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Accumulate or Diversify Ecological Innovation Assets? The Effect of Ecological Innovation Asset Depth and Breadth on Firm Financial Performance

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ABSTRACT

This study investigates the role of innovation portfolio structures in the relationship of ecological innovation and firm financial performance. We draw on the resource-based view and the natural resource–based view to examine the effects of the depth and breadth of firms' ecological innovation assets (EIAs) while conceptually and empirically accounting for the substantial differences between two distinct firm financial performance dimensions. To test our conceptual framework, we rely on a panel data set based on 340 US firms listed in the S&P 500 index over a 10-year period. Fixed-effects regressions confirm that EIA depth and EIA breadth fundamentally differ in their effects on firm financial performance. Moreover, we find that the results vary considerably between accounting-based and value-based financial performance. Thereby, this study makes a significant contribution to the ongoing debate about the nexus of ecological innovation and firm financial performance.

1 | Introduction

Recent studies show that ecological innovations, herein defined as "technological innovations or applications for mitigation or adaption against climate change" (EPO 2024), are one of the most promising ways for firms to reduce their environmental impact (Liang, Zhang, and Qiang 2022; Wang, Li, and Liao 2021). However, they represent a risky investment for firms because of their specific and uncertain characteristics compared with regular innovations (Barbieri, Marzucchi, and Rizzo 2020; DeMarchi 2012; Rennings 2000). To stay competitive in the long term, firms need to develop innovations that are both ecological and profitable. Research is still inconclusive regarding the circumstances in which firms benefit most from ecological innovation (Hermundsdottir and Aspelund 2021; López Pérez, García Sánchez, and Zafra Gómez 2024).

To innovate successfully, firms build up technological portfolios, in which they distribute innovation assets within or across different technology fields (Leten, Belderbos, and van Looy 2007). Market and technology trends, as well as the increasing complexity of products and production processes, are forcing firms to expand their core technological competence and diversify into further technology fields (Leten, Belderbos, and van Looy 2007; Lin, Chen, and Wu 2006). At the same time, increasing evidence shows that building up deep innovation stocks (i.e., the accumulation of technological innovation assets within a single technology field) can enable firms to innovate more easily because a high depth of knowledge in a technology field facilitates the creation of new combinations of that knowledge (Prabhu, Chandy, and Ellis 2005; Zhang and Baden-Fuller 2010). Thus, managers must decide strategically about the distribution of technological innovation assets within and across technology fields to build an innovation portfolio that allows the firm to fully leverage

its value and gain a competitive advantage (Barney 1991; Lin, Chen, and Wu 2006).

Ecological innovations are highly complex (Barbieri, Marzucchi, and Rizzo 2020) and demand specific resources (Cainelli, de Marchi, and Grandinetti 2015; DeMarchi 2012); thus, managers must proceed with particular caution when deciding on the distribution of ecological innovation assets (EIAs) to exploit their full value. The literature on performance outcomes of ecological innovation has widely neglected a detailed analysis of the structure of firms' EIAs within their innovation portfolios. To address this research gap, we strive to answer the following research question: *How does the structure of EIAs influence firms' accounting- and value-based financial performance?* In particular, we investigate the effects of EIA depth and EIA breadth on accounting-based performance (ABP) and value-based performance (VBP) outcomes.

To develop our research framework, we draw on insights from the ecological innovation and technological portfolio literature streams and merge those arguments under the resource-based view (RBV; Barney 1991) and its extension, the natural resource–based view (NRBV; Hart 1995; Hart and Dowell 2011). To test our hypothesized relationships, we rely on patent data from the US Patent and Trademark Office (USPTO) for 340 US firms listed in the S&P 500 index over a period of 10 years (2009–2018), resulting in over 3000 firm-year observations. In total, our analysis includes more than 54,000 ecological patents.

The results of our study provide relevant contributions for research and practice alike. First, by transferring insights from the literature on technological portfolios to the ecological innovation and firm performance research stream, we shed light on the ongoing debate about the effect of ecological innovation on firm performance (Hermundsdottir and Aspelund 2021; López Pérez, García Sánchez, and Zafra Gómez 2024). We expand the existing body of knowledge by examining the nexus of EIA portfolio structures and firm financial performance from both the RBV and NRBV. Using these theoretical lenses, we provide a more fine-grained explanation of the effects of different EIA portfolio structures. Building on extant research that provides initial insights into the effects of EIA breadth (La Leyva-de Hiz, Ferron-Vilchez, and Aragon-Correa 2019), we expand the state of knowledge by including further portfolio structures, such as EIA depth and the interplay of EIA depth and EIA breadth. These differentiated insights into the effects of EIA portfolio structures can support managers in deciding how to distribute EIAs within innovation portfolios to best profit from these innovations.

Second, when testing the effects of EIA portfolio structures on ABP and VBP, we account for the distinct dimensions of firm financial performance identified in our conceptual reasoning, predicting different effects for the outcomes. This is important because they represent related but different dimensions of firm performance (Gentry and Shen 2010; Hoskisson, Johnson, and Moesel 1994; Keats 1988): VBP reflects a long-term, future- and market-oriented measure in which investors' perceptions are considered, whereas ABP reflects a more short-term, past- and operation-oriented measure (Gentry and Shen 2010; Keats 1988). In the context of research on corporate sustainability, Grewatsch and Kleindienst (2017) note that studies on ecological innovation and firm performance have mostly used either only one dimension of firm performance or both without sufficiently recognizing the differences, leading to inconclusive results. We address this shortcoming, and our results show essential differences in the empirical effects of ABP and VBP. By uncovering the effects of EIA portfolio structures on distinct dimensions of firm financial performance, our study can help managers make more effective decisions regarding EIAs based on the expected effects on different financial outcomes.

Third, our study contributes to research on technological portfolio structures by specifically testing the effects of the ecological part of firms' innovation assets. Previous studies in the field of technological portfolios typically consider a firm's entire patent portfolio, not accounting for the peculiarities of ecological innovations (Chen, Yang, and Lin 2013; Kim, Lee, and Cho 2016). In contrast, paying attention to the specific nature of ecological innovations as part of firms' entire innovation portfolios could help explain the variety of outcomes in extant research investigating the effect of portfolio structures.

The rest of the paper is structured as follows. Section 2 introduces the conceptual background of our study. In Section 3, we describe our research framework and develop the hypotheses. Section 4 describes the methodology of the study, followed by Section 5, which presents the results of our analysis. In the last section, we conclude by developing theoretical and practical implications.

2 | Conceptual Background

2.1 | Literature Review on Ecological Innovation and Firm Financial Performance

Ever since Porter and van der Linde's (1995) seminal article, in which they highlight ecological innovations' potential for competitiveness, researchers have been interested in drivers and financial outcomes of ecological innovation. Ecological innovation fundamentally differs from regular innovation in its potential to reduce environmental impact (OECD 2009). The term can refer to "new or modified processes, techniques, practices, systems and products" (Beise and Rennings 2003, 8), and these innovations can range from "end-of-pipe" technologies, which aim at controlling and minimizing pollutants at the end of the production process (Berrone and Gomez-Mejia 2009; Rennings 2000; Xie et al. 2016), to preventive technologies, which focus on minimizing and eliminating the generation of pollution and waste throughout the production process (Berrone and Gomez-Mejia 2009; Xie et al. 2016). Numerous studies have evolved that examine critical drivers of ecological innovation, such as organizational innovation (Bataineh, Sánchez-Sellero, and Ayad 2024a) or green dynamic capabilities (Singh et al. 2022). Based on different conceptualizations of ecological innovation, another research stream focuses on its financial performance outcomes. Table 1 presents an overview of relevant studies in this research stream.

TABLE 1 | Literature review table with relevant studies on ecological innovation and financial performance.

Study	Independent variables	Dependent variables	Conceptual differentiation between ABP and VBP	Theory	Sample
Exemplary studies testing the general effect of eco-innovation					
Aguilera-Caracuel and Ortiz-de-Mandojana (2013)	Green innovation intensity	ROA	—	Institutional theory	70 green innovative vs. 70 non-green innovative firms Cross-sectional
Li (2014)	Environmental innovation practices	Financial performance construct	—	Institutional theory/RBV	148 Chinese manufacturing firms Cross-sectional
Bermúdez-Edo, Hurtado-Torres, and Ortiz-de-Mandojana (2017)	Patented environmental innovations	Tobin's Q	—	NRBV	35 ICT FT 500 firms 2005–2009 116 observations
Cai and Li (2018)	Eco-innovation	Economic performance construct	—	—	442 Chinese firms Cross-sectional
Leal-Rodríguez et al. (2018)	Green innovation performance	Organizational performance construct	—	—	145 Spanish manufacturing firms Cross-sectional
García-Sánchez, Gallego-Álvarez, and Zafra-Gómez (2020)	Eco-innovation	ROA ROE Tobin's Q	Yes	—	6454 international firms 2002–2017 95,489 observations
Rezende et al. (2019)	Green innovation intensity	ROA	—	—	356 firms 2006–2016 2492 observations
Zhang, Rong, and Ji (2019)	Green innovation	Sales growth Net profit	—	—	764 firms 2000–2010 5727 observations
Przychodzen, La Leyva-de Hiz, and Przychodzen (2020)	Green innovation Overconcentration of green innovation	ROA, OM, ROEC, MV/MV	No	—	500 companies 1999–2016 9009 observations

(Continues)

TABLE 1 | (Continued)

Study	Independent variables	Dependent variables	Conceptual differentiation between ABP and VBP	Theory	Sample
Marín-Vinuesa et al. (2020)	Eco-innovation	ROE	—	RBV	87 Spanish firms from industrial, transport, logistics, and waste industry Cross-sectional
Farza et al. (2021)	Environmental innovation	Market-to-book ratio ROA ROIC	No	Theory of slack resources, NRBV	110 German HDAX firms 2008–2019
Singh et al. (2022)	Green innovation	Firm performance construct	—	Stakeholder theory, RBV	248 SME firms from manufacturing sector in Abu Dhabi
Suki et al. (2022)	Green innovation	Business sustainability construct	—	NRBV	243 manufacturing firms in Malaysia Cross-sectional
Tian et al. (2023)	Green innovation	Tobin's Q	—	NRBV	351 Chinese firms 2007–2018 2734 observations
Exemplary studies differentiating between eco-innovation types					
Chen, Lai, and Wen (2006)	Performance of green product innovation Performance of green process innovation	Corporate competitive advantage	—	—	203 firms from the information and electronics industry in Taiwan Cross-sectional
Chang (2011)	Green product innovation Green process innovation	Competitive advantage	—	Institutional theory, stakeholder theory, RBV	106 manufacturing firms in Taiwan Cross-sectional
Amores-Salvadó, Martín-de Castro, and Navas-López (2014)	Environmental product innovation	ROA growth ROS growth ROCE growth	—	RBT/NRBV	157 firms Cross-sectional

