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Is economic growth still driving municipal waste? Evidence from European Union and Western Balkan Countries

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Abstract

Municipal waste generation remains a key obstacle to Europe's transition towards a circular economy and to the achievement of Sustainable Development Goal 12, particularly in macro-regions where European Union (EU) Member States coexist with Western Balkan countries. The Adriatic–Ionian region provides a critical testing ground to assess whether economic growth continues to translate into higher municipal waste generation or whether meaningful decoupling has begun to emerge. This paper examines the extent to which municipal waste generation is driven by economic development between 2008 and 2023, and whether the underlying drivers differ between EU Member States and Western Balkan countries. Using a balanced panel of eight countries, the analysis combines fixed-effects econometric modelling with a decoupling assessment and a regional interaction approach. Results indicate that, once country-specific and time-specific factors are accounted for, economic growth alone does not systematically increase municipal waste generation. In contrast, environmental protection expenditure consistently reduces waste levels, underscoring the central role of policy effort. The analysis also reveals pronounced regional differences. These findings are directly relevant to SDG 12 and offer actionable evidence for three domains of application: (1) for EU cohesion and pre-accession policy design, supporting the case for prioritising environmental funding in Western Balkan countries; (2) for macro regional governance under European Union Strategy for the Adriatic–Ionian Region (EUSAIR), where the evidence of distinct waste growth regimes calls for differentiated decoupling strategies; and (3) for national waste management planning, where investments in environmental awareness and tertiary education should complement infrastructure development to accelerate waste prevention.

Keywords

waste generation, Western Balkans, decoupling, EUSAIR, macro-regional strategy

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Introduction

Municipal waste generation has emerged as one of the most visible environmental externalities of modern economic development (Greyson, 2007; Mazzanti, 2008). As living standards rise, consumption patterns intensify, packaging use expands, and urban lifestyles evolve, municipal waste volumes tend to increase, placing growing pressure on environmental systems, public budgets, and waste-management infrastructures. For European countries, reducing the environmental burden associated with waste generation has become a core policy priority, embedded in the broader transition towards a circular economy and climate-neutral growth.

Within this context, the European Union (EU) has set ambitious objectives aimed not only at improving waste treatment and recycling, but increasingly at preventing waste generation at source. The Circular Economy Action Plan and the revised Waste Framework Directive establish binding targets for recycling and waste reduction, reinforcing the principle that economic growth should progressively decouple from resource consumption and waste generation. While these goals are clearly articulated at the EU level, their achievement remains uneven across countries, reflecting differences in economic structures, institutional capacity, environmental governance, and policy implementation.

The challenge of waste management is particularly salient in the Adriatic–Ionian macro-region, where EU Member States coexist with Western Balkan countries at different stages of economic development and regulatory alignment (Amatore et al., 2025). On the one hand, countries such as Italy and Slovenia have invested for decades in waste management infrastructures,

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separate collection systems, and environmental regulation. On the other hand, many Western Balkan economies are still characterised by landfill dependency and limited recycling capacity, while struggling with incomplete implementation of EU-aligned waste directives, despite ongoing convergence efforts and accession processes (Arias-Navarro et al., 2024).

The prospect of EU enlargement adds an additional layer of complexity to this divergence. For Western Balkan countries, progress in waste management is not only an environmental necessity but also a critical component of alignment with the EU acquis, particularly under Chapter 27 on *Environment and Climate Change*. Advancing towards EU membership requires candidate and potential candidate countries to demonstrate concrete improvements in waste prevention and treatment, often under tight fiscal constraints. At the same time, the enlargement process creates asymmetric pressures: while EU Member States increasingly prioritise waste prevention and circular economy strategies, Western Balkan countries must simultaneously expand basic waste collection systems and comply with increasingly ambitious EU standards.

This heterogeneity raises a crucial empirical question: does economic development inevitably translate into higher municipal waste generation, or can countries achieve growth while reducing environmental pressures? The answer directly relates to the concept of decoupling, which has become central in environmental economics and sustainability policy. Absolute decoupling occurs when environmental pressures decline while the economy grows, whereas relative decoupling refers to a slower growth of environmental pressures compared to economic output (Mazzanti et al., 2012). Understanding whether and where decoupling has occurred is essential for assessing the feasibility of the EU's circular economy objectives.

Despite an extensive literature on waste management and environmental policy in Europe (Ferronato et al., 2019; Hemidat et al., 2022, Malinauskaite et al., 2017; Tsai et al., 2020), several gaps remain. First, much of the existing empirical research focuses either on the EU as a whole or on individual country case studies, while systematic comparisons between EU Member States and neighbouring Western Balkan countries remain limited. Second, studies often document correlations between income and waste generation without isolating within-country dynamics over time, which are crucial for identifying decoupling processes rather than structural differences between countries. Third, less attention has been paid to the role of policy-related variables, such as environmental protection expenditure, and social factors, such as educational attainment, as mediating forces between economic growth and waste generation.

In this respect, the Adriatic–Ionian region represents a particularly relevant empirical setting. The coexistence of advanced and catching-up economies within the same macro-regional framework provides a natural laboratory for examining whether the drivers of municipal waste generation differ across institutional and developmental contexts. Moreover, from a policy perspective, the European Union Strategy for the Adriatic–Ionian Region (EUSAIR) explicitly identifies environmental quality and sustainable waste management as strategic priorities, yet empirical evidence assessing progress towards decoupling within this macro-region remains scarce.

Against this background, this study aims to provide an integrated assessment of municipal waste generation dynamics across EU and Western Balkan countries over the period 2008–2023. By combining descriptive data analysis with fixed-effects panel econometric models, the study seeks to disentangle the relative importance of economic growth, social structure, and policy effort in shaping waste-generation outcomes.

Accordingly, the paper addresses the following research questions. (1) To what extent is municipal waste generation driven by economic development across EU and Western Balkan countries, and is there evidence of decoupling from GDP between 2008 and 2023? (2) Do the drivers of municipal waste generation differ between EU Member States and Western Balkan countries, particularly with respect to income, education, and environmental policy effort?

Answering these questions enables the study to contribute to the empirical literature on waste–growth decoupling while providing policy-relevant insights for macro-regional strategies and convergence-oriented environmental governance.

Context

In the European landscape, the implementation and coordination of macro-regional strategies are crucial mechanisms for regional development. These strategies emerged in the wake of the first macro-regional strategy, the European Union Strategy for the Baltic Sea Region (EUSBSR), established in 2009. The common objective of these frameworks is to promote local and regional development and achieve ambitious transformation goals within the European space.

The EUSAIR is one such initiative, designed as a comprehensive framework to catalyse growth, cooperation, and sustainability. EUSAIR is based on five structural pillars that shape the region's destiny, with the aim of creating a dynamic centre of collaboration, innovation, and sustainable growth. Within this structure, waste management plays a central role, reflected in the EUSAIR's Environmental Quality Pillar. Academic interest in waste management in EUSAIR has grown significantly since 2013, with a further acceleration in the last 3 years.

The literature highlights how the European Union has promoted the Circular Economy (CE) as a key concept for integrating environmental and economic policies, strengthening the links between resource use, waste and emissions (Ahmed et al., 2025; Chioatto et al., 2024; Papamichael et al., 2024). The introduction of the CE, which promotes prevention, reuse and recycling, has made the Sustainable Development Goal on solid waste management more achievable (Luttenberger, 2020). The European Commission (2015) launched an "action plan" to support the CE and promote global competitiveness, ensuring that every stage of the value chain (from production to consumption to waste management) returns to the economy. Building on this framework, the EU legislative landscape was further strengthened by the European Circular Economy

Package. In particular, Directive 2018/851/EC amended the Waste Framework Directive (2008/98/EC) to provide updated definitions and binding long-term targets for municipal waste. The Directive defines municipal waste as mixed and separately collected household waste (including paper, glass, metals, plastics, organic waste, textiles, packaging, Waste Electrical and Electronic Equipment (WEEE), bulky waste) and similar waste from other sources, while excluding industrial, agricultural forestry, fishery, construction and demolition waste, end-of-life vehicles, and sewage sludge. Directive 2018/851 establishes binding recycling targets for municipal waste, progressively increasing over time: 55% by 2025, 60% by 2030, and 65% by 2035.

