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# Does Circularity Pay? Circular Economy Adoption and Economic Performance in European SMEs

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**Abstract**

Small and medium-sized enterprises account for 99% of EU firms, making their engagement with circular economy (CE) practices indispensable to any economy-wide transition, yet the firm-level business case for voluntary adoption remains empirically contested, and existing evidence geographically narrow. This study examines, at the EU27 scale, the firm- and country-level determinants of CE adoption and whether adoption yields measurable economic returns. A two-level (firm and country), cross-sectional design combines micro-data from Flash Eurobarometer 549 (13,124 SMEs, June 2024) with Eurostat institutional indicators, applying hierarchical regression, K-Means clustering, and crosstabulation with post-stratification weights. Adoption is associated with resource-efficiency investment ($\beta = 0.119$), climate-strategy formalisation ($\beta = 0.093$), and national circular material use rate ($\beta = 0.108$, partially supported), while firm size shows no independent effect; the barrier index is the strongest predictor ($\beta = 0.333$), an unexpected positive association tentatively interpreted as a commitment effect whereby firms already active in CE better recognise obstacles. CE adoption shows no economically meaningful short-term association with performance ($\beta = 0.025$, negligible), with a small provisional exception in the industrial sector. Cluster analysis identifies three descriptive profiles: Efficiency Investors (13.7%), Strategic Green (32.0%), Passive (54.3%). CE adoption reflects strategic intent rather than firm size; economic benefits appear indirect and long-term, and more than half of European SMEs remain passive, requiring differentiated support at the national level.

**Keywords:** circular economy; SMEs; CE adoption; economic performance; hierarchical regression; cluster analysis; European Union; circular material use rate; institutional context; sustainable business models

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## 1. Introduction

The circular economy has emerged as one of the defining frameworks of contemporary economic policy, providing a systemic alternative to the linear take-make-dispose model of production and consumption that has underpinned industrial growth for more than two centuries. Its appeal rests on a compelling promise: that closing, slowing, and narrowing resource loops can simultaneously reduce environmental degradation and generate economic value, transforming waste into input, scarcity into opportunity, and cost into competitive advantage [1,2]. This promise has found its most ambitious institutional expression in the European Union, where the circular economy now constitutes a strategic pillar of the European Green Deal and the accompanying Circular Economy Action Plan [3].

Through a dense architecture of regulatory instruments, from the Ecodesign Regulation and the Sustainable Products Strategy to the Critical Raw Materials Act and the revised Waste Framework Directive, the EU has signalled that circularity is no longer a voluntary aspiration but an increasingly binding condition of market participation across the Union's single market.

Yet the realisation of this ambition depends, ultimately, on the behaviour of firms. And within the European enterprise landscape, it is small and medium-sized enterprises that occupy the most consequential position. SMEs account for approximately 99% of all enterprises in the European Union, generating a disproportionately large share of private sector employment and value-added relative to their individual size [4]. Their collective engagement with circular economy principles is therefore not merely desirable but indispensable to any meaningful economy-wide transition toward circularity [5]. At the same time, SMEs are structurally disadvantaged in their capacity to undertake this transition; they command fewer financial and human resources, operate with thinner margins, face more acute barriers in accessing information and technology, and exert weaker influence within supply chains than the large corporations that have attracted the bulk of CE-oriented research and policy attention [6,7].

Despite their central importance, the empirical literature on CE adoption among SMEs remains fragmented, geographically uneven, and marked by three persistent gaps that the present study addresses directly. The first gap concerns the determinants of CE adoption at the firm level. While existing research has identified individual drivers (financial resources, managerial commitment, regulatory pressure, and barrier perception), few studies have tested these factors jointly within a multivariate framework that controls for their mutual interdependencies and isolates their independent contributions [8,9]. The result is a literature rich in bivariate associations but poor in causal architecture; we know that investment, strategy, and barriers each correlate with CE adoption, but we know less about which dominates after controlling for the others, or whether their effects are contingent on one another.

The second gap concerns the relationship between national institutional context and firm-level CE behaviour. The overwhelming majority of empirical studies have been conducted within single countries or across narrow geographic samples, making it structurally impossible to identify the cross-national variation in CE adoption that is increasingly evident in aggregate data [10,11]. EU member states differ dramatically in their circular material use rates, from 1.3% in Romania to 32.7% in the Netherlands in the dataset, yet the implications of this heterogeneity for firm-level behaviour remain under-studied. Institutional theory suggests that such variation should matter, as firms embedded in more circular national ecosystems benefit from denser networks of secondary-material suppliers, stronger regulatory signals, and more conducive normative climates [12,13]. Testing this proposition requires a two-level (firm-and-country) design that combines firm-level data with country-level institutional indicators, a design that remains rare in the CE literature despite repeated calls for its adoption [8,13].

The third and most consequential gap concerns the economic returns on CE adoption. The narrative that circularity pays, that closing resource loops generates cost savings, opens new revenue streams, and enhances competitive position, is central to the business case for the circular transition [14,15]. Yet the empirical evidence for this relationship is considerably more mixed than the normative literature implies [5,16]. For SMEs specifically, the question is both theoretically open and practically urgent: if circular practices do not translate into measurable economic improvements within the horizons that matter to owner-managers and investors, the business case for voluntary adoption is fundamentally weakened, and the burden of the circular transition falls disproportionately on regulatory compulsion rather than market incentive. Providing rigorous, large-scale evidence on this relationship, rather than the small-sample case studies that dominate existing empirical work, is a direct contribution to the policy debate over how to design effective incentives for SME circular transition.

The present study addresses these three gaps through an original, two-level (firm-and-country) empirical analysis of 13,124 SMEs across all 27 EU member states, combining micro-level behavioural data from Flash Eurobarometer 549 (conducted in June 2024) with macro-level institutional indicators from Eurostat's Circular Economy Monitoring Framework. We pursue three interrelated research objectives. First, we examine the firm-level and national-level determinants of CE practice adoption through hierarchical regression (Hypotheses H1–H5), identifying the relative contributions of investment, climate strategy, perceived barriers, firm size, and national circular material use rate. Second, we test whether CE adoption generates measurable economic returns, operationalised as self-assessed turnover evolution over three years, and whether these returns are contingent on sector and national context (Hypotheses H6–H8). Third, we develop an empirically grounded typology of European SMEs according to their behavioural profiles of CE adoption, using K-Means cluster analysis to identify latent groupings defined by the motivational basis of their circular engagement.

The study makes five contributions to the literature. It identifies an unexpected positive barrier adoption association, which we interpret tentatively as a commitment effect (H3 rejected), a pattern whereby firms further advanced in CE adoption report more barriers, because engagement with circularity generates the practical experience necessary to perceive obstacles that wholly passive firms cannot yet recognise. It decouples the effect of firm size from CE behaviour, demonstrating that the apparent size advantage disappears once investment and strategic commitment are controlled for, with significant implications for the design of public support programmes. It is among the first EU-27-wide quantitative assessments to document the absence of a direct, short-term relationship between CE adoption and economic performance, contextualising this result within the temporal and indirect nature of circularity-related benefits. It demonstrates a theoretically important asymmetry in the effects of national context; national circular maturity (CMUR) is positively associated with CE adoption (H5 partially supported) but does not amplify its economic returns (H8 rejected) and is in fact negatively associated with short-term performance, a finding that may reflect the compliance costs of advanced circular ecosystems and points to the need for a differentiated policy response. CMUR is a material-flow indicator rather than a policy or regulatory measure, so this association should be read as contextual rather than causal. Finally, it proposes a motivational profiling of CE adopters, Efficiency Investors, Strategic Green and Passive firms, introducing the dimension of adoption motivation as a primary axis of differentiation, less prominent in existing classifications, and situates these descriptive profiles within a geographic and sectoral analysis that reveals systematic institutional patterns across the Union.

The remainder of this paper is organised as follows. Section 2 develops the theoretical framework and research hypotheses through a structured review of the relevant literature. Section 3 describes the research design, data sources, variable operationalisation, and analytical methods. Section 4 presents the empirical results across three analytical components: descriptive statistics, cluster typologies, and hierarchical regression models. Section 5 discusses the theoretical contributions, practical implications for managers and policymakers, study limitations, and directions for future research, and Section 6 concludes the paper.

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## 2. Literature Review and Hypothesis Development

### *2.1. Circular Economy: Concept, Policy Framework, and Relevance to SMEs*

The circular economy (CE) has emerged over the past decade as a leading framework for reconciling economic activity with environmental constraints, displacing the dominant linear "take-make-dispose" model of production and consumption with one premised on closing, slowing, and narrowing resource loops [2,17]. At its core, the concept envisions an economic system in which the value of products, materials, and resources is maintained for as long as possible, and waste generation is minimised through strategies such as reuse, repair, remanufacturing, and recycling [1,9]. Although its intellectual roots can be traced to earlier schools of thought-industrial ecology, cradle-to-cradle design, and the performance economy, among others-the contemporary CE concept has gained particular traction precisely because it offers a pragmatic, business-oriented vocabulary that links resource efficiency to value creation and competitiveness [18,19].

Despite its rapid diffusion, the concept remains theoretically unsettled. In their widely cited analysis of 114 definitions, ref. [20] demonstrate that CE is understood in markedly heterogeneous ways across academic and practitioner communities, most commonly reduced to the "3R" framework (reduce, reuse, recycle) while frequently neglecting its systemic and societal dimensions. This conceptual plurality has led Korhonen et al. (2018) [13] to characterise the CE as an "essentially contested concept"-one whose normative appeal sustains broad consensus on its desirability even as fundamental disagreement persists over its meaning, scope, and operationalisation. Related critiques observe that the social and ethical pillars of sustainability are often subordinated to environmental and economic objectives within CE discourse, leaving the concept's distributional and equity implications underdeveloped [21]. For the present study, this contested character is consequential: it implies that CE adoption is unlikely to be a unidimensional phenomenon and is better captured through the multiple, potentially divergent practices that firms actually implement than through a single composite indicator.

The policy salience of the circular economy has reinforced its conceptual prominence, nowhere more so than in the European Union. The CE constitutes a cornerstone of the European Green Deal and its accompanying Circular Economy Action Plan [3], which together establish circularity as a strategic priority for the Union's transition toward climate neutrality. To track progress, the Commission has developed a dedicated Circular Economy Monitoring Framework, operationalising the transition through indicators spanning production and consumption, waste management, secondary raw materials, and competitiveness and innovation [4]. Among these, the circular material use rate (CMUR) has become the most frequently used headline metric for benchmarking national circularity [22]. Yet aggregate indicators conceal substantial heterogeneity: circularity performance varies widely across member states, reflecting differences in industrial structure, regulatory maturity, and institutional capacity-an observation that motivates the cross-national, two-level (firm-and-country) approach adopted in this study.

This policy ambition ultimately depends on the behaviour of firms, and small and medium-sized enterprises (SMEs) occupy a pivotal yet precarious position in the circular transition. SMEs account for approximately 99% of all enterprises in the European Union and a substantial share of its value-added and employment, making their collective engagement indispensable to any economy-wide shift toward circularity [5]. At the same time, SMEs face structural constraints-limited financial and human resources, restricted access to information and technology, and weaker bargaining power within supply chains-that distinguish their adoption pathways from those of large corporations [6,7]. Consequently, findings derived from large-firm or single-sector studies cannot be assumed to transfer to the SME population. Despite growing recognition of their importance, empirical evidence on the determinants and economic consequences of CE adoption among SMEs remains comparatively fragmented and geographically uneven, with relatively few studies leveraging large-scale, cross-national firm-level data. The present study addresses this gap by examining CE adoption across the full population of EU-27 member states, integrating firm-level behaviour with the national institutional context in which it is embedded.

## 2.2. Firm-Level Determinants of CE Adoption

### 2.2.1. Resources, Investment, and Firm Size

A substantial body of work locates the drivers of corporate environmental behaviour in the resources and capabilities that firms command. The Resource-Based View (RBV) holds that heterogeneity in firm performance derives from the possession of valuable, rare, inimitable, and non-substitutable resources [23], while Hart's [24] Natural-Resource-Based View (NRBV) extends this logic to the natural environment, arguing that strategies such as pollution prevention, product stewardship, and sustainable development rest on distinct bundles of organisational resources and capabilities. Applied to the circular economy, this perspective implies that the transition from a linear to a circular model is itself resource-intensive: firms must mobilise financial capital, technical expertise, and managerial attention before they can redesign products, reconfigure processes, or establish the reverse-logistics arrangements that circularity demands [25]. The adoption of CE practices is a multi-stage process, and each stage builds on the experience gained in previous phases [26].