(Continues)

TABLE 1 | (Continued)

Study	Independent variables	Dependent variables	Conceptual differentiation between ABP and VBP	Theory	Sample
Ghisetti and Rennings (2014)	Energy and resource efficiency innovation Externality reducing innovation	ROS	—	Porter hypothesis	1063 German firms Cross-sectional
Rexhäuser and Rammer (2014)	Regulation-induced vs. voluntary environmental innovations Efficiency improving vs. other environmental innovations	ROS	—	Porter hypothesis	3618 German firms Cross-sectional
Przychodzen and Przychodzen (2015)	Product eco-innovation Process eco-innovation Market eco-innovation Sources of supply eco-innovation	ROA ROE ERR	—	—	439 firms 2006–2013 632 vs. 2648 observations (eco vs. conventional)
Chan et al. (2016)	Green product innovation	Cost efficiency Firm profitability	—	Contingency theory	250 firms Cross-sectional
Hojnik and Ruzzier (2016)	Process eco-innovation	Company growth Company profitability	—	Porter hypothesis, institutional theory	223 Slovenian firms Cross-sectional
Xie et al. (2016)	Green process innovation (clean technologies, end-of-pipe technologies)	ROA	—	RBT/NRBV	Chinese manufacturing firms 2001–2010 196 observations
Huang and Li (2017)	Green product innovation Green process innovation	Organizational performance construct	—	Dynamic capability perspective/ SNT/ecological modernization theory	418 firms from ICT industry in Taiwan Cross-sectional
Hojnik, Ruzzier, and Manolova (2018)	Product eco-innovation Process eco-innovation Organizational eco-innovation	Firm performance construct	—	Learning theory	151 Slovenian firms Cross-sectional
Tang et al. (2018)	Green product innovation Green process innovation	Firm performance construct	—	Porter hypothesis	188 Chinese manufacturing firms Cross-sectional

(Continues)

TABLE 1 | (Continued)

Study	Independent variables	Dependent variables	Conceptual differentiation between ABP and VBP	Theory	Sample
Tumelero, Sbragia, and Evans (2019)	Product eco-innovation Process eco-innovation Organizational eco-innovation	Socioeconomic performance construct	—	—	221 electrical and electronic manufacturers in Brazil Cross-sectional
Xie, Huo, and Zou (2019)	Green product innovation Green process innovation	ROA	—	RBV	209 firms Cross-sectional
Wang et al. (2021)	Green product innovation Green process innovation	Economic performance construct	—	—	642 industrial Chinese firms Cross-sectional
Iqbal et al. (2022)	Environmental process innovation Environmental product innovation	Market-to-book ratio Tobin's Q	—	RBV	US listed firms 2002–2019 8511 observations
Rahman (2023)	Green product innovation	ROE	—	Instrumental stakeholder theory/resource department theory	US firms 2000–2019 366 observations
Bataineh, Sánchez-Sellero, and Ayad (2024b)	Reduction of energy/material Improvement in HSE Compliance with regulations	Competitive advantage	—	RBV	Spanish firms 2003–2016 21,140 observations
Studies considering the technological distribution of ecological innovation					
La Leyva-de Hiz, Ferron-Vilchez, and Aragon-Correa (2019)	Focused ecological innovation	Tobin's Q	—	Agency theory	75 US companies 2006–2009 216 observations
This study	*Ecological innovation depth* *Ecological innovation breadth*	*Market value* *Net income*	*Yes*	*RBV/NRBV*	*340 US companies* *2009–2018* *3400 observations*

The first group of studies does not explicitly distinguish between different types of ecological innovations. Within this field, various studies examine the performance implications for ABP. For example, Aguilera-Caracuel and Ortiz-de-Mandojana (2013) find that firms introducing ecological innovation do not experience greater performance than other firms. Marín-Vinuesa et al.'s (2020) results support these findings, showing that owning green patents does not enhance firm performance. However, both studies indicate that the level of ecological innovation is positively associated with performance. Other studies find that this relationship is dependent on state ownership (Zhang, Rong, and Ji 2019) or time lags (Rezende et al. 2019). In terms of VBP, Tian et al. (2023) show a positive effect on Tobin's Q, while Bermúdez-Edo, Hurtado-Torres, and Ortiz-de-Mandojana (2017) find that ecological innovation only enhances performance when the innovations' international scope of the knowledge sourcing is high. Some studies simultaneously consider ABP and VBP: While Farza et al. (2021) find a positive effect of ecological innovation for both performance types, Przychodzen, La Leyva-de Hiz, and Przychodzen (2020) show that an over-concentration on ecological innovation harms ABP and VBP. However, acting as a first mover in ecological innovation can increase VBP (Przychodzen, La Leyva-de Hiz, and Przychodzen 2020). In contrast to the aforementioned studies, García-Sánchez, Gallego-Álvarez, and Zafra-Gómez (2020) consider the conceptual differentiation between ABP and VBP and assume different effects for both innovation types. As expected, ecological innovation harms firm profitability but enhances its market value (García-Sánchez, Gallego-Álvarez, and Zafra-Gómez 2020). Further studies in this field rely on varying performance constructs, showing mixed results (e.g., Cai and Li 2018; Leal-Rodríguez et al. 2018; Li 2014; Suki et al. 2022).

A second group of studies distinguishes ecological innovation types. A majority of research in this field differentiates between ecological product and/or process innovation (e.g., Amores-Salvadó, Martín-de Castro, and Navas-López 2014; Chen, Lai, and Wen 2006; Huang and Li 2017; Iqbal et al. 2022; Lin, Tan, and Geng 2013). Other studies include further types, such as organizational eco-innovation (Hojnik, Ruzzier, and Manolova 2018; Tumelero, Sbragia, and Evans 2019) or market and sources of supply eco-innovation (Przychodzen and Przychodzen 2015). Most of these studies indicate a positive influence of ecological innovation types on ABP (Przychodzen and Przychodzen 2015; Rahman 2023; Xie, Huo, and Zou 2019), VBP (Iqbal et al. 2022), and performance constructs (Hojnik and Ruzzier 2016; Huang and Li 2017), although some cannot support direct significant effects of ecological product innovation (e.g., Amores-Salvadó, Martín-de Castro, and Navas-López 2014; Wang et al. 2021). Further distinctions within this group of studies are made with regard to energy and resource efficiency versus externality-reducing innovations (Ghisetti and Rennings 2014), regulation-induced versus voluntary environmental innovations, and efficiency-improving versus other innovations (Rexhäuser and Rammer 2014), reduction-related versus improvement-related and compliance-related innovations (Bataineh, Sánchez-Sellero, and Ayad 2024b), or clean versus end-of-pipe technologies (Xie et al. 2016). These studies find mixed results for the different innovation types on ABP and firms' competitive advantage.

Unlike the aforementioned groups of studies, La Leyva-de Hiz, Ferron-Vilchez, and Aragon-Correa (2019) focus on the technological distribution of EIAs within firms' ecological innovation portfolios. Building on agency theory, the authors examine the influence of slack resources on the relationship between focused ecological innovation and VBP. As we are also interested in the technological distribution of EIAs, our study is most closely related to La Leyva-de Hiz, Ferron-Vilchez, and Aragon-Correa (2019). However, we rely on an RBV and examine the firms' ecological innovation portfolio, considering the depth and the breadth of their EIAs. Moreover, to gain a comprehensive understanding of the effects of ecological innovation, we include VBP as well as ABP.

2.2 | The RBV and the NRBV

The RBV and the NRBV provide the theoretical foundation to further examine the role of EIAs and their distribution within innovation portfolios for firms' competitive advantage. From an RBV, firms' heterogeneous resources can explain performance outcomes in terms of their value, rarity, inimitability, and non-substitutability (Barney 1991). Researchers have argued that innovation assets often meet the required criteria and therefore denote important resources for firm performance (Fang, Palmatier, and Grewal 2011).

The NRBV extends this perspective to include the natural environment and argues that firms can only sustain their competitive advantage if they develop resources and capabilities that incorporate the challenges of the natural environment (Hart 1995). Due to their tacit nature, social complexity, and rareness, such resources and capabilities are costly for other firms to copy. Simultaneously, firms can profit from positive effects of a good reputation through the resources' external orientation, which engenders social legitimacy (Hart 1995). Referring to research on institutional theory (e.g., DiMaggio and Powell 1983), Hart (1995) argues that firms can only create competitive advantage when also achieving social legitimacy. In consideration of the growing environmental burdens firms face currently, the NRBV (Hart 1995; Hart and Dowell 2011) has gained significant importance (Hart and Dowell 2011) and has widely been implemented as a theoretical foundation in research on ecological innovation (Lee and Min 2015; Suki et al. 2022; Tian et al. 2023). Building on these foundations, we classify ecological innovations as critical firm assets for creating and sustaining competitive advantage. Hence, in the remainder of this paper, we consider ecological innovations to be EIAs.

2.3 | Technological Portfolios

Previous research has highlighted innovation performance to be a central driver for long-term success (e.g., Sánchez-Sellero et al. 2015). In line with the RBV, scholars have taken a portfolio perspective to investigate how firms should distribute their innovation assets to best profit from their innovation stock. In that vein, Prahalad and Hamel (1990) extend the RBV by emphasizing the strategic importance of firms' core competencies for gaining superior firm performance. Core competencies emerge

through the harmonization of technology streams, which requires a deep knowledge stock in the corresponding technology fields (Bierly and Chakrabarti 1996; Prabhu, Chandy, and Ellis 2005). By accumulating innovation assets, firms can build up such a deep knowledge stock and thereby profit from specific competencies in their core technological areas.

In contrast to this theory of firms' core competencies, researchers have long focused on the role of technological diversification (Ceipek et al. 2019). Patel and Pavitt (1997) find that large firms are characterized by broad technological competencies outside their 'core' fields and that technological diversification usually exceeds their product diversification. The ability to draw on a broad knowledge base allows firms to be more adaptable and to combine different technologies for new, more complex products and production systems (Bierly and Chakrabarti 1996; Patel and Pavitt 1997). Grantstrand, Patel, and Pavill (1997) highlight the importance of technological diversification, arguing that instead of focusing on a limited amount of core technological competencies, large firms should build up a broader set of these competencies, even if that means that the existing competency stock becomes less deep. By spreading their innovation assets across multiple technology fields, firms can build up the required knowledge stock to develop such a broad set of technological competencies.

