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Business, biodiversity and ecosystem services: Evidence from large-scale survey data

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Abstract

This paper analyses data from a large-scale survey on corporate action to support biodiversity and ecosystem services undertaken by firms of all sizes and across manufacturing industries. The analysis focuses on Germany as the largest economy by GDP in the European Union and analyses the uptake of activities directly aimed at protecting biodiversity and ecosystem services compared to the uptake of other environmental protection activities. It furthermore investigates how activity and tool adoption as well as risk assessments vary with firm size and across industries, and with implementing environmental management systems. The analysis finds tensions between risk perception and activities pursued for biodiversity protection, largely because firms shy away from substantive action. It reveals that smaller and medium-sized firms are less active and that environmental management systems are not conducive to corporate activities in support of biodiversity and ecosystem services.

KEYWORDS

biodiversity, ecosystem services, SME, survey, symbolic action, tensions

1 | INTRODUCTION

Biodiversity sits alongside the atmosphere and land as a key element of natural capital. It has been defined as 'the total variation in organisms, in past times and present, in locations up to and including the entire planet' (Wilson, 2016, p. 227). A large variety of ecosystem services (ES), that is 'the benefits that humans obtain from ecosystems, and that are produced by interactions within the ecosystem' (Millennium Ecosystem Assessment, 2005, p. 3), are derived from biodiversity.

The recent assessment by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) in mid-2019 highlighted unprecedented extinction rates and risks alongside decreasing global trends for the large majority of nature's contributions to humankind's survival (IPBES, 2019). In the context of the Covid-19 crisis, biodiversity loss has furthermore been linked to increasing the likelihood of zoonoses that may result in major pandemic outbreaks (Everard et al., 2020; Schaltegger, 2020). These facts are in stark contrast to ES and biodiversity protection (i.e., restoration or conservation) being a focus of the United Nations (UN) Sustainable Development Goals (SDGs), with profit-oriented firms affecting and needing biodiversity and derived ES, which in turn may create

Abbreviations: ANOVA, Analysis of Variance; CDM, Clean Development Mechanism; EMAS, Eco-Management and Audit Scheme; EMS, Environmental Management System; ES, Ecosystem Services; EU, European Union; GDP, Gross Domestic Product; ICFPA, International Council of Forest and Paper Associations; IPBES, Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services; ISO, International Organization of Standardization; MEA, Millennium Ecosystem Assessment; QMS, Quality Management System; REDD(UNCollaborative Program on), Reducing Emissions from Deforestation and Degradation; SDG, Sustainable Development Goals; SME, Small and Medium-Sized Firms; UN, United Nations; US, United States(of America); VIF, Variance Inflation Factor.

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tensions, resulting from trade-offs between different goals that firms aim to achieve simultaneously. This specifically concerns (Global Reporting Initiative and UN Global Compact, 2017) the SDGs 2 (Zero Hunger), 6 (Clean Water and Sanitation), 14 (Life below Water) and 15 (Life on Land) and indicates issues related to symbolic action at different levels (e.g., firms, industries and countries).

While prior research highlights the importance of comprehensively gauging biodiversity and ES protection based on measures covering different emissions and pollutants (Maas et al., 2018), the need to link this to environmental management system (EMS) usage has also been stressed in the literature (Boiral & Heras-Saizarbitoria, 2017). The literature further argues that the protection of biodiversity and the ES built upon it are of high economic value and a crucial element of social welfare and sustainable development (Costanza et al., 1997; Heller & Zavaleta, 2009; Schaltegger & Beständig, 2010; Westman, 1977). This means that firms' activities aimed at protecting biodiversity and ES are closely scrutinised (Jones & Solomon, 2013; Winn & Pogutz, 2013). However, while conceptually the importance of biodiversity is clear, firms struggle to contribute to biodiversity in practice. For example, the above-mentioned SDGs most closely related to biodiversity are those least reported, partly because of a lack of agreed indicators and guidelines (Addison et al., 2018).

To address the gaps in the literature, this research seeks to clarify the heterogeneity across firms and levels (e.g., organisations or industries) of direct and indirect activities that firms undertake to limit ES and biodiversity degradation, and how this, in conjunction with perceived ES risks and their management may give rise to tensions, for example, from a focus on symbolic action.

This is analysed based on novel primary data from a large-scale survey that, as a rare exception, included larger numbers of small and medium-sized firms (SME). The survey, which was carried out among German manufacturing firms, specifically addressed corporate activities pursued to limit ES degradation, and the tools that firms apply to assess and manage risks related to ES and biodiversity degradation. Alongside enquiring about these aspects, the survey also gathered data on EMS implementation and certification, along with resource inputs for manufacturing firms that are most threatened by biodiversity degradation, in order to make visible tensions that relate to simultaneous management of these and further aspects.

Given that ES and biodiversity are interlinked in a complex manner that poses challenges to other planetary boundaries, such as climate change and freshwater ecosystems (Rockström et al., 2009; Wilson, 2016), the survey also addressed indirect factors affecting biodiversity, such as emissions into the air, water and soil (given those drive river pollution and global warming). In doing so, the survey extends the evidence available based on secondary data (mainly corporate reports) with new primary data, which provides a much-desired update on the state of practice and novel insights into SME activity that are rare in the extant literature.

Building on this, the paper more specifically analyses the degree of diffusion of direct and indirect activities supporting ES and biodiversity and evaluates the degree to which firms consider various resource inputs to be endangered by ES degradation and biodiversity loss. The information derived from this helps to clarify how tensions develop across levels (e.g., firms or industries) and reveals how activities and perceived risks relate in the generation of such tensions.

Ultimately, the paper offers empirical evidence to clarify the relationship between biodiversity and business and probes into tensions in this specific context, for example, with regard to the extent to which firms implement biodiversity protection actions relative to perceived risks and as concerns linkages between biodiversity and EMS. In doing so, the current research contributes by identifying symbolic actions, specific tensions and considerable heterogeneity across firms and industries. It also shows that EMS implementation does not help in reducing tensions and thus provides managers and policymakers with guidance how to develop initiatives that enable broader consideration of biodiversity and ES concerns in the future.

2 | REVIEW OF THE LITERATURE

The following section reviews the extant literature on biodiversity, ES, and natural capital as delineated in the Millennium Ecosystem Assessment (MEA) in order to identify research gaps and help contextualising research questions accordingly.[1]

The MEA (2005) distinguishes between provisioning services (i.e., goods from ecosystems such as water or timber), regulating services (i.e., benefits from nature such as climate regulation or pollination), cultural services (i.e., material benefits from ecosystems such as recreation or tourism) and supporting services (i.e., those underpinning other services such as nutrient cycling and primary production). Whilst arguments in favour of a business case for natural capital exist (Kareiva et al., 2015), at the same time it has been highlighted that this would require more comprehensive and standardised information and that substantial trade-offs may remain that could lead to tensions (Chaplin-Kramer et al., 2015). Yet, it is generally agreed that integrating biodiversity and ES concerns further in firms' sustainability policies would support SDG achievement (Addison et al., 2020).

In stark contrast to this, SDG reporting so far has been scarce, especially concerning the aforementioned SDGs that strongly relate to biodiversity (Addison et al., 2018). For Europe, recent research finds that during 2015 to 2018 only about a third of the stock-listed firms reported on SDGs, with the main emphasis being on specific actions and information on the outcomes of SDG prioritisation (Hummel & Szekel, 2021).

While early research on ES and biodiversity was based on the tenets of economic and natural sciences and focused mainly on quantifying monetary benefits (Costanza et al., 1997; Westman, 1977), work on these topics in the social sciences and management only emerged more recently. These latter works can be broadly classified as being either conceptual or empirical. Empirical work can be further sub-divided into being interview- or case-based (both of which

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constitutes primary data) or building on large-scale primary or secondary data (such as surveys or content analyses of reports).