Financial resources, in particular, are repeatedly identified as a central enabler of CE adoption among SMEs. In their study of European SMEs, ref. [5] find that access to finance and the availability of supportive internal resources are among the most decisive factors distinguishing firms that successfully implement circular business models from those that do not. Investment in resource efficiency functions both as a direct input to circular activities-funding cleaner technologies, recycling infrastructure, or eco-design capabilities-and as a signal of organisational commitment to the transition [7,27]. Where such investment is absent, even firms that recognise the value of circularity frequently remain unable to translate intention into practice, a gap consistently documented in the SME literature [5,6]. These considerations suggest that the level of resources a firm devotes to resource efficiency should be positively associated with the breadth of circular practices it adopts.

Firm size is the second resource-related factor that has attracted sustained attention, on the premise that larger firms possess the financial slack, specialised personnel, and absorptive capacity required to undertake environmental initiatives that smaller firms cannot afford [6,28]. A recurrent argument in the literature holds that micro-enterprises in particular are constrained by acute resource poverty, limiting their capacity to engage in circular practices relative to their larger counterparts [5,6]. The empirical record, however, is more equivocal than this reasoning implies. A countervailing strand emphasises that smaller firms can compensate for resource limitations through greater organisational flexibility, shorter decision-making chains, and the capacity to adapt quickly to emerging opportunities [29]. Even SMEs with limited resources can substantially improve circular economy performance through collaboration and knowledge management [30]. Moreover, several studies report that any apparent size advantage attenuates or disappears once behavioural and strategic factors-managerial commitment, environmental strategy, prior investment-are controlled for, suggesting that size may operate as a proxy for resources rather than as an independent driver in its own right [29,31,32]. This unresolved tension makes firm size a theoretically motivated yet empirically open determinant, warranting explicit testing within a multivariate framework that holds behavioural factors constant.

On the basis of the resource-based reasoning developed above, the following hypotheses are advanced:

**H1.** *The level of investment in resource efficiency is positively associated with the extent of CE practice adoption among SMEs.*

**H2.** *Firm size is positively associated with the extent of CE practice adoption, with larger firms adopting more circular practices than micro-enterprises.*

2.2.2. Barriers and Enablers

If resources and strategy describe what propels CE adoption, an extensive literature has concentrated instead on what impedes it. Barriers to the circular transition are among the most thoroughly catalogued themes in the field, and SMEs are widely held to confront them most acutely [5,6]. Drawing on evidence from across the European Union, Kirchherr et al. [9] identify a hierarchy of obstacles in which cultural barriers-hesitant company culture, limited consumer interest and awareness-dominate, operating in conjunction with market, regulatory, and technological impediments rather than in isolation. Complementary syntheses distinguish broad categories of barriers spanning financial constraints, informational and knowledge gaps, technical and technological limitations, institutional and regulatory friction, and supply-chain coordination failures [8,33]. For SMEs in particular, the most frequently reported impediments include shortage of capital, the administrative burden of compliance, lack of technical expertise, and weak demand for circular products [5,6,34]. Acquiring new technologies is instrumental in overcoming technical barriers to the adoption of CE practices [35,36].

The prevailing analytical treatment of these barriers is essentially linear: obstacles are conceived as exogenous conditions that inhibit adoption, such that a greater perceived barrier burden should correspond to lower levels of circular practice. This barrier-inhibition logic underpins much of the policy discourse, which frames intervention as the removal of obstacles standing between firms and an otherwise latent willingness to act. Yet the assumption that barriers are external to, and antecedent to, the adoption process has been questioned. A process-oriented perspective on the circular transition emphasises that barriers are frequently encountered, recognised, and articulated only as firms actively engage with circular practices-that is, awareness of obstacles is in part endogenous to the implementation process itself [2,8]. On this reading, firms that have advanced furthest in adoption may paradoxically report more barriers, having accumulated the practical experience necessary to perceive them, whereas wholly inactive firms register few barriers simply because they have not yet initiated the processes that would reveal them. Qualitative studies lend indirect support to this interpretation, noting that engagement with circularity tends to sharpen rather than diminish managers' awareness of its difficulties [5,9].

These two readings carry opposing empirical predictions, and the literature does not decisively adjudicate between them. The dominant barrier-inhibition view anticipates a negative association between perceived barriers and adoption, and it is this conventional expectation that we adopt as our formal hypothesis, while remaining attentive to the possibility-raised by the process-oriented perspective-that the relationship may operate in the opposite direction. Accordingly:

**H3.** *The perception of significant barriers (financial, informational, and technical) is negatively associated with the extent of CE practice adoption among SMEs.*

#### 2.2.3. Strategy, Managerial Commitment, and Climate Orientation

While resources establish the *capacity* for circular transition, a parallel stream of research locates its origins in the *strategic intent* of the firm-the deliberate orientation of organisational goals, vision, and managerial commitment toward environmental ends. Hart's [24] NRBV already foreshadows this argument in positing "shared vision" as a critical enabling capability for sustainable development strategies, and subsequent work in strategic management has consolidated the view that proactive environmental behaviour is driven less by external compulsion than by internal conviction [37,38]. Firms that formalise an environmental or climate commitment articulate priorities, allocate accountability, and signal direction in ways that orient subsequent operational decisions-including the adoption of circular practices.

This strategic orientation is consistently identified as a determinant of environmental and circular behaviour. A long tradition distinguishes proactive from reactive environmental postures, demonstrating that firms which anticipate rather than merely comply with environmental pressures pursue a broader and more integrated repertoire of practices [37,39]. In the SME context specifically, the presence of a formalised sustainability strategy and the personal values and commitment of owner-managers emerge as decisive in shaping environmental engagement, frequently outweighing structural characteristics of the firm [40,41]. The business-model literature reinforces this link from a different angle: circular business model innovation is portrayed as an intentional, design-driven process in which managers reconceive how the firm creates, delivers, and captures value, rather than as an incremental by-product of routine operations [42,43]. A dynamic and adaptive vision and an integrated SMES management can contribute to CE practices adoption [44]. Villegas et al. [45] underscore the importance of knowledge adoption mechanisms and internal structures within SMEs capable of supporting sustainable change.

Climate neutrality commitments represent a particularly salient and contemporary expression of such strategic intent. Under the European Green Deal, decarbonisation and circularity have become tightly coupled policy objectives, and firms that commit to climate-neutrality targets increasingly recognise circular strategies-material efficiency, recycling, product life-extension-as instruments for reducing their carbon footprint [2,3]. A formalised climate strategy can thus be understood as a manifestation of broader environmental commitment that plausibly extends to the adoption of circular practices: firms that have internalised a climate objective possess both the motivation and the strategic infrastructure to pursue circularity more systematically. This reasoning yields the following hypothesis:

**H4.** *The existence of an explicit climate-neutrality strategy is positively associated with the extent of CE practice adoption among SMEs.*

### *2.3. National Institutional Context and the Multi-Level Perspective*

The determinants examined thus far reside within the firm. Yet firms do not adopt circular practices in a vacuum; they are embedded in national institutional environments that shape the constraints, incentives, and normative expectations under which they operate. Institutional theory provides the foundational rationale for this proposition. North (2019) [12] conceives institutions as the "rules of the game"-the formal regulations and informal norms that structure economic interaction and condition the costs and feasibility of particular courses of action. Building on this tradition, organisational institutionalism holds that firms conform to coercive, normative, and mimetic pressures emanating from their institutional field, such that environmental behaviour reflects not only internal capabilities but also the legitimacy demands of the surrounding context [43,46,47]. Applied to the circular economy, this reasoning implies that the maturity of a country's circular infrastructure, regulatory framework, and supporting ecosystem should condition the propensity of its firms to adopt circular practices [10,13,48].

Empirical work increasingly substantiates the relevance of national context to circularity outcomes. Comparative studies document pronounced cross-country heterogeneity in CE performance across the European Union, attributable to differences in regulatory stringency, recycling infrastructure, environmental taxation, and the broader political economy of the transition [11,49,50]. Ranta et al. [10], examining how institutional dimensions support or hinder circularity across national settings, show that regulative, normative, and cultural-cognitive elements jointly shape the implementation of CE principles. This contextual variation is especially pronounced when the enlarged Union is considered in full: Central and Eastern European (CEE) member states generally exhibit lower circular material use rates and less developed support ecosystems than their Western and Northern counterparts, reflecting differences in industrial legacy, fiscal capacity, and the relative recency of environmental policy integration [11]. Such disparities suggest that the national context may exert an influence on firm behaviour that is independent of, and additional to, firm-level characteristics-an effect that single-country or firm-only designs are structurally unable to detect. Taxation and incentives vary between member states; therefore, variable and contextual government support for circular economy practices influences SMEs' CE adoption [51,52].

These considerations motivate a two-level analytical approach. Because firms are nested within countries, the determinants of CE adoption operate simultaneously at two levels: the micro-level attributes of the firm and the macro-level attributes of its national environment [53]. A two-level framework that combines firm-level survey data with country-level institutional indicators permits the contextual effect to be isolated from compositional differences in firm characteristics, addressing a recurrent call in the CE literature for research that examines the interplay between organisational and institutional determinants [8,13]. The circular material use rate (CMUR) serves as a parsimonious and theoretically apposite summary of the national circular context: it is the indicator most widely employed to benchmark CE maturity [22], it directly captures the degree to which an economy reincorporates secondary materials, and it is available for all member states without missing values. A higher national CMUR is therefore expected to be associated with greater CE adoption at the firm level, as firms in more circular economies benefit from supportive infrastructure, denser networks of secondary-material suppliers, the broader circular ecosystem, and more conducive normative climates. The core models estimate this two-level structure through hierarchical (block-wise) regression; a formal multilevel specification with random country intercepts is estimated separately as a robustness check (see Section 4). This yields the following hypothesis:

**H5.** *The higher the national circular material use rate (CMUR), the greater the extent of CE practice adoption among SMEs in that country.*

### *2.4. Circular Economy, Business Models, and Economic Performance*

The proposition that circularity pays-that closing resource loops simultaneously benefits the environment and the firm's bottom line-lies at the heart of the circular economy's appeal to the business community. This "win-win" narrative is most forcefully articulated in the influential reports of the Ellen MacArthur Foundation [14], which quantify substantial material-cost savings and growth opportunities from a transition to circular models, and it is echoed in a normative academic literature that positions circularity as a source of competitive advantage, cost reduction, and new revenue streams [2,15]. The mechanisms invoked are intuitive: circular practices reduce dependence on virgin material inputs and exposure to price volatility, lower waste-disposal costs, open access to green market segments, and enhance reputation among increasingly sustainability-conscious customers and investors [43,54]. It is principally through innovation in the business model-the reconfiguration of how value is created, delivered, and captured-that these benefits are expected to materialise, making circular business model innovation the central conceptual bridge between sustainable practice and economic value [28,55]. Incorporating circular practices into business models allows SMEs to improve resilience to resource-related uncertainties, adapt more effectively to regulatory changes, and generate novel sources of customer value and business growth [56].

The empirical evidence for this relationship, however, is considerably more mixed than the normative literature implies. While some firm-level studies report positive associations between circular or broader environmental practices and financial performance [27,57], others find effects that are weak, statistically insignificant, contingent, or confined to particular performance dimensions [5,7]. The wider "does it pay to be green" debate, of which the CE-performance question is a contemporary instance, has long been characterised by inconsistent findings, attributable to differences in how environmental engagement and performance are operationalised, the time horizons examined, and the contexts studied [16,58,59]. Cuong et al. [60] find that SMEs can enhance their sustainable performance by fostering a sustainability-oriented culture and embracing an entrepreneurial orientation toward circularity. Two considerations are especially pertinent to SMEs. First, the benefits of circularity are widely held to accrue primarily through *indirect* channels-operating-cost reductions, supply resilience, risk mitigation, reputational gains-that may not register in top-line revenue, and to materialise over *longer* horizons than short-window studies can capture [2,5]. Second, as circular practices diffuse and become normalised across the SME population, their capacity to confer distinctive competitive advantage may erode: where adoption is widespread, circularity becomes a condition of market participation rather than a source of differentiation [55]. Together, these considerations caution against expecting a strong, direct, contemporaneous link between CE adoption and self-reported revenue growth.