However, when diversifying technological portfolios, firms must be careful not to lose their focus on developing strong competencies within specific technological fields (Leten, Belderbos, and van Looy 2007). Moreover, diversified portfolios are often accompanied by high costs, such as coordination or communication costs (Leten, Belderbos, and van Looy 2007). In summary, the foundations discussed herein support the notion that firms should consider both the depth (accumulation of innovation assets within technology fields) and breadth (diversification of innovation assets across technology fields) of their technological portfolio when developing their portfolio structure.

3 | Research Framework and Hypotheses

3.1 | Research Framework

Building on the previous discussion, we assume that EIAs significantly influence firms' financial performance. In line with the NRBV, EIAs can provide firms with a competitive advantage because of their tacit nature, social complexity, and rareness (Barney 1991; Hart 1995; Hart and Dowell 2011). However, the greater novelty and complexity of ecological innovation compared with regular innovation make it more difficult for firms to build up a substantial EIA stock. Moreover, high development costs mean firms must consider that it usually takes some time before EIAs pay off (Hermundsdottir and Aspelund 2021).

Consequently, it is important for firms to carefully evaluate how to strategically build up such critical assets. Therefore, we examine two specific characteristics of EIA portfolio structures by drawing on knowledge from research on technological portfolios: In line with the theory of firms' core competencies (Prahalad and Hamel 1990) and research on technological diversification (e.g., Grantstrand, Patel, and Pavill 1997), we assume distinct effects for EIA depth (accumulation of EIAs in the corresponding technology fields of the firm) and EIA breadth (diversification of EIAs throughout various technology fields) on firm financial performance. To shed light on the effects of EIA depth and EIA breadth and to allow for a comparison of results, we rely on two performance outcomes: ABP and VBP. Figure 1 summarizes our research framework.

3.2 | Hypotheses

The NRBV contends that firms must consider the natural environment when developing strategic resources (Hart 1995). As ecological innovations are characterized by rareness, tacitness, and social complexity, which make them difficult to copy, they serve as promising resources to provide firms with a competitive

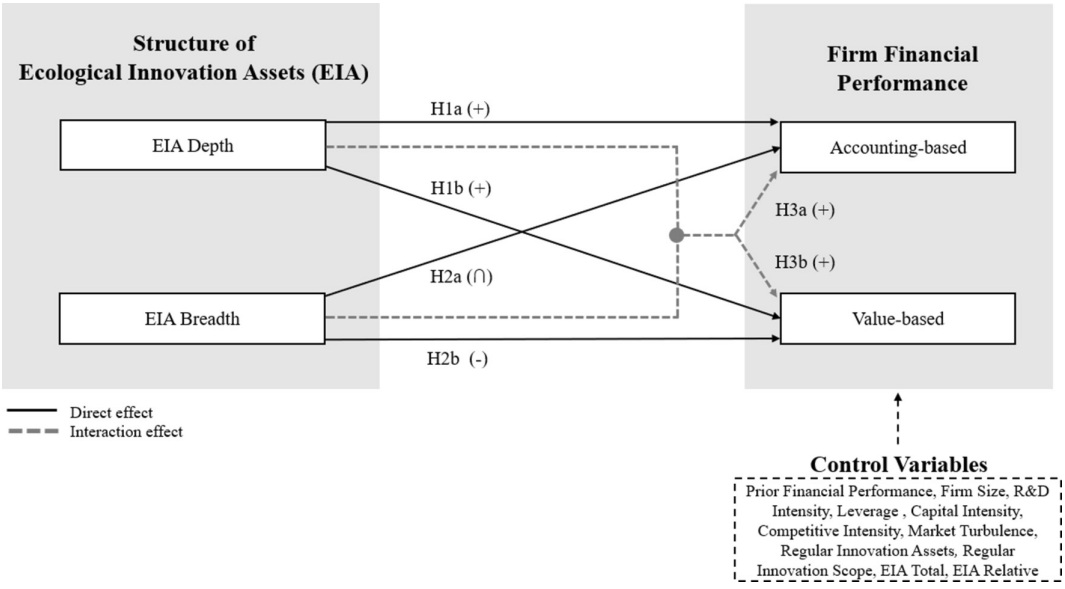

FIGURE 1 | Research framework.

advantage (Barney 1991; Hart 1995; Hart and Dowell 2011). A notable strand of research has developed that highlights ecological innovations' potential for competitive advantage (e.g., Bataineh, Sánchez-Sellero, and Ayad 2024b) and that finds a positive relationship between ecological innovation and ABP (Przychodzen and Przychodzen 2015; Xie, Huo, and Zou 2019) as well as VBP (García-Sánchez, Gallego-Álvarez, and Zafra-Gómez 2020; Przychodzen, La Leyva-de Hiz, and Przychodzen 2020).

With regard to ABP, scholars argue that ecological innovation improves firm financial performance through cost savings and firm differentiation (Aguilera-Caracuel and Ortiz-de-Mandojana 2013). Technology-related ecological innovations can increase cost savings through resource efficiency, savings of energy and raw materials, or pollution and waste reduction, which in turn lowers penalty costs (Aguilera-Caracuel and Ortiz-de-Mandojana 2013; Bataineh, Sánchez-Sellero, and Ayad 2024b; Cai and Li 2018; Porter and van der Linde 1995). Moreover, ecological innovation can bolster firm reputation, such that firms can profit from price premiums and increasing sales (Aguilera-Caracuel and Ortiz-de-Mandojana 2013; Bataineh, Sánchez-Sellero, and Ayad 2024b).

Consistent with the NRBV (Hart 1995; Hart and Dowell 2011), ecological innovation can also enhance a firm's VBP because investors increasingly consider environmental and social aspects when defining their portfolios (Global Sustainable Investment Alliance 2021). Indeed, recent studies show that firms' ecological performance and sustainability/ecological reporting positively affect their valuation (Bendig, Wagner, and Lau 2023; Friske, Hoelscher, and Nikolov 2023; Hoang et al. 2020). Because ecological innovation improves firms' ecological performance (Liang, Zhang, and Qiang 2022; Wang et al. 2021), it can serve as a predictor for firms' ecological performance and firms' efforts in becoming more sustainable. Therefore, investors can use ecological innovations as a positive signal for their evaluation (Connelly et al. 2011; Long 2002).

Other researchers challenge the value of EIA, emphasizing the high costs associated with developing ecological innovations (García-Sánchez, Gallego-Álvarez, and Zafra-Gómez 2020; Palmer, Oates, and Portney 1995) and thereby questioning their role as a strategic resource for firms (Barney 1991; Hart 1995). Studies finding negative effects of ecological innovation on financial performance highlight the risks of such innovations (García-Sánchez, Gallego-Álvarez, and Zafra-Gómez 2020; Hoang et al. 2020). The high complexity and novelty of ecological innovations, which typically require specific and more intensive resources (Cainelli, de Marchi, and Grandinetti 2015; DeMarchi 2012), can render investments very costly and increase the time firms must wait until they can profit from their investment. In addition, the double externality problem, denoting knowledge and environmental spillovers, might also lower firms' returns when investing in ecological innovation.

3.2.1 | The Effect of EIA Depth on Firm Financial Performance

The previous discussion underscores the tension between the benefits of ecological innovation and their potential drawbacks. Therefore, to profit from ecological innovation, firms must be able to effectively handle high complexity and novelty. From a resource-based perspective, the theory of core competencies (Prahalad and Hamel 1990) suggests that firms benefit from building up deep asset stocks in specific technological areas in which the firm already has competencies. Deep EIA stocks can help firms create new knowledge more easily because they can build on an intense knowledge base in their core areas and have a specific understanding of those technologies (Fang, Palmatier, and Grewal 2011; Prabhu, Chandy, and Ellis 2005). Studies have shown that technological core competencies can foster innovation (Prabhu, Chandy, and Ellis 2005; Qu et al. 2021) and financial performance (Kim, Lee, and Cho 2016; Kim, Lim, and Park 2009).

In the context of ecological innovation, deep EIA stocks can foster firms' understanding of the ecological potential of the underlying technologies. The ability to draw on a large knowledge base of EIAs in the corresponding technology fields allows firms to manage and develop ecological innovations more effectively and at a lower cost (Chen 2008; Fang, Palmatier, and Grewal 2011). Therefore, firms might profit earlier from benefits such as cost savings and better manage the risk that goes along with ecological innovation. Moreover, firms with deep EIAs gain from very rare and difficult-to-copy technological insights (Fang, Palmatier, and Grewal 2011), which can diminish negative impacts with regard to knowledge and environmental spillovers. Thus, in addition to engendering investors' trust in the effectiveness of ecological innovations due to the firm's deep knowledge base, deep EIAs can strengthen investors' trust that the firm will be financially successful in the short and the long term, leading to more favorable firm evaluations. Investors are increasingly considering environmental aspects when defining their portfolios (Global Sustainable Investment Alliance 2021); thus, firms with deep EIAs potentially benefit from perceptions of greater authenticity and credibility in their ecological innovation efforts because deep asset stocks might signal a high commitment within the technological areas. We therefore propose the following hypotheses:

Hypothesis 1. *EIA depth has a positive effect on (a) ABP and (b) VBP.*

3.2.2 | The Effect of EIA Breadth on Firm Financial Performance

Contrary to the view that firms' resources should be consolidated into core competencies to gain a competitive advantage (Prahalad and Hamel 1990), scholars have argued that firms have a better chance to benefit from their resources if they diversify into different technology fields (Grantstrand, Patel, and Pavill 1997; Patel and Pavitt 1997). Various studies have shown that increased diversity of technological assets positively influences innovation and ABP because of, for example, economies of scope (Chiu et al. 2008; Garcia-Vega 2006; Kim et al. 2021; Suzuku and Kodama 2004).

Building up a broad knowledge base can help firms strengthen their competencies in their core technology fields (Kim, Lee, and Cho 2016), which can increase the quality of their innovations.

In the context of ecological innovation, research has highlighted the importance of external cooperation (DeMarchi 2012; Goodman, Korsunova, and Halme 2017), indicating that when developing ecological innovations, firms profit from additional knowledge outside their core technological fields. Especially when developing highly innovative and complex technologies, firms can benefit from knowledge sharing across diverse technology fields (Bierly and Chakrabarti 1996; Patel and Pavitt 1997). Therefore, the ability to draw on EIAs from a variety of technology fields can enable firms to develop more effective ecological innovations from which they can extract greater cost efficiencies and image benefits. Scholars have also argued that technological diversification increases firms' adaptability to changing environments (Bierly and Chakrabarti 1996; Kim, Lee, and Cho 2016), and Ran et al. (2024) find that technological diversification enhances firms' resilience. This is particularly important in the context of ecological innovation because firms are confronted with fast-changing stakeholder expectations and regulations (Cai and Li 2018; Fabrizi, Guarini, and Meliciani 2018).

