., 2020; Gurney et al., 2023). Categories range from strict nature reserves and wilderness areas (with highly restricted human presence), through national parks and habitat management areas (where protection is combined with recreation and targeted interventions), to protected landscapes or managed resource areas (Dudley, 2008). Some authors argue that only IUCN categories I–IV constitute "effective" protection, whereas categories V–VI allow such extensive human activity that they should instead be conceptualised as sustainable development areas (Locke and Dearden, 2005; Oldekop et al., 2015).

Assessing impacts across IUCN categories is further complicated by variation in the enforcement of protection rules, both across categories and across individual sites. A recurring concern is the presence of "paper parks" (Dudley and Stolton, 1999), where legal designation is not matched by effective on-the-ground management. Weak enforcement may result from ineffective local site management (e.g. lack of management plans, limited managerial capacity, or shortages in staffing and resources) or from broader institutional shortcomings, such as inadequate enforcement of national or transnational regulations. An example is the slow resolution of Natura 2000 infringement proceedings by the European Commission (Hildt and Weyland, 2022).

A global WWF assessment of forest protected areas (2004) found that management was generally effective in establishing sites and defining objectives, but weaker in areas such as monitoring, enforcement, and planning; only 12% of sites had a management plan in place (Dudley et al., 2004). More recently, a UK-wide assessment of 23 protected area types found that site-level management was at most partially effective, and did not indicate systematic differences in effectiveness across categories (IUCN National Committee UK Protected Areas Working Group, 2023).

Given this diversity, it is unlikely that the socioeconomic impacts of PAs are uniform across protection regimes; nevertheless, differentiated impacts remain insufficiently examined. In their meta-analysis, Oldekop et al. (2015) find that socioeconomic benefits are more likely under "sustainable use" forms of protection (IUCN V–VI and biosphere reserves). By contrast, stricter regimes (IUCN I–IV, including nature reserves and national parks) show no consistent association with development outcomes. The authors argue that synergies between conservation and development are most likely under intermediate or integrative models, where leveraging social-development opportunities, rather than enforcing strict protection alone, supports stronger conservation effectiveness.

However, these relationships remain context-dependent, suggesting that economic and geographic factors may moderate observed effects. For example, in Mexico, PAs of varying restrictiveness were associated with similar levels of social marginalization and deforestation, but more restrictive regimes reinforced development constraints in already peripheral regions (Auliz-Ortiz et al., 2023). In the Brazilian Amazon, strict protection was associated with reduced industrial production, without adverse effects in other sectors (Kauano et al., 2020). Conversely, detailed country-level studies often identify national parks as having the most positive economic effects and poverty-reduction potential, largely due to their capacity to attract tourism (Reinius and Fredman, 2007; Sims, 2010; Buongiorno and Intini, 2021).

In Europe, Natura 2000 constitutes a distinctive and relatively recent conservation regime. Introduced in the 1990s through the Habitats and Birds Directives, it covered approximately 18% of the EU's land area in 2023. Natura 2000 sites vary substantially in their protection measures, which are determined locally in line with ecological requirements and socioeconomic conditions. Nevertheless, Natura 2000 designation imposes constraints on spatial planning, investment decisions, and production processes. Consequently, national Natura 2000 rollouts were perceived as a potential threat to local socioeconomic development in parts of Europe, including Poland (Grodzińska-Jurczak and Cent, 2011; Grodzińska-Jurczak et al., 2012; Blicharska et al., 2016; Strzelecka et al., 2021).

Existing economic research, including studies for Poland, generally suggests that these concerns were not substantiated, as no negative impacts have been detected for aggregate investment, employment, or production (Gantioler et al., 2014; Cieślak et al., 2015; Dziemianowicz et al., 2015; Gutowska, 2015). At the same time, Natura 2000 designation has been linked to new tourism and recreation opportunities, except in areas with very high conservation requirements (Cruz et al., 2011; Warchalska-Troll, 2018), and to increased EU funding for municipal budgets (Dziemianowicz et al., 2015). Beyond these channels, Natura 2000 can generate multiple benefits for local communities in terms of the provision of ecosystem services, such as water retention and regulation, air quality improvement and carbon storage, whose economic value may well exceed direct market returns (Cruz et al., 2011; Gantioler et al., 2014; Schirpke et al., 2018).

Taken together, the literature points to a persistent research gap in comparative quantitative assessments of how different PA regimes shape socioeconomic outcomes. In particular, more evidence is needed on how the relatively new Natura 2000 regime compares with more traditional forms such as nature reserves and national parks. To address this gap, we focus on three distinct PA types in Poland that correspond to widely recognised conservation models: nature reserves (NR), national parks (NP), and Natura 2000 Special Protection Areas (SPA).[1]

3. Material and methods

3.1. Study area

We conduct the analysis at the level of 2476 Polish municipalities (LAU, according to the EU Nomenclature of Territorial Units for Statistics), i.e. local administrative units with an average area of 126 km^2 and a mean population of 15,300 inhabitants. Municipalities constitute the lowest tier of local government in Poland, enabling a fine-grained assessment of local development dynamics and their correlates. Their relatively high degree of fiscal autonomy implies that local characteristics, including the share of protected areas (PAs), play an important role in shaping development trajectories.

Poland's current PAs network largely emerged during the post-

[1] Compared to Special Areas of Conservation (median = 0.0, SD = 22.45), the share of Special Protection Areas in a given municipality (median = 1.6, SD = 16.04) offers greater differentiation among low-value cases, lower dispersion, and a more informative distribution for further use in regression modeling.

socialist transition, in two main waves. The first took place in the early 1990s, when several new national parks were established on top of the pre-existing network. Eight out of the 23 national parks were designated between 1989 and 1996. In 2000, local authorities gained the ability to veto the creation of new parks, which has since constituted a major constraint on the expansion of this protection regime. As a result, only around 0.6% of the national territory remains under strict protection (IUCN categories I–II), compared to approximately 3.5% across the EU (Cazzolla Gatti et al., 2023). The second wave followed Poland's accession to the European Union (2004–2012), when Natura 2000 sites were designated nationwide. As noted earlier, these processes were accompanied by social tensions, as stakeholders invoked different normative frameworks and competing land-use preferences. Such conflicts remain visible today, with concerns about the economic future of local communities continuing to shape debates over PAs expansion (Niedziałkowski et al., 2014; Strzelecka et al., 2021; Boćkowski et al., 2024).

The key characteristics of the three selected forms of PAs are explained in Table 1.

The three types of PAs regimes represent distinct and relatively coherent forms of nature protection. This is particularly evident for nature reserves and national parks, which are comparatively homogeneous in terms of legal frameworks and institutional arrangements, as they are governed by uniform national regulations. Natura 2000 sites are more heterogeneous by design, reflecting their focus on specific habitats and species. However, this variation follows a clearly defined regulatory logic, whereby economic activities are generally permitted unless they are demonstrated to significantly harm conservation objectives, typically through impact assessment procedures (Sobieraj, 2013; Chmielewski and Głogowska, 2015). All three PA types are coordinated by central government institutions. However, their day-to-day functioning and enforcement have been shaped by processes of decentralization and regionalization, resulting in some regional variation in implementation practices (Niedziałkowski et al., 2016).