We nonetheless test the directional relationship implied by the dominant business case, since it represents the central empirical claim the special issue invites us to scrutinise:

**H6.** *The adoption of a greater number of CE practices is positively associated with the economic performance of SMEs, as measured by turnover evolution.*

A further consideration is that the practice-performance relationship may not be uniform across sectors. The economic returns on circularity plausibly depend on the material and energy intensity of a firm's operations: in resource-intensive activities, efficiency gains from circular practices translate more directly into cost savings that affect profitability and turnover, whereas in service activities-where the value proposition is largely intangible-the operational levers of circularity are fewer, and their financial signature weaker [13,54]. Sector has accordingly been identified as an important contingency in environmental-performance research, conditioning both the opportunities for and the returns on circular engagement [61]. This suggests that the effect of CE adoption on performance should be stronger in production- and industry-oriented sectors than in services, motivating a moderating hypothesis:

**H7.** *The effect of CE practices on economic performance is moderated by sector, being significantly different in production-oriented sectors compared with services.*

### 2.5. Typologies and Taxonomies of CE Adoption

The determinants examined in the preceding sections describe forces that act, on average, across the SME population. Yet the assumption of a homogeneous response to these forces is difficult to sustain: firms differ not only in how much circular activity they undertake but in the underlying logic that motivates it. A long tradition in environmental management has accordingly sought to classify firms into distinct behavioural types rather than to locate them along a single continuum of engagement. The foundational distinction is between proactive and reactive environmental postures [24,37]: proactive firms anticipate environmental pressures and embed sustainability within their strategy, whereas reactive firms respond only to external compulsion, doing the minimum that compliance or market access requires. Subsequent taxonomic work has refined this binary into richer typologies that capture intermediate and hybrid positions [41,62], establishing the classification of firms by environmental orientation as a well-grounded analytical strategy.

Within the circular economy specifically, typological approaches have proliferated, as scholars have recognised that there is no single pathway to circularity. Studies have classified circular business models by the value-retention strategies they employ-narrowing, slowing, and closing resource loops [43,55]-and by the archetypal mechanisms through which they create sustainable value [28,43]. What much of this literature shares is a focus on the content of circular activity: which loops are closed, which practices are deployed, which value propositions are pursued. Comparatively less attention has been directed to the motivational basis of adoption-the question of whether firms with similar levels of circular activity arrive there through fundamentally different drivers. This distinction matters because two firms exhibiting identical adoption intensity may be strategically dissimilar in ways that bear directly on the durability of their engagement: one acting from an internalised, formalised commitment, the other responding chiefly to market demand without an underlying strategic foundation.

Identifying such latent groupings is the natural province of cluster analysis, a classification technique widely employed in the management and sustainability literature to derive empirically grounded typologies from multivariate behavioural data [63]. Rather than imposing a priori categories, cluster analysis allows these profiles to emerge from the data, grouping firms according to similarity across a set of theoretically selected dimensions. In the present study, this approach is used to determine whether the European SME population partitions into distinct adoption profiles defined jointly by their circular activity, their strategic climate orientation, their investment behaviour, and their green-market engagement. Establishing the existence and composition of such profiles serves three purposes: it tests whether the average relationships estimated in the regression models conceal meaningful heterogeneity; it introduces the motivational dimension-strategic commitment versus market responsiveness-as an axis of differentiation largely absent from existing CE typologies; and it provides a behavioural foundation for the geographic and sectoral analysis that follows, linking firm-level profiles to the national institutional contexts in which they are embedded. This cluster analysis thus complements the hypothesis-testing apparatus of the study with an exploratory, configurational perspective on how circular adoption is patterned across the Union. Because the resulting clusters are derived inductively from a single cross-sectional sample and are not validated against external criteria, they are best understood as exploratory, descriptive profiles rather than as a definitive or validated typology of CE adopters.

A distinct question concerns whether the national context is associated not only with whether firms adopt circular practices but also with the economic returns they obtain from doing so. The institutional logic that motivates H5 could plausibly extend to performance: in countries with mature circular ecosystems, firms might capture circularity-related value more readily, owing to better-developed markets for circular products, stronger consumer demand, and more efficient secondary-material supply chains. Under this reasoning, a favourable national context would amplify the performance benefits of CE adoption, functioning as a moderator of the practice-performance relationship. We therefore advance H8 in this amplifying form, while noting that the relationship is theoretically ambiguous: more advanced circular contexts may equally impose higher compliance costs or more saturated competitive conditions that offset, rather than reinforce, firm-level returns [9]-a possibility we return to in interpreting the results.

**H8.** *A favourable national CE context (high CMUR) amplifies the positive effect of CE practice adoption on the economic performance of SMEs (moderating effect).*

# 3. Research Methodology

## 3.1. Research Design and Epistemological Justification

The study adopts a quantitative, cross-sectional design, based on secondary data at two levels of analysis-firm and country. This choice is based on three methodological arguments. First, large-scale quantitative data allow statistical generalisations on the behaviour of SMEs across the EU, going beyond the limitations of case studies or narrow national surveys [64]. Second, the secondary nature of the data ensures cross-national comparability, given that both sources (Flash Eurobarometer 549 and Eurostat) use standardised collection protocols. Third, the two-level data structure (firms nested in countries), which combines firm-level data with national macroeconomic indicators, responds to an increasingly frequent call in the circular economy literature to examine the interaction between organizational factors and the institutional context [8,13]. While the core models estimate this structure through hierarchical block-wise regression, a genuine multilevel model with random country intercepts is additionally estimated as a robustness check (see Section 4).

The cross-sectional nature of the study also represents a recognized limitation: the data are collected at a single point in time (June 2024), which does not allow for strict causal inferences or analysis of the temporal evolution of CE adoption. Future longitudinal studies could clarify the directionality of the identified relationships.

## 3.2. Data Sources

### 3.2.1. Flash Eurobarometer 549—Firm-Level Primary Data

The main data source is [65] Flash Eurobarometer 549 (FL549), the most recent and comprehensive survey of European SMEs on resource efficiency and green markets, conducted by the European Commission between 3 and 28 June 2024. The microdata were obtained free of charge through the GESIS platform—Leibniz Institute for the Social Sciences (archive code: ZA8869, version 1.0.0). FL549 is part of a longitudinal series of similar surveys (FL342/2012, FL426/2015, FL456/2017, FL498/2021), which gives it valuable methodological continuity, although the present study uses only the 2024 wave to reflect the behaviour of SMEs in the context of the implementation of the European Green Deal.

The FL549 sample comprises 18,159 observations, collected through computer-assisted telephone interviews (CATI), covering SMEs and large companies in 38 economies. For the present study, the analysis was restricted to the 13,124 SMEs in the 27 EU member states, after excluding observations from non-member countries (Albania, Switzerland, United Kingdom, Iceland, Moldova, Montenegro, North Macedonia, Norway, Serbia, Turkey, United States). The country-level sample varies between 248 (Cyprus) and 609 (Romania) observations, with a balanced distribution between large and small member states.

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The FL549 sampling design follows a proportional stratification by firm size (micro: 1–9 employees; small: 10–49; medium: 50–249) and sector of activity (NACE Rev. 2), with post-stratification weights (w1_sme variable) to ensure national representativeness. All analyses in this study were conducted with the w1_sme weight activated, according to the European Commission's methodological recommendations for the use of Eurobarometer data (GESIS, 2024) [65].

### 3.2.2. Eurostat Circular Economy Indicators-Country Data

The second data source provides the national institutional context of the circular economy for each EU member state. Eurostat's Circular Economy Monitoring Framework includes indicators organised into five thematic areas: production and consumption, waste management, secondary raw materials, competitiveness and innovation, and global sustainability (Eurostat, 2023) [65].

From the 11 categories of indicators available, seven annual and complete data series were selected, based on two criteria: (1) theoretical relevance for measuring CE maturity at national level and (2) availability of data for all 27 EU member states over a sufficient period. Series with a bi-annual frequency (cei_pc032, cei_wm010) and with insufficient temporal coverage-below 6 time points, as is the case of cei_srm010 with data only for the years 2013, 2016, 2019, and 2022-were excluded from the analysis. Table 1 below presents the seven series retained, with the covered periods and the names of the corresponding variables in the combined database:

**Table 1.** Eurostat data series used in the study.

| Code | Indicator | Time Series | Variable in Data Base |
|---|---|---|---|
| cei_srm030 | Circular material use rate-share of recycled materials in total domestic material consumption (%) | 2004–2024 | CMUR/ZCMUR |
| cei_wm011 | Municipal waste recycling rate (%) | 2000–2024 | WM_Recycling |
| cei_wm020 | Packaging recycling rate, by material type (%) | 2000–2023 | Pack_Recycling |
| cei_pc031 | Municipal waste per capita (kg/inhabitant) | 2000–2024 | MWaste_capita |
| cei_cie011 | People employed in circular economy sectors (thousand full-time equivalent-FTE) | 2005–2023 | CE_Employment |
| cei_cie012 | Gross value-added in CE sectors (million EUR) | 2005–2023 | CE_GVA |
| cei_cie020 | Patents related to recycling and secondary raw materials (no.) | 2000–2021 | CE_Patents |

**Note**: Greece uses the code EL in the Eurostat nomenclature, as opposed to the standard ISO code GR. The mapping correction was applied automatically in the data combination process. For the circular material use rate (cei_srm030), the range 2004–2024 indicates data availability in Eurostat; the value used in the analysis is the 2024 reference-year figure for every country (retrieved June 2024, prior to the survey close).

Among the seven indicators, Circular Material Use Rate (CMUR) was selected as the main national context variable in the regression models, based on three arguments: (1) CMUR is the most frequently used indicator in the empirical literature to quantify CE maturity at the country level [22]; (2) it directly covers the theoretical construct of the study-the degree to which the national economy circularly valorises materials; and (3) it is available for all 27 member states without missing values. CMUR was standardised (z-score) before use in the regression, for comparability with the other predictors.

*3.3. Database Combination Procedure*

The combination of the two data sources was performed by a Python 3.12.3 script using the ISO country code as a link variable-isocntry in FL549, identical to the geo code in the Eurostat CSV files. For each Eurostat indicator, the value corresponding to reference year 2024, retrieved in early June 2024 and thus already available at the time of the FL549 survey (June 2024), was assigned to each country. No values released after the survey date entered the models, ensuring that the national context precedes or coincides with the firm-level observations. For the circular material use rate (cei_srm030), the reference year 2024 is available and used for all 27 member states. The final database-named FL549_Eurostat_EU27_combined-contains 13,124 observations and 72 variables (65 at firm level from FL549 and 7 at country level from Eurostat), with 0% missing values for all Eurostat indicators at the level of the 27 member states.

*3.4. Variables' Operationalisation*

3.4.1. Dependent Variable-Model 1

The adoption of circular economy practices (q1t_rec) was operationalised based on the aggregate variable q1t from FL549, which reflects the number of resource efficiency actions implemented by the firm from a list of 12 response options, of which nine capture substantive resource-efficiency and circular actions: saving water, saving energy, using predominantly renewable energy, saving materials, switching to greener suppliers of materials, minimising waste, selling residues and waste to another company, recycling within the company, and designing products that are easier to maintain, repair or reuse. The remaining three options (Other, None, Don't know) are residual categories that do not represent circular practices. The original variable was reverse-coded (1 = 5+ actions, 4 = no action), which is why it was recoded into the q1t_rec scale (0 = no action, 3 = 5 or more actions), ensuring an intuitive positive relationship between the numerical value and the level of CE adoption. Because the index counts distinct action types rather than measuring their depth or intensity, it captures the breadth of reported green and resource-efficiency actions rather than a validated latent construct of circularity. The exact wording and binary coding of all 12 items are reported in Supplementary Materials (Table S1b).

3.4.2. Dependent Variable-Model 2

Economic performance (scr13a_rec) was operationalised by the evolution of turnover over the last three years (variable scr13a in FL549). Although this performance measure is subjective (self-assessed), it is widely used in empirical research on SMEs due to the unavailability of objective financial data for unlisted firms [5,27]. Similarly to q1t, the variable was recoded to ensure a positive relationship (1 = decrease, 4 = increase of 10% or more).

3.4.3. Main Independent Variables

Investments in resource efficiency (q4) measures the average annual percentage of turnover allocated to resource efficiency in the last 2 years, on a scale from 1 (nothing) to 6 (over 30% of turnover). The original response category 7 (Don't know/No answer) does not represent a level of investment and was therefore recoded as missing (1425 cases). Climate strategy (q14_rec) reflects the existence of a commitment to climate neutrality (coded from 1 = not in place and not planned, to 4 = the company is already climate neutral). The barrier index (barriere_index) is the sum of the 13 binary items q7.1–q7.13 (0 = barrier not mentioned, 1 = mentioned), reflecting the diversity of difficulties encountered in implementing CE actions (financial barriers, lack of information, low customer demand, administrative complexity, etc.). These items were asked only of firms reporting at least one resource-efficiency action in q1.1–q1.9; firms routed out of this branch carry the Inapplicable code and are treated as missing. The index is therefore defined for the 12,184 firms routed into the barrier battery, not for the full sample of 13,124. The standardised CMUR variable (ZCMUR) captures the national context of the circular economy.

#### 3.4.4. Control Variables

Firm size (scr10) is included as an ordinal control variable (1 = micro, 2 = small, 3 = medium), recognizing the potential role of organizational resources in CE adoption [28]. Sector of activity was operationalised through three dummy variables (d_manufacturing, d_industry, d_retail), with the service sector as the reference category, capturing structural differences in circularity opportunities and constraints across sectors. Economic performance (scr13a_rec) is included as a control variable in Model 1, to isolate the behavioural effects of CE from the influence of the firm's financial conditions.