The literature confirms that inadequate urban waste management is a crucial problem in the Balkan region, which is characterised by high pollution and poor management policies. Most of the Western Balkans (with the exception of Montenegro) dispose of urban waste in unsanitary landfills (municipal or illegal), with recycling rates remaining negligible (European Environment Agency, 2022). As of 2021, Albania was the only country in the Western Balkans with waste incineration plants. However, infrastructure investments are underway in Kosovo, North Macedonia and Montenegro, focusing on sorting, composting and mechanical-biological treatment plants. In terms of economic performance, EUSAIR is generally in line with environmental protection expenditure, although some EUSAIR member countries such as Croatia have made only modest progress. A recent overview confirms these disparities across Adriatic-Ionian countries, highlighting persistent challenges in waste infrastructure and recycling rates. For example, in 2017, the urban waste recycling rate in Croatia was significantly low (23.6%), falling short of the 50% target set by the European Union for 2020 (Eurostat, 2022).

Inadequate urban waste management remains a crucial problem in the Balkan region, which is characterised by extreme pollution and poor waste management policies (Ignjatović et al., 2024).

Most Western Balkan countries still lag behind in this area, while countries such as Italy and Slovenia are leading the way in overall waste management and recovery. Municipal waste generation has increased per capita in Kosovo, North Macedonia, and Serbia since 2015. In contrast, in Albania, Bosnia and Herzegovina, and Montenegro, waste generation has decreased or remained stable. A key observation is that most Western Balkan countries show a significant increase in waste generation as a result of economic growth. Although there are signs of success in decoupling growth from waste generation in Albania, Bosnia and Herzegovina, San Marino and Slovenia, this remains a persistent challenge for most of the Western Balkans and Greece, where there is an alarming negative trend (Eurostat, 2022). Despite economic efforts, the EUSAIR macro-region is generally in line with environmental protection expenditure, with the exception of North Macedonia and Slovenia, where there is a misalignment.

However, there is a significant disparity in waste management systems between countries. Dependence on landfills is high, and recycling is often negligible with very low rates (Arias et al., 2024). In most of the Western Balkans (with the exception of Montenegro), municipal waste is disposed of in unsanitary landfills, some municipal and others illegal. As of 2021, only Albania had waste incineration plants in the region (although two new ones are planned), but investments in infrastructures (e.g. sorting, composting, and mechanical-biological treatment plants) are underway in Kosovo, North Macedonia, and Montenegro. Despite clear obstacles, Balkan countries have adopted regulatory frameworks that reflect EU waste legislation, including targets and extended producer responsibility (EPR) schemes. These schemes (adopted by Bosnia and Herzegovina, Serbia, North Macedonia) represent opportunities for additional financing based on the "polluter pays" principle (Ndoka and Alimehmeti, 2024). However, harmonisation between policymakers and implementers lags behind other EU countries. Furthermore, the lack of reliable data is a persistent problem, as data on waste quantities are often estimates and many landfills do not have weighing equipment.

Literature review

Academic literature on municipal waste management (MWM) in the Adriatic-Ionian region has shown growing interest since 2013, with a significant acceleration in the last 3 years. A central theme in the literature review concerns the drivers of waste generation and the decoupling of economic growth from waste generation (Luttenberger, 2020). Decoupling is a central concept in strategies that aim to reconcile economic growth with environmental protection, and it is fundamental to the post-2015 sustainable development agenda (Fletcher and Rammelt, 2017). Broadly defined, decoupling refers to the strategic effort to promote economic growth–typically measured through GDP–while simultaneously reducing the use of natural resources and greenhouse gas emissions. The ultimate objective, particularly in the context of waste and resource management, is to detach economic expansion from its environmental impacts.

The literature distinguishes between two main forms of decoupling: relative and absolute decoupling (Haberl et al., 2020). Relative decoupling occurs when resource use or emissions continue to rise, but at a slower rate than GDP growth; this phenomenon is also referred to as "dematerialization"; absolute decoupling, by contrast, occurs when GDP grows while resource use or emissions decrease in absolute terms. Achieving long-term absolute decoupling is a logical necessity for aligning ambitious climate and sustainability goals with continued GDP growth; however, empirical evidence shows that sustained absolute decoupling is rare. Typically, absolute reductions in material flows are observed only during periods of very low economic growth or recession (Fletcher and Rammelt, 2017).

Despite its conceptual limitations and the limited empirical evidence supporting its long-term feasibility, decoupling remains

a cornerstone of sustainable development discourse. Several authors argue that decoupling functions as a "key fantasy," obscuring fundamental tensions between reducing poverty, achieving environmental sustainability, and sustaining profitable enterprise.

Most countries in the Western Balkans are experiencing a significant increase in waste generation as a result of economic growth. Although Albania, Bosnia and Herzegovina, San Marino, and Slovenia show signs of successful decoupling, Greece is experiencing an alarming negative trend. Furthermore, mass tourism is identified as a crucial driver, contributing, in the case of Croatia (HRV), to 9.1% of total municipal waste. With regard to infrastructure, the research emphasises that industrial policies promoting different options (landfill, waste-to-energy (WtE), composting) are the backbone of an efficient system (Di Foggia and Beccarello, 2021). The introduction of WtE plants is recommended to prevent landfill and generate energy. The Italian case shows that uneven industrialisation leads to a failure to comply with the principles of self-sufficiency in solid waste management, with regions such as Lombardy and Emilia-Romagna compensating for the low WtE capacities of other regions (e.g. Sicily and Lazio).

The literature highlights that, despite having adopted a regulatory framework that mirrors EU waste legislation, including targets and ERP schemes, the region faces crucial challenges in terms of governance and implementation. EPR schemes have been adopted by Bosnia and Herzegovina, Serbia, and North Macedonia, representing an opportunity for additional funding based on the "polluter pays" principle. However, there is a delay in harmonisation between policymakers and implementers of their policies compared to other EU countries. Often, waste quantities are estimated, and many landfills do not have weighing equipment, making data on treated waste uncertain (European Environment Agency, 2022).

The case of Croatia further illustrates the challenges of governance: despite investments following EU accession in 2013, the country has made only modest progress, missing the EU recycling target of 50% for 2020 and reaching only 23.6% in 2017 (Luttenberger, 2020). Contributing factors include unsatisfactory regulatory frameworks, lack of cooperation between policymakers and waste operators, and a lack of innovation, such as the scarcity of recycling-related patents.

Moreover, recent research highlights the importance of identifying the structural determinants that shape municipal waste generation across heterogeneous economic and governance contexts (D'Adamo et al., 2022; D'Adamo et al., 2024). To investigate the underlying drivers of municipal waste generation and the persistent challenge of decoupling economic growth from waste production, this study employs a set of carefully selected variables that capture the socioeconomic structure, demographic dynamics, and policy effort of the EUSAIR countries. Drawing on environmental economic theory and the consolidated empirical evidence on MWM in the Adriatic-Ionian region, the analysis incorporates economic, social, and governance-related indicators designed to explain variations in per-capita waste generation.

Looking at specific variables that are taken into consideration in the literature, GDP per capita is included as the primary indicator of economic development, consistent with the Environmental Kuznets Curve theory, which suggests that waste generation initially increases with income growth before declining once societies invest in cleaner technologies (Blagoeva et al., 2023; Grdić et al., 2020). As widely documented, GDP per capita remains a standard proxy for capturing the influence of economic development on waste generation. Tertiary education attainment is incorporated to reflect social and behavioural dimensions associated with environmental awareness. Higher educational levels are generally linked to greater environmental consciousness and a higher probability of adopting sustainable consumption practices and waste-prevention behaviours (Hasan, 2025). Meanwhile, environmental protection expenditure serves as a proxy for national policy effort, as it directly affects the availability and performance of key waste-management infrastructures, including collection, recycling, and treatment. Higher levels of environmental spending are theoretically expected to improve waste-management outcomes and reduce environmental impacts (Blagoeva et al., 2023). Finally, the Environmental Performance Index (EPI) is used to capture the broader environmental and governance context. As a composite index integrating multiple environmental indicators, including waste-related metrics, EPI is widely recognised as a benchmark for assessing policy effectiveness and sustainability performance (Ansari et al., 2019). It reflects the institutional conditions shaping national waste-generation patterns.