In national parks and nature reserves, protection rules rely on strict, broadly applicable prohibitions covering activities such as construction, resource extraction, hunting, agriculture, and most forms of business activity, with tourism permitted only under specified conditions. These prohibitions apply regardless of whether detailed management plans are in place, which are often absent due to limited administrative capacity. While this weakens strategic planning, it does not substantially reduce the restrictive scope of these regimes, as enforcement is largely based on statutory bans (Sobieraj, 2013; NIK, 2023, 2024).

By contrast, Natura 2000 relies primarily on site-specific management plans to define concrete restrictions, while the overarching legal constraint applies only to activities that may significantly harm conservation objectives. This regulatory structure has two main implications. On the one hand, it may deter investors faced with uncertainty about the permissible scope of economic activity. On the other, it can weaken enforcement in contexts where local economic interests take precedence over conservation goals. Although management plans exist for most Natura 2000 sites, their implementation varies considerably due to uneven regional administrative capacity, legal ambiguities, competing sectoral interests - particularly in forestry (Logmani et al., 2017) and spatial planning (Gorzym-Wilkowski, 2016; Hełdak et al., 2025) - as well as differences in participation and political support (Grodzińska-Jurczak et al., 2012).

Despite these qualitative differences and potential heterogeneity, we analyse the three PA types as internally homogeneous groups. This choice is motivated by two considerations. First, it reflects the relative institutional coherence of the respective protection regimes. Second, it acknowledges data limitations, particularly regarding enforcement practices and the detailed content of site-level management plans.

The spatial distribution of the three PA types is illustrated in Fig. 1a. Nature reserves are the most spatially dispersed, although they typically occupy only a small share of municipal territory. In contrast, Special Protection Areas (SPAs) tend to cover extensive territories, concentrated mainly in northern and eastern Poland. National parks are most prevalent in mountainous regions in the south, along the Baltic coast in the north, and in the north-eastern part of the country. A clear spatial overlap is observable between the location of large PAs and the natural amenities index, as shown in Fig. 1b. This pattern highlights the importance of accounting for the potentially non-random placement of PAs when analysing their effects on local development (Sims, 2010).

3.2. Sources and description of data

We employ three composite indices as dependent variables to assess the impacts of protected areas (PAs) on key dimensions of local development: economic development (ECON), social inclusion (SOCI), and environmental infrastructure (INFR). Each index combines two complementary indicators capturing core aspects of the respective development dimension. This composite approach enables a more comprehensive representation of local change and reduces the risk of bias associated with relying on single indicators. Domain-specific indices for baseline and final years were constructed as the sum of standardized component variables using z-score normalization.[2] The dependent variable (ΔECON, ΔSOCI, and ΔINFR, respectively) represent changes in index values over the study period, thus capturing the net dynamics of economic, social, and infrastructural development.

The economic development index (ECON) includes: (1) municipal own revenues per capita and (2) the number of business entities registered per 1000 inhabitants. Municipal own revenues include shares in personal and corporate income taxes, property taxes, agricultural taxes, and other revenues linked to local economic activity. This measure is widely used as a proxy for the scale of local economies where GDP data are unavailable at the municipal level (Biedka et al., 2022; Rok and Herbst, 2023). The number of business entities complements this measure by capturing entrepreneurial activity and economic density (Śleszyński, 2017). The social inclusion index (SOCI) consists of: (1) the unemployment rate and (2) the share of social assistance beneficiaries below the income threshold.[3] The unemployment rate is a long-standing indicator of social exclusion, pointing to the inability of individuals to fully participate in the social and economic life of their communities. The social assistance beneficiaries measure adds a complementary perspective, reflecting income-based scale of poverty in a community. Together, these two variables capture key dimensions of contemporary measures of social deprivation (Ministry of Housing, Communities and Local Government, 2019). Finally, the environmental infrastructure index (INFR) comprises: (1) the share of population with access to a sewage network, and (2) capital investment expenditures from municipal budgets on environmental protection infrastructure per capita. The former is a widely used indicator of access to essential environmental services, and a fundamental public good under municipal jurisdiction. Following Poland's EU accession, sewage infrastructure development has been strongly supported by competitive EU funding (Piasecki, 2019). Investment in environmental infrastructure[4] broadens the scope, allowing to assess the degree to which municipalities have actively committed resources to various environmental improvements.

[2] Z-score normalization involves subtracting the mean from the value of a given indicator and dividing the result by its standard deviation. This method is widely used in composite index construction and is particularly suitable when the dataset contains extreme values, as it reduces their influence without excluding them (OECD, 2008).

[3] In 2022 the net income threshold for a single-person household equaled 776 PLN per month.

[4] The official name of this budget category is environmental protection and public utilities, and it covers wastewater and waste management, street cleaning, maintenance of green spaces, air and climate protection, animal shelter operations, and public lighting infrastructure.

Table 1
Forms of analysed PAs and their characteristics.

	Nature Reserves (NR)	National Parks (NP)	SPA N2000 (Birds Directive) (SPA)
Institutional arrangement	No institutional representation at the local level	Locally-based, staffed institution responsible for managing the park	No institutional representation at the local level
Protective regime (IUCN category)	Mostly IV: with a dedicated plan of protection of certain species / habitats. Only activities specified in the plan are allowed.	Mostly II: tourism and recreation, as well as some active protection and wood extraction allowed	Diverse, mostly IV and VI: also includes conservation through management intervention. Environmental impact assessment is required for economic activity, including investment and housing.
Size and prevalence	Common and small: Exist in 793 communes (out of 2476 in total), with the average size of 1.26% of total commune area.	Rare and large: Exist in 117 communes (out of 2476 in total), with average size of 17.16% of total commune area.	Common and large: Exist in 1508 communes (out of 2476 in total), with the average size of 14.87% of total commune area.

Source: own elaboration, based on (GUS BDL, 2024).

Given the ecological assets associated with PAs, municipalities with higher PA shares may have both stronger incentives and greater financial opportunities to invest in environmental infrastructure.

For all dependent variables we apply a consistent timeframe, covering the period from 2009 to 2022.[5] This timeframe coincides with a near freeze in the creation and expansion of PAs in Poland (see Fig. 2). Comparing two 14-year periods (1996–2009 and 2009–2022), the growth rate of PAs coverage declined substantially. For national parks, growth slowed from 4.5% to 0.2%, and for nature reserves from 27.7% to 4.9% (GUS BDL, 2024). The most pronounced change occurred for Natura 2000, whose network expanded rapidly after accession in 2004, reaching roughly 18% of national territory by 2009. Over the next 14 years, only minor adjustments occurred, with SPA and SAC areas expanding by roughly 2.5%. Explanatory variables include three indicators capturing the share of municipal territory covered by national parks (NP), nature reserves (NR) and Special Protection Areas (SPA) in 2022.[6] While this operationalization does not capture site-level variation in enforcement or management quality, these categories exhibit relatively limited within-group institutional variation and reflect distinct protection regimes. Surface-based measures therefore provide a consistent proxy for dominant protection regimes across municipalities, enabling comparison across a large number of municipalities.