Conceptual studies have investigated how procedural innovations have enabled certain practical advances in biodiversity conservation but also at the same time have limited the development of alternative approaches, for example, in the context of the Red List of Threatened Species (Cuckston, 2018). Other works in this stream of literature have considered the issue of how to appropriately discount the value generated at different points in time during projects supporting biodiversity and ES protection (Freeman & Groom, 2013). Together, these conceptual works can guide empirical studies and provide important benchmarks against which actual corporate activities can be gauged.

The interview-based empirical work available includes that of Boiral et al. (2018) who carried out 39 semistructured interviews and show that firms adopt biodiversity management standards mainly to improve the social acceptability of operations that harm natural habitats. A subsequent work, relying largely on the same interviews, finds that employee involvement is essential to improve biodiversity practices (Boiral et al., 2019). This second study also reveals that almost half of the interviewees mentioned an increased relevance of biodiversity without prompting, in turn reinforcing the observations cited above in the introduction. Another qualitative interview study by Maas et al. (2018) examines investor influence on biodiversity and the protection of natural capital by firms and reports a lack of standardised information in this context.

Tregida (2013) provides a case study illustrating how specific biodiversity accounting practices can create trade-offs and based on this, highlights a need to go beyond interviews and document analysis in order to understand how widespread practices are. Other case studies examine biodiversity issues in the context of the Kyoto protocol mechanisms, such as carbon trading (Cuckston, 2013) and indirect links of environmental and social activities of firms with ES payments in Thailand (Thompson, 2019). Finally, Khan (2014) studies the implementation of an integrated biodiversity measuring, monitoring, and reporting model in the context of the UN Collaborative Program on Reducing Emissions from Deforestation and Degradation (REDD) in Borneo. Overall, interview- and case-based work points to issues from symbolic action, and that tensions can derive from this.

Large-scale empirical work to date has almost exclusively used secondary data, usually firms' annual or sustainability reports, but also data published by government agencies (Siddiqui, 2013). Work in this stream has, for example, focused on stakeholder pressures in mining and forestry companies based on an analysis of sustainability reports. Findings include that corporate activities can be categorised into research and conservation measures, socio-political actions, and management practices (Boiral & Heras-Saizarbitoria, 2017). Talbot and Boiral (2021) study local government agencies and combine interviews with reports and action plans of such agencies. They find that the public organisations studied tend to pursue symbolic actions, which can lead to tensions and contradictions.

Other work building on secondary data has looked at biodiversity reporting in European countries. Both Rimmel and Jonäll (2013) and Van Liempd and Busch (2013) find that in both Sweden and Denmark, between 2006 and 2011, the extent of biodiversity reporting was low. Since activities aimed at limiting ES and biodiversity degradation are necessary precursors for any meaningful reporting, this finding also suggests that corporate activities in this period were even more limited. More recently, Hassan et al. (2020) studied biodiversity-related disclosures of the largest 200 Fortune Global firms for the years 2012, 2014 and 2016. Testing how different determinants affect a complex disclosure index, their regression study finds that disclosure is robustly associated with a firm receiving environmental awards, cooperating with others on biodiversity, and being headquartered in a developing country.

Finally, and as a rare exception to secondary data, Krause et al. (2020) carried out a survey of German firms in the secondary and tertiary sector. They find that corporate benefits and proenvironmental strategies of firms support voluntary biodiversity conservation action, and that lack of funds and competencies, as well as lack of strong external stakeholder pressure, counteract this.

The literature indicates that while there is an emerging body of work on ES and biodiversity in the social sciences and more narrowly the field of management, such work remains mainly conceptual, or is based on interviews or case studies involving small numbers of firms, or on secondary data. From our literature review it becomes clear that what is largely unavailable in the extant literature are large-scale, standardised, quantitative studies generating primary data that permit researchers to offer independent and systematic evidence based on a broader population of firms. Delivery of such evidence would also require that instruments (such as questionnaire surveys) link to established research foci on EMS implementation and the literature on environmental management activities more generally (Boiral & Heras-Saizarbitoria, 2017; Guenther et al., 2016; Tregida, 2013).

Specifically, the more general literature on environmental activities has identified firm size and industry as well as EMS as important factors in need of further consideration (Guenther et al., 2016). This is especially true for firm size with regard to SME, where there is almost no evidence beyond a few cases owing to those firms seldom publishing reports, which constitutes another an important gap to be addressed (Windolph et al., 2014). Therefore, building on the insights from reviewing the literature, the next section develops research questions.

3 | THEORETICAL PERSPECTIVES AND DEVELOPMENT OF RESEARCH QUESTIONS

As identified at the beginning of the literature review, the often-quoted business case for sustainability in profit-oriented firms (at least in the long-term) implies growth aspirations that may be too demanding to remain within desirable limits to growth (Randers, 2012), especially given biodiversity is one of the planetary boundaries that has already been breached (Rockström et al., 2009). Consequently, a business case for natural capital in general and as part

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of this biodiversity in particular (Kareiva et al., 2015) is also challenged by the issue that, while business relies on resources sourced from nature, its operations are simultaneously a major contributor to the erosion of biodiversity. Therefore, it is possible that tensions emerge in this context.

This is likely even more so, if a multilevel perspective is adopted, for example, in terms of countries at the macro-level, industries at the meso-level, and firms at the micro-level (Barbier et al., 2018). Here, firm-level capabilities or characteristics, such as the availability and utilisation of management or accounting systems or techniques that record and indicate environmental damage (Gibassier et al., 2018; Maas et al., 2016; Schaltegger & Wagner, 2006) and industry-level structures seeking to institutionalise solution processes interact and create heterogeneity that requires a nuanced assessment.

Tensions that result from the aforementioned conditions can emerge from firms resorting to symbolic, rather than substantive action (Cañón-de-Francia & Garcés-Ayerbe, 2009; Christmann & Taylor, 2006). Symbolic action for firms avoids costly investments and at the same time produces favourable impressions and addresses institutional or isomorphic pressures, for example, within industries (DiMaggio & Powell, 1983; Goffman, 1959; Solomon et al., 2013).

Whilst symbolic action (i.e., lack of sufficient and substantive activities) does not always result in tension, it may lead to prisoner dilemma situations, for example, when short-term cost savings from avoiding substantive action result in increased long-term cost to businesses from stricter future regulations. Tensions may also surface in terms of contradictions between assessments and actions within one firm. For example, this is the case, if firms perceive high risks in specific areas (such as ES and biodiversity degradation), but only pursue limited action in relation to this. Such a situation would result in contradictions and tensions between a firm's projected image and implemented activities (Solomon et al., 2013; Talbot & Boiral, 2021; Ylönen & Laine, 2015).

Building on these arguments, this study attempts to shed more light on activities and tensions in the context of biodiversity, especially concerning ES and biodiversity risks as well as activities and their drivers and heterogeneity across levels (e.g., firms or industries). We therefore focus on the following research question, specifically aiming to identify tensions with regard to each of them:

1. What (direct and indirect) activities are implemented to limit ES and biodiversity degradation, and is there heterogeneity across firms (e.g., in terms of size or depending on EMS adoption) or levels (e.g., in terms of organisation versus industry)?
2. How are activities related to risks directly or indirectly linked to ES degradation, and is there heterogeneity across firms or levels?
3. When have firms adopted tools to assess and manage risks related to ES and biodiversity degradation, and is there heterogeneity across firms or levels?

Acknowledging the state of the literature, this study contributes to answering the identified research questions, based on a rare large-scale empirical survey, on the relevance and management of ES and biodiversity. This also clarifies how biodiversity interacts with other corporate sustainability aspects, and differentiates results with regard to firm characteristics and industries, which contributes to a multilevel perspective on the issues raised.