Methodology

This study investigates the relationship between economic, social, and policy development and municipal waste generation across the Adriatic–Ionian macro-region, with particular attention to differences between EU Member States and Western Balkan countries. The analysis is guided by two research questions:

1. To what extent is municipal waste generation driven by economic development across EU and Western Balkan countries, and is there evidence of decoupling from GDP between 2008 and 2023?
2. Do the drivers of municipal waste generation differ systematically between EU Member States and Western Balkan countries?

To address these questions, the methodological approach combines descriptive analysis, fixed-effects panel econometrics, a decoupling assessment, and a regional interaction strategy. This layered design allows the study to distinguish between simple correlations, within-country dynamics over time, and structural differences across regions.

Scope of the analysis and country coverage

The empirical analysis focuses on the Adriatic–Ionian macro-region, which brings together European Union Member States and Western Balkan countries at different stages of economic development and regulatory alignment. The study considers the following countries: Italy, Slovenia, Croatia, Greece, as EU Member States, and Albania, Bosnia and Herzegovina, North Macedonia, Montenegro, and Serbia as Western Balkan economies.

The time horizon of the analysis spans the period 2008–2023, which captures both the post-financial-crisis recovery phase and the years preceding and following major EU circular-economy policy initiatives. This period is particularly relevant for assessing medium-term waste–growth dynamics and potential decoupling processes.

San Marino is included exclusively in the descriptive and exploratory analysis (stage 1), but excluded from the econometric estimations. This choice is driven by both conceptual and methodological considerations. From a conceptual standpoint, San Marino is a micro-state with unique demographic, economic, and institutional characteristics that are not fully comparable with those of larger EU and Western Balkan countries. From a methodological perspective, data limitations and structural breaks in key variables prevent the construction of a balanced panel suitable for fixed-effects estimation. Including San Marino in the econometric stage would therefore risk distorting coefficient estimates and undermining the validity of within-country inference.

Nevertheless, San Marino remains informative in the descriptive analysis, where it provides a useful benchmark illustrating how very small economies with high income levels can exhibit distinct waste-generation patterns. Restricting its role to the exploratory stage ensures analytical transparency while preserving the robustness of the econometric results.

Data and variables

The empirical analysis relies on a balanced panel dataset covering eight countries in the Adriatic–Ionian region over the period 2008–2023. The sample includes four EU Member States (Italy, Greece, Slovenia, Croatia) and four Western Balkan countries (Albania, Bosnia and Herzegovina, Montenegro, Serbia). The period is dictated by data availability and captures both post-financial-crisis recovery and the consolidation phase of EU circular-economy policies.

The dependent variable is municipal waste generation per capita (kg per inhabitant), a standard indicator used in EU waste policy monitoring and environmental economics literature.

The explanatory variables capture economic development, social structure, and policy effort (Table 1).

Apart from the explanatory statistics analysis, population variable is excluded from the main specification due to its conceptual incompatibility with a per-capita dependent variable and strong multicollinearity with GDP, as confirmed by variance inflation factors (>5).

Data were cleaned and harmonised, ensuring a consistent panel dataset spanning 2008–2023, with missing or anomalous values addressed. Data are sourced primarily from Eurostat and the World Bank, complemented by national statistical sources where necessary for environmental expenditure. The dataset is harmonised to ensure consistency across countries and time.

Analytical strategy

The empirical analysis unfolds in four sequential stages, each addressing a distinct aspect of the research questions.

Stage 1: Explanatory statistics and correlation structure. The analysis begins with descriptive statistics and visual inspection of temporal trends and scatterplots, comparing EU and Western Balkan (WB) countries. A correlation matrix is used to assess initial associations between variables and to diagnose multicollinearity. The correlation structure consistently shows a strong positive association between GDP and waste generation, while education and environmental expenditure display weaker relationships. These preliminary diagnostics guide the econometric specification.

Stage 2: Fixed-effects panel estimation of waste drivers. A fixed-effects panel model is deployed to estimate the structural drivers of municipal waste and isolate within-country variation over time, the study employs a two-way fixed-effects (FE) panel regression model:

$$\text{Waste}it = \alpha i + \gamma t + \beta 1\text{GDCAP}it + \beta 2\text{TERED}it + \beta 3\text{ENVEXP}it + \varepsilon it$$

where i indexes countries and t indexes years.

- αi captures country-specific, time-invariant characteristics (such as geography, long-standing waste management practices, cultural attitudes, institutional capacity, spatial structure).
- γt captures year-specific shocks common across countries (e.g. EU legislation, economic crises, consumption, and macroeconomic cycles).
- $\beta 1, \beta 2$ and $\beta 3$ represent the marginal effects of GDP, education, and environmental expenditure.

The FE estimator is appropriate because it controls for unobserved heterogeneity that may bias pooled OLS estimates, and because the drivers of waste generation are likely to differ systematically across countries but remain stable over time. This specification isolates within-country variation over time, which is essential for identifying decoupling dynamics rather than

cross-sectional differences. Robust standard errors clustered at the country level are used to account for heteroscedasticity and serial correlation.

Stage 3: Decoupling assessment. To assess whether municipal waste has decoupled from economic growth, we evaluate the sign, magnitude, and statistical significance of β1 (GDP coefficient). A positive and significant β1 indicates no decoupling; a positive but declining elasticity reflects relative decoupling; and a non-significant or negative coefficient would support absolute decoupling. Additionally, GDP–waste elasticities are computed to compare EU and WB groups.

More in detail, based on the relative magnitude and direction of these changes, countries are classified into:

- Absolute decoupling (GDP increases while waste declines)
- Relative decoupling (both increase, but waste grows more slowly)
- No decoupling (waste grows faster than GDP or increases during economic contraction).

This stage complements the fixed-effects results by providing an intuitive, country-level interpretation of waste–growth dynamics over the full period.

Stage 4: Regional comparison and interaction model. To address the second research question, whether the determinants of waste differ between EU and WB countries, the model is extended to include interaction terms. The econometric framework is extended to explicitly test whether waste drivers differ between EU Member States and Western Balkan countries.

An interaction model is estimated:

$$\text{Waste}it = \alpha i + \gamma t + \beta \text{X}it + \delta\left(Xit \times \text{WB}i\right) + \varepsilon it$$

where:

- β = effect for EU countries
- δ = interaction coefficients that capture how the marginal effects of GDP per capita, tertiary education, and environmental expenditure differ between the two regions.
- WBi = is a dummy variable, 1 for Western Balkans, 0 for EU

As a robustness check, separate fixed-effects models are also estimated for EU and Western Balkan subsamples.

Stage 5: Robustness checks. Two robustness checks are performed: (1) estimating the same model with log-transformed variables to compare elasticities instead of marginal effects; (2) estimating a pooled OLS model with clustered standard errors to verify whether results are sensitive to the estimator.

Consistency of coefficient signs and significance across specifications strengthens the reliability of the findings.

Methodological limitations

The analysis is subject to several limitations. The small number of countries limits statistical power, particularly in interaction models. Data quality for municipal waste in some Western Balkan countries remains imperfect, reflecting measurement constraints. Results should therefore be interpreted as policy-consistent associations rather than causal estimates.

Low within R^2 is expected given the strong role of fixed effects, which absorb structural cross-country differences in waste systems.

Nevertheless, the combination of fixed effects, decoupling analysis, and regional comparison provides a robust and policy-relevant framework for understanding waste–growth dynamics in a heterogeneous macro-regional context.

Results

This section presents the empirical results covering nine Southern European and Western Balkan countries over the period 2008–2023, complemented by preliminary projections for 2024–2030. The data include key socioeconomic indicators (GDP, GDP per capita, population), education-related variables (tertiary enrolment rate), environmental commitment measures (environmental protection expenditure, waste generation, and waste treatment), as well as environmental performance indicators.