A potential concern in assessing the impact of PAs on local development is endogeneity, particularly reverse causality (where protection regimes are established in response to factors that also shape socioeconomic outcomes) or omitted variables that simultaneously influence both PAs designation and subsequent development trajectories (Mouillot et al., 2024). In the Polish context, however, the risk of such endogeneity is arguably limited due to the historical and institutional background of nature protection. Most national parks were established in the twentieth century, with the most recent designation occurring in 2001. As a result, any potential selection bias related to their placement is likely to have stabilized well before the beginning of our study period in 2009. Only in the last two decades - after local governments gained the ability to veto new national park initiatives - have economic arguments been used to advocate additional protection regimes. These arguments have largely been deployed in attempts to persuade local policymakers that protected areas could serve as development stimuli for stagnating or peripheral regions, but such initiatives have rarely translated into new designations (Wesołowski et al., 2018). In the case of Natura 2000 areas, the top-down nature of the designation process further reduces concerns about endogenous placement. Planning and implementation were driven primarily by scientific and conservation priorities, as well as by the interests of environmental institutions and organizations, rather than by local socioeconomic conditions (Grodzińska-Jurczak and Cent, 2011; Grodzińska-Jurczak et al., 2012). Early empirical studies support this interpretation, showing only weak - and generally positive - correlations between the presence of Natura 2000 sites and indicators such as tourism potential, income levels, or employment dynamics (Stanny, 2010; Cieślak et al., 2015; Gutowska, 2015; Dziemianowicz et al., 2015).

To further mitigate the risk of endogeneity and omitted-variable bias, our analysis focuses on the dynamics of change over the 2009–2022 period rather than on absolute levels of development. We include baseline values of the dependent variables as controls, thereby accounting for pre-existing differences across municipalities that may shape their development trajectories. Specifically, we control for initial values of the social (SOCI_09), economic (ECON_09), and infrastructural (INFR_09) development indices. We also introduce additional control variables capturing key structural and spatial factors. First, peripherality (PERI) is measured as the distance between a municipality and the regional capital (voivodeship seat). Given the spatial concentration of development processes, peripheral areas often face structural disadvantages, including weaker endogenous growth potential and higher depopulation pressures (Smętkowski, 2018). Second, municipality type (TYPE) captures the urban–rural divide, which remains a fundamental determinant of local development trajectories. We distinguish three categories: urban municipalities (larger towns and cities), mixed municipalities (a small town and its surrounding hinterland), and rural municipalities (the least urbanized). Finally, to address the non-random placement of PAs, we include an aggregate natural amenities index (AMNI). PAs are often located in regions characterized by high environmental attractiveness, which may independently stimulate development through channels such as tourism, migration, or amenity-driven economic activity (Backman et al., 1991; McGranahan, 2008; Waltert et al., 2011). Failing to account for these factors could lead to an overestimation of PAs effects (Sims, 2010; Andam et al., 2013). To capture this dimension, the index combines information on forest cover, elevation, the presence of inland water bodies, and access to the seacoast.[7]

[5] To address the volatility of (1) municipal own revenues, and (2) capital investment expenditures on environmental protection infrastructure, we calculate its values as an average over a three-year period centered around the target year.

[6] Optimally, the 2009 data should be used here, to represent the impact of the baseline level of PAs for subsequent changes in measures of local development. However, due to the data constraints, we use the current (2022) data. It may be justified on the grounds of the almost complete halt of the establishment of new PAs or enlargement of the already existing ones, over the 2009–2022 period.

[7] The index is calculated as the sum of ranks of four landscape-related variables, i.e. (1) percentage of the municipality's area covered by forests, weight: 1; (2) percentage of the municipality's area covered by inland waters, weight: 1; (3) average altitude above sea level in the municipality, weight: 1; (4) share of sea coast land strip 1 km wide within the municipality's area, weight: 2. For each variable a rank of 0–3 was ascribed based on the following criteria: variable (1) – 4 classes based on Jenks natural break optimization, variable (2) – 5 classes based on Jenks natural break optimization, and top 2 classes merged into one, variable (3) - 10 classes based on Jenks natural break optimization, and low 7 classes merged into one, variable (4) – zero as the lowest class, and the remaining three classes based on the equal count criterion.

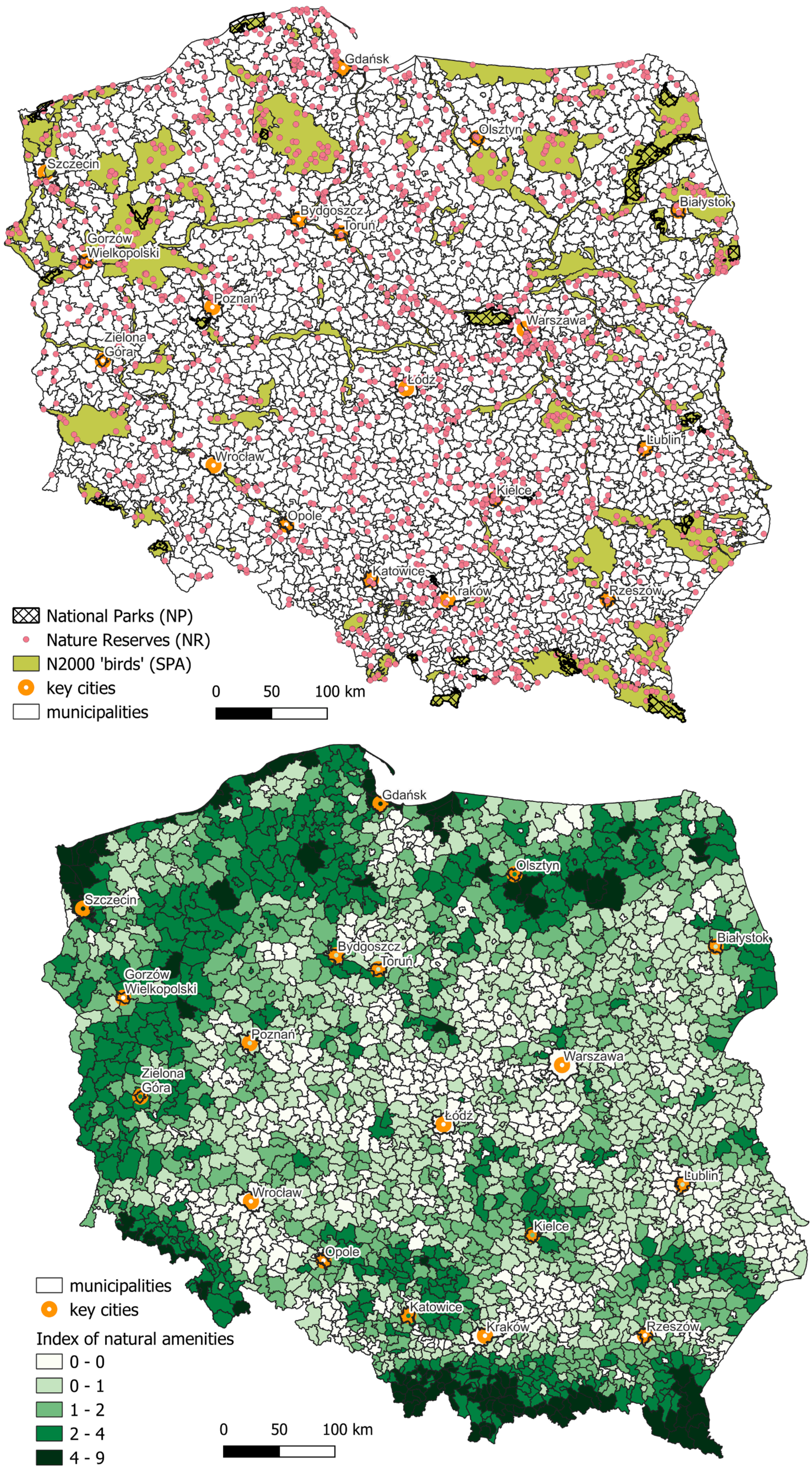

Fig. 1. Spatial distribution of Protected Areas (a) and of the Index of natural amenities (b).
Source: own elaboration, based on (GDOŚ 2024, GUS BDL, 2024)