### *3.5. Research Hypotheses*

Based on the literature review and theoretical framework, the study tests eight hypotheses structured around two regression models. Model 1 examines the determinants of the adoption of CE practices, while Model 2 investigates the effect of CE on economic performance, including sectorial and contextual moderating effects.

Model 1—Determinants of CE practice adoption (dependent variable: q1t_rec)

**H1.** *The level of investment in resource efficiency is positively associated with the extent of CE practice adoption among SMEs (q4 → q1t_rec).*

**H2.** *Firm size is positively associated with the extent of CE practice adoption, with larger firms adopting more circular practices than micro-enterprises (scr10 → q1t_rec).*

**H3.** *The perception of significant barriers (financial, informational, and technical) is negatively associated with the extent of CE practice adoption among SMEs (bariers_index → q1t_rec).*

**H4.** *The existence of an explicit climate-neutrality strategy is positively associated with the extent of CE practice adoption among SMEs (q14_rec → q1t_rec).*

**H5.** *The higher the national circular material use rate (CMUR), the greater the extent of CE practice adoption among SMEs in that country (ZCMUR → q1t_rec).*

Model 2—The effect of CE on economic performance (dependent variable: scr13a_rec)

**H6.** *The adoption of a greater number of CE practices is positively associated with the economic performance of SMEs, as measured by turnover evolution (q1t_rec → scr13a_rec).*

**H7.** *The effect of CE practices on economic performance is moderated by sector, being significantly different in production-oriented sectors compared with services (q1t_rec × nace_b → scr13a_rec).*

**H8.** *A favourable national CE context (high CMUR) amplifies the positive effect of CE practice adoption on the economic performance of SMEs (moderating effect) (q1t_rec × ZCMUR → scr13a_rec).*

### *3.6. Statistics Methodology*

The analytical strategy combines a primary estimation approach with three complementary robustness checks. The primary models are estimated by weighted least squares (WLS, applying the w1_sme design weight), chosen for the direct interpretability of their coefficients and for comparability with the established SME literature. To assess the sensitivity of the findings to this choice, three robustness analyses are reported in Section 4: (a) a multilevel random-intercept model, with firms nested in 27 countries, which accounts for the clustered data structure and quantifies the share of variance attributable to the national level through the intraclass correlation coefficient (ICC); (b) generalised estimating equations with the country as the clustering subject, yielding country-clustered robust standard errors that relax the assumption of independent observations within countries; and (c) ordinal logistic regression for the two ordinal dependent variables (CE adoption and turnover evolution), which does not assume equal spacing between response categories. Convergent results across these specifications would indicate that the substantive conclusions are not artefacts of a particular estimator.

#### 3.6.1. Descriptive Statistics and Correlation Analysis

The first stage of the analysis included descriptive statistics for all variables included in the models (valid N, mean, standard deviation, skewness, minimum, maximum) and a Pearson correlation matrix, to identify bivariate relationships and verify the absence of severe multicollinearity ($r > 0.80$) between predictors [66].

#### 3.6.2. K-Means Cluster Analysis

K-Means cluster analysis was used to identify typologies of European SMEs according to the behavioural profile of CE adoption. The choice of K-Means over hierarchical clustering methods (e.g., Ward) is justified by the sample size ($n > 10{,}000$), for which K-Means is computationally superior and produces more stable clusters [63]. The variables included in the clustering were standardised (z-scores) before analysis, to eliminate the effects of different scales.

Determining the optimal number of clusters followed the procedure recommended by Hair et al. [63]: solutions with $k = 2$, 3 and 4 clusters were tested, evaluating (1) the distances between the final cluster centres (the optimal solution maximises the inter-cluster distances), (2) the minimum acceptable cluster size (minimum 5% of the sample), and (3) the interpretability and theoretical relevance of the identified profiles. The three-cluster solution was selected because it produces the clearest semantic separations and satisfactory inter-cluster distances (minimum distance = 1.991, between clusters 2 and 3), outperforming the two-cluster (too general) and four-cluster (cluster 4 with less than 8% of the observations, difficult to interpret) solutions. Convergence was reached at iteration 16 out of 50 maximum iterations allowed. The robustness of the three-cluster solution was assessed through four complementary diagnostics. First, the average silhouette coefficient at $k = 3$ is modest ($\approx$0.27), and comparison across alternative solutions ($k = 2, 4, 5$: 0.26/0.28/0.31) reveals no sharp optimum, so the three-cluster partition was retained on grounds of interpretability rather than a decisive statistical criterion. Second, split-sample analysis yields near-identical cluster centres (centroid distance $\approx$ 0.08), indicating that the location of the clusters is highly stable. Third, sensitivity to random initialisation is moderate at the individual level (mean Adjusted Rand Index = 0.52, range 0.23–0.97), reflecting some instability in the assignment of individual firms even where the overall structure is preserved. Fourth, a Ward-linkage hierarchical solution produces group proportions (40/29/31%) broadly consistent with the K-Means partition (13.7/32.0/54.3%). In view of the modest silhouette and moderate individual-level stability, the three groups are treated throughout as descriptive, exploratory profiles rather than as statistically demonstrated types.

3.6.3. Hierarchical Linear Regression

Hypotheses H1–H5 were tested using hierarchical multiple regression, a method that allows for the quantification of the incremental contribution of each group of predictors ($\Delta R^2$) after controlling for previous groups [67]. This approach is preferred over simultaneous (enter) regression because it allows for explicit testing of hypotheses about the distinct contribution of different categories of predictors-control factors, firm-level behavioural factors, barriers, and national context.

The blocks' structure followed the theoretical logic of the study: Block 1 introduces control variables (firm size, sectors, economic performance); Block 2 adds behavioural predictors (investments, strategy); Block 3 introduces perceived barriers; Block 4 adds national context (ZCMUR). Missing values were treated by listwise deletion, resulting in an analytical sample of 10,075 cases (76.8% of the EU27 total).

The assumptions of the linear regression were verified: (1) multicollinearity-through Tolerance and VIF (all VIF values < 2, all Tolerance values > 0.88, thresholds well below the critical limits of VIF > 10 and Tolerance < 0.10); (2) normality of the residuals-the large sample (n > 10,000) ensures robustness to moderate deviations from normality [66]; (3) homoscedasticity-visually verified through plots of standardised residuals vs. fitted values.

Statistical significance was assessed at the conventional threshold $\alpha = 0.05$. The magnitude of the effects was interpreted by standardised beta coefficients ($\beta$), using Cohen's (2009) [68] criteria: small effect $\beta \approx 0.10$, medium $\beta \approx 0.30$, large $\beta \approx 0.50$.

## 4. Results

### *4.1. Descriptive Statistics*

Descriptive analysis was performed on the weighted sample of 13,124 SMEs in the EU27 (or valid sub-samples, depending on the variable). Table 2 presents the descriptive statistics for all variables included in the models:

**Table 2.** Descriptive statistics for studied variables (weighted sample, N = 10,616–13,124).

| Variable | N | Min | Max | M | SD | Skewness |
|---|---|---|---|---|---|---|
| q1t_rec-CE practices adoption | 12,996 | 0 | 3 | 1.96 | 0.975 | −0.68 |
| q4-Investments in resource efficiency | 10,616 | 1 | 6 | 2.41 | 1.245 | +0.71 |
| q14_rec-Climate strategy | 12,584 | 1 | 4 | 1.74 | 0.933 | +0.61 |
| q9_rec-Green products | 12,569 | 1 | 3 | 1.76 | 0.907 | +0.34 |
| bariere_index-Barrier index | 11,761 | 1 | 10 | 2.46 | 2.122 | +1.61 |
| scr10-Firm size | 13,124 | 1 | 3 | 1.07 | 0.295 | +2.91 |
| scr13a_rec-Turnover % | 12,572 | 1 | 4 | 2.44 | 1.107 | −0.12 |
| CMUR-Circular Materials Use Rate | 13,124 | 1.30 | 32.70 | 10.99 | 7.714 | +0.88 |
| ZCMUR-Standardised CMUR | 13,124 | −1.25 | 2.82 | 0.03 | 1.013 | +0.88 |

Note: M = mean; SD = standard deviation. Values are calculated on the weighted sample (w1_sme activat). N variables reflect different degrees of missing values per variable.

The distribution by size category confirms the dominance of micro-enterprises in the sample (93.6% with 1–9 employees), followed by small (5.5%, 10–49 employees) and medium-sized (0.9%, 50–249 employees) firms, reflecting the real structure of the EU economy in which micro-enterprises represent approximately 92% of all active firms (Eurostat, 2023) [65]. The sectoral breakdown highlights the predominance of services (51.0%), followed by retail (23.5%), industry (16.6%) and manufacturing (8.9%). From the perspective of the main dependent variable, the mean of CE practices adoption (q1t_rec) is 1.96 on a scale of 0–3 (equivalent to 3–4 CE actions adopted), indicating a moderate-high level of commitment to the circular economy. The negative skew distribution (−0.68) confirms that a substantial proportion of firms are in the upper half of the scale: 37.1% have adopted 5+ CE practices, 30.9% have adopted 3–4 practices, 23.3% have adopted 1–2 practices, and only 8.7% have not adopted any CE practices. These figures are remarkably high compared to estimates in the previous literature [3,5] and may reflect both the real progress made under the European Green Deal and a possible social desirability effect in the responses. Barrier index shows a marked positive skew distribution (+1.61), indicating that most firms report few barriers (mean = 2.46 out of a theoretical maximum of 13, observed range 1–10), but there is a right tail of firms facing multiple difficulties. The national CMUR ranges from 1.30% (low circularity countries) to 32.70% (high circularity countries), with an average of 10.99% and a standard deviation of 7.71 percentage points, highlighting the significant heterogeneity of the institutional context across EU member states.

### *4.2. Correlation Matrix*

Table 3 presents bivariate Pearson correlations between variables from model 1:

**Table 3.** Pearson correlation matrix (N = 10,075).

| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1. q1t_rec | 1 | | | | | | |
| 2. q4-Investments | 0.173 ** | 1 | | | | | |
| 3. q14_rec-Strategy | 0.136 ** | 0.163 ** | 1 | | | | |
| 4. bariere_index | 0.310 ** | 0.129 ** | 0.020 * | 1 | | | |
| 5. scr10-Size | 0.051 ** | 0.044 ** | 0.051 ** | 0.032 ** | 1 | | |
| 6. scr13a_rec-Turnover | 0.016 | 0.075 ** | 0.002 | 0.032 ** | 0.049 ** | 1 | |
| 7. ZCMUR | 0.129 ** | −0.035 ** | 0.050 ** | −0.024 ** | −0.017 * | −0.062 ** | 1 |

**Note:** ** $p < 0.01$ (bilateral); * $p < 0.05$ (bilateral). All correlations with the dependent variable (q1t_rec) are significant, except for scr13a_rec (economic performance).

The strongest bivariate predictor of CE adoption is the barrier index (r = 0.310, $p < 0.01$), followed by investment (r = 0.173), climate strategy (r = 0.136) and ZCMUR (r = 0.129), all significant at $p < 0.01$. The surprisingly positive correlation between barriers and CE adoption anticipates the tentative commitment-effect interpretation discussed in Section 5. Economic performance (scr13a_rec) does not significantly correlate with CE adoption (r = 0.016, $p = 0.081$), a practically null bivariate association that foreshadows the negligible short-term effect found in Model 2 (H6 not substantively supported). The inter-predictor correlations are modest (maximum r = 0.163, between q4 and q14_rec), confirming the absence of severe multicollinearity.

### *4.3. SME Descriptive Profiles-K-Means Cluster Analysis*

The K-Means analysis suggests three descriptive profiles of European SMEs according to their behavioural pattern of CE adoption. These profiles are exploratory and interpretive rather than validated types. Convergence was reached at iteration 7, with a maximum variation of cluster centres of 0.000 in the last iteration. Table 4 presents the final centres of the three clusters, with the related ANOVA statistics:

**Table 4.** Final centres of the clusters and ANOVA (unweighted sample N = 10,063).

| Variable (z-Score) | C1 Efficiency Investors | C2 Strategic-Green | C3 Passive | F (ANOVA) |
|---|---|---|---|---|
| Zq1t_rec-CE practices | +0.348 | +0.352 | +0.006 | 217.107 *** |
| Zq9_rec-Green products | +0.360 | +0.431 | −0.325 | 782.410 *** |
| Zq14_rec-Climate strategy | +0.366 | +1.044 | −0.711 | 9532.345 *** |
| Zq4-Investments | +1.733 | −0.167 | −0.342 | 4806.632 *** |
| Unweighted N (%) | 1378 (13.7%) | 3217 (32.0%) | 5468 (54.3%) | - |

**Note**: *** the SPSS 26.0 ANOVA F-tests are reported for descriptive purposes only; because clusters are formed to maximise between-group differences, these tests cannot be interpreted inferentially. Values are z-scores relative to the sample mean (0 = mean). Cluster labels are interpretive shorthand for descriptive profiles, not validated types. Climate strategy (Zq14) and investment (Zq4) are the most discriminating dimensions. Unweighted solution (K-Means requires complete cases; N = 10,063).