4 | DATA AND METHODOLOGY

4.1 | Sampling and database

The empirical analysis is based on 270 complete responses received to a survey of manufacturing firms in Germany in 2016. Building on earlier survey rounds (Doluca et al., 2018), a random sample derived from the Amadeus database of Bureau van Dijk of the population of German manufacturing firms (including both, listed and nonlisted firms) was utilised to administer the survey.

Germany was chosen because it is the largest economy in the European Union (EU) by GDP and because it is challenged by a loss of biodiversity. This includes a huge decline in insect, spider, and butterfly species (Hallmann et al., 2017) as well as in pollinators and honeybees, as part of a broader challenge affecting the EU more generally, and at the global level also the United States (Romi & Longing, 2016).

Furthermore, Germany has a large number of internationally active small- and medium-sized firms in the manufacturing sector owing to its strong export focus. Therefore, we can address the role of such firms and compare it with that of large firms to better understand issues such as differences in activity profiles. Given the size and development level of the German economy, as well as the generic nature of biodiversity challenges, this makes it possible to derive prototypical insights that can be transferred to other industrialised states (e.g., other EU countries and United States which also have similar levels of population density and urbanisation) facing similar biodiversity issues.

Our survey was administered electronically via the internet, and the invitation mail requested that the person most knowledgeable with regard to the topics covered should complete it. The response rate amounted to 5%.[2] The data collected in the survey addressed an inventory of technological environmental activities by firms, including those directly or indirectly related to biodiversity, and also information on availability and quality risks with regard to ES. The survey introduced the ES definition of the MEA to ensure a common definitional basis for all firms responding to the questions. Furthermore, the survey gathered information on the tools employed to assess and manage risks related to ES, as well as on firm characteristics such as ownership status, the specific industry, the economic condition of the firm, quality management initiatives, and EMS implementation and certification.

Assessing of response bias by comparing the means for all involved variables between the first and last 10% of respondents reveals that the characteristics and response behaviour of early respondents was not significantly different from that of those who replied later (except for some individual environmental activities, which were however all not directly related to biodiversity).

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Furthermore, the responses indicate that even environmentally and socially less active firms responded. These findings also suggest that social desirability is not an issue in the data.

Use of only one survey instrument may also be a concern with regard to common method and source bias. To forestall this issue, different response formats were used, the question order was counterbalanced, and the anonymity of respondents was guaranteed to reduce socially desirable responses and item ambiguity. Furthermore, applying Harman's single-factor test revealed an unrotated factor solution yielding 41 factors with Eigenvalues larger than unity. The first three factors explain 11.5%, 6.9% and 3.8%, respectively. All remaining factors with Eigenvalues larger than one explain between 0.7 and 3.6% of the variance in the data. Therefore, no common method and source bias exists in the data.

Concerning industry and size distributions, the database contains a significant share (37%) of SME (with up to 249 employees). Despite the high share of SME, larger firms are somewhat overrepresented in the responses, which is however a common problem of firm surveys (Armstrong & Overton, 1977). The industry composition is broadly representative for the population (Federal Statistical Office, 2016) with firms in the chemicals (17%), materials (glass, ceramics and metals) processing (14%), consumer goods (12%) and machinery and transport equipment (11%) segments having the largest shares for individual industries in the responses.

4.2 | Empirical methods and variables

We analyse the data using different quantitative and partly qualitative methods, such as content analysis and statistical techniques including cross-tabulations, distributional comparisons, correlational analysis, χ^2- as well as *t*-tests, analysis of variance (ANOVA) and multivariate regression analysis. Such a combined approach is advocated, since it allows for more comprehensive insights.

In several analyses binary dummy variables for a firm's main industry are involved, based on the following sectors: consumer goods, paper/wood & printing, chemicals, materials processing, machinery and transport equipment, electric and electronic equipment (Wagner, 2020). As well, based on employee data, three categories of firm size and a continuous measure of firm size defined as the logarithm of the number of staff (since the distribution of the employee data is rightward-skewed) are involved in some of the analyses.

To address our first research question, we involve cross-tabulations and compare corporate biodiversity actions against environmental management activities (that can also indirectly contribute to biodiversity and ES protection), as well as *t*-tests and multivariate regression analyses to reliably gauge heterogeneity.

The analysis of our second research question is based on combining content analysis and ANOVA with cross-tabulations, *t*-tests and correlational analysis. Drawing inferences across these methods allows to identify tensions emerging from the data.

To address the third research question, we apply *t*-tests in combination with distributional comparisons and ANOVA. Again, jointly evaluating the results of these analyses allows to pinpoint tensions that become visible in the data.

In the multivariate regressions, a number of additional explanatory and control variables are taken into account beyond firm size and industry membership (involved to account for institutional and structural effects related to industry and size), as detailed in the following. Building on Wagner (2020), EMS certification is measured with two variables based on the firm being certified or verified in accordance with ISO 14001 or EMAS. If there is a certification according to the relevant scheme, the corresponding variable value assumes 1, otherwise it is 0. The EMS experience variable is measured as the time passed since the initial implementation of an EMS. To avoid endogeneity with the activities surveyed (i.e., the activity could be implemented before certification was achieved), implementation time was calculated until 2012 (Wagner, 2020).

Christmann (2000) argues that a quality management system (QMS) in accordance with ISO 9001 complements environmental standards. Therefore, if a firm had a QMS certified according to ISO 9001 was included in the regression models as a binary dummy variable (*yes* coded as 1, *no* as 0), as was firm type because processes and structures of parent companies may require that activities beyond those stipulated by environmental management standards are the implementation (Wagner, 2020). To account for this effect, a dummy variable was created and coded as 1 if the firm was fully independent, and 0 if it had a parent company. Further to these explanatory and control variables, based on Dess and Beard (1984), growth in the main market was incorporated in the regression analysis to account for possible effects of munificence using a 5-point scale anchored with *decreased significantly* (coded as 1) and *increased significantly* (coded as 5). Finally, in line with Martin-Tapia et al. (2008), organisational uncertainty is measured as an index referring to how much technologies, customers preferences, suppliers and regulations affect the company. The index has a Cronbach's alpha value of .71. All variables involved in the statistical analyses referred to above are summarised, together with a detailed definition, in Table 1.

Table A1 provides an overview of descriptive statistics for all variables listed in Table 1. It exhibits the broad variation found in the data, which underscores the high variability of the responses. This confirms that a meaningful statistical analysis is feasible. Table A2 provides correlations and variance inflation factors (VIF) of all independent variables used in the multivariate regression analyses, both of which suggest that multicollinearity is not an issue, as is also reflected in the mean VIF being 2.63.

5 | RESULTS

5.1 | Analysis of direct and indirect activities

The first part of the survey asked firms to state which technical activities they conducted that indirectly support biodiversity and the provision of ES, and also enquired whether the firm undertook three direct activities supporting biodiversity and ES protection, namely,

TABLE 1 Summary of variable definitions for variables used in the empirical analysis