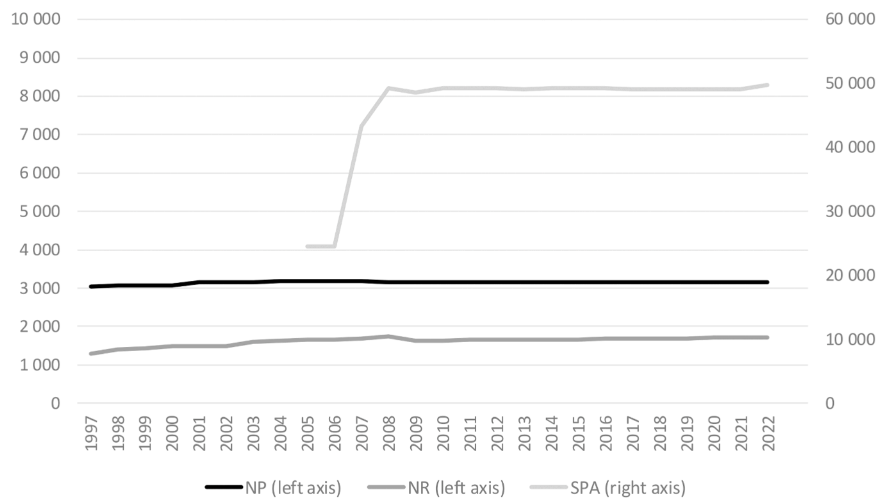

Fig. 2. Total area covered by NP, NR and SPA in Poland, 1996–2022 [sq. km]. Source: GUS BDL (2024).

All variables used in the analysis are listed in Table 2.

All data used in the analysis were obtained from open public sources. Socioeconomic data for municipalities were retrieved from Statistics Poland (Statistics Poland, 2025), while spatial data on PAs were obtained from the General Directorate for Environmental Protection (GDOŚ, 2024). Spatial datasets for municipalities and PAs were processed and merged using Quantum GIS. In the first step, the socioeconomic database was joined to a spatial layer of municipal polygons. In the second step, municipal boundaries were intersected with the boundaries of different PAs categories to calculate the proportion of each PA type within each municipality. Finally, the resulting spatial database was analysed in R using the following packages: spdep, sf, ggplot2, stargazer, and spatialreg.

3.3. Methodological approach

Ordinary Least Squares (OLS) regression is typically used to investigate the determinants of a given dependent variable, but such a model relies on the assumption of unrelated and homoscedastic error terms. When using spatially disaggregated data, these assumptions are frequently violated due to spatial autocorrelation, which may bias parameter estimates and inference (Anselin, 2022). As articulated by Tobler's Law, spatial proximity tends to generate similarity between neighbouring units (Tobler, 2004), making spatial modelling particularly relevant in the present context.

To account for spatial dependence, we first construct a spatial weights matrix. We employ a row-standardized second-order queen contiguity criterion, inclusive of lower orders. This specification assumes spatial interdependence not only between neighbouring municipalities but also among second-order neighbours ('neighbours of neighbours'), which is particularly relevant in cases where urban municipalities are fully embedded within rural administrative units. The resulting matrix has a mean neighbourhood size of 18.9 (2 ÷ 43). While the choice of spatial weights is inherently somewhat arbitrary, empirical evidence suggests that well-specified spatial models are generally robust to reasonable alternative weighting schemes (LeSage, 2014).

Following the well-established approach (Kauano et al., 2020), we begin the model specification with a non-spatial OLS regression model as a benchmark and subsequently test whether extending the baseline model to account for spatial interaction effects improves model fit. The spatially blind OLS model is specified as follows:

$$LD_i = \beta_0 + \beta_1 PA_i + \beta_2 PERI_i + \beta_3 AMNI_i + \beta_4 LD_{it=0} + \beta 5TYPE_i + \varepsilon_i (1)$$

where i refers to the i-th municipality, βn are the estimated coefficients of explanatory variables, and ε is the standard error term. LD_i denotes the change in local development (ΔECON, ΔSOCI, or ΔINFR), PA_i represents the share of protected areas (NP, NR, or SPA). Control variables include peripherality PERI, natural amenities AMNI, baseline development levels ($LD_{it=0}$) and municipality type dummy (TYPE) - with URBAN municipalities being a reference category for RURAL and MIXED municipalities.

We subsequently assess spatial dependence in OLS residuals using Lagrange Multiplier (LM) diagnostics based on the same spatial weights matrix. LM tests allow us to distinguish between alternative sources of spatial dependence. Spatial diffusion, where neighbouring units directly influence each other, can be addressed using spatial lag models. Attributional dependence, where neighbouring units share similar underlying conditions without direct interaction, is typically modelled using spatial error models (SEM). When both mechanisms may be present, more general specifications such as the Spatial Durbin Error Model (SDEM) can be employed. In our case, we expect spatial autocorrelation to be primarily attributional, reflecting georaphicaly clustered development processes consistent with the New Economic Geography arguments (Krugman, 2011).

Given that spatial dependence is detected, as indicated by low p-values in the LM diagnostics, the assumption of independent observations is violated and standard OLS estimates may be biased. To address this issue, we apply spatial econometric models (LeSage, 2014). Across all nine model variants, Robust LM error tests return lower p-values than their lag counterparts (Table 3), suggesting that attributional spatial dependence dominates and motivating the use of SEM and SDEM specifications. These results align with theoretical expectations, and corroborate the notion that model selection should be guided not only by diagnostics, but also by prior theoretical considerations, as emphasized by Rüttenauer (2022), either by ruling out some dependence mechanisms or by motivating the choice between global and local spillovers.

Where $\lambda W\varepsilon$ represents the spatially structured error component, with the spatial error ε weighted by the autoregressive term λ, and by the W, i.e. the row-normalized coefficient derived from a spatial weight matrix described above. The term u denotes random error unexplained by the model, and X_i denotes independent variables described under equation (1).

To allow for local spatial spillovers in covariates, we estimate Spatial Durbin Error Models (SDEM), which extend SEM by incorporating spatial lags of explanatory variables:

$$LD_i = \beta X_i + WX_i\theta + \lambda W\varepsilon + u \quad (3)$$

Here, W is the row-normalized coefficient derived from a spatial weight matrix described above, X_i represents covariates described under

Table 2
The variables used in the study.