Nevertheless, spreading EIAs over too many technology fields may harm firms' financial performance, putting into question their value as a strategic resource for competitive advantage (Barney 1991; Hart 1995). Scholars argue that high diversity of technological assets implies higher coordination and integration costs and that it may prevent firms from developing economies of scale within their core technology fields (Leten, Belderbos, and van Looy 2007). Research has supported these arguments with findings of negative and inverted-U-shaped effects of technological diversification on innovation and ABP (Chen, Yang, and Lin 2013; Kim, Lee, and Cho 2016; Leten, Belderbos, and van Looy 2007). Therefore, while firms investing in ecological innovation can profit from a broad knowledge base by diversified EIAs, spreading their EIAs over too many technology fields may reverse the positive effect because high coordination costs and a low level of exploitation of EIAs in these diverse technology fields exceed the benefits in terms of ABP.

With regard to VBP, research has shown that diversification is negatively related to firm value (Agarwal et al. 2011; Lamont and Polk 2002). Similarly, Rong and Xiao (2017) find that value rather increases when firms' innovations are related to existing business lines. Studies showing negative effects of technological diversification on VBP further support these findings (Chen, Yang, and Lin 2013; Kim, Lim, and Park 2009; Lin, Chen, and Wu 2006). The concept of myopic loss aversion (Benartzi and Thaler 1995) could explain these results, assuming that investors are more sensitive to losses than to gains and that they tend to frequently evaluate their investment outcome. Considering the drawbacks of a diverse portfolio, investors might see a high risk in such a portfolio. Moreover, scholars have argued that broad portfolios need a longer time period to generate returns because of longer periods of adoption and adaptation (La Leyva-de Hiz, Ferron-Vilchez, and Aragon-Correa 2019), which does not align with investors' frequent evaluations. Considering the high complexity and uncertainty of ecological innovations, the perceived risk of a broad EIA portfolio might be even stronger. Additionally, firms with a broad EIA portfolio might suffer from lower authenticity in their ecological innovation efforts because this portfolio might evoke the impression of superficially spreading EIAs to increase the firm's image by signaling that it is trying to operate more sustainably in various technology fields. These arguments align with La Leyva-de Hiz, Ferron-Vilchez, and Aragon-Correa (2019), who find a positive effect of focused environmental innovation on VBP. Altogether, the preceding arguments lead to the following hypotheses:

Hypothesis 2. *EIA breadth has (a) an inverted-U-shaped effect on ABP and (b) a negative effect on VBP.*

3.2.3 | The Joint Effect of EIA Depth and Breadth on Firm Financial Performance

As the preceding discussion shows, effective distribution of EIAs is important to exploit their full potential as a strategic resource (Hart 1995; Hart and Dowell 2011). Hypothesis 1 and 2 hypothesize that EIA depth positively influences firms' financial performance, while EIA breadth has an inverted-U-shaped effect on ABP and a negative effect on VBP. The latter effects are rooted in the reasoning that firms with broad EIAs face several drawbacks (e.g., high coordination and integration costs; Leten, Belderbos, and van Looy 2007) and that they might suffer from investors' perceptions of high risk. Another problem is that those firms miss out on developing specific competencies in the firm's core fields (Kim, Lee, and Cho 2016). Such missing competencies and low expertise in the diverse technology fields can hamper knowledge spillover across multiple technologies; such spillover is particularly important for developing complex innovations such as ecological innovations.

In contrast, other studies indicate that firms benefit most from a portfolio that considers innovation asset depth and breadth. Kim, Lee, and Cho (2016) find that firms with a high level of firm-specific core-technology competence are better able to handle the harmful effects of excessive technological diversification because, on that level, the benefits of technological diversification outweigh the costs, thereby securing firm growth. Sorescu, Chandy, and Prabhu (2003) show that radical innovations are valued more highly if the firm can draw on a large product scope (i.e., high depth and breadth of knowledge). In addition, Pan, Chen, and Ning (2017) find that the combination of technological depth and breadth positively affects VBP.

Building up technological competence within the diverse fields by accumulating EIAs can help firms transfer and integrate environmental-specific knowledge more easily. Hence, firms can not only benefit from synergies based on knowledge transfer but also profit from economies of scale (Sorescu, Chandy, and Prabhu 2003), allowing them to develop EIA effectively and efficiently, which should enhance their ABP. Moreover, potential communication and coordination costs incurred through the high number of external partnerships for ecological innovation (DeMarchi 2012) can be reduced.

From an investor's perspective, building up deep EIAs in the diverse fields can also serve as a positive signal and reduce the perceived risk of broad EIA portfolios, which can positively affect VBP. A narrow focus on deep core competencies may be associated with innovation rigidities (Leonard-Barton 1992; Sorescu, Chandy, and Prabhu 2003), which is precarious for

the characteristics of ecological innovation. Consequently, by broadening their EIA portfolio to open opportunities for knowledge transfer and integration, firms can indicate greater adaptability to a changing environment. While a solely broad portfolio of EIAs may be accompanied by several drawbacks and high-risk perceptions (e.g., Leten, Belderbos, and van Looy 2007), simultaneously building up deep EIAs in the corresponding technology fields can serve as a signal to investors that the firm is truly engaging in ecological innovation and that it can manage the drawbacks of highly diversified portfolios. Building on this reasoning, we hypothesize the following relationships:

Hypothesis 3. *The joint effect of EIA depth and EIA breadth positively influences (a) ABP and (b) VBP.*

4 | Methodology

4.1 | Data

To test the effect of EIA on firms' financial performance, we compiled a panel data set based on companies listed in the S&P 500 index. We chose this index as it contains 500 of the largest firms in the US market, covering the majority of available market capitalization and thus serving as a benchmark for other businesses (Vadakkepatt, Shankar, and Varadarajan 2021). For the analysis, we excluded firms that are active in the financial, insurance, and real estate sectors because of their low level of technological innovation and their specific reporting standards. For the remaining sample, we observed companies over a period of 10 years, from 2009 until 2018, which we consider an appropriate time frame between external shocks such as the 2008 financial crisis and the COVID-19 pandemic. We also excluded from the sample firms with missing data for ABP and VBP within the observed time frame. Within the remaining sample, we replaced missing values for financially related control variables with zero, except for R&D intensity: Because several firms do not report their R&D expenditures, we replaced the missing values with industry means for each year. We obtained financial data from the COMPUSTAT database. To measure innovation-related variables, we used patent data obtained from the USPTO.[1]

Although patent data have drawbacks (e.g., not all inventions are patentable nor are all inventions patented, propensity varies across industries and firms, patents differ in value; Griliches 1990), researchers widely acknowledge these data as a suitable indicator for measuring technological innovation activities (Belderbos et al. 2010; Ceipek et al. 2021; Hagedoorn and Cloodt 2003; Hall, Jaffe, and Trajtenberg 2005; Leten, Belderbos, and van Looy 2007; Schoenmakers and Duysters 2010; Zuo, Fisher, and Yang 2019) because they are publicly available, are available at the firm level, cover long time spans, are objective due to the requirements a patent must fulfill to be granted, and contain rich information on the invention (e.g., the assigned standard patent classification, which allocates the invention to specific technological fields covered by the patent).

While a majority of studies rely on survey data to measure ecological innovation (e.g., Ghisetti and Rennings 2014; Rexhäuser and Rammer 2014), others highlight the potential of patent data as an indicator for ecological innovation (Marin and Lotti 2017; Oltra, Kemp, and de Vries 2010; Wagner 2007). The European Patent Office (EPO) and the USPTO collaborated to harmonize their patent classification systems, and the EPO subsequently introduced the new Y02 tagging scheme. The new classification Y02 serves as a meta class and comprises all patents that contain technologies and applications developed to mitigate climate change (Haščič and Migotto 2015). Compared with complex search strategies that combine classification and keyword-based patent search (Lee, Veloso, and Hounshell 2011; Nameroff, Garant, and Albert 2004), the new classification Y02 allows researchers to more easily identify ecological innovations (Bermúdez-Edo, Hurtado-Torres, and Ortiz-de-Mandojana 2017; La Leyva-de Hiz, Ferron-Vilchez, and Aragon-Correa 2019). Therefore, we consider patent data a suitable indicator in our research context.

We follow earlier studies by collecting patent data on a consolidated level (i.e., data from the parent firm as well as its majority-owned subsidiaries; Belderbos et al. 2010; Belderbos et al. 2014; Leten, Belderbos, and van Looy 2007; Phelps 2010). To match the data, we used yearly lists of subsidiaries as shown in Exhibit 21 of firms' 10-K reports. Because research suggests that technological knowledge loses most of its relevance and economic value within three to five years (Griliches 1979) and because the number of patents a firm applies for varies in different years (Griliches 1990; Hall, Jaffe, and Trajtenberg 2001; Zhang, Baden-Fuller, and Mangematin 2007), scholars have agreed that a moving window of five years is an appropriate time frame for capturing the firm's patenting activities in a given year (Leten, Belderbos, and van Looy 2007; Petralia 2020; Zhang, Baden-Fuller, and Mangematin 2007). Hence, the patent stock we measure in year t is based on the interval $t-4$ until t. Thus, following Leten, Belderbos, and van Looy (2007), the consolidated patent portfolio of the parent firm in year t consists of all patents in the past 5 years by the entities (i.e., parent firm and subsidiaries) that were part of the firm in year t. When assigning patents to a firm, we use the application date of the granted patents. This date is the closest to the actual invention because, on average, it takes about 2 years for a patent to be granted (USPTO 2024). We further excluded from the sample firms for which patents could not have been clearly assigned on a consolidated level because of missing Securities and Exchange Commission filings, name inconsistencies, or unclear subsidiary affiliations. Figure 2 depicts the detailed sample selection process.

After merging the financial data with the patent data, we had a panel data set consisting of 340 firms with data from 2009 to 2018, resulting in over 3000 firm-year observations, which is comparable to other studies in the field (e.g., Rezende et al. 2019). In total, our analysis includes more than 54,000 ecological patents.