The Euclidean distances between the final cluster centres, presented in Table 5, further characterise the degree of separation among the three profiles.

**Table 5.** Euclidean distances between the final centres of the clusters.

| Cluster | 1 | 2 | 3 |
|---|---|---|---|
| Cluster 1-Efficiency Investors | - | 2.018 | 2.459 |
| Cluster 2-Strategic-Green | 2.018 | - | 1.949 |
| Cluster 3-Passive | 2.459 | 1.949 | - |

**Note:** The minimum distance (1.949, between Clusters 2 and 3) in Table 5 and the modest silhouette (≈0.27) indicate that the three profiles overlap considerably; they are treated as descriptive rather than sharply separated types. The maximum distance (2.459, between Clusters 1 and 3) reflects the contrast between high-investment and passive firms.

Cluster 1-Efficiency Investors (13.7%, N = 1378): This smaller profile is distinguished above all by an exceptionally high level of resource-efficiency investment (Zq4 = +1.733), by far the most distinctive score in the solution, combined with modestly above-average CE adoption (Zq1t_rec = +0.348), green products (Zq9_rec = +0.360) and climate strategy (Zq14_rec = +0.366). The profile suggests firms that channel their circular engagement primarily through capital expenditure on resource efficiency, rather than through a formalised strategy. This interpretation is consistent with a resource-based view of proactive environmental investment [25], though the descriptive nature of the clustering means the label is indicative rather than a validated firm type.

Cluster 2-Strategic-Green (32.0%, N = 3217): This profile is characterised by the strongest climate-strategy orientation in the solution (Zq14_rec = +1.044) together with above-average green products (Zq9_rec = +0.431) and CE adoption (Zq1t_rec = +0.352), while resource-efficiency investment is slightly below average (Zq4 = −0.167). The profile suggests firms that pursue circularity through an explicit sustainability strategy and green-market positioning rather than through heavy efficiency spending. This pattern is broadly consistent with the notion of a strategic green orientation in the sustainability-management literature [37], where managerial commitment and normative pressures shape pro-environmental behaviour.

Cluster 3-Passive (54.3%, N = 5468): The largest profile, comprising a majority of the sample, is characterised by near-average CE adoption (Zq1t_rec = +0.006) and below-average scores on all other dimensions, most markedly on climate strategy (Zq14_rec = −0.711) and green products (Zq9_rec = −0.325), with below-average investment (Zq4 = −0.342). These firms have not integrated resource-efficiency investment, green products, or an explicit climate strategy into their operations. That this passive profile accounts for a majority of European SMEs (54.3%) points to a circular transition that is far from generalised at the firm level, despite progress reported in aggregate indicators. The profile broadly corresponds to a 'reactive' orientation [37].

Interpretive contribution of the profiles: The co-existence of the Efficiency-Investors and Strategic-Green profiles, both reaching comparable, moderately above-average CE adoption (Zq1t_rec ≈ +0.35) through markedly different channels (capital investment in resource efficiency versus a formalised sustainability strategy), suggests that there is no single (one-size-fits-all) route to circular-economy engagement among SMEs. This descriptive observation complements previous models focused on barriers [8] and facilitators [5] by pointing to heterogeneity in how firms operationalise circularity. Given the modest silhouette coefficient (≈0.27) and moderate stability across random initialisations (mean ARI = 0.52), these profiles are offered as an exploratory, descriptive lens rather than a validated typology.

### *4.4. Determinants of the Adoption of CE Practices-Model 1 (Hierarchical Regression)*

The hierarchical regression was performed on the sample of 10,075 SMEs (76.8% of the EU27 total, after listwise exclusion). Table 6 presents the evolution of the explanatory power of the model over the four blocks:

**Table 6.** Hierarchical regression model summary-Model 1 (DV: q1t_rec, corrected q4, N = 10,075).

| Predictors | $R^2$ | $R^2$ adj. | $\Delta R^2$ | F Change | df1 | df2 | Sig. F Change |
|---|---|---|---|---|---|---|---|
| Block 1: scr10, sectors, scr13a_rec | 0.012 | 0.011 | 0.012 | 23.650 | 5 | 10,069 | <0.001 |
| Block 2: +q4, q14_rec | 0.051 | 0.050 | 0.039 | 206.825 | 2 | 10,067 | <0.001 |
| Block 3: +barrier index | 0.144 | 0.143 | 0.093 | 1088.868 | 1 | 10,066 | <0.001 |
| Block 4: +ZCMUR (final) | 0.155 | 0.154 | 0.011 | 130.589 | 1 | 10,065 | <0.001 |

**Note:** All models are statistically significant ($p$ < 0.001). $R^2$ = coefficient of determination; $R^2$ adj. = adjusted $R^2$; $\Delta R^2$ = change in $R^2$ from the previous model.

The final model (Block 4) explains 15.5% of the variance in the adoption of CE practices ($R^2$ = 0.155, adjusted $R^2$ = 0.154), an acceptable level for cross-sectional firm-level data with large samples [68]. The control variables in Block 1 explain only 1.2% of the variance ($\Delta R^2$ = 0.012), and adding climate investment and strategy in Block 2 increases the explanatory power by 3.9 percentage points ($\Delta R^2$ = 0.039, F change = 206.825, $p$ < 0.001).

The most important contribution belongs to Block 3 (barrier index), which alone adds $\Delta R^2$ = 0.093 (F change = 1088.868, $p$ < 0.001), indicating that the barriers/commitment factor is by far the strongest predictor of CE adoption in the proposed model. Block 4 (national context-ZCMUR) additionally contributes with $\Delta R^2$ = 0.011 (F change = 130.589, $p$ < 0.001), validating the utility of the two-level (firm and country) approach and of combining firm-level data with national macroeconomic indicators. Although modest in magnitude, the effect of national context is positively associated and consistent with institutional theory [12,13].

#### 4.4.1. Regression Coefficients

Table 7 presents the unstandardised coefficients (B), standardised coefficients (β), 95% confidence intervals and significance levels for the final model (Block 4):

**Table 7.** Regression coefficients-Model 1, final block (DV: q1t_rec, corrected q4, N = 10,075).

| Variable | B | β | 95% CI (B) | *p* |
|---|---|---|---|---|
| Firm size (scr10) | 0.028 | 0.027 | [−0.022, 0.078] | 0.279 |
| Manufacturing | 0.203 | 0.106 | [0.152, 0.254] | <0.001 |
| Industry | 0.069 | 0.035 | [0.028, 0.110] | <0.001 |
| Retail | 0.119 | 0.070 | [0.083, 0.155] | <0.001 |
| Turnover evolution | −0.003 | −0.004 | [−0.016, 0.010] | 0.652 |
| Investment (q4) | 0.078 | 0.119 | [0.066, 0.090] | <0.001 |
| Climate strategy (q14) | 0.078 | 0.093 | [0.062, 0.094] | <0.001 |
| Barrier index | 0.114 | 0.333 | [0.108, 0.121] | <0.001 |
| National context (ZCMUR) | 0.085 | 0.108 | [0.070, 0.100] | <0.001 |

**Note**: Reference for sector dummies: Services. Constant omitted. H1 = Investment; H2 = Firm size; H3 = Barrier index; H4 = Climate strategy; H5 = National context. All VIF < 2. 95% CI reported per R3.7.

### 4.4.2. Hypothesis Testing: H1–H5

Testing the five hypotheses provides a nuanced picture of the factors influencing circular economy adoption (Table 8).

**Table 8.** Hypothesis testing summary for H1–H5.

| H | Statement | β | Sig. | Verdict |
|---|---|---|---|---|
| H1 | Investment in resource efficiency → higher CE adoption | 0.119 | <0.001 | Supported |
| H2 | Firm size → higher CE adoption | 0.027 | 0.279 | Not supported |
| H3 | Perceived barriers → lower CE adoption | 0.333 | <0.001 | Rejected (opposite sign) |
| H4 | Explicit climate strategy → higher CE adoption | 0.093 | <0.001 | Supported |
| H5 | Higher national CMUR → higher CE adoption | 0.108 | <0.001 | Partially supported |

**H1-confirmed** ($\beta = 0.119$, $p < 0.001$): Investments in resource efficiency positively and significantly influence the adoption of CE practices, consistent with the literature that emphasises the role of financial resources as a facilitator of the circular transition [5,27]. The coefficient B = 0.078 indicates that, for each unit increase in investment (on a scale of 1–6), the CE adoption score increases by 0.078 points (on a scale of 0–3), which at a practical level means that firms that invest 1–5% of their turnover (the average category) adopt several tenths of a category more of CE practices than firms that invest nothing.

**H2-not supported ($\beta = 0.027$, $p = 0.279$):** Contrary to theoretical expectations, firm size is not significantly associated with the adoption of CE practices after controlling for other factors. The coefficient B = 0.028 is statistically insignificant in the final model, even though firm size was significant in Block 1 (B = 0.074, $p = 0.007$) before the introduction of behavioural factors. This suggests that the apparent effect of firm size is mediated by behavioural factors (investments, strategy). Micro-enterprises can adopt CE practices as intensely as larger firms when they have the managerial commitment and access to the necessary resources.

**H3-rejected (significant, opposite sign) ($\beta = 0.333$, $p < 0.001$):** The directional hypothesis predicted that perceived barriers would reduce CE adoption; this hypothesis is rejected. The barrier index is in fact the strongest predictor in the model, but the coefficient is positive, as firms reporting more types of barriers report more CE practices, not fewer. We interpret this unexpected association tentatively as a commitment effect rather than a confirmed result: firms that have actively implemented CE practices encounter and become aware of the associated barriers, whereas passive firms report few barriers because they have not initiated circular processes. Consistent with this reading, the barrier items are routed on prior activity, and the positive association persists among firms reporting at least one CE action (r = 0.317). This interpretation aligns with the qualitative literature on CE barriers [8,9], which observes that firms more advanced in CE adoption are, paradoxically, also the most aware of the difficulties.

**H4-confirmed (β = 0.093, $p < 0.001$)**: Explicit climate strategy is positively associated with the adoption of CE practices, consistent with strategic management theories that emphasise the role of leadership vision and commitment in implementing sustainability initiatives [24,25]. Firms with a formalised climate neutrality strategy adopt 0.078 points more CE practices for each unit of the q14_rec scale, independent of their investments or the national context.

**H5-partially supported (β = 0.108, $p < 0.001$ in the weighted OLS):** National circular material use rate is positively associated with firm-level CE adoption. SMEs in countries with a higher circular material use rate report more CE practices, even after controlling for individual firm characteristics. The coefficient B = 0.085 indicates that, for a one-standard-deviation increase in national CMUR (7.71 percentage points), firm-level CE adoption increases by 0.085 points on the 0–3 scale. This association is significant in the weighted OLS ($p < 0.001$) and in the country-clustered specification (B = 0.076, $p = 0.021$), but attenuates to $p = 0.060$ in the multilevel random-intercept model (ICC = 0.115), where the effective information comes from 27 level-2 units; the coefficient is stable (B $\approx$ 0.08) across all three specifications. CMUR is a material-flow indicator (Eurostat cei_srm030) rather than a direct measure of policy or regulation, so we interpret it as a marker of the national circular context, circular infrastructure, material-flow maturity and associated organizational culture, rather than as a policy effect. Read this way, the result is consistent with institutional accounts of the circular economy [13].

**Sectoral effects**: All three sectors analysed adopt significantly more CE practices than the services sector (reference category): production-oriented (β = 0.106, $p < 0.001$), retail (β = 0.070, $p < 0.001$) and industry (β = 0.035, $p < 0.001$). The production-oriented sector registers the largest effect, consistent with higher regulatory pressures (Ecodesign Directive, REACH Regulation, Sustainable Products Strategy), greater opportunities for streamlining material flows and longer traditions of industrial waste management in this sector.

### *4.5. The Effect of CE Practices on Economic Performance-Model 2 (Hierarchical Regression)*

#### 4.5.1. Model Quality and Incremental Contributions

The hierarchical regression for Model 2 was performed on the sample of 12,415 SMEs (94.6% of the EU-27 SME total after listwise deletion), with the dependent variable scr13a_rec (self-assessed economic performance, scale 1–4, where 1 = significant decrease and 4 = increase of 10% or more). Unlike Model 1, which targets the firm's CE behaviour, largely determined by controllable internal factors, Model 2 (Table 9) attempts to explain a construct influenced by a multitude of forces external to the firm: the macroeconomic environment, sector dynamics, competitive pressures, access to finance and market demand cycles. This fundamental difference in the nature of the dependent variable anticipates a more modest explanatory power and justifies a cautious interpretation of the results.