Statistic	Description	Year	N	Mean	SD	Min	Max
Dependent variables (components of composite indices)							
ECON: component variable 1	Municipal own revenues, annual average, PLN per capita	2008–10	2476	1085.5	952.6	282.8	35127.7
		2021–23	2476	2529.6	1357.1	838.9	40701.9
ECON: component variable 2	Number of business entities registered, per 1000 inhabitants	2009	2476	705.1	315.1	262.0	3818.0
		2022	2476	986.0	374.3	338.0	9005.0
INFR: component variable 1	Capital investment expenditures from municipal budgets on environmental protection infrastructure, annual average, PLN per capita	2008–10	2476	105.9	185.2	0	3538.5
		2021–23	2476	226.5	300.4	0	5941.1
INFR: component variable 2	The share of population with access to sewage networks, percentage of the total population	2009	2476	40.63	30.57	0	100
		2023	2476	55.81	30.41	0	100
SOCI: component variable 1	Unemployment rate, percentage	2009	2476	9.232	3.939	1.7	28.4
		2023	2476	4.526	2.431	0.5	17.2
SOCI: component variable 2	Social assistance beneficiaries below the income threshold, percentage of the total population	2009	2476	8.790	5.758	0	15.3
		2023	2476	2.998	1.904	0	15.3
Explanatory variables							
NP	The percentage of the municipality's area covered by the NP	2022	2476	0.811	5.393	0	85.9
NR	The percentage of the municipality's area covered by the NR	2022	2476	0.403	1.305	0	21.2
SPA	The percentage of the municipality's area covered by the SPA	2022	2476	9.059	16.038	0	100
Control variables							
ECON_09	Value of the ECON index in the baseline year	2009	2476	0	1.730	−2.113	35.7
INFR_09	Value of the INFR index in the baseline year	2009	2476	0	1.471	−1.901	20.16
SOCI_09	Value of the SOCI index in the baseline year & multiplied by [−1]	2009	2476	0	1.767	−10.24	3.188
PERI	Distance from the municipality's centroid to the voivodeship seat, in km	2022	2476	60.744	29.92	0	179
AMNI	Index of natural amenities in municipalities	2022	2476	1.631	1.501	0	9
TYPE:RURAL	Dummy variable for rural municipalities	2022	2476	0.611			
TYPE:URBAN	Dummy variable for urban municipalities	2022	2476	0.122			
TYPE:MIXED	Dummy variable for mixed municipalities	2022	2476	0.267			

Table 3
The results of Lagrange Multiplier tests.

	ΔSOCI	*ΔECON*	*ΔINFR*
NP	LMerr = 470.64***	LMerr = 23.914***	LMerr = 12.211***
	LMlag = 315.66***	LMlag = 12.44***	LMlag = 3.814*
	RLMerr = 164.42* **	**RLMerr = 35.458*** **	**RLMerr = 12.313*** **
	RLMlag = 9.439***	RLMlag = 23.983***	RLMlag = 3.915**
NR	LMerr = 461.82***	LMerr = 19.497***	LMerr = 11.241***
	LMlag = 322.31***	LMlag = 11.538***	LMlag = 3.711*
	RLMerr = 147.06* **	**RLMerr = 28.899*** **	**RLMerr = 10.812*** **
	RLMlag = 7.552***	RLMlag = 20.939***	RLMlag = 3.282*
SPA	LMerr = 479.04***	LMerr = 18.755***	LMerr = 12.037***
	LMlag = 319.66***	LMlag = 11.033***	LMlag = 3.721*
	RLMerr = 170.66* **	**RLMerr = 26.798*** **	**RLMerr = 12.245*** **
	RLMlag = 11.286***	RLMlag = 19.076***	RLMlag = 3.929**
Model	SEM / SDEM	SEM / SDEM	SEM / SDEM

*Note:**p < 0.1; **p < 0.05; ***p < 0.01.

Thus, the next stage in the analytical approach is fitting the nine SEM models that address the spatial dependence of error terms. The SEM specification is given by:

$$LD_i = \beta X_i + \lambda W \varepsilon + u \quad (2)$$

.

equation (1), and the term θ denotes a vector of spatial spillover parameters, including a distinct spatial effect for each covariate. The term $\lambda W\varepsilon$ is the spatially structured error described under Eq. (2), u denotes random error unexplained by the model. The SDEM specification allows us to jointly model spatial clustering in unobservables and geographically bounded spillovers in explanatory variables (LeSage, 2014).

Model fit is evaluated using likelihood-based metrics. Log-likelihood is used to assess improvements among nested spatial models, while the Akaike Information Criterion (AIC) enables comparison across models with differing levels of complexity, including non-spatial and spatial specifications. Model diagnostics further include tests for heteroskedascity using the studentized Breusch-Pagan statistic and visual inspection of residual distributions.

Comparisons across model families indicate that spatial specifications substantially outperform OLS benchmarks, confirming the importance of spatial dependence. Moreover, SDEM models consistently improve fit relative to SEM, supporting the inclusion of spatially lagged covariates as part of the baseline modelling strategy. Accordingly, SDEM is retained as the primary specification in subsequent analysis, while OLS and SEM results are reported in supplementary materials.

A potential concern in assessing the impact of PAs on local development is endogeneity, including reverse causality and omitted-variable bias. Institutional arguments regarding the limited risk of reverse causality in the Polish context are discussed in Section 3.2 and suggest no strong theoretical motivation for instrumental-variable (IV) strategies (Wooldridge, 2010). As an additional robustness check, we assess coefficient stability by comparing parsimonious baseline models with fully specified SDEM models and reporting both coefficient ratios and changes in model fit (ΔAIC), following stability-based diagnostics (Oster, 2019). Full results are presented in Appendix Table A1. Overall, estimates exhibit substantial stability across specifications, particularly for NP. Importantly, no coefficient reversals are observed when moving from baseline to fully specified spatial models, and the overall pattern of statistical significance remains largely unchanged across all specifications. The largest deviations occur for NR in the economic and infrastructural dimensions, where coefficients are smaller in fully specified models, suggesting that parsimonious specifications partly captured correlated structural characteristics rather than reflecting reverse causality. Taken together, the institutional context and empirical stability checks do not provide compelling support for IV estimation.

We further examine whether nonlinear relationships between PAs coverage and development outcomes are present. Following standard econometric practice (Wooldridge, 2010), we first augment the regressor vector with quadratic terms to allow for smooth nonlinearities. In the SDEM framework, both protected-area coverage and its squared term enter the model directly and via spatial lags. Quadratic specifications improve model fit in only two out of nine PA-development index combinations (SPA × ΔSOCI and SPA × ΔECON), while linear models remain preferred in the remaining cases (Appendix Table A2).

To assess whether nonlinearities reflect regime-type behavior rather than smooth curvature, we additionally estimate threshold-augmented SDEM models (Hansen, 2000). These models introduce an indicator for exceeding a coverage threshold and its interaction with protected-area shares, allowing slope changes at empirically determined breakpoints. Candidate thresholds are selected through grid searches over empirical quantiles of positive coverage values, subject to minimum subsample-size constraints. Across the cases where quadratic terms improve fit, threshold models do not yield meaningful additional improvements in AIC relative to quadratic SDEM specifications (Appendix Table A3).

Overall, robustness analyses indicate limited support for nonlinear or endogenous specifications. While nonlinear patterns emerge in a small subset of cases, they are not pervasive and do not materially alter the direction or magnitude of the main findings. Accordingly, linear SDEM models are retained as the primary specification to ensure consistency and interpretability of results, whereas two quadratic specifications that improve the model fit are reported in supplementary materials.

4. Results

Given the procedure described above, we report the key results of the nine SDEM models, presented in Table 4. Breusch-Pagan (BP) tests indicate significant heteroskedasticity in all specifications, implying that p-values close to conventional significance thresholds should be interpreted with caution. At the same time, visual inspection of QQ plots and fitted residuals, together with the relatively large sample size, reduces the risk of substantially distorted inference. Nonetheless, to account for heteroskedasticity in interpretation, we primarily emphasize coefficients that are significant at a relatively strict 0.01 threshold.