Explanatory statistics and correlation structure

The 2024 Environmental Performance Index (EPI) for waste management in the Adriatic-Ionian region highlights a pronounced heterogeneity across countries. Slovenia and Italy stand out as the strongest performers in both overall waste management and recovery processes, while most Western Balkan countries, except for HRV, continue to lag behind. Although some countries in the region achieve acceptable results in specific control-related processes, the overall picture reveals substantial disparities in waste management systems, with persistent structural challenges, particularly in the Western Balkans. Notably, Bosnia and Herzegovina (BIH) constitutes one of the few exceptions, showing comparatively better performance than its regional peers. Overall, the results indicate clear and enduring challenges in both waste management and waste generation throughout the Western Balkans.

Figure 1 visually summarises these differences and highlights the pronounced performance gap within the macro-region.

Figure 2 illustrates the relationship between municipal solid waste (kg/capita) and GDP per capita across the Adriatic–Ionian region, comparing the initial and the most recent year available.

The visualisation captures how economic growth has evolved alongside waste generation, allowing an assessment of whether

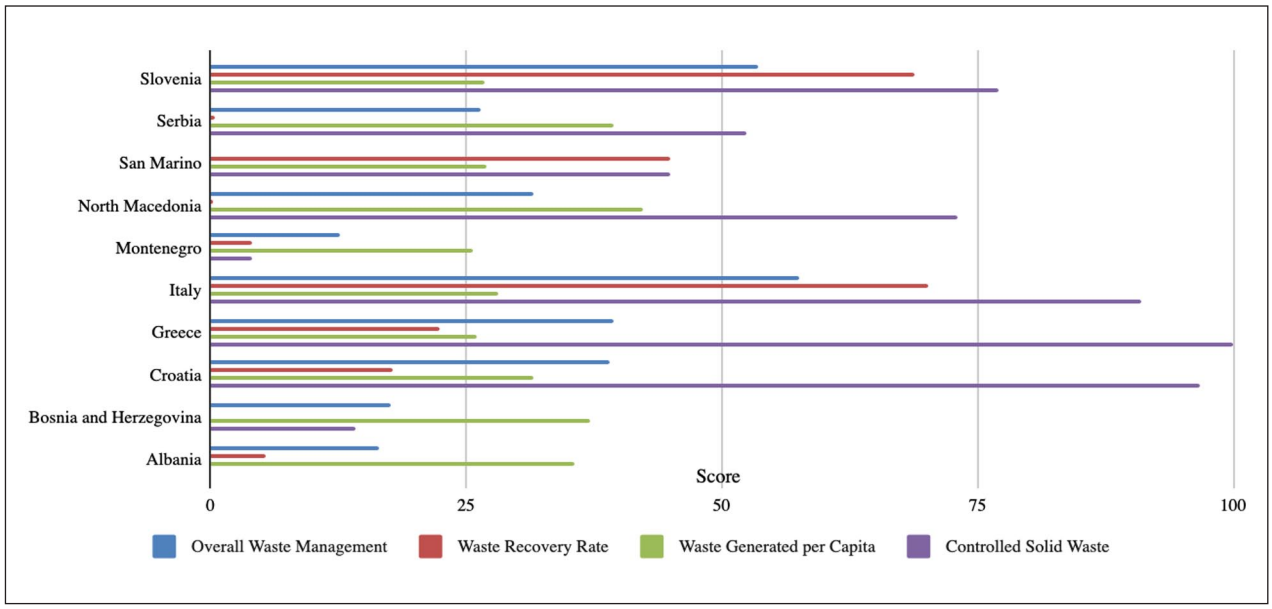

Figure 1. Overview of waste management EPI scores in 2024 (*Author's own elaboration based on 2024 EPI–data*).
EPI: Environmental Performance Index.

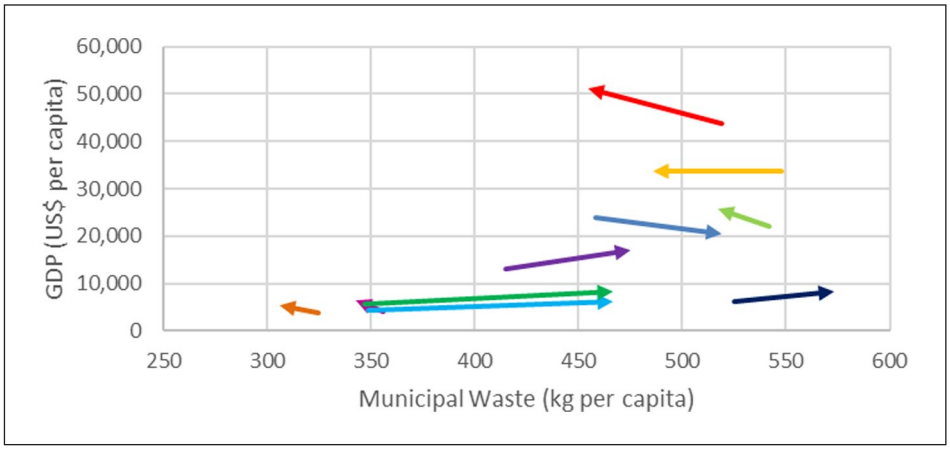

Figure 2. Municipal waste and GDP: earliest versus latest year (2008 vs 2023: the arrows start from the 2008 value and point to the 2023 value. *Author's own elaboration based on Eurostat statistics*).

countries are progressing towards, or struggling with, decoupling. Overall, the data reveal that most Western Balkan countries continue to show a parallel increase in GDP and municipal waste, indicating that economic expansion has not yet been accompanied by a reduction or stabilisation in waste production. However, the chart also highlights notable cases of successful decoupling: Albania (ALB), BIH, San Marino (SMR), and Slovenia (SVN) have managed to increase economic output without a proportional rise in waste. In contrast, Greece (GRC) displays an alarming negative trajectory, where changes in economic performance are associated with a disproportionate increase in waste generation. Taken together, the visual evidence points to significant regional obstacles in decoupling economic growth from waste production, with the Western Balkans and Greece facing the greatest challenges, while Bosnia and Herzegovina emerges as one of the few positive exceptions.

A further perspective on the relationship between economic performance and environmental commitment emerges when examining environmental protection expenditure as a percentage of GDP. As illustrated in Figure 3, the trajectories of the EUSAIR economies diverge markedly.

Albania, Bosnia and Herzegovina, Croatia, and Serbia have aligned economic growth with an expansion of environmental spending, suggesting an increasing prioritisation of environmental governance. Conversely, Slovenia and North Macedonia show persistent misalignment between growth and green spending. Despite periods of economic strain, both Italy and Greece have continued to prioritise environmental protection expenditure.

Taken together, these patterns indicate that, with the notable exceptions of North Macedonia and Slovenia, the EUSAIR macro-region has generally increased its environmental investment efforts even under adverse economic conditions.

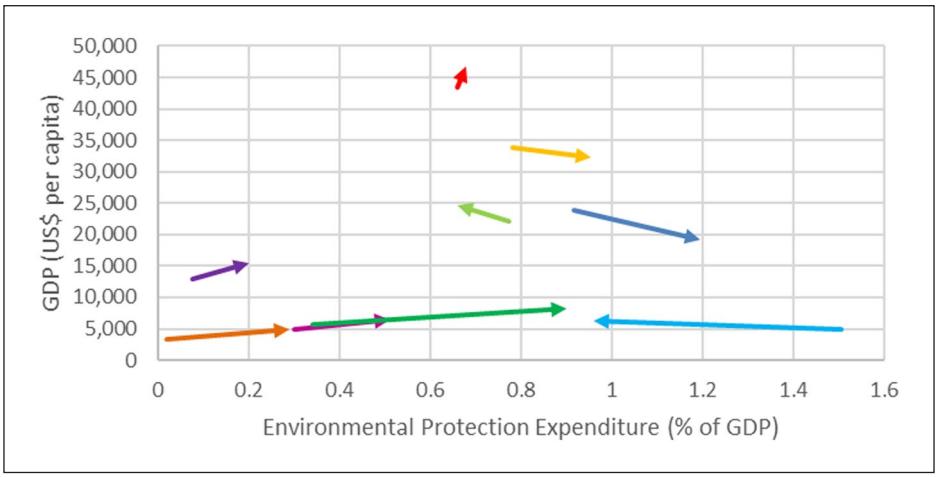

Figure 3. Environmental protection expenditure and GDP: earliest versus latest year (2008 vs 2023: the arrows start from the 2008 value and point to the 2023 value. *Author's own elaboration based on Eurostat statistics*).