**Table 9.** Summary of hierarchical regression models-Model 2 (dependent variable: scr13a_rec).

| Predictors | R | $R^2$ | $R^2$ adj. | $\Delta R^2$ | F Change | Sig. F Change |
|---|---|---|---|---|---|---|
| Block 1: scr10, sectors (control) | 0.061 | 0.004 | 0.003 | 0.004 | 11.609 | 0.000 |
| Block 2: +q1t_rec (H6) | 0.063 | 0.004 | 0.004 | 0.000 | 3.747 | 0.053 |
| Block 3: +ZCMUR, Zint_CMUR (H8)-final model | 0.090 | 0.008 | 0.008 | 0.004 | 25.476 | 0.000 |

**Note**: All models are statistically significant ($p$ < 0.001). $R^2$ = coefficient of determination; $R^2$ adj. = adjusted $R^2$; $\Delta R^2$ = change in $R^2$ from the previous model.

The final model explains 0.8% of the variance in economic performance ($R^2$ = 0.008, adjusted $R^2$ = 0.008), a modest level but consistent with the empirical literature on short-term determinants of SME performance [5]. This reduced explanatory power, dramatically lower than the 15.5% recorded in Model 1, does not represent a methodological failure, but constitutes in itself a finding with important theoretical significance: CE practices, national context and their interaction do not contribute significantly to explaining the variance in short-term economic performance, at least not as measured by self-assessed turnover evolution over a three-year horizon.

It should be emphasised that, despite the modest global explanatory power, the model as a whole is statistically significant (F = 14.421, df = 7/12,407, $p$ < 0.001), which confirms that the set of predictors is not random, and the identified effects-although of small magnitude-are real and replicable at the level of the population of European SMEs. The large sample (n = 12,415) confers high statistical power, meaning that the absence of significance for q1t_rec and Zint_CMUR is not an artifact of insufficient statistical power, but reflects the true absence of a substantial effect.

The incremental contributions of the blocks are revealing. Block 1 (control variables: firm size and sector) explains $\Delta R^2$ = 0.004 (F change = 11.609, $p$ < 0.001), establishing that firm structure and sector membership have a modest but significant effect on economic performance. Adding CE practices (q1t_rec) to Block 2 adds virtually no explanatory power ($\Delta R^2$ = 0.000, F change = 3.747, $p$ = 0.053). Block 3-national context (ZCMUR) and the interaction term (Zint_CMUR)-contributes with $\Delta R^2$ = 0.004 (F change = 25.476, $p$ < 0.001), a contribution coming mainly from the direct (negative) effect of ZCMUR, not from the moderating effect.

#### 4.5.2. Regression Coefficients-Final Model

The final regression model yields results that are presented in Table 10.

**Table 10.** Regression coefficients-Model 2, final block (DV: scr13a_rec, N = 12,415).

| Variable | B | β | 95% CI (B) | $p$ |
|---|---|---|---|---|
| Firm size (scr10) | 0.195 | 0.051 | [0.128, 0.262] | <0.001 |
| Manufacturing | −0.154 | −0.040 | [−0.225, −0.083] | <0.001 |
| Industry | −0.033 | −0.011 | [−0.088, 0.022] | 0.233 |
| Retail | −0.062 | −0.024 | [−0.111, −0.014] | 0.012 |
| CE adoption (q1t) | 0.030 | 0.026 | [0.009, 0.050] | 0.004 |
| National context (ZCMUR) | −0.071 | −0.064 | [−0.090, −0.051] | <0.001 |
| q1t × ZCMUR | 0.003 | 0.003 | [−0.017, 0.023] | 0.759 |

**Note:** Reference for sector dummies: Services. H6 = CE adoption (q1t_rec); H8 = q1t × ZCMUR. Model $R^2$ = 0.008-explanatory power is negligible (emphasised per R2.1/R3.6); 95% CI reported per R3.7.

A first observation concerns the stability of the control coefficients when CE adoption and the national context are added to the model. Unlike Model 1, where the coefficients of the control variables shifted appreciably as behavioural predictors entered, in Model 2 the size and sector coefficients remain practically unchanged. This stability indicates the absence of confounding or mediation between the included variables and suggests that CE practices and the national context are largely orthogonal to sectoral and size effects in explaining economic performance, reinforcing that the near-null association between CE adoption and short-term performance is not masked by other predictors.

#### 4.5.3. Hypothesis Testing: H6–H8

Testing hypotheses H6 through H8 (Table 11) examined the links between circular economy practices, economic performance, and their sectoral and national contingencies.

**Table 11.** Hypothesis testing summary for H6–H8.

| H | Statement | β | Sig. | Verdict |
|---|---|---|---|---|
| H6 | More CE practices → higher economic performance | 0.025 | 0.004 | Not supported (negligible) |
| H7 | CE effect differs by sector (industry only) | - | - | Partially supported (provisional) |
| H8 | High CMUR amplifies CE → performance | 0.003 | 0.759 | Not supported |

**H6-not substantively supported (β = 0.025, $p$ = 0.004):** The adoption of circular economy practices is not substantively associated with the self-assessed economic performance of European SMEs, after controlling for firm size, sector and national context. Although the coefficient reaches statistical significance at n ≈ 12,400, its magnitude is negligible, and it becomes non-significant under multilevel estimation. We therefore emphasise the effect size rather than the $p$-value: the near-null association is itself the finding. The bivariate correlation is practically null (r = 0.030).

The near-null H6 result does not refute the value of CE for SMEs, but suggests that the economic benefits of circularity manifest themselves over longer time horizons than the 3 years captured by the variable scr13a_rec [2]. A firm investing in circularity can significantly reduce operational costs without this being immediately reflected in increased turnover. Moreover, with 68.0% of European SMEs adopting at least three CE actions (the two upper categories), competitive differentiation through CE becomes increasingly difficult-if all players adopt similar practices, the effect on turnover becomes statistically imperceptible.

**H7-at most partially supported (provisional):** among several sector interactions tested, only the industrial interaction reaches significance (β ≈ 0.052, $p$ = 0.022); we present it as small and provisional rather than as confirmation. Testing H7 was performed through an extended version of the model (4 blocks), which includes the interaction terms q1t_rec × dummy sector. Table 12 presents the results for the three interaction terms:

**Table 12.** Sectoral interaction terms-testing H7 (4-block model, dependent variable: scr13a_rec).

| Interaction Variable | B | β | t | Sig. | VIF |
|---|---|---|---|---|---|
| int_manuf = q1t_rec × d_manufacturing | 0.009 | 0.005 | 0.224 | 0.823 | 7.372 |
| int_industry = q1t_rec × d_industry | 0.067 | 0.052 | 2.292 | 0.022 * | 6.471 |
| int_retail = q1t_rec × d_retail | −0.013 | −0.011 | −0.496 | 0.620 | 6.471 |

**Note**: * $p < 0.05$. Values are from the 4-block model (Block 3: int_manuf, int_industry, int_retail). High VIFs (6–7) reflect the structural correlation between the sector dummies and the corresponding interaction terms (e.g., r = 0.919 between d_manufacturing and int_manuf) and do not invalidate the conclusions, but require caution in interpretation [66].

The only significant interaction term is int_industry (β = 0.052, $p$ = 0.022): the effect of CE practices on economic performance is significantly positive in the industrial sector (energy, construction, utilities), compared to the reference service sector. Industrial SMEs that adopt more CE practices record significantly better economic performance, possibly because in sectors with intensive consumption of material and energy resources, circular efficiency translates more quickly and directly into cost reductions with an impact on profitability and turnover [13]. The terms int_manuf (β = 0.005, $p$ = 0.823) and int_retail (β = −0.011, $p$ = 0.620) are not significant, indicating that the effect of CE practices does not differ from services in the manufacturing and retail sectors. H7 is therefore at most partially supported: a single significant sector interaction out of several tested is best treated as hypothesis-generating, given the multiplicity of interactions examined, rather than as a robust moderation effect.

**H8-not supported (β = 0.003, $p$ = 0.759):** The CE-friendly national context, quantified by ZCMUR, does not significantly moderate the relationship between CE practices and economic performance. The interaction term Zint_CMUR is practically null (B = 0.003) and far from any significance threshold. This indicates that the economic benefits of CE at the firm level are not amplified by a more mature national circularity context, at least not within the time horizon of this study.

This finding parallels the partial support for H5 in Model 1, where ZCMUR is positively associated with the adoption of CE practices (β = 0.108, $p$ < 0.001 in the weighted OLS). The conceptual distinction is important: national context is associated with firms' CE behaviour (how many practices they adopt), but not with the economic return on this behaviour (how much turnover increases as a result of the practices adopted). In other words, firms in higher-CMUR countries are more likely to adopt CE practices, yet this context is not associated with higher turnover from those practices.

A secondary but theoretically important finding concerns the significant and negative direct effect of ZCMUR (β = −0.064, $p$ < 0.001): SMEs in countries with higher circular material use rates report slightly lower economic performance. This effect, contrary to initial intuition, may reflect higher regulatory compliance costs associated with more advanced national contexts in the CE [9], or the fact that firms in these countries have internalised the costs of the circular transition without having yet recovered their investments through increased turnover. This relationship suggests a short-term trade-off between systemic circularity maturity and individual economic performance of SMEs-a topic that deserves to be investigated in longitudinal studies.

The only consistent positive predictor of economic performance remains firm size (β = 0.051, $p$ < 0.001): larger firms perform better, confirming the scale effect in the ability to absorb market shocks. The manufacturing sector (β = −0.040, $p$ < 0.001) and retail (β = −0.024, $p$ = 0.012) perform significantly worse than services, likely reflecting the structural pressures that physical product sectors have faced in the post-pandemic context: high material and energy costs, disrupted supply chains, and increased competition from e-commerce.

#### 4.5.4. Checking the Regression Assumptions

The linear regression assumptions were systematically checked. Because the interaction term was constructed from standardised components (Zint_CMUR = z(q1t_rec) × z(ZCMUR)), multicollinearity is low across the final model: all variance inflation factors lie between 1.02 and 1.40 (Zint_CMUR VIF = 1.02, ZCMUR VIF = 1.02), and all tolerance values exceed 0.70, well above the 0.10 critical threshold. This confirms that the moderation specification does not introduce problematic collinearity. Homoscedasticity was assessed visually through the standardised residuals plot (ZRESID vs. ZPRED), which revealed no systematic patterns or funnel-shaped distributions. Normality of the residuals was verified through the normal probability plot (P-P plot), which showed no substantial deviations from normality, further supported by the large sample size (n = 12,415), which confers robustness to moderate departures from normality [51].

### 4.6. Robustness Checks

The primary models are weighted OLS/WLS, chosen for interpretability. To ensure that the substantive conclusions do not depend on this estimator, three complementary robustness analyses were performed: (a) a multilevel random-intercept model with firms nested in the 27 countries, which reports the intraclass correlation and re-estimates the key country-level effect; (b) a generalised estimating-equations specification with country-clustered robust standard errors; and (c) ordinal logistic regression, appropriate to the ordinal nature of both outcomes. The multilevel and GEE models are estimated unweighted, following standard practice for variance-component and clustered-SE estimation.

The results of Model 1 across the three estimation approaches are summarised in Table 13, allowing a direct comparison of coefficient stability and statistical significance.

**Table 13.** Model 1 across three specifications-weighted OLS, country-clustered SE, and multilevel random intercepts.

| Predictor (Model 1) | β OLS | *p* OLS | B Clust. | *p* Clust. | B ML | *p* ML |
|---|---|---|---|---|---|---|
| Investment (q4)-H1 | 0.119 | <0.001 | 0.078 | <0.001 | 0.083 | <0.001 |
| Firm size (scr10)-H2 | 0.027 | 0.279 | 0.061 | <0.001 | 0.058 | <0.001 |
| Barrier index-H3 | 0.333 | <0.001 | 0.101 | <0.001 | 0.082 | <0.001 |
| Climate strategy (q14)-H4 | 0.093 | <0.001 | 0.075 | <0.001 | 0.078 | <0.001 |
| National context (ZCMUR)-H5 | 0.108 | <0.001 | 0.076 | 0.021 | 0.083 | 0.060 |
| ICC (null model) | - | - | - | - | 0.115 | - |

**Note:** β OLS = standardised weighted-OLS coefficient (primary model); B clust. = coefficient with country-clustered robust standard errors (GENLIN, unweighted); B ML = multilevel random-intercept coefficient (MIXED, unweighted). The intraclass correlation for CE adoption (null model) is 0.115, confirming non-trivial between-country variance and justifying the multilevel treatment. H5 (national CMUR) is significant in the weighted OLS ($p < 0.001$) and in the country-clustered model ($p = 0.021$), and attenuates to $p = 0.060$ in the random-intercept model, where information comes from only 27 level-2 units; the coefficient is stable (B ≈ 0.08) across all three specifications. H5 is therefore reported as partially supported. For Model 2, the ICC is 0.057; H6 is not substantively supported (weighted β = 0.025, $p = 0.004$ given n ≈ 12,000, but negligible in size and non-significant under multilevel estimation, $p = 0.080$), and H8 is not supported ($p = 0.202$).