4.2 | Measures

4.2.1 | Independent Variables

We constructed our independent variables based on the firms' Y02 patents. EIA depth refers to the accumulation of EIAs held within certain technology fields. In line with earlier research,

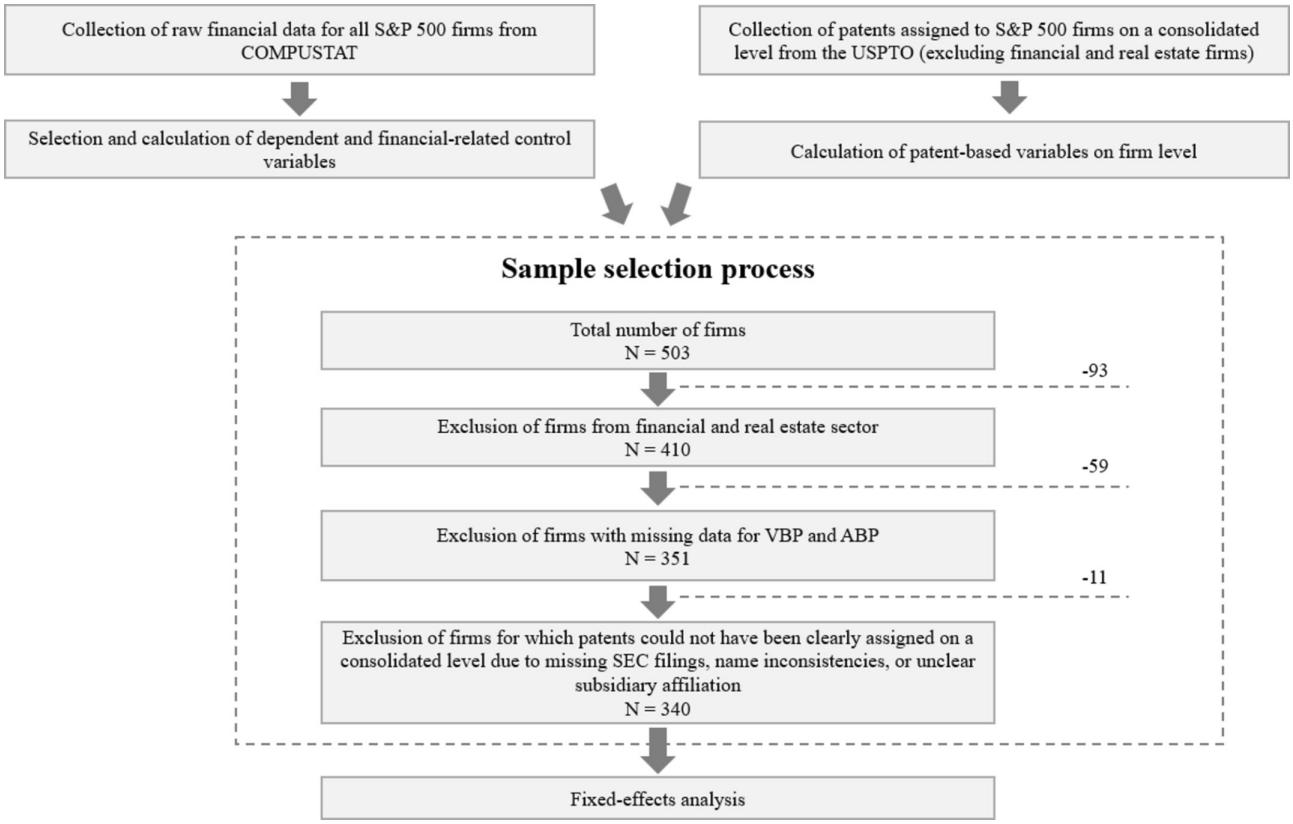

FIGURE 2 | Research method diagram.

we measured *EIA depth* as the average amount of ecological patents per technological subclass for each firm in each year (Prabhu, Chandy, and Ellis 2005; Xu and Cavusgil 2019). Following common practice in the research field, we used the four-digit International Patent Classification (IPC) level to determine the technological subclasses (Gao et al. 2021; Kim, Lee, and Cho 2016; Zabala-Iturriagagoitia, Porto Gómez, and Aguirre Larracoechea 2020).

EIA breadth refers to the diversification of EIAs across various technology fields. Among other measures, researchers have widely used the entropy measure of diversification to measure technological diversification (Ceipek et al. 2019; Sorescu, Chandy, and Prabhu 2003). Compared with other measures, the entropy measure also considers the proportion of patents in each of the classes and thus takes the distribution into account (Hitt, Hoskisson, and Kim 1997). Therefore, we define the measure for *EIA breadth* as follows:

$$EIA\ breadth = \sum_{j=1}^{n}\left[ep_j \times \ln\left(\frac{1}{ep_j}\right)\right], \quad (1)$$

where ep_j is the fraction of the firm's ecological patents in the j_{th} technology subclass relative to its overall ecological patent portfolio. We calculated ep_j by dividing the number of a firm's ecological patents in a specific technology subclass at time t by the firm's overall number of ecological patent-related technology subclass assignments at time t (Sorescu, Chandy, and Prabhu 2003). Again, we used the four-digit IPC level for determining technological subclasses.

4.2.2 | Dependent Variables

To measure firms' ABP, we used net income in year $t+1$, and to measure VBP, we relied on the market value of the firm in year $t+1$. By lagging the dependent variables by 1 year, we addressed the possibility of potential endogeneity caused by reverse causality (Fang, Palmatier, and Grewal 2011; Kim, Lee, and Cho 2016). This problem can occur because firms' prior performance might influence the innovation portfolio strategy (Miller 2006). Moreover, lagging the dependent variables reduces the possibility of EIAs and our dependent variables being simultaneously influenced by omitted variables, which we did not include in our analysis (Miller 2006).

4.2.3 | Control Variables

Although we already accounted for time-invariant omitted variables by including fixed-effects in our models, thereby diminishing the possibility of omitted firm characteristics influencing the dependent variable (Wooldridge 2010), we further included variables to control for firm-specific impacts. First, we included *prior financial performance*, which we measured as the earnings before interest, taxes, depreciation, and amortization (EBITDA; Cacciolatti et al. 2020). By including EBITDA to capture prior performance instead of relying on lagged dependent

variables, we avoid the risk of biased estimators that arise with dynamic models in the context of panel data (Das 2019). Moreover, we controlled for *firm size*, which is measured as the log-transformation of the number of employees (Chen, Yang, and Lin 2013; Fang, Palmatier, and Grewal 2011). Further, we included *R&D intensity*, defined as the R&D expenditures divided by the sales (Chen, Yang, and Lin 2013); *leverage*, which refers to the long-term debt divided by the total assets of the firm; and *capital intensity*, which refers to the ratio of capital expenditure and sales (Bendig, Wagner, and Lau 2023).

To control for industry-specific impacts, we also included competitive intensity and market turbulence in our model. To measure *competitive intensity*, we used the Herfindahl index and squared the market share of the top four firms in the same Global Industry Classification (GIC) sector as the focal firm (Saboo and Grewal 2003). For *market turbulence*, we used the ratio of sales and general administrative expenses to the sales of all firms in the same GIC sector as the focal firm (Saboo and Grewal 2003).

Finally, we included firm-specific innovation-related variables. To control for general effects of EIAs, we included the variables *EIA total*, measured as the absolute number of ecological patents a firm holds in year t (Bermúdez-Edo, Hurtado-Torres, and Ortiz-de-Mandojana 2017), and *EIA relative*, which refers to the relative number of ecological patents compared with the total amount of patents a firm held in year t (Aguilera-Caracuel and Ortiz-de-Mandojana 2013). To account for potential effects resulting from firms' regular innovation activity, we also considered as control variables *regular innovation assets*, which refer to the total number of all non-ecological patents a firm applied for in year t, and *regular innovation scope*, which refers to the number of technological subclasses in which a firm holds non-ecological patents. Table 2 provides an overview of all variables and their operationalization.

4.3 | Model Specification

To determine our model specification, we conducted several preliminary econometric tests. First, a Hausman test supported the hypot heses of fixed-effects in our data ($p < 0.05$), and the Lagrange multiplier test indicated that firm-specific as well as time-specific effects were present in our data

TABLE 2 | Description of dependent and explanatory variables.

Dependent variables	
ABP	Net income of firm i in year $t+1$
VBP	Market value of firm i in year $t+1$
Independent variables	
EIA depth	Accumulation of EIA within certain technology fields, measured by the average amount of ecological patents per technological subclass (i.e., four-digit IPC level) for firm i in year t
EIA breadth	Overall breadth of EIA, measured by the entropy measure of EIA across technological subclasses (i.e., four-digit IPC level) for firm i in year t
Control variables	
Prior financial performance	Measured as the earnings before interest, taxes, depreciation, and amortization (EBITDA) for firm i in year t
Firm size	Log-transformation of the number of employees for firm i in year t
R&D intensity	R&D expenditures divided by sales for firm i in year t
Leverage	Long-term debt divided by sales for firm i in year t
Capital intensity	Capital expenditure divided by sales for firm i in year t
Competitive intensity	Herfindahl index, measured by the squared market share of top five firms within the same GIC sector as the focal firm in year t
Market turbulence	Sales and general administrative expenses divided by the sales for all firms in the same GIC sector as the focal firm in year t
Regular innovation assets	Absolute number of all non-ecological patents for firm i in year t
Regular innovation scope	Number of technological subclasses with non-ecological patents for firm i in year t
EIA total	Absolute number of ecological patents for firm i in year t
EIA relative	Relative number of ecological patents compared with the total amount of patents for firm i in year t

Note: The number of patents in year t is based on the 5-year moving average of patent applications.

($p < 0.001$). Therefore, we relied on a fixed-effects model with firm- and time-specific effects to control for unobserved heterogeneity.[2] Second, we tested for heteroskedasticity and serial correlation. The Breusch–Pagan test confirmed heteroskedasticity in our data ($p < 0.001$), and the Wooldridge test confirmed serial correlation ($p < 0.001$). To address these issues, we applied Newey–West company-clustered robust standard errors. Our final models for ABP and VBP outcomes are specified as follows:

$$ABP_{i(t+1)} = \beta_0 + \beta_1 EIA\ depth_{it} + \beta_2 EIA\ breadth_{it} + \beta_3 (EIA\ breadth)^2_{it} + \beta_4 \left(EIA\ depth_{it} * EIA\ breadth_{it}\right) + \beta_5 X_{it} + \beta_6 Y_t + \varepsilon_{it} \quad (2)$$

$$VBP_{i(t+1)} = \beta_0 + \beta_1 EIA\ depth_{it} + \beta_2 EIA\ breadth_{it} + \beta_3 (EIA\ breadth)^2_{it} + \beta_4 \left(EIA\ depth_{it} * EIA\ breadth_{it}\right) + \beta_5 X_{it} + \beta_6 Y_t + \varepsilon_{it}, \quad (3)$$

where i stands for firm and t for time, βs are regression coefficients, *ABP* stands for accounting-based performance, *VBP* stands for value-based performance, X represents the set of control variables and a dummy variable for the sample firms, Y represents the year dummy variable, and $\mathcal{E}$ captures the idiosyncratic error.