We begin by examining coefficients on control variables to verify whether the models yield expected results. First, baseline levels of local development are strong and consistent predictors of subsequent change. The poorer the initial level captured by ECON_09, INFR_09, and SOCI_09, the higher the observed rate of improvement in the respective dimension.[8] This is consistent with earlier evidence on convergence dynamics in Central and Eastern Europe (Smętkowski and Wójcik, 2012). In general, baseline conditions emerge as the most influential predictors. Peripherality (PERI) is a statistically significant and negative predictor of both economic and social development, suggesting that more remote municipalities face persistent disadvantages in these dimensions. At the same time, PERI does not exert a statistically significant effect on infrastructural development, which may reflect the relatively strong emphasis on territorial cohesion within EU regional policy. Rural municipalities (relative to urban ones) exhibit higher rates of improvement in social and economic development, consistent with convergence-type dynamics. In contrast, infrastructural development follows the opposite pattern: both rural and mixed municipalities perform worse than their urban counterparts, suggesting that despite substantial investment efforts, urban units retain a structural advantage in infrastructure access and modernization. Finally, in line with established evidence (Waltert and Schläpfer, 2010; Waltert et al., 2011), natural amenities (AMNI) significantly predict economic development, while their relationship with social development is not statistically significant.

The most consistent positive effects of PAs are observed for the economic dimension of development (ΔECON), although magnitudes remain modest. The strongest economic association is found for national parks (NP): each additional percentage point of municipal area covered by an NP corresponds to a 0.019 standard deviation increase in ΔECON. The direct effect of PAs on infrastructural development (ΔINFR) is statistically insignificant for national parks and nature reserves, while a small but statistically significant positive effect is observed for SPA areas. For social development (ΔSOCI), the relationship is predominantly negative. Statistically significant negative effects are observed for both national parks (−0.013) and nature reserves (−0.041). In practical terms, a 10% national park coverage corresponds to a deterioration in ΔSOCI by 0.13 standard deviations and an improvement in ΔECON by 0.19 standard deviations. Assuming equal contributions of the index components, this translates into an approximately 0.28 percentage point smaller improvement in unemployment and about a 0.40 percentage point smaller decline in social assistance coverage. For the economic dimension, a 10% national park coverage corresponds to an increase of roughly 90 PLN in municipal revenues per capita and 30 additional business entities per 1000 inhabitants. These figures reflect gains above or below the average pace of change observed across municipalities in the study period.

SDEM estimations allow us to examine broader determinants of local development processes, including spatially lagged explanatory variables. The most consistent results relate to the positive contribution of natural amenities in neighbouring municipalities to infrastructural and social development in the unit of interest. This pattern may reflect the supralocal nature of labour market opportunities and infrastructural development driven by landscape attractiveness. By contrast, indirect effects for the economic dimension are negligible, as the revenues tend to be captured directly by the municipality that hosts such amenities. The lagged baseline terms for SOCI_09 and ECON_09 are statistically significant but carry signs opposite to those of corresponding direct effects, suggesting diffusive dynamics whereby development poles generate positive spillovers into adjacent areas.

Finally, we report the direct, indirect, and total effects of different types of PAs on the three dimensions of local development (Table 5). The results for the social dimension reveal a consistent pattern of negative and statistically significant indirect impacts. These spillovers suggest that the adverse effects of stricter protection regimes are not limited to the municipalities that host them, but extend to neighbouring areas, likely due to the supra-local integration of labour markets (Marcińczak and Bartosiewicz, 2018). For the economic dimension, the indirect effects are negligible, confirming that there are no significant spatial spillovers in this respect. At the same time, this suggests that the positive effect of NP and SPA felt locally does not come at the expense of hindering the development of neighbouring municipalities. Regarding infrastructural development, a consistent negative indirect effect is visible. This may point to redistributive competition over infrastructure investment, where limited regional resources (e.g. EU co-financing) are concentrated in PAs, possibly at the expense of nearby municipalities. In summary, the spatial effects of PAs are most pronounced and problematic in the social domain, where both direct and indirect impacts tend to be negative. For economic development, the impacts are largely localized and positive, while infrastructure-related effects appear more mixed, suggesting potential allocation tensions.

Additional tests allowing for quadratic functional forms provide some evidence of smooth nonlinearities in SPA models, specifically in social and economic dimensions. However, these patterns are not pervasive across specifications and do not alter the overall conclusions.

5. Discussion

According to the estimations, there was a positive and statistically significant correlation between NP and SPA areas and the rate of economic development within a municipality. Therefore, claims that PAs hinder economic activity in general are not supported by our findings. However, the observed benefits in terms of local revenue and entrepreneurship are modest. The insignificance of spatial effects further suggests that these positive outcomes are not achieved at the expense of neighbouring municipalities, but rather stem from the mobilization of local resources. In other words, no trade-off between nature protection and local economic development was observed in Poland – an outcome that aligns with earlier assessments of the Natura 2000 network rollout (Gantioler et al., 2014; Cieślak et al., 2015; Gutowska, 2015). This conclusion applies to both business density and municipal revenues, implying that any restrictions on industrial activity, construction, or

[8] The negative sign of the SOCI_09 coefficients means that the "worse" (i.e. higher) the initial level of unemployment and poverty had been, the better outcome in terms of improvement in levels of said phenomena (indicated by ΔSOCI) was achieved.

Table 4
SDEM estimation results.

Dependent var.	ΔINFR	ΔECON	ΔSOCI		ΔINFR	ΔECON	ΔSOCI		ΔINFR	ΔECON	ΔSOCI
Model no.	(1)	(2)	(3)		(4)	(5)	(6)		(7)	(8)	(9)
INFR_09	−0.526***				−0.526***				−0.529***		
	(0.018)				(0.018)				(0.018)		
ECON_09		−0.079***				−0.073***				−0.074***	
		(0.009)				(0.010)				(0.009)	
SOCI_09			−0.259***				−0.261***				−0.262***
			(0.014)				(0.014)				(0.014)
NP	**0.007**	**0.019*** **	**−0.013*** **	**NR**	**0.003**	**0.005**	**−0.041** **	**SPA**	**0.004** **	**0.003** **	**−0.002**
	(0.004)	(0.002)	(0.004)		(0.018)	(0.010)	(0.016)		(0.002)	(0.001)	(0.001)
PERI	−0.001	−0.002**	−0.003***		−0.001	−0.002**	−0.003***		−0.001	−0.002**	−0.003***
	(0.001)	(0.000)	(0.001)		(0.001)	(0.001)	(0.001)		(0.001)	(0.001)	(0.001)
AMNI	0.044**	0.030**	0.020		0.048**	0.042***	0.019		0.026	0.030**	0.021
	(0.017)	(0.010)	(0.014)		(0.017)	(0.010)	(0.014)		(0.019)	(0.011)	(0.016)
RURAL	−0.568***	0.106*	0.229***		−0.566***	0.116*	0.228***		−0.584***	0.109*	0.219***
	(0.080)	(0.046)	(0.063)		(0.080)	(0.047)	(0.063)		(0.080)	(0.047)	(0.063)
MIXED	−0.221**	0.003	0.193**		−0.222**	0.003	0.202**		−0.239**	−0.005	0.203**
	(0.081)	(0.048)	(0.069)		(0.081)	(0.048)	(0.069)		(0.082)	(0.048)	(0.069)
lag.INFR_09	0.042				0.066				0.053		
	(0.062)				(0.060)				(0.062)		
lag.ECON_09		0.098***				0.095***				0.100***	
		(0.027)				(0.027)				(0.028)	
lag.SOCI_09			0.174***				0.128**				0.154***
			(0.038)				(0.040)				(0.039)
lag.NP	**−0.030***	**−0.010**	**−0.054** **	**lag.NR**	**−0.212** **	**−0.058**	**−0.305*** **	**lag.SPA**	**−0.004**	**0.000**	**−0.020** **
	(0.015)	(0.009)	(0.018)		(0.067)	(0.040)	(0.082)		(0.005)	(0.003)	(0.006)
lag.PERI	−0.001	0.003**	0.006**		−0.001	0.003**	0.006*		−0.001	0.003**	0.007**
	(0.002)	(0.001)	(0.002)		(0.002)	(0.001)	(0.002)		(0.002)	(0.001)	(0.002)
lag.AMNI	0.143***	−0.024	0.169***		0.143***	−0.029	0.171***		0.141**	−0.037	0.233***
	(0.043)	(0.024)	(0.049)		(0.041)	(0.024)	(0.049)		(0.047)	(0.027)	(0.055)
lag.RURAL	0.066	0.216	−0.160		0.154	0.243	−0.193		0.097	0.263	−0.285
	(0.306)	(0.183)	(0.305)		(0.302)	(0.183)	(0.306)		(0.308)	(0.185)	(0.306)
lag.MIXED	−0.192	0.377*	0.084		−0.155	0.390*	0.089		−0.154	0.390*	0.173
	(0.297)	(0.179)	(0.331)		(0.292)	(0.179)	(0.332)		(0.298)	(0.179)	(0.331)
Observations	2476	2476	2476		2476	2476	2476		2476	2476	2476
Log Likelihood	−3752.8	−2415.7	−3419.7		−3750.9	−2444.0	−3420.3		−3752.1	−2441.5	−3422.9
AIC	7535.6	4861.4	6898.9		7531.9	4917.9	6870.6		7534.3	4913.0	6875.8
Lambda	0.130*	0.142*	0.519***		0.101+	0.124*	0.524***		0.136*	0.130*	0.517***
BP test	82.65***	165.2***	382.2***		83.39***	91.33***	381.7***		85.27***	98.94***	396.0***
Note:	+ p < 0.1;*p < 0.05;**p < 0.01;***p < 0.001										