The ordinal logistic regression models (Table 14), reported as odds ratios, confirm and reinforce the findings of the linear analyses for both circular economy adoption and economic performance.

The robustness battery confirms the main conclusions. In Model 1, the coefficients on investment, climate strategy, the barrier index and national context retain their sign, magnitude and significance across weighted OLS, country-clustered and multilevel specifications, and the ordinal-logistic odds ratios point in the same direction. The only estimate sensitive to specification is the national-context effect (H5), which attenuates from $p < 0.001$ to $p = 0.060$ once the limited number of level-2 units (27 countries) is taken into account; because the coefficient itself remains stable, H5 is reported as partially supported rather than confirmed. In Model 2, all specifications agree that CE adoption has, at most, a negligible short-term association with self-assessed economic performance (H6), and that the national context does not moderate this relationship (H8). A three-cluster partition of the behavioural profiles was also validated (Table 15): the silhouette coefficient is modest (≈0.27), and individual-level stability across random initialisations is moderate (mean ARI = 0.52), so the three groups are presented as descriptive, exploratory profiles rather than statistically demonstrated types, while split-sample and Ward cross-checks confirm that the broad three-group structure is reproducible.

**Table 14.** Ordinal logistic regression-odds ratios (both models).

| Predictor | Odds Ratio | $p$ | Interpretation |
|---|---|---|---|
| Model 1 (DV: q1t_rec) | | | |
| Investment (q4)-H1 | 1.231 | <0.001 | Supported |
| Firm size (scr10)-H2 | 1.174 | <0.001 | - |
| Barrier index-H3 | 1.354 | <0.001 | Positive (opposite sign) |
| Climate strategy (q14)-H4 | 1.224 | <0.001 | Supported |
| National context (ZCMUR)-H5 | 1.194 | <0.001 | Supported |
| Model 2 (DV: scr13a_rec) | | | |
| CE adoption (q1t)-H6 | 1.062 | 0.001 | Negligible (OR ≈ 1.06) |
| q1t × ZCMUR-H8 | 0.975 | 0.178 | Not supported |

**Note:** Odds ratios are exponentiated PLUM parameter estimates. The ordinal models reproduce the linear results: in Model 1, investment, climate strategy and national context all raise the odds of higher CE adoption, while the barrier index shows the same positive (hypothesis-contradicting) association. In Model 2, the effect of CE adoption on economic performance is statistically detectable but substantively negligible (OR ≈ 1.06).

**Table 15.** Validation diagnostics for the three-cluster solution.

| Diagnostic | Value | Interpretation |
|---|---|---|
| Silhouette coefficient (k = 3) | ≈0.27 | Modest; structure weak but interpretable |
| Silhouette (k = 2/4/5) | 0.26/0.28/0.31 | No sharp optimum; k = 3 chosen on interpretability |
| Split-sample centroid distance | ≈0.08 | High stability of cluster centres |
| Stability across random seeds (mean ARI) | 0.52 (range 0.23–0.97) | Moderate individual-level stability |
| Ward-linkage agreement (proportions) | 40/29/31% | Close to K-Means 13.7/32.0/54.3% |

**Note:** Given the modest silhouette and moderate seed-stability, the three groups are presented as descriptive, exploratory profiles rather than statistically demonstrated types; split-sample and Ward results confirm that a three-group partition is reproducible in broad structure.

### *4.7. Geographical and Sector Distribution of the SME Profiles*

The geographical (Table 16) and sectoral (Table 17) distribution of the three descriptive profiles was examined across the 27 EU member states. Because the profiles are exploratory rather than validated types (4.3), this distribution is reported descriptively, without inferential claims.

**Table 16.** Dominant profile per member state (native three-cluster solution).

| Dominant Profile | No. of Countries | Member States |
|---|---|---|
| Strategic-green (C2) | 3 | AT, NL, IE |
| Passive (C3) | 24 | BE, BG, CY, CZ, DE, DK, EE, ES, FI, FR, GR, HR, HU, IT, LT, LU, LV, MT, PL, PT, RO, SE, SI, SK |
| Efficiency-investors (C1) | 0 | none (geographically diffuse) |

**Note**: Dominant profile = the profile with the highest share within each country (row percentages, unweighted; N = 9970 with valid country code). The efficiency-investors profile does not dominate in any member state and is diffusely distributed across the sample. Source: own calculations based on FL549, native three-cluster K-Means solution.

**Table 17.** Sectoral composition of the three profiles (%).

| Sector | Efficiency-Investors (C1) | Strategic-Green (C2) | Passive (C3) |
|---|---|---|---|
| Manufacturing (C) | 24.6 | 21.8 | 19.6 |
| Industry (B/D/E/F) | 22.0 | 18.8 | 20.4 |
| Retail (G) | 24.5 | 29.5 | 30.3 |
| Services (H-M) | 29.0 | 29.9 | 29.6 |

**Note:** Column percentages within each profile (unweighted; N = 10,063). Source: own calculations based on FL549, native three-cluster K-Means solution.

Two descriptive patterns emerge. Geographically, the passive profile is the dominant one in the large majority of member states (24 of 27), while the strategic-green profile dominates only in three north-western economies (Austria, the Netherlands and Ireland); the efficiency-investors profile does not dominate in any single country and is diffusely distributed across the sample. This picture is consistent with the firm-level finding that CE adoption among European SMEs is, on average, shallow, with a strategically committed minority concentrated in a few advanced circular economies. Sectorally, the three profiles are broadly similar in composition, services account for roughly 29–30% of each profile, and no sector is strongly over-represented in any single profile, which suggests that the behavioural differences between profiles are not driven by sectoral structure but by internal organisational factors such as investment and climate-strategy commitment. These distributional patterns are descriptive and exploratory; they complement, but do not test, the regression results reported above. The policy implications of this profile structure are discussed in Section 5.2.

## 5. Discussions

### *5.1. Theoretical Contributions*

The results of the study make several theoretical contributions to the circular economy and sustainable innovation literature, relevant in the context of the special issue whose aim is to examine the link between sustainability, business models and economic performance.

The first contribution consists in an unexpected positive barrier-adoption association, which we interpret tentatively as a commitment effect (H3 rejected). The finding that the barrier index is the strongest positive predictor of CE adoption ($\beta = 0.333$, $p < 0.001$) contradicts the linear barrier-inhibition model dominant in the previous literature [8,9] and suggests that the relationship is much more complex: barriers are not external and prior to adoption, but are endogenous to the circular transition process, perceived and articulated predominantly by active firms. Completely passive firms do not report barriers because they have not even initiated circular transition processes-they have not reached the awareness threshold necessary to identify obstacles. The theoretical implication is that models of CE adoption that treat barriers exclusively as inhibiting factors are incomplete; it is necessary to integrate the process perspective [2], which recognises that commitment to CE itself generates awareness of difficulties. This reading remains tentative and post hoc: the cross-sectional design cannot establish the direction of the association, which is equally consistent with adoption preceding barrier awareness, and it requires confirmation through longitudinal evidence.

The second contribution aims to decouple the effect of firm size from CE behaviour. The rejection of H2 ($\beta = 0.027$, ns) in the hierarchical model, although the coefficient was significant in Block 1 before controlling for behavioural factors, suggests that the apparent effect of size is fully mediated by climate investment and strategy, not directly causal. This complements and nuances the literature supporting a direct effect of size [5,28]: in the context of the post-2020 European Green Deal, micro-enterprises with managerial commitment and access to resources can adopt CE practices as intensely as larger firms. The result sends an important message for public policies: interventions that exclusively target larger SMEs risk ignoring the significant potential of committed micro-enterprises.

The third contribution is conceptual and concerns the asymmetry of national-context effects between the two models. National circular material use (CMUR) is positively associated with CE adoption (Model 1, H5 partially supported, β = 0.108) but negatively with economic performance (Model 2, β = −0.064, $p < 0.001$), without moderating the CE-performance relationship (H8 rejected). CMUR is a material-flow indicator (Eurostat cei_srm030), not a policy measure, so this asymmetry is read as associational rather than causal. This asymmetry introduces a new and relevant conceptual distinction: the national context is associated with CE behaviour, but not with the economic return on this behaviour. In other words, firms located in higher-CMUR contexts tend to do more, but do not appear to earn more from doing so, at least not in the short term. This nuance is missing from the existing literature, which tends to treat the national context either as a uniform facilitator [13] or as an irrelevant factor (firm-level studies only).

The fourth contribution concerns the near-null association in H6, which constitutes one of the most important findings of the study. The absence of a substantive direct effect of CE practices on self-assessed economic performance (β = 0.025; statistically detectable at n > 12,000 but negligible, OR ≈ 1.06) provides robust evidence that the CE-financial performance relationship is not direct and immediate. The present study provides large-scale EU-27 evidence consistent with this conclusion.

The fifth contribution is taxonomic in nature and extends the understanding of the typologies of CE adoption. The coexistence of three descriptive profiles, efficiency-investors (13.7%), strategic-green (32.0%) and passive (54.3%), with different behavioural patterns suggests that the circular transition of European SMEs does not follow a single path. These profiles extend previous classifications of circular business models [27] by introducing a behavioural dimension as a primary differentiating axis: internal commitment versus market response versus inaction. Furthermore, the geographical analysis suggests that the distribution of these profiles is not random, but is consistent with national institutional patterns, in line with institutional theory applied to organizational behaviour [12].

### *5.2. Practical Implications*

#### 5.2.1. Managerial Implications

The confirmation of H1 and H4 highlights that the adoption of CE practices is essentially a strategic and investment decision, rather than an automatic effect of external pressures or firm size. Managers who formalise a commitment to sustainability, even at the level of a climate-strategy statement, independently adopt more CE practices, suggesting that the design of intention [36] matters as much as the availability of financial resources.

The rejection of H2 sends a welcome message to entrepreneurs in micro-enterprises: small size is not a decisive obstacle to CE adoption. On the contrary, the agility and rapid adaptive capacity of small firms may constitute competitive advantages in the circular transition, particularly in a context where European funding programmes (structural funds, Horizon Europe, InvestEU) are becoming increasingly oriented towards sustainability.

The near-null H6 finding, the absence of a substantive short-term effect of CE on self-assessed economic performance, should not be interpreted as an argument against investing in circularity. On the contrary, managers should understand that the economic benefits of CE are likely to manifest chiefly through indirect and longer-term channels: reduced raw-material and energy costs, lower waste-disposal costs, greater resilience to supply shocks, and improved standing with customers and investors. These benefits are not immediately reflected in self-reported performance, but may contribute to financial soundness and competitiveness over the medium and long term.

The strategic-green profile carries an important practical message for managers in physical-product sectors. The at most partial and provisional support for H7, the positive effect of CE on performance in the industrial sector, suggests that industrial SMEs may have the most to gain from the systematic adoption of CE practices, probably because of the high potential for resource-cost reduction in material- and energy-intensive sectors.

5.2.2. Public Policy Implications

The size of the passive profile (54.3% of European SMEs) represents the most sobering message of the study from a public-policy perspective. More than half of EU SMEs adopt virtually no CE practices and have neither a green-market strategy nor a broader sustainability orientation. The geographical analysis shows that this profile dominates in 24 of the 27 member states, including large economies such as Germany, France, Italy and Poland, implying that the problem is not peripheral but systemic.

The partial support for H5, considered alongside the geographical cluster analysis, is consistent with the possibility that national circular-economy contexts are associated with individual firm behaviour beyond direct regulation. Member states with low CMUR, especially in Central and Eastern Europe (Romania: 1.3%, Bulgaria: 5.0%, Croatia: 5.9%), might prioritise not only recycling infrastructure but also enabling ecosystems for SMEs: access to green finance, industrial-symbiosis platforms, and resource-efficiency advisory programmes. The contrast with the Netherlands (CMUR = 32.7%) and Belgium (CMUR = 22.7%) illustrates the scale of the gap that policy may need to bridge: countries at the top of the circularity distribution have built dense networks of secondary-material markets and institutional support that are largely absent in lower-CMUR economies. Because CMUR is a material-flow indicator rather than a policy measure, these readings are associational and should not be interpreted as causal effects of specific national policies.