5 | Results

Table 3 depicts the descriptive statistics and Pearson correlations for all variables. To ensure that multicollinearity was not an issue, we further calculated the variance inflation factor (VIF) values and did not find any values exceeding the accepted level (max VIF = 5.72). Therefore, we conclude that multicollinearity is not an issue with our data (Hair et al. 2013).

5.1 | Fixed-Effects Regression

Table 4 shows the regression results for the ABP and VBP outcomes. For each of the outcome variables, we estimated four models. Using hierarchical regression with a stepwise inclusion of variables, we evaluated how much of the variance can be explained by the variables of interest. Models 1 and 5 contain the control variables only; Models 2 and 6 add the linear effects for the EIA structure variables *EIA depth* and *EIA breadth*; Models 3 and 7 include the quadratic effect of EIA breadth as hypothesized in our model, and Models 4 and 8 depict the full models containing all previous variables as well as the interaction effect of EIA depth and EIA breadth.

We next test our hypotheses. We can confirm Hypothesis 1a, as we find a significant positive effect of EIA depth on ABP (Model 4: ß = 0.095, $p < 0.01$). For the effect of EIA depth on VBP, we did not find a significant effect (Model 8: ß = 0.064, $p > 0.05$). Therefore, our data do not support Hypothesis 1b. For the effect of EIA breadth, we expected a negative curvilinear relationship for ABP and a negative linear relationship for VPB. Model 4 shows a negative effect for the squared term of EIA breadth on ABP and thus confirms Hypothesis 2a (ß = −0.232, $p < 0.01$). We find a significant negative effect for EIA breadth on VBP (Model 8: ß = −0.112, $p < 0.05$). However, we also find a positive effect for the squared term of EIA breadth on VBP (Model 8: ß = 0.133, $p < 0.05$), indicating that the effect of EIA breadth on VBP is not negative, as we expected in Hypothesis 2b, but is actually curvilinear. Regarding the interaction effect of EIA depth and breadth, we expected a positive effect for both outcome variables. Models 4 and 8 show positive effects for both variables. Therefore, we can confirm Hypothesis 3a,b (Model 4: ß = 0.150, $p < 0.01$; Model 8: ß = 0.151, $p < 0.001$).

5.2 | Robustness and Supplementary Analyses

To test the sensitivity of our results, we conducted several supplementary analyses. First, we tested a potential curvilinear relationship for EIA depth by including the squared term of EIA depth in our analyses. The results do not support a curvilinear relationship between EIA depth and ABP or VBP (Table 5, Models 2 and 4).

Second, we additionally tested our models with innovation-related variables that capture the firm's patenting activity in a given year based on patent applications from the same year only; hence, the firm's patent stock in year t is based on its patents in the same year (t) instead of $t-4$ until t. Table 6 shows the results. For the ABP outcome, we found the same significant effects for EIA depth and its interaction effect with EIA breadth, though the values are much smaller than in our main analysis. For the single effect of EIA breadth, we observed no significant effects. These results support earlier research arguing for a 5-year moving window to capture a firm's innovative activity because of varying patent applications throughout the years (Leten, Belderbos, and van Looy 2007; Petralia 2020; Zhang, Baden-Fuller, and Mangematin 2007).

For the firm's VBP, the results support the squared effect of EIA breadth, which is even higher when we only consider the patent stock in year t. However, we did not find a significant effect for the interaction of EIA depth and EIA breadth. One possible reason is that investor reaction is more dependent on current changes and developments. This supposition is supported by the stronger effects found for EIA breadth, which has a negative impact on the valuation. This result suggests that investors see a risk in EIA diversification, in line with the assumption that investors tend to be loss averse (Benartzi and Thaler 1995). However, when considering the broader window for the patent stock, we see that the positive gains of EIA depth can balance the perceived risk of EIA breadth (Table 4).

Third, we lagged our dependent variables by one more year to see if any changes resulted. The positive effects of EIA depth and the interaction effect of EIA depth and EIA breadth on ABP are constant over 2 years. For EIA breadth, we do not observe a significant effect, which indicates that, profit-wise, firms benefit more in the long term from focusing on EIA depth. With regard to VBP, the results support our main analysis findings (Table 7).

Fourth, we winsorized the dependent variables at a 1% level to lower the impact of extreme outliers. The results greatly

TABLE 3 | Descriptive statistics and correlations.

	Mean	SD	VIF	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ABP	1886.28	4353.09	N/A	1.00														
VBP	38,427.23	74,584.30	N/A	0.82	1.00													
Prior financial performance	3924.10	7299.79	1.73	0.85	0.81	1.00												
Firm size (log)	3.04	1.38	1.58	0.38	0.40	0.47	1.00											
R&D intensity	0.06	0.25	1.07	−0.02	0.00	−0.04	−0.19	1.00										
Leverage	0.25	0.23	1.02	−0.05	−0.05	−0.03	0.03	−0.01	1.00									
Capital intensity	0.08	0.11	1.23	−0.05	−0.01	0.04	−0.21	−0.02	0.07	1.00								
Competitive intensity	0.02	0.00	1.21	0.12	0.15	0.15	−0.07	0.01	0.00	0.15	1.00							
Market turbulence	1.58	2.27	1.13	−0.01	0.02	−0.02	−0.11	0.08	−0.02	−0.07	0.27	1.00						
Regular innovation assets	663.37	2195.36	2.16	0.44	0.49	0.46	0.29	0.04	−0.06	−0.05	−0.02	−0.03	1.00					
Regular innovation scope	47.38	66.68	5.72	0.39	0.45	0.45	0.41	0.01	−0.06	−0.17	−0.09	0.01	0.63	1.00				
EIA total	59.23	246.97	3.22	0.30	0.32	0.40	0.28	0.02	−0.03	−0.03	−0.11	−0.08	0.59	0.65	1.00			
EIA relative	0.06	0.15	1.43	0.02	0.01	0.07	0.00	−0.02	0.02	0.23	−0.10	−0.06	0.01	0.07	0.19	1.00		
EIA depth	1.17	2.26	2.96	0.35	0.34	0.39	0.18	0.10	−0.08	−0.04	−0.08	−0.02	0.60	0.59	0.75	0.29	1.00	
EIA breadth	1.13	1.21	3.73	0.31	0.36	0.36	0.28	0.05	−0.09	−0.13	−0.09	0.06	0.39	0.79	0.39	0.27	0.48	1.00

TABLE 4 | Effects of EIA on accounting- and value-based performance.

	Dependent variable: ABP ($t+1$)				Dependent variable: VBP ($t+1$)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Control variables								
Prior financial performance	0.769*** (0.079)	0.760*** (0.078)	0.760*** (0.078)	0.747*** (0.078)	0.487*** (0.077)	0.482*** (0.077)	0.481*** (0.077)	0.468*** (0.076)
Firm size (log)	−0.022 (0.045)	−0.019 (0.044)	−0.025 (0.044)	−0.033 (0.044)	0.116* (0.048)	0.123** (0.047)	0.128** (0.048)	0.120* (0.048)
R&D intensity	0.001 (0.002)	0.001 (0.002)	0.002 (0.002)	0.002 (0.002)	−0.001 (0.002)	−0.002 (0.002)	−0.002 (0.002)	−0.003 (0.002)
Leverage	0.014 (0.015)	0.013 (0.015)	0.014 (0.015)	0.013 (0.015)	0.034** (0.013)	0.034** (0.013)	0.033** (0.013)	0.032** (0.013)
Capital intensity	−0.078* (0.033)	−0.079* (0.032)	−0.079* (0.032)	−0.079* (0.032)	0.040** (0.014)	0.038** (0.014)	0.038** (0.014)	0.038** (0.014)
Competitive intensity	−0.018 (0.027)	−0.018 (0.027)	−0.024 (0.028)	−0.027 (0.028)	−0.008 (0.023)	−0.008 (0.024)	−0.004 (0.024)	−0.007 (0.023)
Market turbulence	0.015 (0.014)	0.013 (0.014)	0.013 (0.014)	0.015 (0.014)	0.005 (0.012)	0.004 (0.012)	0.004 (0.012)	0.007 (0.012)
Regular innovation assets	0.086 (0.087)	0.080 (0.085)	0.097 (0.086)	0.067 (0.083)	0.311 (0.162)	0.306 (0.161)	0.295 (0.160)	0.264 (0.161)
Regular innovation scope	−0.062 (0.085)	−0.022 (0.087)	0.053 (0.089)	0.052 (0.088)	0.619*** (0.144)	0.663*** (0.146)	0.613*** (0.137)	0.612*** (0.136)
EIA total	−0.112 (0.069)	−0.164* (0.071)	−0.162* (0.071)	−0.292*** (0.089)	−0.076 (0.059)	−0.098 (0.060)	−0.100 (0.060)	−0.232*** (0.059)
EIA relative	0.006 (0.009)	−0.003 (0.010)	−0.004 (0.010)	0.002 (0.010)	0.006 (0.004)	0.009 (0.006)	0.010 (0.006)	0.016* (0.006)
Independent variables								
EIA depth		0.102** (0.033)	0.080* (0.032)	0.095** (0.035)		0.034 (0.033)	0.049 (0.032)	0.064 (0.033)
EIA breadth		−0.039 (0.023)	0.126* (0.053)	0.185*** (0.055)		−0.059*** (0.017)	−0.171*** (0.051)	−0.112* (0.051)
EIA breadth^2			−0.218** (0.073)	−0.232** (0.072)			0.147* (0.065)	0.133* (0.065)
Interaction effect								
EIA depth × EIA breadth				0.150** (0.051)				0.151*** (0.043)
Wald-χ^2	1238.95	1258.34	1275.37	1296.94	1704.80	1718.56	1731.54	1769.45

(Continues)

TABLE 4 | (Continued)

	Dependent variable: ABP ($t+1$)				Dependent variable: VBP ($t+1$)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Observations	3400	3400	3400	3400	3400	3400	3400	3400
R^2	0.290	0.293	0.296	0.299	0.359	0.361	0.363	0.368
Adjusted R^2	0.206	0.209	0.212	0.216	0.284	0.285	0.287	0.293
F statistic	112.632***	96.796***	91.098***	86.463***	154.982***	132.197***	123.681***	117.964***

Note: This table reports standardized coefficients; robust standard errors are in parentheses.
*$p<0.05$; **$p<0.01$; ***$p<0.001$.

support our main findings (see Table 8). For VBP, all effects are supported, and we see an additional positive effect for EIA depth. For ABP, the main effect of EIA depth is supported as well as its interaction effect with EIA breadth. While winsorizing the data reduces the influence of extreme outliers, it can distort the distribution and potentially exclude relevant information, which is why we rely on the full range of data in our main analysis.