Variable name	Variable description	Variable type
Technological environmental activities	Inventory of activities by firms that are indirectly related to biodiversity, corresponding to items (1) to (16) in Table 2	Binary; *yes* coded as 1, and *no* as 0 for each individual activity in the inventory
Biodiversity restoration	Investments in ecosystem/biodiversity restoration	Binary; *yes* coded as 1, and *no* as 0
Biodiversity conservation	Investments in ecosystem/biodiversity conservation	Binary; *yes* coded as 1, and *no* as 0
Emissions offsetting	Offsetting in the context of CDM, carbon trading, or similar mechanisms	Binary; *yes* coded as 1, and *no* as 0
Total ES risk of firms main activity	Joint evaluation of firms availability and quality risk assessments	Continuous, averaging two 5-point scale items, each anchored with *no* (1) and *very high* (5) exposure to risks
Tools to assess and manage risks related to ES degradation	Degree to which the firm employs tools to assess and manage ES risks	Ordinal; 4-point scale anchored with *yes* (4) and *no* (1), with additional levels being *considering* (2) and *in progress* (3)
Organisational uncertainty	Joint evaluation of change frequency and influence range for external factors and the business environment	Continuous; averaging four 7-point scale items, each anchored with *fully disagree* (1) and *fully agree* (5)
Industry uncertainty	Sector volatility based on the five years preceding the time of the survey	Continuous; measured as the volatility of sectoral revenue over the preceding five years
Firm fully independent	Legal status of the firm	Binary; *completely independent* coded as 1, else as 0
Quality management system	Presence of a quality management system in accordance with ISO 9001	Binary; *yes* coded as 1, and *no* as 0
Munificence	Degree of decrease or increase in size of the firms main market	Ordinal; 5-point scale anchored with *decreased significantly* (1) and *increased significantly* (5), with additional levels being *declined slightly* (2), *stayed the same* (3) and *increased slightly* (4).
Sectoral controls *Consumer goods*	Firm operates in the consumer goods sector	Dummy (base category)
Paper, wood & printing	Firm operates in the paper, wood or printing sectors	Dummy
Chemicals	Firm operates in the chemical industry sectors	Dummy
Glass, ceramics & metal processing	Firm operates in the glass, ceramics or metal processing sectors	Dummy
Machinery & transport equipment	Firm operates in the machinery or transport equipment sectors	Dummy
Electric or electronic equipment	Firm operates in the electric or electronic equipment sectors	Dummy
Other manufacturing	Firm operates in other manufacturing sectors	Dummy
ISO 14001 certification	Firm is certified according to ISO 14001	Binary; *yes* coded as 1, and *no* as 0
EMAS certification	Firm is certified according to the EU eco-management and audit scheme	Binary; *yes* coded as 1, and *no* as 0
EMS implementation time	Time elapsed since initial EMS implementation	Continuous; measured in number of years
Firm size	Number of employees	Continuous; measured in logarithms due to skewed distribution

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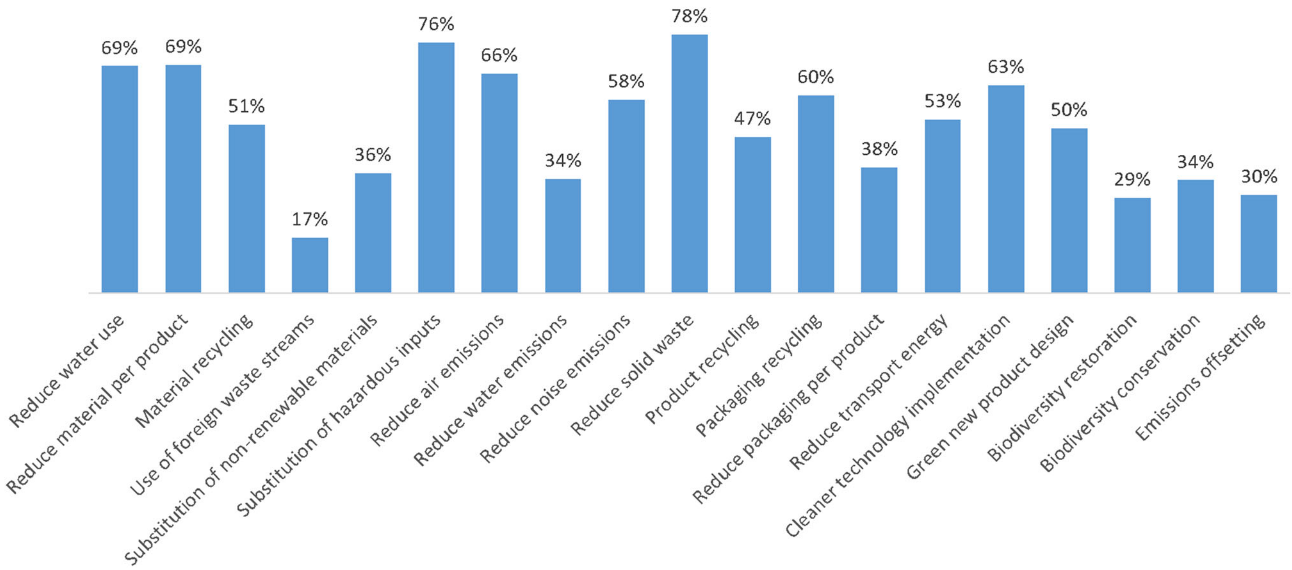

FIGURE 1 Extent of direct and indirect technical activities in support of ES and biodiversity

(1) investments in ecosystem/biodiversity restoration, (2) investments in ecosystem/biodiversity conservation and (3) emissions offsetting. These three aggregate areas (see bottom of Figure 1) correspond closely to those identified by Schaltegger and Beständig (2010), and also Cuckston (2013) who links biodiversity and ES protection to carbon trading activities, such as forest carbon crediting.

In contrast to activities directly supporting biodiversity, the indirect technical environmental protection activities surveyed have an implicit bearing on biodiversity, despite their focus nominally being on other areas such as energy and materials usage, waste, air, or water pollution. To illustrate, at the industry level, the International Council of Forest and Paper Associations (ICFPA) has committed the wood products sector globally to reducing air emissions, increasing recycling and higher energy efficiency, all of which are indirect activities (ICFPA, 2006). Similarly, pollution of the river Rhine or lake pollution in Germany from power plants will have lasting adverse effects on biodiversity and ES provision (Raptis et al., 2016). Indirect effects typically depend on many industries jointly reducing their demands and impacts to protect biodiversity, which potentially can create tensions. The inventory of indirect activities is based on the International Business Environment Barometer surveys (Belz & Strannegård, 1997; Kestemont & Ytterhus, 2001), and all items are listed in Figure 1.

Figure 1 compares the extent of the direct activities (i.e., the last three bars) relative to activities that indirectly contribute the protection of biodiversity and ES (i.e., all other bars). Figure 1 in this respect reveals that indirect actions are most widespread, especially those aimed at substitution of nonrenewable materials, as well as waste and material usage reductions. Compared to this, the adoption of direct measures supporting biodiversity restoration or conservation and emissions offsetting is far more limited.

Firm size and industry are fundamental firm characteristics and our research question also asks to establish whether they are significantly associated with the implementation of activities to support ES protection and biodiversity. The literature review revealed that the role of SME on the issue of biodiversity remains rather opaque. The survey relied on in this study is one of the first to cover a significant number of SME and can therefore provide new insights into how firm size relates to heterogeneity in the activities adopted. For example, Table 2 reveals that large firms in particular pursue more activities (both, directly and indirectly) to support biodiversity conservation and restoration, and also engage more often in offsetting emissions such as greenhouse gases through forestation in developing countries in the context of the CDM.

Conducting *t*-tests revealed significant differences in the average size of firms adopting biodiversity conservation ($t = 1.66$, $p = .05$) and restoration ($t = 1.57$, $p = .06$) initiatives, and emissions offsetting ($t = 1.83$, $p = .03$). It is the significantly larger firms that implement activities directly supporting ES and biodiversity. This in turn suggests that smaller and medium-sized firms are comparatively less proactive in this respect.

At the same time, the somewhat higher values for small- versus mid-sized firms may indicate tensions in that the former are locally more embedded and therefore are better able to support local biodiversity initiatives. That notion would also be consistent with the linear increase in adoption rates in association with firm size that is found for emissions offsetting, because the latter is more global and compensatory in scope and therefore small firms would not benefit equally from local involvement here.