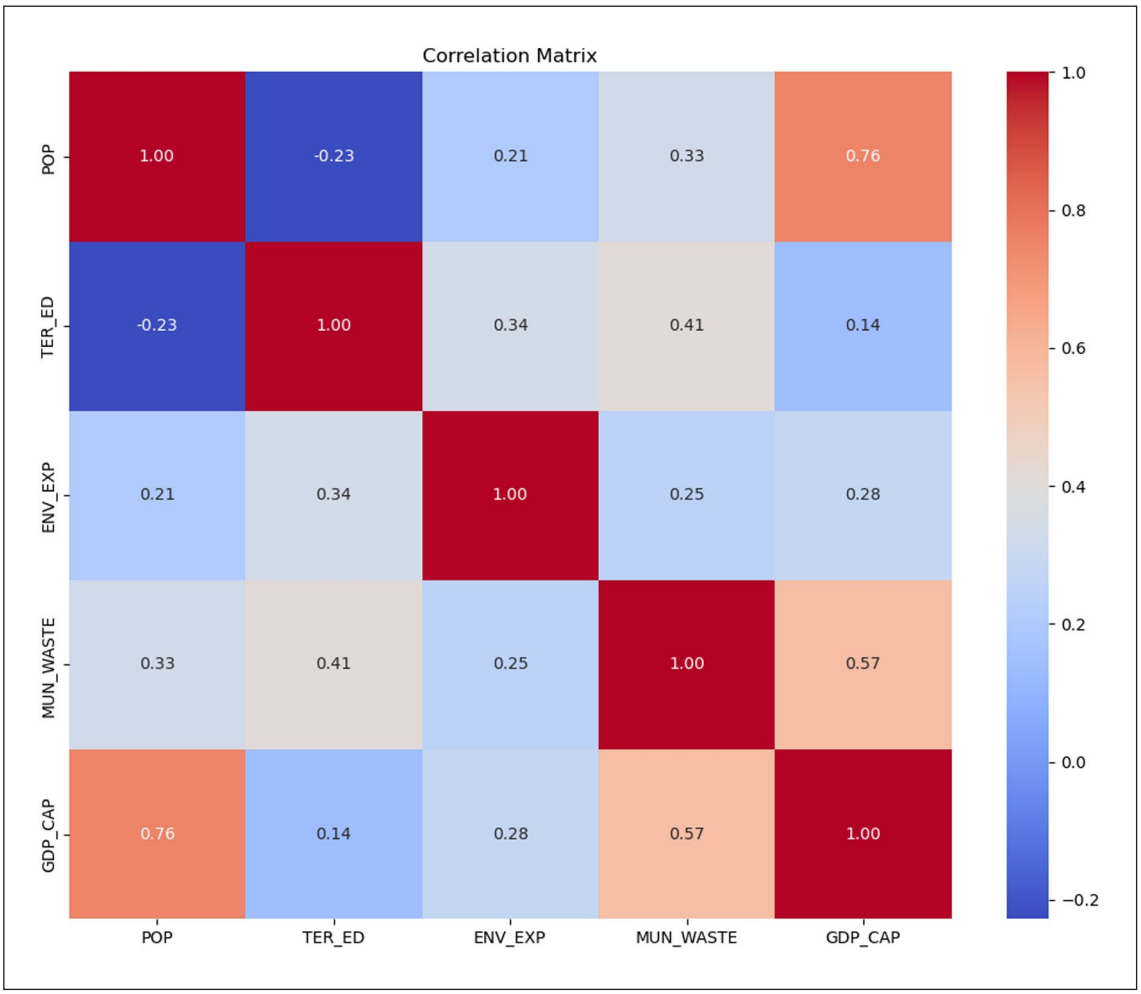

Figure 4. Correlation matrix (*Author's own elaboration based on Eurostat statistics*).

The correlation analysis, conducted through the correlation matrix, and visible in Figure 4, aims to identify patterns of linear interdependence among key socio-environmental variables, without implying causal links. The variables examined include: *Population* (*POP*); *Tertiary Education* (*TER_ED*), *Environmental Protection Expenditure* (*ENV_EXP*), *Municipal Waste per Capita* (*MUN_WASTE*), and *GDP per Capita* (*GDP_CAP)*, as shown in Figure 5.

Each value in the matrix represents a pairwise correlation coefficient ranging from −1 to +1, where +1 indicates a perfect

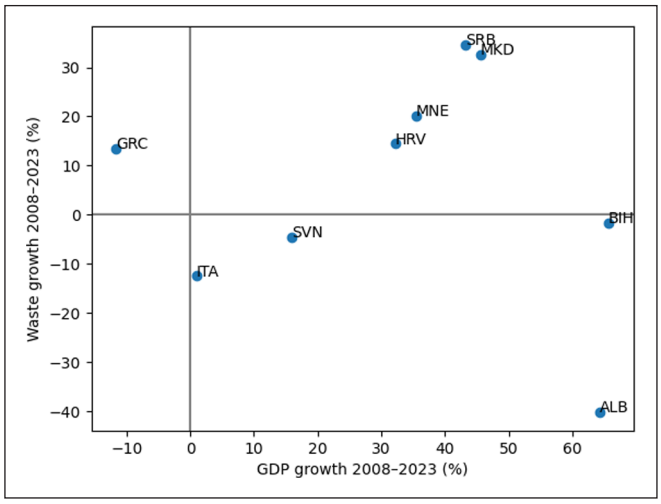

Figure 5. Decoupling scatter: GDP versus waste growth (*Author's own elaboration*).

positive linear relationship, −1 a perfect negative linear relationship, and 0 the absence of a linear association. Accordingly, the analysis focuses on detecting statistical patterns rather than establishing causal mechanisms.

POP exhibits a strong positive correlation with GDP per capita ($r=0.76$), indicating that the most populous countries in the sample also tend to be the wealthiest. Beyond economic scale, population also shows a weak positive association with municipal waste generation ($r=0.33$), suggesting that larger countries tend to produce slightly more waste per capita, although the relationship is not particularly pronounced. Moving from demographic to educational dynamics, POP displays a slight negative correlation with tertiary education attainment ($r=-0.23$), reflecting the fact that smaller countries, often newer EU member states, tend to register higher rates of tertiary-level education.

TER_ED shows a moderate positive correlation with municipal waste generation ($r=0.41$), suggesting that populations with higher levels of education also tend to produce more waste, a pattern that may reflect more intensive consumption patterns rather than lower environmental awareness. TER_ED is also moderately correlated with environmental protection expenditure ($r=0.34$), indicating that countries investing more in environmental policies are often those with higher education levels. By contrast, its correlation with GDP per capita is weak ($r=0.14$), implying that in this sample the wealthiest countries are not necessarily those with the highest tertiary education attainment.

ENV_EXP displays weak to moderate positive correlations with all other variables, indicating that richer, more educated, and more populous countries tend to allocate greater resources to environmental protection, although no single factor emerges as a dominant driver of this spending pattern.

Turning to environmental outcomes, MUN_WASTE shows its strongest associations with GDP per capita ($r=0.57$) and tertiary education ($r=0.41$), suggesting that waste generation increases alongside socioeconomic prosperity and higher education levels. Its correlations with population ($r=0.33$) and environmental expenditure ($r=0.25$) are weaker, indicating only modest links with country size and environmental policy effort.

Finally, GDP_CAP is very strongly correlated with population ($r=0.76$), reflecting the influence of large economies in shaping regional income patterns. Its association with municipal waste is moderate ($r=0.57$), reinforcing the connection between economic affluence and waste generation, while its correlations with environmental expenditure ($r=0.28$) and tertiary education ($r=0.14$) remain relatively weak, suggesting that higher income does not automatically translate into greater environmental investment or higher educational attainment.