Fifth, one issue that could diminish the validity of our results is that of common method bias stemming from the use of the same data for independent and dependent variables. Although we relied exclusively on secondary data, the fact that we extracted the data from independent data sources reduces the possibility for common method bias (Podsakoff et al. 2003). Besides including further variables and lagging our dependent variables to account for the possibility of reverse causality and omitted variables, we relied on a two-stage least squares (2SLS) instrumental variable (IV) approach to further address the issue of potential endogeneity. Following extant research, we used the industry mean of our variables of interest (i.e., EIA depth and EIA breadth) as primary instruments (Dotzel and Shankar 2019; Iqbal et al. 2022; Kim, Lee, and Cho 2016) because, while it is likely that firms' EIA portfolio structure could be influenced by that of their competitors, the competitors' EIA portfolios are unlikely to have a direct impact on the focal firms' performance outcomes. The results of the 2SLS IV regression are consistent with our results in the main analysis, suggesting that the estimates are not biased (see Table 9). Altogether, considering the conceptual development of the study and our methodological implementation, we conclude that the potential for biases rooted in endogeneity is rather low in our study.

6 | Discussion

To respond to growing stakeholder pressure regarding firms' environmental impact and to remain competitive in an environment increasingly characterized by resource scarcity, firms can rely on ecological innovations to reduce their environmental impact. This study investigates the role of firms' EIA portfolio structures for the financial performance outcome of ecological innovation.

6.1 | Theoretical Implications

Extant research shows varying results regarding the performance outcomes of ecological innovation: Whereas several studies demonstrate a positive relationship (e.g., Aguilera-Caracuel and Ortiz-de-Mandojana 2013; Farza et al. 2021), others find a negative relationship (e.g., Bermúdez-Edo, Hurtado-Torres, and Ortiz-de-Mandojana 2017) or no effects (e.g., Cai and Li 2018). Various studies have made attempts to uncover the circumstances in which firms can benefit from their ecological innovations (García-Sánchez, Gallego-Álvarez, and Zafra-Gómez 2020; La Leyva-de Hiz, Ferron-Vilchez, and Aragon-Correa 2019). Our research builds on these attempts, delving more deeply into the management of EIAs by taking the perspective of core competencies

TABLE 5 | Effects of nonlinear EIA depth on accounting- and value-based performance.

	Dependent variable: ABP ($t+1$)		Dependent variable: VBP ($t+1$)	
	(1)	(2)	(3)	(4)
Control variables				
Prior financial performance	0.747*** (0.078)	0.747*** (0.078)	0.468*** (0.076)	0.467*** (0.076)
Firm size (log)	−0.033 (0.044)	−0.033 (0.044)	0.120* (0.048)	0.117* (0.048)
R&D intensity	0.002 (0.002)	0.002 (0.002)	−0.003 (0.002)	−0.002 (0.002)
Leverage	0.013 (0.015)	0.013 (0.015)	0.032** (0.013)	0.033** (0.013)
Capital intensity	−0.079* (0.032)	−0.079* (0.032)	0.038** (0.014)	0.038** (0.014)
Competitive intensity	−0.027 (0.028)	−0.027 (0.027)	−0.007 (0.023)	−0.005 (0.023)
Market turbulence	0.015 (0.014)	0.015 (0.014)	0.007 (0.012)	0.006 (0.012)
Regular innovation assets	0.067 (0.083)	0.067 (0.084)	0.264 (0.161)	0.263 (0.161)
Regular innovation scope	0.052 (0.088)	0.051 (0.089)	0.612*** (0.136)	0.602*** (0.136)
EIA total	−0.292*** (0.089)	−0.292** (0.093)	−0.232*** (0.059)	−0.221*** (0.061)
EIA relative	0.002 (0.010)	0.002 (0.010)	0.016* (0.006)	0.012 (0.007)
Independent variables				
EIA depth	0.095** (0.035)	0.098^{+} (0.054)	0.064 (0.033)	0.104* (0.044)
EIA depth^2		−0.003 (0.051)		−0.042 (0.038)
EIA breadth	0.185*** (0.055))	0.184*** (0.055)	−0.112* (0.051)	−0.114* (0.051)
EIA breadth^2	−0.232** (0.072	−0.231** (0.073)	0.133* (0.065)	0.139* (0.065)
Interaction effect				
EIA depth × EIA breadth	0.150** (0.051)	0.150** (0.050)	0.151*** (0.043)	0.158*** (0.042)
Wald-χ^2	1296.94	1296.53	1769.45	1771.81
Observations	3400	3400	3400	3400
R^2	0.299	0.299	0.368	0.369
Adjusted R^2	0.216	0.215	0.293	0.293
F statistic	86.463***	81.033***	117.964***	110.738***

Note: This table reports standardized coefficients; robust standard errors are in parentheses.
$^{+}p<0.1$; $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$.

(Prahalad and Hamel 1990) and technological diversification (Grantstrand, Patel, and Pavill 1997). In doing so, we disentangle EIA into EIA depth and EIA breadth to examine how different portfolio structures of EIAs influence firms' financial performance. We find different effects of EIA depth and breadth, which indicates that the effect of ecological innovation on financial performance depends on how firms structure their EIA portfolio. These results highlight the importance of considering the management and efficient deployment of resources when considering adding ecological innovation to a firm's portfolio, which is in line with resource-based perspectives (Amit and Schoemaker 1993; Barney 1991; Fang, Palmatier, and Grewal 2011; Hart and Dowell 2011). In contrast to studies considering EIAs in aggregated terms (e.g., Cai and Li 2018; Iqbal et al. 2022; Xie et al. 2016), we disaggregate EIAs into depth and breadth, which offers a more detailed picture of when EIAs provide a competitive advantage (Barney 1991). This approach enables a better understanding of the effective distribution of EIAs, emphasizing the strategic importance of technological portfolios in maximizing EIAs' value. Therefore, research on ecological innovation and firm performance can benefit from incorporating insights from the broader innovation literature, such as core competencies (Prahalad and Hamel 1990) and technological diversity (Grantstrand, Patel, and Pavill 1997).

Building on our findings, our study also points to the potential presence of nonlinear effects in the context of ecological innovations' performance outcomes. Extant studies have neglected nonlinear effects, which has sometimes led them to underestimate the complex and multifaceted nature of ecological innovation. Especially in the context of innovation

TABLE 6 | Effects of EIA based on patent stock *t* on accounting- and value-based performance.

	Dependent variable: ABP ($t+1$)				Dependent variable: VBP ($t+1$)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Control variables								
Prior financial performance	0.778*** (0.079)	0.776*** (0.078)	0.777*** (0.078)	0.770*** (0.078)	0.532*** (0.083)	0.534*** (0.083)	0.529*** (0.083)	0.526*** (0.084)
Firm size (log)	−0.014 (0.044)	−0.016 (0.044)	−0.016 (0.044)	−0.016 (0.044)	0.189** (0.063)	0.192** (0.063)	0.191** (0.062)	0.191** (0.061)
R&D intensity	0.001 (0.002)	0.002 (0.002)	0.002 (0.002)	0.001 (0.002)	0.001 (0.002)	0.001 (0.002)	0.00003 (0.002)	−0.0001 (0.002)
Leverage	0.017 (0.015)	0.016 (0.015)	0.017 (0.015)	0.016 (0.015)	0.047*** (0.014)	0.048*** (0.014)	0.045*** (0.014)	0.045** (0.014)
Capital intensity	−0.075* (0.032)	−0.075* (0.032)	−0.075* (0.032)	−0.076* (0.032)	0.040** (0.014)	0.041** (0.015)	0.039** (0.014)	0.039** (0.014)
Competitive intensity	−0.014 (0.027)	−0.012 (0.027)	−0.012 (0.027)	−0.016 (0.028)	0.029 (0.022)	0.027 (0.022)	0.028 (0.022)	0.026 (0.022)
Market turbulence	0.017 (0.014)	0.015 (0.014)	0.015 (0.014)	0.016 (0.014)	−0.009 (0.013)	−0.007 (0.013)	−0.006 (0.013)	−0.005 (0.013)
Regular innovation assets	−0.032 (0.043)	−0.031 (0.042)	−0.031 (0.042)	−0.033 (0.041)	−0.103 (0.059)	−0.105 (0.059)	−0.107 (0.061)	−0.108 (0.060)
Regular innovation scope	−0.073 (0.059)	−0.068 (0.059)	−0.059 (0.060)	−0.050 (0.060)	0.462*** (0.075)	0.459*** (0.075)	0.408*** (0.070)	0.412*** (0.070)
EIA total	0.014 (0.064)	−0.003 (0.067)	−0.002 (0.067)	−0.088 (0.086)	−0.010 (0.042)	0.008 (0.044)	0.005 (0.044)	−0.026 (0.059)
EIA relative	−0.001 (0.009)	−0.007 (0.009)	−0.008 (0.009)	−0.006 (0.009)	0.005 (0.004)	0.013* (0.006)	0.018** (0.006)	0.019** (0.006)
Independent variables								
EIA depth		0.034 (0.020)	0.032 (0.019)	0.045^{+} (0.023)		−0.038* (0.018)	−0.020 (0.017)	−0.016 (0.021)
EIA breadth		0.0005 (0.017)	0.024 (0.041)	0.020 (0.041)		−0.006 (0.012)	−0.147** (0.047)	−0.148** (0.047)
EIA breadth^2			−0.030 (0.059)	−0.008 (0.061)			0.180** (0.063)	0.188** (0.065)
Interaction effect								
EIA depth × EIA breadth				0.081* (0.035)				0.029 (0.032)
Wald-χ^2	1226.65	1230.66	1230.77	1247.31	1283.24	1290.73	1317.90	1320.62

(Continues)

TABLE 6 | (Continued)

	Dependent variable: ABP ($t+1$)				Dependent variable: VBP ($t+1$)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Observations	3400	3400	3400	3400	3400	3400	3400	3400
R^2	0.287	0.288	0.288	0.291	0.297	0.298	0.303	0.303
Adjusted R^2	0.203	0.204	0.204	0.206	0.214	0.215	0.220	0.220
F statistic	111.514***	94.667***	87.913***	83.154***	116.659***	99.287***	94.136***	88.042***

Note: This table reports standardized coefficients; robust standard errors are in parentheses.
$^{+}p<0.1$; $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$.

portfolio management, technological diversification research suggests a nonlinear effect of EIA breadth (e.g., Kim, Lee, and Cho 2016). Our findings expand on this by revealing an inverted U-shaped effect for EIA breadth on ABP and a U-shaped effect on VBP. Delineating EIA into more fine-grained effects allows a more thorough accounting of the multifaceted aspects of ecological innovation. In doing so, we demonstrate that spreading ecological innovation among too many different technology fields can be harmful for firms. This finding highlights the importance of leveraging and transferring theoretical foundations from the innovation literature to explain the nuanced effects of ecological innovation, which are not always straightforward.