Table 5
Direct and indirect effects of PAs on local development – SDEM estimation.

	Direct	Indirect	Total
ΔSOCI			
NP	−0.013***	−0.054**	−0.067***
NR	−0.041**	−0.305***	−0.346***
SPA	−0.002	−0.020**	−0.021***
ΔECON			
NP	0.019**	−0.010	0.008
NR	0.005	−0.058	−0.053
SPA	0.003**	0.000	0.003
ΔINFR			
NP	0.007	−0.030*	−0.024
NR	0.003	−0.212**	−0.209**
SPA	0.004**	−0.004	0.001

Note:+ p < 0.1; *p < 0.05; **p < 0.01; ***p < 0.001.

timber harvesting were, on average, offset by gains in other sectors of the local economy. The results obtained are consistent with previous analyses of the relationship between PAs and municipal revenues (Cieślak et al., 2015; Zawilińska et al., 2021), as well as with studies highlighting the role of national parks in fostering tourism and recreation in Poland (Czeszczewik et al., 2019; Zawilińska et al., 2021). These findings add nuance to previous evidence suggesting that socioeconomic benefits are more likely to emerge under less restrictive forms of protection (Oldekop et al., 2015; Auliz-Ortiz et al., 2023). In our case, positive economic effects were also observable under stricter protection regimes, particularly national parks, indicating that the relationship between protection strictness and local development outcomes is likely to be context-dependent. Additional robustness checks revealed a limited departure from linearity for SPA areas only, where the relationship with economic development followed a U-shaped pattern, suggesting scale-dependent dynamics.

Conversely, the extent of both national parks and nature reserves was negatively correlated with the social dimension of local development, as measured by changes in unemployment rates and reliance on social assistance. Combined with the positive results observed for economic development, this finding suggests that the benefits associated with protected areas are not evenly distributed across local communities. One possible explanation is that the economic structure of municipalities hosting these two types of PAs may be less conducive to stable employment. In particular, the tourism and recreation sector in Poland – unlike industry – tends to generate seasonal, low-wage jobs concentrated in micro-enterprises and often characterized by precarious working conditions (Bednarska and Szutowski, 2013; Ministerstwo Sportu i Turystyki, 2017). Under such circumstances, gains in municipal revenues and entrepreneurship may not translate into comparable improvements in employment opportunities or poverty reduction. Moreover, spatial dependencies appear to amplify these effects, as negative social effects extend to neighbouring municipalities across all types of PAs. Some of the concerns voiced by local communities regarding employment opportunities thus find support in the empirical evidence. Similar tensions between economic and social dimensions of development have been documented in other European contexts (Lundmark et al., 2010; Cremer-Schulte and Dissart, 2015), yet our findings extend this evidence by showing that negative social effects are accompanied by significant spatial spillovers. Additional robustness checks revealed a similar departure from linearity for SPA areas, where the relationship with social development exhibited diminishing marginal benefits, again suggesting scale-dependent dynamics.

The relationship between PAs and the third dimension of local development – environmental infrastructure – proved generally weaker than in the case of economic or social outcomes.[9] A statistically significant positive association was observed only for SPA areas. This partially supports the argument that protected areas may facilitate access to external resources for environmental investments, particularly where conservation overlaps with inhabited and economically utilized landscapes, as is often the case for Natura 2000 sites in Poland. By contrast, no significant direct effects were identified for national parks or nature reserves, suggesting that other factors, such as local natural amenities endowment and the rural character of a municipality, may play a more important role in shaping infrastructure outcomes. At the same time, the indirect effects were predominantly negative, particularly for national parks and nature reserves. One possible explanation is competition for limited external funding available for municipal infrastructure expansion. The generally ambiguous results for this dimension may reflect the persistence of historical land use patterns, with infrastructure development still largely shaped by geographic constraints and legacy settlement structures (Churski et al., 2020). Given the relatively weak and mixed results for this dimension, however, these interpretations should be treated with caution.

Taken together, the results point to a complex relationship between nature protection regimes and local development outcomes. Positive effects are concentrated in the economic dimension, while negative effects are more pronounced in the social dimension. At the same time, some impacts remain localized, whereas others generate significant spillovers to neighbouring municipalities. The conservation-development relationship therefore cannot be reduced to a simple trade-off, but varies across development dimensions, protection regimes and spatial scales. The observed differences between protection regimes lend support to the institutional fit perspective. While all three forms of protection pursue biodiversity conservation, they differ substantially in their governance arrangements, regulatory restrictions, and interactions with local economies. The more favourable economic outcomes associated with national parks and Natura 2000 areas suggest that the developmental consequences of conservation depend not only on the extent of protection, but also on the institutional design through which conservation objectives are implemented. Finally, the coexistence of positive economic and negative social effects may help explain why conflicts around protected areas persist even when aggregate economic indicators improve. Earlier studies of Natura 2000 implementation in Poland emphasized concerns related to procedural and recognition justice (Grodzińska-Jurczak et al., 2012; Strzelecka et al., 2021). Our findings suggest that distributional considerations may also play an important role. Improvements at the municipal level may coexist with worsening labour-market outcomes and increased risks of social exclusion for some groups within local communities.