Economic scale, as demonstrated by the correlation matrix, plays a central role in shaping the relationships among the variables: GDP per capita and population mutually reinforce one another and together account for a substantial share of the variation observed in waste generation. At the same time, education and environmental protection expenditure tend to rise in parallel, although their link to income levels remains relatively weak, an interesting pattern indicating that policy commitment to environmental protection is not solely driven by economic capacity. The positive correlations between municipal waste, GDP per capita, and tertiary education further show that higher levels of socioeconomic development are associated with increased waste generation, a trend commonly observed in EU contexts where full decoupling between growth and waste production has yet to materialise.

Stage 2: Fixed-effects panel estimation of waste drivers

To assess the socioeconomic drivers of municipal waste generation while controlling for unobserved heterogeneity, we estimate a two-way fixed-effects panel model with country and year effects over the period 2008–2023. This specification isolates within-country variation over time, net of time-invariant country characteristics and common shocks affecting all countries.

The results are reported in Table 1. Overall, the model displays limited explanatory power in terms of within variation, which is not uncommon in environmental panel analyses covering relatively short time spans and small cross-sections. Nevertheless, the joint significance of the fixed effects is confirmed by the F-test for poolability ($p<0.01$), supporting the use of a fixed-effects specification rather than a pooled model.

GDP per capita exhibits a positive coefficient, but its effect on municipal waste generation is not statistically significant once country and year fixed effects are included. This suggests that, within countries, changes in income levels over time are not systematically associated with proportional changes in waste generation. This finding points towards a weakening relationship between economic growth and waste generation and anticipates the decoupling patterns explored in the subsequent analysis.

The share of the population with tertiary education displays a negative coefficient, indicating that higher educational attainment is associated with lower municipal waste generation per

Table 1. Variables' description (*authors' own elaboration*).

Variable	Description	Source/database
Municipal waste (MUN_WASTE)	Dependent variable. Generated municipal waste per capita (kg/capita)	Eurostat
GDP per capita (GDP_CAP)	Proxy for economic development and consumption intensity.	World Bank–World Development Indicators
Environmental protection expenditure (ENV_EXP)	Percentage of GDP devoted to environmental protection, used as a proxy for policy effort and institutional commitment	International Monetary Fund; National Statistical Offices (Bosnia and Herzegovina (BIH), North Macedonia (MKD), Serbia (SRB)
Tertiary education attainment (TER_ED)	Share of the population with tertiary education, capturing social and behavioural dimensions linked to environmental awareness.	World Bank–World Development Indicators
Environmental Performance Index (EPI)	Governance and environmental context (used just for descriptive analysis)	Yale Center for Environmental Law & Policy

BIH: Bosnia and Herzegovina.

capita. However, this effect is not statistically significant at conventional levels. While the direction of the coefficient is consistent with the notion that education may foster more sustainable consumption patterns and waste prevention behaviour, the lack of significance suggests that education alone may not be a decisive short-run driver of waste dynamics within countries.

By contrast, environmental protection expenditure emerges as a statistically significant determinant. The estimated coefficient is negative and significant at the 5% level, indicating that increases in environmental expenditure as a share of GDP are associated with reductions in municipal waste generation per capita. Substantively, this result suggests that policy effort and public investment in environmental protection play a measurable role in mitigating waste generation, even after controlling for income dynamics and structural country characteristics.

These findings highlight a clear asymmetry between structural and policy-driven factors. While economic growth alone does not appear to mechanically translate into higher waste generation once fixed effects are accounted for, targeted environmental spending is associated with tangible reductions in waste. This reinforces the view that decoupling is not an automatic outcome of economic development, but rather a policy-mediated process.

These econometric results provide the empirical foundation for the subsequent decoupling assessment and the regional comparison between EU member states and Western Balkan countries, where differences in policy intensity and institutional capacity may lead to divergent waste-generation trajectories.

Table 1 reports the results from the baseline two-way fixed-effects panel regression, which controls for unobserved country-specific and time-specific factors.

As a robustness check, the baseline fixed-effects model was re-estimated using log-transformed municipal waste and GDP per capita, allowing coefficients to be interpreted as elasticities. Results confirm the baseline findings. GDP per capita exhibits no statistically significant association with waste generation, supporting the presence of decoupling. In contrast, environmental protection expenditure exerts a strong and negative effect, with a one-percentage-point increase associated with a reduction of approximately 13% in municipal waste per capita. Tertiary education attainment also shows a negative and weakly significant effect. The consistency of coefficient signs and significance across specifications strengthens the robustness of the main findings.

Again, as a second robustness check, the baseline specification was re-estimated using pooled OLS with standard errors clustered at the country level. In this framework, GDP per capita is strongly and positively associated with municipal waste generation, reflecting persistent cross-country differences in income and consumption levels. However, environmental expenditure and tertiary education are not statistically significant. In contrast, the fixed-effects specifications isolate within-country dynamics and show that environmental expenditure is consistently associated with lower waste generation, while GDP per capita loses significance. This divergence confirms that economic development primarily explains cross-sectional variation, whereas policy effort drives within-country decoupling dynamics over time.

Stage 3: Decoupling assessment

This stage assesses whether economic growth between 2008 and 2023 has been accompanied by proportional increases in municipal waste generation, or whether evidence of decoupling can be observed across EU and Western Balkan countries. Following standard practice in the environmental economics literature, decoupling is evaluated by comparing cumulative percentage changes in GDP per capita and municipal waste generation over the period.

Table 2 reports country-level growth rates and the corresponding classification of decoupling outcomes.

Several countries exhibit absolute decoupling, where municipal waste generation declines despite economic expansion. Albania shows the strongest case, with waste generation decreasing by over 40% while GDP per capita increased by more than 60%. Similar patterns are observed in Italy and Slovenia, where modest economic growth is accompanied by substantial

Table 2. Fixed-effects panel estimates (2008–2023). Dependent variable: Municipal waste per capita (kilograms; *Authors' own elaboration*).

Variables	Coefficient	Robust standard error
GDP per capita	0.0033	(0.0056)
Tertiary education (%)	−4.3147	(2.6442)
Environmental expenditure (% GDP)	−43.107	(18.328)
Country fixed effects	Yes	
Year fixed effects	Yes	
Observations	128	
Countries	8	
Years	2008–2023	
R^2 (within)	−0.069	
F-statistic (robust)	2.54	
Prob > F	0.060	

Table 3. Country-level growth rates and the classification of decoupling outcomes (*Author's own elaboration*).

Country	Waste growth (%)	GDP growth (%)	Interpretation
ALB	−40.2	+64.3	Absolute decoupling (strong)
BIH	−1.66	+65.7	Absolute decoupling (waste slightly down)
GRC	+13.4	−11.6	*Not decoupling*: GDP fell, waste rose
HRV	+14.5	+32.2	Relative decoupling
ITA	−12.5	+0.9	Absolute decoupling
MKD	+32.6	+45.6	Relative decoupling
MNE	+20.1	+35.4	Relative decoupling
SRB	+34.6	+43.1	Relative decoupling
SVN	−4.6	+15.9	Absolute decoupling

ALB: Albania; BIH: Bosnia and Herzegovina; GRC: Greece; HRV: Croatia; ITA: Italy; MKD: North Macedonia; MNE: Montenegro; SRB: Serbia; SVN: Slovenia.

reductions in waste generation. Bosnia and Herzegovina also falls into this category, although the magnitude of waste reduction is comparatively small.

These cases suggest a clear dissociation between economic development and waste generation, potentially reflecting structural changes in consumption patterns, improvements in waste management systems, or stronger environmental policy implementation.

A second group of countries displays relative decoupling, meaning that waste generation increases, but at a slower pace than economic growth. Croatia, North Macedonia, Montenegro, and Serbia fall into this category. In these cases, economic expansion remains associated with rising waste generation; however, the elasticity of waste with respect to GDP is less than one, indicating partial mitigation of environmental pressure.

Relative decoupling appears particularly relevant for Western Balkan countries, where rapid economic convergence is still underway, and waste prevention mechanisms may be less mature.

Greece represents a distinct case where no decoupling is observed. Over the period considered, GDP per capita declined while municipal waste generation increased. This pattern suggests that factors other than economic growth, such as structural inefficiencies, tourism pressure, or delayed adjustments in waste management systems, may drive waste dynamics during periods of economic contraction.