With regard to industry-related heterogeneity, Table 3 reveals that activities in firms which directly foster ES and biodiversity protection (i.e., those in the last three rows of the table) are considerably

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TABLE 2 Direct and indirect activities in support of ES and biodiversity by firm size

Size category activity	Small (1–49 employees)	Medium-sized (50–249 employees)	Large (>249 employees)
Reduce water consumption (1)	36.4%	61.9%	77.9%
Reduce material per unit (2)	50.0%	69.8%	75.2%
Material recycling (3)	40.9%	44.4%	53.1%
Use of foreign waste streams (4)	13.6%	12.7%	14.5%
Substitution non-ren. materials (5)	22.7%	39.7%	40.0%
Substitution hazardous input (6)	40.9%	76.2%	83.4%
Reduce air emission (7)	36.4%	55.6%	75.9%
Reduce water emission (8)	18.2%	27.0%	40.0%
Reduce noise emission (9)	36.4%	61.9%	58.6%
Reduce waste (10)	81.8%	74.6%	76.6%
Product recycling (11)	59.1%	47.6%	46.9%
Packaging recycling (12)	68.2%	65.1%	58.6%
Reduce packaging per unit (13)	50.0%	33.3%	42.1%
Reduce transport energy (14)	40.9%	42.9%	61.4%
Cleaner technology (15)	45.5%	54.0%	73.1%
Green new product (16)	40.9%	46.0%	60.0%
Biodiversity restoration (17)	31.8%	20.6%	33.8%
Biodiversity conservation (18)	36.4%	23.8%	41.4%
Emissions offsetting (19)	13.6%	19.0%	35.9%

Note: Values refer to the percentage share of adopting firms in each size category.

TABLE 3 Direct and indirect activities in support of ES and biodiversity by industry

Industry Activity	Consumer goods	Paper, wood & printing	Chemical industry	Glass, ceramic & metal proc.	Machinery & transport eqpt.	Electric & electronics eqpt.	Other manufacturing
(1)	74.1%	60.0%	75.7%	63.3%	87.5%	52.2%	70.0%
(2)	63.0%	90.0%	75.7%	76.7%	79.2%	69.6%	61.4%
(3)	44.4%	60.0%	64.9%	40.0%	54.2%	56.5%	41.4%
(4)	7.4%	20.0%	13.5%	20.0%	16.7%	0.0%	15.7%
(5)	51.9%	50.0%	45.9%	20.0%	25.0%	47.8%	35.7%
(6)	63.0%	80.0%	70.3%	86.7%	91.7%	78.3%	77.1%
(7)	70.4%	65.0%	62.2%	73.3%	83.3%	56.5%	62.9%
(8)	25.9%	30.0%	35.1%	30.0%	54.2%	26.1%	35.7%
(9)	51.9%	65.0%	64.9%	70.0%	70.8%	39.1%	48.6%
(10)	59.3%	90.0%	91.9%	60.0%	91.7%	91.3%	68.6%
(11)	63.0%	45.0%	59.5%	43.3%	58.3%	60.9%	32.9%
(12)	74.1%	65.0%	64.9%	56.7%	70.8%	69.6%	48.6%
(13)	44.4%	55.0%	51.4%	30.0%	50.0%	43.5%	30.0%
(14)	63.0%	35.0%	59.5%	50.0%	62.5%	47.8%	54.3%
(15)	70.4%	70.0%	75.7%	63.3%	79.2%	78.3%	50.0%
(16)	55.6%	55,0%	64.9%	53.3%	75.0%	65.2%	37.1%
(17)	37.0%	20.0%	27.0%	13.3%	29.2%	26.1%	40.0%
(18)	37.0%	30.0%	37.8%	10.0%	41.7%	26.1%	48.6%
(19)	25.9%	40.0%	24.3%	30.0%	29.2%	21.7%	32.9%

Note: Activities are numbered as in Table 1; values refer to the percentage share of adopting firms in an industry.

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more limited than other technical environmental protection activities that contribute indirectly to the protection of biodiversity. Furthermore, the highest percentage of firms implementing biodiversity restoration activity operates in the consumer goods and other (miscellaneous) manufacturing industries, whereas in the case of biodiversity conservation, the highest percentage of firms implementing operates in machinery and transport equipment and other manufacturing sectors.

In the case of emission offsetting, the bulk of the firms implementing operates in the paper, wood and printing sector, and in other manufacturing industries. The high percentage figure for other manufacturing firms is linked to the fact that it was often (especially municipal) utility companies responding to the survey here, and these typically have a high level of environmental exposure. Overall, the disaggregated analysis of activity adoption depending on firm- and industry-level factors suggests considerable heterogeneity with regard to the adoption of important direct activities relating to the restoration and conservation of biodiversity and ES protection and also emissions offsetting, pointing to complex tensions interacting across multiple levels.

Finally, with regard to a multivariate assessment of heterogeneity that also incorporates EMS implementation effects, the binary logit analyses, reported in Table 4, reveal that for direct activities in support of biodiversity and ES protection (i.e., investments in ecosystem/biodiversity restoration, investments in ecosystem/biodiversity conservation, and emissions offsetting), firm size is the strongest predictor, which is consistent with the prior analyses. Industry effects are found to be weaker with only glass, ceramics and metal processing

TABLE 4 Estimations by individual direct activity for biodiversity and ES protection

Explanatory variables	Restoration, no interaction	Restoration, with interaction	Conservation, no interaction	Conservation, with interaction	Offsetting, no interaction	Offsetting, with interaction
Firm fully independent	0.04 (0.33)	0.02 (0.34)	0.08 (0.32)	0.07 (0.32)	−0.17 (0.33)	−0.19 (0.33)
Quality management system	−0.76 (0.51)	−0.83 (0.50)	−0.88 (0.49)†	−0.91 (0.49)†	−1.33 (0.47)**	−1.37 (0.48)**
Munificence	0.16 (0.16)	0.17 (0.16)	0.18 (0.16)	0.19 (0.16)	−0.15 (0.17)	−0.14 (0.17)
Paper, wood & printing	−0.39 (0.76)	−0.34 (0.75)	0.16 (0.69)	0.20 (0.68)	0.96 (0.73)	0.99 (0.72)
Chemicals	−0.53 (0.63)	−0.59 (0.61)	−0.02 (0.62)	−0.06 (0.60)	−0.16 (0.64)	−0.20 (0.65)
Glass, ceramics & metal processing	−1.37 (0.79)†	−1.40 (0.77)†	−1.79 (0.85)*	−1.80 (0.83)*	0.02 (0.73)	0.0002 (0.72)
Machinery & transport equipment	−0.83 (0.74)	−0.88 (0.74)	−0.30 (0.70)	−0.31 (0.69)	−0.85 (0.73)	−0.89 (0.73)
Electric & electronic equipment	−0.69 (0.69)	−0.59 (0.70)	−0.79 (0.73)	−0.73 (0.72)	−0.69 (0.85)	−0.64 (0.82)
Other manufacturing	−0.27 (0.61)	−0.26 (0.60)	0.10 (0.60)	0.11 (0.58)	−0.23 (0.64)	−0.24 (0.63)
ISO 14001 certification	−0.79 (0.49)	−1.48 (0.68)*	−0.56 (0.47)	−0.93 (0.65)	−0.28 (0.44)	−0.62 (0.61)
EMAS certification	0.75 (0.46)	−0.04 (0.83)	0.49 (0.45)	−0.01 (0.88)	0.59 (0.45)	0.13 (0.83)
ISO × EMAS	-	1.25 (0.98)	-	0.73 (0.99)	-	0.66 (0.94)
EMS implementation time	0.01 (0.03)	0.04 (0.04)	0.03 (0.03)	0.04 (0.04)	0.02 (0.03)	0.03 (0.04)
Firm size	0.25 (0.09)**	0.24 (0.09)*	0.27 (0.09)**	0.26 (0.09)**	0.42 (0.09)***	0.42 (0.09)***
Constant	−2.02 (0.86)*	−1.94 (0.86)*	−2.20 (0.81)**	−2.14 (0.81)**	−2.14 (0.85)*	−2.09 (0.86)*
Log-likelihood	−119.55	−118.67	−124.92	−124.59	−112.69	−112.45
Number of observations	220	220	220	220	220	220
Pseudo-R^2	.09	.10	.12	.13	.16	.16
Wald	17.05	22.50†	25.67*	28.57*	37.41***	37.80***

Note: Robust standard errors in parentheses; industry relative to consumer goods as base category.
†$p < .10$.
*$p < .05$. **$p < .01$. ***$p < .001$.