6. Limitations and future research

A key limitation of this study stems from the operationalization of protected areas through a quantitative measure of their spatial coverage. While this approach allows for a consistent comparison of protection regimes at the national scale, it does not capture variation in governance and implementation between individual sites. Although national parks, nature reserves and Natura 2000 SPA sites constitute relatively coherent institutional regimes, some heterogeneity inevitably remains. This is particularly relevant for Natura 2000 areas, where conservation objectives are implemented through site-specific management plans and enforcement may vary depending on administrative capacity, stakeholder participation and competing sectoral interests. However, such qualitative differences could not be incorporated into the analysis due to the limited availability of comparable data at the national scale. Future research should therefore move beyond area-based indicators of protection and investigate how specific governance arrangements and implementation practices shape the developmental consequences of conservation. Particular attention should be paid to the role of institutional fit, participation, financing and enforcement in explaining differences between protection regimes.

A second limitation concerns the temporal and spatial aggregation of the analysis. Due to data constraints, protected area coverage was measured using 2022 data rather than using data from the beginning of the study period. Although changes in PA extent were limited during 2009–2022, this choice may introduce some measurement error. Moreover, the use of municipality-level indicators captures aggregate development outcomes but does not allow the changing distribution of costs and benefits among different groups of residents to be examined directly. Future research should therefore investigate the mechanisms through which conservation affects local development at a more granular level, particularly with regard to economic structure, labour-market outcomes, and income distribution.

7. Conclusions

This study examined the relationship between three major protected area regimes in Poland - national parks, nature reserves and Natura 2000 SPA sites - and local development outcomes between 2009 and 2022. Using spatial econometric models and a multidimensional approach to development, we found that the relationship between protected areas and local development is more complex than often assumed, varying across development dimensions, protection regimes and spatial scales. National parks and Natura 2000 SPA areas were associated with modest but positive economic outcomes, while national parks and nature reserves were linked to less favourable social outcomes. Effects on environmental infrastructure proved weaker and less consistent, while several impacts extended beyond municipalities directly hosting protected areas. These findings suggest that the conservation-development relationship involves both synergies and trade-offs, depending on the outcome considered.

These insights are especially relevant in light of earlier critiques of Natura 2000 implementation, which emphasized that conflicts emerged when local communities perceived the policy as unfair, particularly in terms of recognition and representational justice (Strzelecka et al., 2021). However, participation alone does not guarantee just outcomes if unequal distribution leads to widening inequalities. In fact, the dual effect of PAs – fostering economic development while hindering social inclusion – may reinforce perceptions of structural inequality and fuel local resentment. To prevent such outcomes, conservation policy should be accompanied by measures addressing distributional injustice, including mechanisms that mitigate adverse labour-market impacts and ensure a more equitable sharing of conservation-related benefits. More broadly, the local impacts of conservation are mediated by wider labour-market and social policy arrangements that shape how costs and benefits are distributed across different groups. In this regard, just transition programmes developed in the context of decarbonization may provide a promising framework for designing compensation and support tools for localities affected by the expansion of protected areas. This is particularly relevant in light of the ambitious targets outlined in the EU Biodiversity Strategy for 2030, which aims to increase strictly protected areas to 10% of the EU's land territory by 2030, compared to 3.4% at present (Cazzolla Gatti et al., 2023). Given the identified role of negative spatial spillovers, proposed mitigation policies should extend beyond municipalities directly affected by conservation restrictions, and involve coordinated planning efforts that reflect the supra-local nature of labour

[9] It should be noted, however, that when sewage network expansion is used as the sole measure of infrastructural development, the positive effects become more pronounced and are observable in both SPA and NP areas.

markets and the competitive character of infrastructure investments. At the same time, currently absent positive spillovers from economic development could be enhanced through deliberate efforts to disperse tourist infrastructure, which tends to cluster around sites perceived as 'gateways' to PAs (Wesołowski et al., 2018).

Nature protection is a scientifically grounded response to the accelerating biodiversity crisis, and PAs remain the most established tool for safeguarding ecosystems. As demonstrated in our study, trade-offs between conservation and development do exist, particularly in the social dimension. Rather than serving as arguments against conservation, these trade-offs highlight the need for new policies that address distributional injustices. While the expansion of PAs has generated many conflicts, they can also help to advance environmental justice (Bontempi et al., 2023). Their potential depends on embedding them within broader equity-oriented policies, conceived as an integral dimension of the urgently needed just transition.

CRediT authorship contribution statement

Jakub Rok: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Maciej Grodzicki:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Martyna Podsiadło:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization.

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.

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Appendix A

Table A1
Coefficient stability - baseline and full SDEM models

	β: base	β: full	ratio	AIC: base	AIC: full	ΔAIC
ΔSOCI						
NP	-0.012^{**}	-0.013^{***}	1.080	6898.905	6869.468	−29.437
NR	-0.034^{*}	-0.041^{**}	1.215	6901.058	6870.576	−30.482
SPA	−0.001	−0.002	2.564	6910.235	6875.849	−34.386
ΔECON						
NP	0.020^{***}	0.019^{**}	0.929	4885.012	4861.357	−23.654
NR	0.015	0.005	0.340	4950.958	4917.944	−33.015
SPA	0.004^{***}	0.003^{**}	0.735	4937.659	4912.979	−24.680
ΔINFR						
NP	0.008^{+}	0.007	0.824	7615.096	7535.567	−79.529
NR	0.012	0.003	0.249	7613.602	7531.895	−81.707
SPA	0.005^{***}	0.004^{**}	0.960	7608.117	7534.286	−73.831

Note: $^{+}$ $p < 0.1$; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.
β_base denotes the coefficient of the protected-area variable in the baseline SDEM specification, while *β_full* refers to the coefficient in the fully specified SDEM model. Ratio close to one indicate coefficient stability across specifications.

Table A2
Comparison of linear and quadratic SDEM specifications

	β_PA	β_PA²	AIC: linear	AIC: quad	ΔAIC
ΔSOCI					
NP	0.026	0.000	6869.468	6868.379	1.089
NR	0.018	−0.002	6870.576	6870.383	0.193
SPA	0.007	−0.0001	6875.849	6869.139	**6.710**
ΔECON					
NP	0.013	0.000	4861.357	4864.072	−2.715
NR	−0.006	0.001	4917.944	4921.096	−3.153
SPA	−0.003	0.0001	4912.979	4906.754	**6.225**
ΔINFR					
NP	0.010	0.000	7535.567	7538.174	−2.607
NR	−0.039	0.004	7531.895	7533.493	−1.599
SPA	0.004	0.000	7534.286	7536.748	−2.463

Note: *β_PA* denotes the linear coefficient of the protected-area variable, while *β_PA²* represents the coefficient on its quadratic term.
Positive values of ΔAIC indicate improved fit relative to the linear SDEM specification. Following Burnham and Anderson (2002), $\Delta AIC > 2$ suggests moderate support for the alternative specification, while $\Delta AIC > 4$ indicates substantial support.

Table A3
Threshold SDEM diagnostics for cases where quadratic specifications improved model fit

	τ	N high	N low	AIC: quad	AIC: threshold	ΔAIC
Δ*SOCI*						
SPA	6.7%	824	1652	6869.139	6867.910	1.229
Δ*ECON*						
SPA	1.3%	1272	1204	4906.754	4906.589	0.165

Note:Positive values of ΔAIC indicate improved fit relative to the quadratic SDEM specification. Following Burnham and Anderson (2002), ΔAIC > 2 suggests moderate support for the alternative specification, while ΔAIC > 4 indicates substantial support.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.landusepol.2026.108201.

Data availability

Data will be made available on request.

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