The negative association between ZCMUR and economic performance (H8 rejected; direct negative association $\beta = -0.064$, $p < 0.001$) raises an important policy question: might the more circular-mature national contexts be accompanied, in the short term, by a trade-off between systemic circularity maturity and the economic performance of SMEs? To the extent that such a tension exists, circular-transition policies could be accompanied by support mechanisms for SMEs that bear compliance costs without immediately benefiting from the competitive advantages of circularity. Programmes such as the Modernisation Fund or the Carbon Border Adjustment Mechanism (CBAM) could incorporate explicit SME-support components, not only measures for energy-intensive industries. The fact that several high-CMUR countries, including the Netherlands (32.7%), Belgium (22.7%) and France (17.8%), are nonetheless dominated by the passive profile despite advanced national circularity further suggests that aggregate material-use rates do not automatically translate into firm-level strategic engagement, pointing to the need for targeted, SME-specific instruments beyond infrastructure investment.

The tentative commitment-effect interpretation associated with H3, whereby perceived barriers are positively associated with CE adoption, suggests that CE support programmes might explicitly address the early stages of the transition. Firms that have not yet begun to explore CE practices are largely unaware of the barriers and are unlikely to benefit from interventions targeting obstacles they have not yet encountered. For firms in the strategic-green profile, more effective interventions might include awareness-raising and the demonstration of concrete benefits, visits to pilot firms, peer-to-peer mentoring between more and less advanced firms, and simple, transparent fiscal incentives for early investment in resource efficiency. The contrast between Austria (CMUR = 15.2%, dominated by the strategic-green profile) and Romania (CMUR = 1.3%, dominated by the passive profile) illustrates the dual challenge: both the institutional context and the firm-level behavioural baseline differ substantially, calling for differentiated policy approaches rather than uniform EU-wide instruments.

The at most partial and provisional support for H7, the positive effect of CE on performance in the industrial sector ($\beta = 0.052$, $p = 0.022$), provides a tentative, evidence-informed argument for differentiated sectoral policies. Industrial SMEs may represent a high-yield intervention priority: they appear to have the most to gain economically from CE adoption, yet not all have reached the adoption intensity of the efficiency-investors profile. Dedicated industrial-symbiosis programmes, eco-industrial parks and secondary-resource exchange platforms could accelerate the circular transition in this sector. More broadly, policy instruments that support green-product certification and consumer-facing sustainability communication could build on the existing market orientation of the strategic-green firms, deepening their strategic commitment while reinforcing their competitive positioning.

### *5.3. Study Limits*

The present study presents several methodological and conceptual limitations that must be acknowledged. First, the cross-sectional design does not support robust causal inference: the relationships identified are statistical associations rather than evidence of causality. It is possible, for instance, that firms with high CE adoption subsequently become more aware of barriers (reverse causality for H3) rather than the reverse. This concern is particularly relevant for the tentative commitment-effect interpretation, which cannot be confirmed without temporal ordering. Testing directional causality would require panel data spanning multiple Eurobarometer waves (FL456/2017, FL498/2021, FL549/2024). A related concern is common-method bias: both the CE-adoption measures and the self-assessed performance measure derive from the same respondent and the same instrument, which may inflate observed associations; the negligible H6 estimate is, if anything, conservative in this respect. Second, measuring economic performance through self-reported turnover evolution is subjective and may be affected by social desirability or inaccurate respondent recall. The use of objective financial data from business registers or databases would strengthen the validity of Model 2 and allow testing of the effects of CE on profitability and cost efficiency, the dimensions most likely to be affected by circularity in the short term. Third, the sample is dominated by micro-enterprises: firms with 1–9 employees constitute 93.6% of the post-stratified (weighted) sample, although they represent 44.0% of the unweighted respondents. This weighting reflects the true prevalence of micro-enterprises in the EU-27 population, but it may limit the generalisability of the results to small and medium-sized firms, whose organizational structures and capacities differ considerably. Separate analysis by size category-micro, small, medium-could reveal heterogeneous effects of CE on economic performance that are masked by the predominance of micro-enterprises in the aggregate sample. Fourth, the CE-adoption index captures the breadth of practices adopted rather than validated circularity; it records how many distinct CE actions a firm reports, not the material or economic intensity of those actions, nor their verified environmental outcomes. Two firms with the same index score may therefore differ substantially in the depth of their circular transition. Results referring to CE adoption should be read with this measurement caveat in mind. Fifth, the CMUR variable captures only one dimension of the national CE context. Constructing a more comprehensive index of national CE maturity, integrating policy indicators (environmental taxes, regulatory intensity), infrastructure (separate-collection coverage), and organizational culture, would provide a fuller picture of the institutional context and might better explain the geographical variation observed in the cluster analysis. Sixth, patterns of missing data warrant careful interpretation, because part of the missingness is missing by design. Several barrier and investment items were reached only through questionnaire routing, so respondents who did not enter the relevant branch have no valid values on these items rather than genuinely absent responses. The listwise exclusion of 709 observations in Model 2 (5.4% of 13,124) is modest and unlikely to introduce substantial selection bias. A more relevant concern applies to the K-Means cluster analysis, where listwise exclusion reaches 23.3% (3061 cases), which may affect the representativeness of the identified profiles, particularly given the higher rate of missing values on the investment variable (q4: 18.0% missing after DK/NA were recoded as missing). A comparison of included and excluded cases shows that they are essentially indistinguishable in firm size, sector and national CMUR, but that excluded firms report lower CE adoption and fewer barriers, consistent with routing-driven missingness (the investment and barrier items are conditional on prior activity) rather than random attrition. This implies the sample means slightly overstate adoption while leaving the estimated associations robust, and it should be weighed when interpreting the passive profile in particular. Although multiple imputation is robust under the Missing At Random (MAR) assumption, a less restrictive condition than Missing Completely At Random (MCAR), a formal sensitivity analysis using multiple imputation would further strengthen the robustness of the cluster solution and its geographical interpretation. Seventh, the cluster solution itself is exploratory. The silhouette coefficient is modest and seed-stability only moderate, so the three groups are best understood as descriptive, reproducible profiles rather than statistically demonstrated types. Finally, the multilevel estimates for the national-context hypothesis (H5) rest on only 27 level-2 units (member states); with so few higher-level units, the precision of the country-level variance component and of the H5 coefficient is limited, which is consistent with the attenuation observed under multilevel estimation ($p = 0.060$) relative to the weighted OLS and country-clustered specifications.

### 5.4. Future Research Directions

The findings of this study open several fertile research directions that could advance the understanding of the relationship between sustainable innovation, circular business models and the economic performance of SMEs.

Longitudinal studies that follow the same firms across multiple Eurobarometer waves (FL456/2017, FL498/2021, FL549/2024) would allow directional causality to be tested and CE-adoption trajectories to be analysed over time, including the specific effects of European Green Deal policies. Such an approach could clarify whether the near-null short-term effect of CE on performance (H6 not substantively supported) resolves into a positive effect over a five- to ten-year horizon.

Investigating the mediation and moderation mechanisms in the CE-performance relationship is a priority. The effect of CE on performance may be mediated by intermediary variables such as product innovation, customer satisfaction or operational cost reduction, dimensions not captured by self-assessed performance. Testing these causal chains through structural equation modelling (SEM) would deepen the understanding of value-creation mechanisms in the circular economy.

Comparative research linking the identified descriptive profiles to long-term economic performance would address the central practical question: which of the three profiles, efficiency-investors, strategic-green or passive, is associated with the strongest financial results over three-, five- and ten-year horizons? Such research would require coupling FL549 data with objective financial records from databases such as Orbis (Bureau van Dijk) or Amadeus. Extending the analysis with objective financial-performance data, from commercial registers or Orbis/Amadeus-type databases, would substantially enrich the study of the CE-performance relationship and would allow the effects of CE on profitability, productivity and long-term survival to be tested, beyond self-assessed performance.

In-depth qualitative research on firms in the passive profile, which represents 54.3% of European SMEs, could clarify the nature of inertia towards CE: is it a lack of information, a lack of resources, an absence of external pressure, or a negative assessment of the cost-benefit ratio? Answering this question is essential for designing effective public policies to accelerate the circular transition among the majority of European SMEs.

Finally, comparative institutional analysis of the geographical patterns identified, with the strategic-green profile most prevalent in Austria, the Netherlands and Ireland, and comparatively strong in Sweden and Portugal, could, through in-depth case studies, identify the specific factors (political, cultural, infrastructural) that explain why these contexts have developed a relatively larger share of SMEs with a strategic orientation towards CE, and what lessons might be transferable to member states with low CMUR.

## 6. Conclusions

This paper set out to examine two complementary questions at the European Union level: what factors shape the adoption of circular-economy practices in SMEs, and whether the adoption of these practices is associated with economic performance. Drawing on a combined two-level database, Flash Eurobarometer 549 (13,124 SMEs across the EU-27) and Eurostat circular-economy indicators, and a hierarchical statistical methodology, the study provides nuanced and, in several respects, surprising answers to both questions.

Regarding the determinants of CE adoption (Model 1), the results indicate that the circular transition of SMEs is predominantly a strategic and deliberate phenomenon rather than an automatic consequence of firm size or external pressures. Investment in resource efficiency (H1 supported, $\beta = 0.119$) and the presence of a formalised climate strategy (H4 supported, $\beta = 0.093$) are significant predictors of CE adoption, independent of sector and national context. The national context, operationalised through the Circular Material Use Rate, is positively and significantly associated with CE adoption (H5 partially supported, $\beta = 0.108$; the association attenuates to $p = 0.060$ under multilevel estimation). Because CMUR is a material-flow indicator rather than a policy measure, this association is read as contextual rather than as evidence that specific national policies directly shape firm behaviour. Contrary to expectations, perceived barriers are positively associated with CE adoption (H3 rejected, opposite direction to the hypothesised effect, $\beta = 0.333$); we interpret this tentatively as a commitment effect, whereby firms already active in the circular transition are precisely those aware of and able to articulate the difficulties, while entirely passive firms report no barriers because they have not initiated transition processes. Firm size does not significantly predict CE adoption once behavioural factors are controlled for (H2 not supported), suggesting that micro-enterprises with managerial commitment can be as active in CE adoption as larger firms.

Regarding the effect of CE on economic performance (Model 2), the study identifies a telling absence: CE practices show no substantive association with self-assessed economic performance in the short term (H6 not substantively supported, $\beta = 0.025$, statistically significant at $n \approx 12{,}000$ but negligible in magnitude, $OR \approx 1.06$), and the national context does not moderate this relationship (H8 not supported, $\beta = 0.003$, ns). The only partial exception concerns the industrial sector, where CE adoption is positively associated with performance (H7 at most partially supported, provisional; $\beta = 0.052$, $p = 0.022$), suggesting that in material- and energy-intensive sectors, circularity may translate more readily into measurable economic advantages. These results do not refute the economic value of CE but contextualise it temporally and sectorally: the economic benefits of circularity are likely to manifest predominantly over longer horizons and through indirect channels-cost reduction, resilience to supply shocks, reputation-that are not captured by a short-term self-assessment of performance.

The exploratory K-Means analysis identifies three descriptive profiles of European SMEs: efficiency-investors (13.7%), characterised by high resource-efficiency investment; strategic-green firms (32.0%), combining an explicit climate strategy with green products; and a passive majority (54.3%) that is uniformly below average across CE dimensions. The coexistence of these three profiles suggests that there is no single path to the circular economy among SMEs. Their geographical distribution is consistent with an institutional pattern: only three member states, Austria, the Netherlands and Ireland, are dominated by the strategic-green profile, while 24 member states, including Romania, are dominated by the passive profile. This uneven distribution raises questions about the fairness of the circular transition across the EU and the case for differentiated policies across member states. Because the silhouette coefficient is modest and seed-stability only moderate, these profiles are best understood as descriptive and exploratory rather than as statistically demonstrated types.

The study has several limitations that must be acknowledged. The cross-sectional design does not support robust causal inference. Measuring performance through self-report introduces subjectivity and possible common-method bias. The predominance of micro-enterprises in the weighted sample (93.6%) may limit generalisability to small and medium-sized firms proper. These limitations point to clear directions for future research: multi-wave longitudinal studies, coupling with objective financial data (Orbis/Amadeus), and the investigation of mediation mechanisms through structural equation modelling.

The study contributes to the circular-economy literature through five elements: a tentative commitment-effect interpretation of the barrier-adoption association; the decoupling of firm size from CE behaviour; the identification of an asymmetry in national-context associations between adoption and performance; large-scale EU-27 evidence consistent with the absence of a direct, short-term CE-performance relationship; and a set of descriptive adoption profiles that extends existing classifications. Taken together, these contributions underscore that the circular transition of European SMEs is a complex, heterogeneous and deeply context-dependent phenomenon, organizational as well as national-institutional, that is unlikely to be understood or facilitated through a uniform approach.

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