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having a significant negative effect. Regarding EMS implementation, no positive effect of firms being certified according to ISO 14001 or verified according to EMAS can be identified. Furthermore, there is also neither significant interaction effect of firms that have implemented both ISO 14001 and EMAS, nor has the time elapsed since implementation started a significant effect.

Concerning joint implementation of all three direct activities in support of biodiversity and ES protection, a multivariate ordered logit estimation reveals that the findings for EMS implementation from the binary logit estimations are essentially reproduced in Table 5. In the ordered logit model, given that three activities may or may not be pursued by a firm, the dependent variable can take one of four discrete values (i.e., 0, 1, 2 or 3). As Table 5 shows, again firm size is found to be the strongest predictor whereas industry effects are as before weaker.

TABLE 5 Estimations for the sum of direct ES activities for biodiversity and ES protection

Explanatory variables	Sum of direct activities, no interaction	Sum of direct activities, with interaction
Firm fully independent	−0.004 (0.27)	−0.02 (0.28)
Quality management system	−1.18 (0.48)*	−1.22 (0.47)*
Munificence	0.04 (0.13)	0.05 (0.13)
Paper, wood & printing	0.25 (0.63)	0.29 (0.63)
Chemicals	−0.19 (0.65)	−0.24 (0.64)
Glass, ceramics & metal processing	−0.86 (0.67)	−0.87 (0.65)
Machinery & transport equipment	−0.59 (0.67)	−0.61 (0.65)
Electric & electronic equipment	−0.78 (0.69)	−0.71 (0.69)
Other manufacturing	−0.17 (0.63)	−0.16 (0.62)
ISO 14001 certification	−0.57 (0.40)	−0.91 (0.48)†
EMAS certification	0.55 (0.34)	0.04 (0.75)
ISO × EMAS	-	0.71 (0.80)
EMS implementation time	0.03 (0.03)	0.05 (0.04)
Firm size	0.34 (0.08)***	0.33 (0.08)***
Log-likelihood	−244.05	−243.62
Number of observations	220	220
Pseudo-R^2	.08	.09
Wald Chi^2	37.50***	41.35***

Note: Robust standard errors in parentheses; industry relative to consumer goods as base category.
†$p < .10$.
*$p < .05$. **$p < .01$. ***$p < .001$.

5.2 | Relationship of activities to ES risks

To analyse how different activities relate to ES risks, we asked firms to estimate the degree to which their activities are exposed to risks directly or indirectly linked to ES degradation and biodiversity loss. Based on the responses to two questions assessing exposure for (1) availability and (2) quality of raw materials, an overall index gauging a firm's total ES risk was calculated by averaging the availability and quality risk assessments of each firm.

Total ES risk is in this way as a firm-level construct that relates to heterogeneity across firms with regard to negative impacts of biodiversity loss or declining ES availability. This interpretation is confirmed by the correlation of total ES risk with the measure of organisational uncertainty at the firm level that was also included in the survey ($r = .17$, $p = .02$). In contrast, total ES risk does not correlate ($r = -.01$, $p = .91$) with an established measure of industry uncertainty that is based on sectoral revenue volatility over time (Canella et al., 2008). This leads us to conclude that total ES risk is a firm-specific measure of risk that specifically relates to the context of ES and underlying biodiversity. Accordingly, ES risk measures that part of firm-specific uncertainty relating to biodiversity loss and reduced availability of ES, but not other aspects of uncertainty that the firm faces. Furthermore, these findings again suggest the need for a multilevel perspective when analysing biodiversity issues, since in the case of ES risk, links are stronger to the firm, than the industry level.

Statistical analysis reveals significant associations between the activities aimed directly at biodiversity and ES protection, but in a differentiated fashion. More specifically, *t*-tests reveal levels of total risk relating to raw materials linked to ES degradation and biodiversity loss are significantly higher for firms pursuing biodiversity conservation ($t = 2.56$, $p = .01$) and emissions offsetting ($t = 2.49$, $p = .01$), but not biodiversity restoration ($t = 1.28$, $p = .10$). Therefore, while a higher perceived risk generally corresponds to higher activity levels, the analysis suggests that even the most exposed firms invest less comparatively in ecosystem regeneration and thus may not realise their full potential to contribute to biodiversity remediation and ES protection. The situation reveals a tension between business objectives and societal goals.

With regard to SME effects, the Pearson correlation between the number of employees and total ES risk is not significant ($r = .08$, $p = .24$), and nor is the Spearman rank correlation ($r = .04$, $p = .56$). In both cases, the nonsignificant correlations are independent of whether the number of employees is in logarithms or not to account for skewedness in the firm size distribution of our response sample. This suggests a potentially important role for SME in the future, since

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FIGURE 2 Total ES risk score by industry

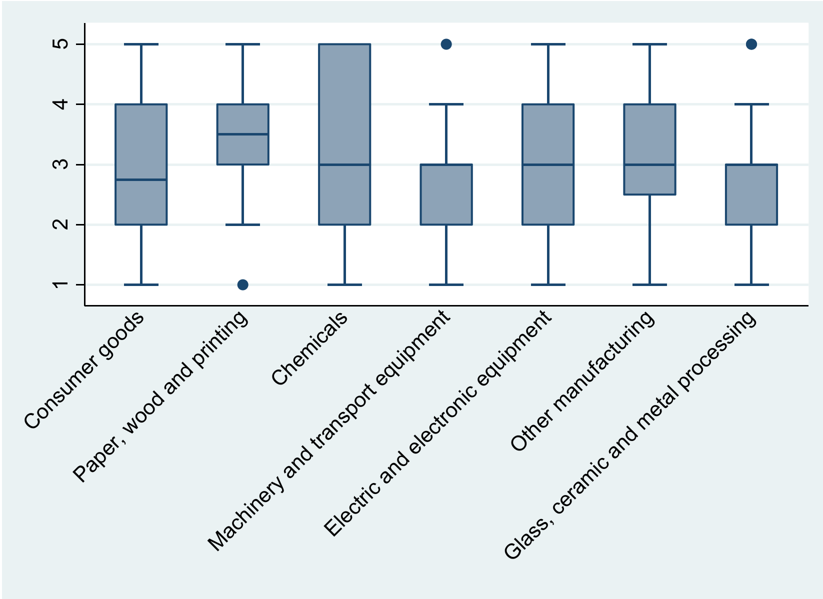

TABLE 6 Measures visualised in Figure 2 by industry

Industry Measure	Consumer goods	Paper, wood & printing	Chemical industry	Machinery & transport eqpt.	Electric & electronics eqpt.	Other manufacturing	Glass, ceramic & metal prod.
Median	2.75	3.5	3	3	3	3	3
5% percentile	1	1.5	1	1	1	1	1
95% percentile	5	5	5	4.5	5	5	4.5
Skewedness	0.18	−0.57	−0.22	0.16	0.03	−0.28	−0.46

they seem just as concerned with and threatened by losses of biodiversity and the declining availability of ES as large firms are.

Alongside firm size, the industry level is also an important factor in the context of ES risk. Figure 2 in this respect shows the total ES risk scores by industry are quite similar, with firms in the wood products sector being somewhat more concerned about ES risks than firms generally, which is consistent with stronger goal commitments in this industry (Barbier et al., 2018).

However, as it is also borne out in Table 6, the levels of activity in this sector are not higher than in other industries, since an ANOVA does not reveal any significant difference between any two industries ($F = 1.35$, $p = .24$). This points to an industry-level tension since other industries that are less concerned about ES risks may be creating negative spillover effects to the wood products sector.