Stage 4: Regional comparison and interaction model

To assess whether the drivers of municipal waste generation differ systematically between EU Member States and Western Balkan countries, a regional interaction model is estimated. The baseline two-way fixed effects specification is augmented by interactions between the explanatory variables and a dummy identifying Western Balkan countries.

Table 3 shows the country-level growth rates with the decoupling outcomes, while Table 4 reports the estimated coefficients from the interaction model.

For EU Member States, GDP per capita is positively and significantly associated with municipal waste generation, indicating that higher levels of economic development are still linked to increased waste per capita. Environmental expenditure also shows a positive average association, although the estimate likely reflects higher environmental spending in countries with historically higher waste levels rather than a causal increase in waste.

In contrast, the interaction terms (Figure 6) reveal markedly different dynamics in the Western Balkans. The coefficient on GDP per capita interacted with the Western Balkan dummy is positive and highly significant, implying a substantially stronger income–waste relationship than in the EU. This suggests that economic growth in Western Balkan countries remains closely

Table 4. Estimated coefficients from the interaction model (*Author's own elaboration*).

Region	Variable	Coefficient	Lower	Upper	Var_label
EU	GDP_CAP	0.011535	0.000606	0.022463	GDP per capita
WB	GDP_CAP	0.076519	0.037235	0.115803	GDP per capita
EU	TER_ED	4.754077	−1.517766	11.025920	Tertiary education (%)
WB	TER_ED	−9.722264	−21.492123	2.047594	Tertiary education (%)
EU	ENV_EXP	65.798697	5.791307	125.806088	Env. expenditure (% GDP)
WB	ENV_EXP	−80.265395	−178.692647	18.161857	Env. expenditure (% GDP)

EU: European Union; WB: Western Balkan; TER_ED: tertiary education; ENV_EXP: environmental protection expenditure; GDP_CAP: GDP per capita.

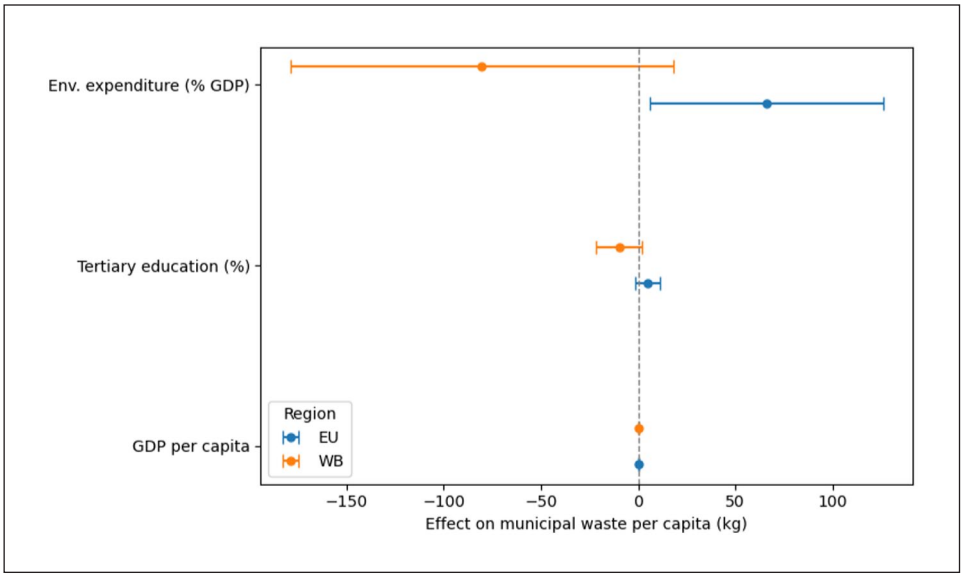

Figure 6. Drivers of municipal waste: EU versus Western Balkans (FE model with interactions; *Author's own elaboration*).
EU: European Union; FE: fixed-effects.

coupled with rising municipal waste generation, indicating limited progress towards decoupling.

The interaction for tertiary education is negative and significant, indicating that increases in tertiary education attainment reduce waste generation in the Western Balkans relative to EU countries. This result is consistent with the idea that educational improvements may play a more transformative role in waste-related behaviour in catching-up economies.

Finally, environmental expenditure exhibits a strong negative interaction effect for Western Balkan countries. While environmental spending in EU countries is not associated with significant waste reductions, in the Western Balkans higher environmental expenditure is linked to substantial decreases in municipal waste per capita. This suggests that marginal environmental investments yield larger returns in countries where waste management systems and infrastructure are less mature. Overall, the results provide robust evidence of regional heterogeneity in the determinants of municipal waste generation.

Taken together, these findings indicate asymmetric decoupling trajectories across regions. EU Member States show signs of partial or relative decoupling, where income growth translates only weakly into increased waste generation, and policy variables exhibit limited marginal effects. In contrast, Western Balkan countries display stronger coupling between GDP growth and waste generation, while education and environmental expenditure act as powerful mitigating forces.

This divergence reflects differences in institutional maturity, waste management infrastructure, consumption patterns, and policy effectiveness. It also suggests that strategies successful in the EU may not directly transfer to the Western Balkans without adaptation.

Discussion

This study set out to examine two closely related questions: first, whether municipal waste generation remains structurally driven by economic development in the Adriatic–Ionian and Western Balkan region, or whether evidence of decoupling from GDP has emerged between 2008 and 2023; and second, whether the determinants of municipal waste differ systematically between EU member states and Western Balkan countries.

Taken together, the fixed-effects panel estimates and the decoupling assessment provide a coherent answer to the first research question. Once persistent country characteristics and common time shocks are controlled for, changes in GDP per capita are not statistically associated with changes in municipal

waste generation. This result is robust across specifications, including the log-transformed model, where GDP elasticities remain small and insignificant.

This finding has an important implication: economic growth alone does not mechanically translate into higher waste generation within countries over time. In other words, at least within the period and group of countries examined, waste generation is not an automatic by-product of rising income levels. The descriptive decoupling analysis strongly reinforces this interpretation. Several countries exhibit absolute decoupling, with municipal waste declining despite sustained GDP growth. Albania represents the most pronounced case, while Italy and Slovenia also display clear evidence of dissociation between growth and waste production. Bosnia and Herzegovina, although still facing structural challenges in waste governance, shows a similar directional pattern.

At the same time, the existence of relative decoupling in several countries and the absence of decoupling in Greece indicate that decoupling is neither universal nor inevitable. Rather, it appears contingent on institutional capacity, policy effort, and the structure of national waste management systems (Chioatto et al., 2024; Goddard, 1995; Triguero et al., 2016). The fixed-effects results capture this directly: once income dynamics are netted out, it is environmental protection expenditure, not GDP, that emerges as the only statistically significant determinant of waste reduction.

This points to a central conclusion of the paper. Decoupling between economic growth and municipal waste is not a passive outcome of development; it is an active, policy-driven process. Countries that have reduced waste generation while growing economically are precisely those that have expanded waste-related policies and infrastructural and regulatory capacity. This interpretation aligns closely with the circular economy logic embedded in EU waste policy, where prevention, efficiency, and investment are designed to weaken the growth–waste link rather than simply manage its consequences (Chioatto and Sospiro, 2023).

The second research question concerns whether these dynamics differ between EU member states and Western Balkan countries. Here, the evidence is particularly clear. The interaction model and subsample estimates reveal that EU and Western Balkan countries operate under markedly different waste–growth regimes.

In EU member states, GDP per capita has only a weak and marginal association with municipal waste generation. This suggests that economic expansion has already been partially internalised within more mature waste-management systems. Waste generation in these countries appears less responsive to short-term changes in income and more strongly shaped by long-standing infrastructure, regulatory frameworks, and consumption norms. In this context, additional environmental expenditure shows limited marginal impact on waste levels, likely reflecting diminishing returns once basic systems are already in place.

By contrast, the Western Balkans exhibit a fundamentally different pattern. GDP growth remains strongly and significantly associated with increases in municipal waste generation, indicating that economic convergence is still closely coupled with material consumption and waste production. This is consistent with the descriptive decoupling results, where most Western Balkan countries fall into the category of relative decoupling rather than absolute decoupling.