To sum up, a disaggregated analysis of ES risk perception finds limited industry-level effects but suggests that at the firm level, the more concerned firms pursue more activities directly targeting ES and biodiversity protection, which in turn points to tensions modulated across levels.

Beyond quantitatively gauging ES risks, our survey also asked respondents to name the two raw materials used by the firm that are most exposed to risks directly or indirectly linked to the degradation of ES. Applying qualitative content coding to the responses yielded five categories, namely, water, electricity, nonrenewable energy, renewable and nonrenewable resources. Of these, electricity and nonrenewable energy are indirectly relevant, because if firms can rely less on these as a result of climate change being more seriously addressed, this would lead to increased demand for renewable energy. That demand would, for example, mean heightened pressure to grow energy crops, and doing so would have a negative qualitative effect by reducing plant variety and a negative quantitative effect by increasing land use, both of which are detrimental to biodiversity and the ES provision building on it. Likewise, a need to reduce nonrenewable resource use would morph into increased renewable resource demands with similarly detrimental effects due to resource depletion. For the five categories, the distribution across industries is shown in Table 7.

An important insight from the qualitative content coding and its subsequent analysis is that energy resources have an overall low relevance in terms of being threatened by biodiversity loss or declining ES. Furthermore, the chemical, machinery, electrical, and the glass and metal industries are mainly concerned about nonrenewable resources. This suggests the respondents from those industries are concerned about the initially largely indirect effects of ES deterioration in terms of limited or curtailed access to relevant reserves. At the same time, the increasing demand for nonrenewable resources, as suggested by

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TABLE 7 Raw materials at risk by industry

Industry Category	Consumer goods	Paper, wood & printing	Chemical industry	Glass, ceramic & metal prod.	Machinery & transport eqpt.	Electric & electronics eqpt.	Other manufacturing
Water	11.1%	10.5%	2.7%	6.7%	0%	0%	16.7%
Nonrenewable energy	3.7%	0%	0%	3.3%	0%	0%	21.7%
Nonrenewable resources	14.8%	15.8%	37.8%	56.7%	45.8%	47.8%	28.3%
Renewable resources	59.3%	84.2%	10.8%	6.7%	0%	4.3%	21.7%
Electricity (renewable/ fossil)	0%	0%	2.7%	0%	4.2%	8.7%	8.3%

Note: Figures represent the percentage of firms in the industry stating the corresponding category.

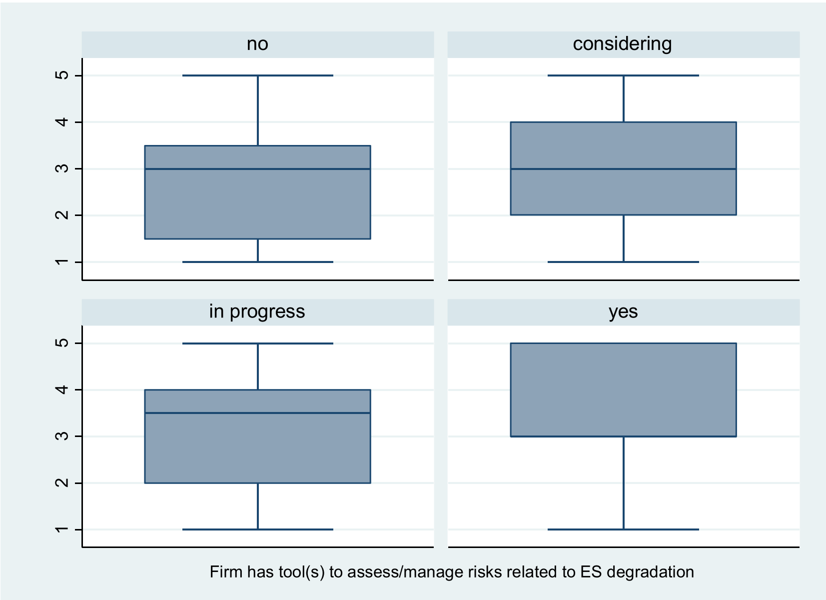

FIGURE 3 Distribution of total ES risk score for different use levels of tools supporting ES

the responses of firms from the above industries, indicates a strong future potential for tensions arising from usage conflicts between exploiting nonrenewable resources and protecting biodiversity and ES. The results of this study indicate that this tension is further aggravated by the majority of manufacturing industries being likely to have negative impacts in this respect, and as a result probably not pushing for stricter regulation to protect biodiversity and ES.

Consistent with the heightened stakes in biodiversity identified in other analyses (e.g., Barbier et al., 2018), in the consumer goods and the wood and paper industries, renewable resources are perceived most at risk. Furthermore, across all industries and categories, the percentage of firms agreeing that renewable resources are at risk is higher than for all other categories in these two industries (see Table 7). The findings indicate the presence of tensions between industries with regard to the protection of biodiversity and ES.

5.3 | Analysis of tool implementation and ES risks

To clarify if the tensions identified between perceived risks and activities undertaken can be at least partly resolved by the adoption of specific tools related to ES and biodiversity degradation, the survey respondents were asked if they use any tool to assess or manage risks directly or indirectly linked to ecosystem services degradation (i.e., beyond direct or indirect activities, or EMS implementation/certification). Figure 3 indicates that only those firms perceiving very strong aggregate ES risks are at a more advanced stage in implementing tools (i.e., rather than not having implemented, or just considering implementation, they are actually in progress or have implemented tools).

The median values for ES risk perception are 3 if tools are not implemented or only considered (5% percentile: 1; 95% percentile: 5; skewedness: −0.01 and 0.01, respectively). For tool implementation

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being in progress or tools being implemented, the median value for ES risk perception is 3.5 (5% percentile: 1; 95% percentile: 5; skewedness: −0.52 and −0.26, respectively). An ANOVA analysis confirms that only the difference between firms having implemented tools and those having not at all is significant ($F = 6.48$, $p < .001$), but that the differences for firms evaluating tools or being in process to implement tools are not significant. Therefore, a considerable number of firms that perceive risks were not yet using relevant tools in a comprehensive manner.

To further illuminate this finding, a differential analysis of cross-level effects of the tools and activities to assess and manage risks related to ES and biodiversity degradation was carried out. An ANOVA for tool implementation by industry yielded insignificant results ($F = 0.74$, $p = .61$) indicating that there are no differences across sectors. However, the corresponding ANOVA of tool implementation by firm size revealed significant differences ($F = 3.41$, $p = .02$). A Scheffé test clarified that these differences affect firms that are evaluating whether to implement tools and those that have commenced implementation. Whereas the size of firms in the former group is around 1300 employees on average, the size of firms in the latter group averages around 45,000 employees. This discrepancy indicates that larger firms are considerably more proactive in this respect, whereas SME have adopted a more reactive stance to date.

6 | DISCUSSION AND CONCLUSIONS

In summary, this paper addresses three sets of research questions conceptually informed by perspectives on symbolic action and tensions, to further the state of biodiversity management research field. This paper reports the results of one of the first large-scale empirical surveys on corporate activities related to biodiversity protection and concerns about ES provision in manufacturing firms, and in doing so offers a number of novel insights. To start, overall levels of activities directly related to biodiversity conservation and ES protection remain very low compared to those of indirect protection activities. A possible explanation for this lies in to date mainly symbolic action of businesses in the context of biodiversity (Talbot & Boiral, 2021). However, larger firms currently undertake comparatively more direct biodiversity conservation and ES protection activities than SME do. Furthermore, while firms, regardless of size, perceive similar levels of ES risk exposure, only larger firms match this with correspondingly higher activity, which indicates interactions across levels of analyses (e.g., firms versus industries).

Secondly, biodiversity and ES are not integral to the major environmental management standards ISO 14001 and EMAS, and therefore a more intensive analysis on a broad scale can extend the body of knowledge relating to the literature on environmental management in general, as has been called for by, for example, Boiral et al. (2018). Specifically, it has been suggested that linking information on biodiversity and ES with that on EMS usage might be very valuable (Boiral & Heras-Saizarbitoria, 2017) and our analysis contributes to that aim. However, our data reveal that while ISO 14001 and EMAS are widely diffused among firms, there is no support from these for activities aimed at directly supporting ES and biodiversity. This points to a void that carries the potential for tensions, since the mainstream management systems seem unable to contribute to more biodiversity and ES protection.

In addition to this, our survey confirms that most industries are heavily dependent on nonrenewable resources, a situation likely to be detrimental to the preservation of biodiversity. Yet, only a few industries are so heavily reliant on renewable resources that they would have an incentive to support biodiversity and the provision of ES by substantively adopting tools to assess ES risks and implementing activities to maintain or enhance biodiversity. The lack of tool implementation also confirms that firms mainly pursue symbolic actions and thus do not have suitable management control or accounting systems in place that can reveal tensions and identify the most salient biodiversity issues. This is of special concern, since the analysis also indicates that traditional (quality or environmental) management systems tend to be detrimental to the implementation of direct activities to support biodiversity and the provision of ES. This implies that traditional systems are unlikely to reveal or reduce longer-term tensions from predominantly symbolic action in time.

By providing broader descriptive evidence from comprehensive primary data, this study closes a research gap and provides important guidance for the conceptual refinement of the research field. This is an important contribution given that Jones and Solomon (2013, p. 682) diagnose a '… dearth of reported activity' on biodiversity and ES protection and highlight a need for broader primary studies, which initially should be descriptive, given the field's early stage of development. As well, this study also canvasses opinion from SME, which have not been considered in broader empirical analyses to date due to their limited reporting capability. At the same time, it moves beyond published company reports, which enables more systematic comparative evaluations.

Combining evidence from a large number of firms on the topic of biodiversity and ES protection also offers a more nuanced view of differences across and between levels (such as firms or industries). This is particularly relevant given that reviews have identified site-level management as an important approach to protecting ES (Heller & Zavaleta, 2009). For example, this research is one of the first large-scale empirical studies surveying actions supporting biodiversity and ES to involve SME. Given the scant knowledge available from the literature on the role of SME in biodiversity protection, the study provides crucial insights and knowledge on their current state of practice.

While this analysis is to the best of our knowledge one of the very few studies using primary data on corporate activities targeting biodiversity protection and ES maintenance across different levels in a broader industry context (and surveying smaller and medium-sized firms), it must be acknowledged, that it is based on German data alone. Therefore, it would be desirable if future research were to include other countries and encapsulate recent trends, for example, what contribution to the relevant UN SDGs (especially the SDGs 14 and 15, but also the SDGs 2 and 6) can be expected.

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Several further directions for future research can be identified. The differentiated findings in this large-scale study suggest a need to expand the investigation of how more substantive action can be enacted and coordinated across firms and industries (e.g., through industry associations such as the World Business Council for Sustainable Development, which has proposed some ambitious initiatives on biodiversity, albeit with limited effect to date). Furthermore, country-level regulation or global initiatives extending beyond nation states (such as the IPBES mentioned in the introduction) which have a broader scope related to the level of complete ecosystems should be examined more closely too, as doing so could reveal further multilevel tensions. Equally, future research might focus on the level of the business unit, especially since this could help to shed more light on how employing spatial separation enables a reduction of tensions. As well, this would simultaneously enable to further the contributions to preserving biodiversity from better integration of the social sciences that the literature calls for (Heller & Zavaleta, 2009). Finally, more comprehensive inclusion of questions on accounting tools supporting biodiversity would be desirable in future survey work.

The results of the current research have practical implications for managers and policymakers. Making informed decisions on governmental and other initiatives requires an awareness of heterogeneity across firms with regard to levels of activity, risk assessments and tool implementation directed at safeguarding biodiversity and ES. Our findings suggest various practical steps that could be taken. For example, policymakers could consider supporting SME with generic toolkits or guidelines that mitigate tensions. That requirement is also applicable to other levels, such as the industry context, that should be accounted for simultaneously.

As well, firms and policymakers should collaborate with non-governmental organisations and industry associations to enable more substantive action and to reduce tensions. Managers should equally be aware of both the firm and industry levels, which would help them to benchmark the state of affairs in their firm, and then assess what initiatives would suit their specific situation. Second, managers should proactively drive concerted action, since ultimately the implementation of biodiversity and ES protection resides at the firm level.

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ENDNOTES

[1] Whilst a more in-depth review is beyond the scope of this study, readers are referred to Roberts et al. (2020) for a recent comprehensive review that systematically assesses the field over the same period.

[2] The survey questionnaire is available on request from the corresponding author.

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APPENDIX A.

TABLE A1 Descriptive statistics for variables defined in Table 1

Variable	Mean	Std. dev.	Min	Max
Index of restoration, conservation and offsetting	0.93	1.13	0	3
Total ES risk	3.01	1.24	1	5
Tools to manage risks related to ES degradation	1.98	1.20	1	4
Organisational uncertainty	5.21	1.20	1.75	7
Industry uncertainty	0.07	0.05	0.02	0.28
Firm size	6.36	2.20	1.79	13.32
Firm fully independent	0.57	-	0	1
QMS	0.85	-	0	1
Munificence	3.18	1.07	1	5
Paper, wood & printing	0.09	-	0	1
Chemicals	0.17	-	0	1
Glass, ceramics & metal processing	0.14	-	0	1
Machinery & transport	0.11	-	0	1
Electric & electronic equipment	0.10	-	0	1
Other manufacturing	0.27	-	0	1
ISO 14001 certification	0.39	-	0	1
EMAS certification	0.32	-	0	1
EMS implementation time	9.15	-	0	24

Note: The index of restoration, conservation and offsetting as the dependent variable in the regression estimations is defined as the sum of the items biodiversity restoration, biodiversity conservation and emissions offsetting in Table 1.

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TABLE A2 Correlations of explanatory variables of the regression analysis

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	VIF
1. Firm size	1.00												1.43
2. Firm fully independent	−0.17**	1.00											1.13
3. QMS	0.15**	−0.07	1.00										1.30
4. Munificence	0.05	0.03	0.18***	1.00									1.15
5. Paper, wood & printing	−0.19***	−0.03	−0.003	−0.26***	1.00								1.67
6. Chemicals	−0.09	0.05	0.09	0.09	−0.14**	1.00							2.01
7. Glass, ceramics & metal processing	0.01	−0.001	0.17**	−0.03	−0.12*	−0.18***	1.00						1.88
8. Machinery & transport	0.29***	−0.08	0.11	0.01	−0.11	−0.16**	−0.14**	1.00					1.87
9. Electric & electronic equipment	0.06	0.12*	0.06	0.11	−0.11	−0.15**	−0.14**	−0.12*	1.00				1.75
10. Other manufacturing	0.03	−0.15**	−0.33***	0.05	−0.19***	−0.28***	−0.24***	−0.21***	−0.21***	1.00			2.61
11. ISO 14001 certification	0.29***	−0.23***	0.19***	0.07	0.06	−0.06	0.09	0.14**	−0.09	−0.02	1.00		4.34
12. EMAS certification	0.01	−0.07	−0.003	0.07	0.03	0.03	0.09	0.04	−0.14**	−0.07	0.54***	1.00	5.54
13. EMS implementation time	0.29***	−0.16**	0.16**	0.11	0.001	0.01	0.10	0.08	−0.11*	−0.03	0.72***	0.66***	3.73

Abbreviations: ES, ecosystem services; VIF, variance inflation factor.
**p* < .10. ***p* < .05. ****p* < .01.

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