Crucially, however, the interaction results also show that policy and social variables matter more in the Western Balkans than in the EU. Environmental protection expenditure has a strong negative association with waste generation in this group, and tertiary education attainment is associated with lower waste levels. These findings suggest that, in catching-up economies, incremental improvements in environmental governance and human capital yield substantial environmental returns. Where waste management systems are less mature, investments and behavioural changes appear to be far more effective in altering waste trajectories.

This asymmetry between regions reflects differences in institutional maturity rather than differences in environmental awareness alone. In the EU, waste prevention increasingly depends on system-level factors such as infrastructure saturation, regulatory enforcement, and circular-economy integration (Sund et al., 2025). In the Western Balkans, by contrast, basic investments in governance capacity, education, structural changes, and waste services still play a decisive role in shaping outcomes. As a result, the same policy instruments generate very different marginal effects across regions.

The combined evidence from the econometric models and decoupling assessment suggests that a single, uniform decoupling pathway does not exist across the Adriatic–Ionian macroregion. Instead, countries appear to be located at different stages of the waste–growth transition.

EU member states largely exhibit partial or advanced decoupling, where economic growth continues with only weak environmental pressure from municipal waste. In these contexts, further progress is likely to depend on systemic innovations, such as improved waste prevention and circular business models, rather than on marginal increases in expenditure alone.

Western Balkan countries, on the other hand, are still in a phase where economic growth and waste generation move together. Yet the strong mitigating effects of environmental expenditure and education indicate that decoupling is achievable. Importantly, the results suggest that EU-style policy frameworks cannot simply be transplanted without adaptation. While regulatory alignment matters, the effectiveness of policies in the Western Balkans appears to depend on complementary investments in human capital and governance structure.

More broadly, the findings underscore that decoupling should be understood as a dynamic, context-specific process rather than a universal outcome of development. Economic growth sets the stage, but policy effort determines the direction of travel. This

conclusion carries direct relevance for EUSAIR and EU enlargement strategies, where the challenge is not only to promote convergence, but to ensure that convergence occurs along environmentally sustainable pathways (Amatore et al., 2024, 2025).

The findings of this study carry several important implications for waste management policy design across the Adriatic–Ionian macro-region, particularly in the context of the EU Circular Economy agenda and the EUSAIR Environmental Quality Pillar. By explicitly distinguishing between EU Member States and Western Balkan countries, the analysis highlights that uniform policy approaches are unlikely to be equally effective across heterogeneous institutional and developmental contexts.

First, the empirical results challenge the assumption that economic growth necessarily leads to higher municipal waste generation. Once country-specific characteristics and time shocks are accounted for, income dynamics lose explanatory power, especially within EU countries. This suggests that economic development alone is neither a sufficient nor a necessary driver of municipal waste growth.

From a policy perspective, this implies that growth-compatible waste reduction strategies are feasible, but only when accompanied by targeted governance and infrastructure investment. Policymakers should therefore move beyond narratives that frame waste escalation as an unavoidable by-product of development, and instead focus on institutional and policy levers that actively shape waste outcomes.

One of the most consistent findings across specifications is the significant and negative association between environmental protection expenditure and municipal waste generation. This effect is particularly strong in Western Balkan countries, where additional spending appears to yield disproportionately large reductions in waste generation.

This result has two key policy implications. First, it suggests that environmental expenditure is not merely a symbolic commitment, but a concrete mechanism through which waste prevention and management outcomes can be improved. Investment in collection systems, sorting infrastructure, recycling facilities, and institutional capacity appears to translate into tangible reductions in waste generation per capita.

Second, the heterogeneous effects across regions indicate diminishing marginal returns to environmental expenditure in more mature system contexts, such as in long-standing EU Member States. In contrast, countries with less developed waste systems benefit more strongly from incremental investments. This underscores the importance of prioritising environmental funding in catching-up economies, where basic infrastructure deficits still constrain waste prevention efforts.

The regional comparison reveals two distinct waste–growth regimes. In EU Member States, waste generation appears relatively decoupled from income dynamics, and the marginal effects of education and environmental spending are weaker. This suggests that many EU countries may have already exhausted low-hanging policy fruits and now face structural and behavioural challenges, such as consumption habits, packaging intensity, and tourism-related waste.

For these countries, future policy efforts should focus on: (1) waste prevention at source, (2) product design and EPR, (3) fiscal instruments targeting consumption patterns rather than disposal alone, (4) circularity. In the Western Balkans, by contrast, waste generation remains strongly coupled with economic growth. However, education and environmental expenditure emerge as powerful mitigating factors. This implies that policy sequencing matters: early and sustained investments in education, institutional capacity, and waste governance can prevent the lock-in of inefficient waste systems during periods of rapid economic growth.

Accordingly, Western Balkan countries would benefit from: (i) accelerating alignment with EU waste directives not only in law but in implementation, (ii) channelling pre-accession and cohesion-related funds towards waste-related infrastructure, (iii) strengthening administrative capacity and data quality to support evidence-based policymaking.

Finally, the results have direct implications for macro-regional strategies such as EUSAIR. The observed heterogeneity suggests that macro-regional coordination should emphasise differentiated pathways rather than uniform targets. While shared objectives remain essential, flexibility in policy instruments and investment priorities is crucial to accommodate varying levels of institutional maturity. EUSAIR governance structures could therefore play a critical role in facilitating knowledge transfer from EU frontrunners to Western Balkan countries, coordinating cross-border infrastructure investments, and promoting region-specific decoupling strategies tailored to local economic structures.

Conclusion

This study set out to investigate two central questions: whether municipal waste generation has decoupled from economic growth across EU and Western Balkan countries between 2008 and 2023, and whether the drivers of waste generation differ systematically between the two regions. By combining fixed-effects panel estimation, decoupling analysis, and regional interaction models, the paper provides a cohesive and policy-relevant answer to both.

The results show that economic development is no longer a dominant within-country driver of municipal waste generation once structural differences and common shocks are controlled for. Instead, waste trajectories increasingly depend on institutional and policy factors. This finding challenges conventional assumptions embedded in growth-oriented environmental narratives and suggests that the relationship between income and waste is weakening over time.

At the same time, the analysis reveals profound regional asymmetries. EU Member States exhibit signs of partial or absolute decoupling, consistent with more mature waste management systems and long-standing environmental policies. In contrast, many

Western Balkan countries remain in a phase where economic growth is still closely coupled with increasing waste generation. However, the strong mitigating role of environmental expenditure and education in these countries indicates that decoupling is achievable, provided that policy effort is sustained and effectively targeted.

Taken together, the findings point to the existence of distinct waste–growth regimes within the same macro-region. The challenge ahead is therefore not only to strengthen waste policy in absolute terms but also to ensure that strategies are aligned with each country's stage of institutional and economic development. Decoupling, as this study shows, is less a universal trajectory than a differentiated policy outcome.

Some limitations of this study should be acknowledged. First, the analysis relies on a relatively small and balanced panel, constrained by data availability in the Western Balkans. While fixed-effects estimation mitigates bias from unobserved heterogeneity, the limited cross-sectional dimension reduces statistical power and calls for cautious interpretation of coefficient magnitudes. Second, municipal waste data in several Western Balkan countries are partly based on estimates rather than direct measurement, reflecting the absence of weighing systems and standardised reporting. Although these data limitations are widely recognised in the literature and do not invalidate the observed patterns, they highlight the need for continued efforts to improve waste statistics in the region. Third, the study focuses on aggregate municipal waste generation rather than waste composition or treatment pathways. As a result, it cannot distinguish between changes driven by prevention, recycling, tourism dynamics, or structural shifts in consumption.

Future research could address these limitations in several ways. First, rolling-window or sub-period decoupling analyses could be performed to identify turning points associated with EU accession, regulatory reforms, or macroeconomic shocks. Second, extending the framework to include tourism intensity, urbanisation, or waste treatment infrastructure indicators would allow a more granular understanding of waste dynamics. Third, exploiting region-level or city-level data, where available, could reveal within-country divergences concealed by national averages. Finally, comparative analysis with other EU macro-regions could help assess whether the Adriatic–Ionian experience reflects broader European patterns or unique regional characteristics.

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