Furthermore, considering distinct types of performance outcomes provides a more comprehensive understanding of the effects of EIA compared with studies that only consider one performance dimension. Our findings reveal essential differences in the effects of EIA depth and EIA breadth for ABP and VBP, highlighting the necessity of accounting for distinct dimensions of financial performance and of considering these differences in theoretical reasoning, because the underlying mechanisms driving these outcomes differ. The results suggest that conclusions cannot be generalized across performance outcomes because they result in different implications. Therefore, we follow Grewatsch and Kleindienst (2017) in suggesting that studies in the field should account for those differences in their theoretical considerations.

Finally, from the perspective of research on technological portfolio structures, this study contributes by specifically testing the effects of the ecological part of firms' innovation assets. Most technological portfolio studies consider a firm's entire patent portfolio (Kim, Lee, and Cho 2016), without differentiating specific innovation types. Considering that earlier works have highlighted that ecological innovations substantially differ from regular innovations (Cainelli, de Marchi, and Grandinetti 2015), researchers in this area should consider those remarkable differences when investigating firms' technological portfolios. Doing so could help explain the varying outcomes other researchers have observed when investigating the effect of portfolio structures (e.g., Chiu et al. 2008; Huang and Chen 2010; Kim, Lee, and Cho 2016).

6.2 | Managerial Implications

For managerial practice, the results provide important insights for firms to remain financially successful by creating a dedicated and systematic EIA portfolio management strategy. They suggest that it is favorable for firms' profits to accumulate EIA in technology fields in which the firm already has knowledge (i.e., high depth), because firms can benefit from this deep knowledge stock with the ability to create new and complex knowledge more easily. Moreover, such deep assets serve as important strategic resources because they support firms in building up specific competencies that are rare and inimitable. With regard to EIA breadth, firms profit from an increasing breadth to a certain extent, after which overdiversifying EIA has a negative impact on firms' profit.

TABLE 7 | Effects of EIA on accounting- and value-based performance in Year $t+2$.

	Dependent variable: ABP ($t+2$)				Dependent variable: VBP ($t+2$)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Control variables								
Prior financial performance	0.465*** (0.084)	0.455*** (0.084)	0.456*** (0.084)	0.438*** (0.084)	0.535*** (0.123)	0.529*** (0.122)	0.528*** (0.122)	0.512*** (0.118)
Firm size (log)	0.117* (0.050)	0.117* (0.050)	0.114* (0.050)	0.104* (0.050)	0.206* (0.091)	0.215* (0.092)	0.221* (0.092)	0.212* (0.093)
R&D intensity	0.0005 (0.002)	0.001 (0.002)	0.001 (0.002)	0.001 (0.002)	−0.003 (0.003)	−0.004 (0.003)	−0.004 (0.003)	−0.005 (0.003)
Leverage	0.057*** (0.017)	0.056** (0.017)	0.056** (0.017)	0.055** (0.017)	0.055*** (0.016)	0.055*** (0.016)	0.054*** (0.015)	0.053*** (0.015)
Capital intensity	−0.023 (0.025)	−0.023 (0.025)	−0.024 (0.025)	−0.024 (0.025)	0.036 (0.027)	0.035 (0.027)	0.035 (0.026)	0.034 (0.026)
Competitive intensity	−0.042 (0.037)	−0.043 (0.037)	−0.046 (0.038)	−0.050 (0.038)	0.006 (0.031)	0.006 (0.031)	0.012 (0.030)	0.009 (0.030)
Market turbulence	0.016 (0.022)	0.013 (0.022)	0.013 (0.022)	0.015 (0.022)	−0.019 (0.017)	−0.020 (0.017)	−0.019 (0.017)	−0.017 (0.017)
Regular innovation assets	0.213 (0.113)	0.208 (0.110)	0.216 (0.112)	0.176 (0.109)	0.247 (0.174)	0.242 (0.173)	0.224 (0.171)	0.186 (0.173)
Regular innovation scope	0.025 (0.123)	0.052 (0.126)	0.086 (0.125)	0.087 (0.124)	0.774*** (0.192)	0.825*** (0.195)	0.745*** (0.179)	0.746*** (0.178)
EIA total	−0.194** (0.073)	−0.251** (0.076)	−0.250** (0.076)	−0.418*** (0.100)	−0.068 (0.072)	−0.090 (0.072)	−0.093 (0.072)	−0.252*** (0.066)
EIA relative	−0.003 (0.012)	−0.018 (0.013)	−0.018 (0.013)	−0.010 (0.013)	0.001 (0.005)	0.007 (0.008)	0.008 (0.008)	0.016* (0.008)
Independent variables								
EIA depth		0.116** (0.041)	0.106** (0.040)	0.127** (0.043)		0.031 (0.041)	0.055 (0.038)	0.075 (0.041)
EIA breadth		−0.013 (0.029)	0.064 (0.076)	0.138 (0.074)		−0.071*** (0.020)	−0.250*** (0.074)	−0.180* (0.079)
EIA breadth^2			−0.102 (0.109)	−0.118 (0.107)			0.236* (0.092)	0.220* (0.092)
Interaction effect								
EIA depth × EIA breadth				0.192** (0.059)				0.181** (0.062)
Wald-χ^2	395.64	407.32	409.25	428.78	1252.05	1261.40	1279.51	1308.54

(Continues)

TABLE 7 | (Continued)

	Dependent variable: ABP ($t+2$)				Dependent variable: VBP ($t+2$)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Observations	3359	3359	3359	3359	3359	3359	3359	3359
R^2	0.117	0.120	0.120	0.125	0.295	0.296	0.299	0.304
Adjusted R^2	0.011	0.014	0.014	0.019	0.210	0.211	0.215	0.220
F statistic	35.967***	31.333***	29.232***	28.585***	113.823***	97.031***	91.394***	87.236***

Note: This table reports standardized coefficients; robust standard errors are in parentheses.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

In contrast, our results support the notion that stock markets pay greater attention to the breadth of a portfolio and do not value moderate levels of diversification, as we find a positive U-shaped effect of EIA breadth on VBP and no effect for EIA depth. In other words, investors seem to prefer either low or high diversification of EIA across different technology fields and tend to be skeptical with respect to a medium level of diversification. Although firms can profit from a medium level of EIA breadth, they should consider that investors evaluate performance frequently, and this medium level may initially increase investors' risk perception to the extent that the potential gains of a broad portfolio are neglected. However, when diversification reaches a high level, investors seem to appreciate the benefits resulting from an extensive diversification. Consequently, managers must be careful when diversifying their firm's EIA portfolio and be aware that even if firms profit from a medium level of EIA breadth, the market value could drop. Our research shows that although firms can partially benefit from knowledge outside their core technological areas, the drawbacks of such a diverse portfolio often surpass its advantages unless the firm can rely on a highly diverse portfolio.

If firms aim to diversify their EIAs across different technology fields to exploit the advantages, they should simultaneously build up deep knowledge stocks in the corresponding technology fields, as indicated by our finding of a positive interaction effect of EIA depth and EIA breadth for both performance outcomes. However, we suggest firms should expand gradually so that they can develop deep knowledge stocks in the new technology fields. That way, they can leverage the advantages of EIA breadth and depth simultaneously and consequently increase both ABP and VBP. The advantages of a deep knowledge stock in the various technology fields seem to offset the risks of a broad EIA portfolio, especially for investor perceptions. Having a deep EIA knowledge stock in various technology fields seems to increase investor trust that the firm can overcome difficulties resulting from broad portfolios and that its technological competencies are strong enough to exploit the advantages of a broad EIA portfolio.

6.3 | Limitations and Future Research

Although our study provides important implications for theory and practice, it is not without limitations. The analysis of EIA portfolio structures provides important insights into the successful management of ecological innovation. However, we analyzed the distribution of EIA in isolation, without considering the distribution of firms' other innovation assets. The effectiveness of EIA portfolios might be dependent on the optimal configuration of EIA and these other innovation assets. Future research should elaborate on this interplay in greater depth, along with potential contingency factors. In this context, further theoretical development is needed on the interconnections between ecological and regular innovation.

It is also important to note that we tested our hypotheses on a sample of large US firms, which limits the generalizability of our findings to other contexts. The firms we relied on operate in a specific regulatory and economic environment that may not apply to firms in other regions. For instance, investors in

TABLE 8 | Effects of EIA on winsorized accounting- and value-based performance.

	Dependent variable: ABP ($t+1$)				Dependent variable: VBP ($t+1$)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Control variables								
Prior financial performance	0.503*** (0.069)	0.494*** (0.069)	0.494*** (0.069)	0.481*** (0.070)	0.211*** (0.041)	0.206*** (0.041)	0.205*** (0.040)	0.193*** (0.040)
Firm size (log)	0.077 (0.044)	0.080 (0.044)	0.078 (0.044)	0.070 (0.044)	0.120*** (0.031)	0.121*** (0.031)	0.125*** (0.030)	0.118*** (0.030)
R&D intensity	0.003 (0.002)	0.003 (0.002)	0.003 (0.002)	0.003 (0.002)	0.001 (0.002)	0.001 (0.002)	0.0004 (0.002)	0.0001 (0.002)
Leverage	−0.004 (0.015)	−0.005 (0.015)	−0.005 (0.015)	−0.006 (0.015)	0.016 (0.010)	0.015 (0.010)	0.014 (0.010)	0.013 (0.010)
Capital intensity	−0.068*** (0.020)	−0.069*** (0.020)	−0.069*** (0.020)	−0.069*** (0.020)	0.0004 (0.008)	0.0001 (0.008)	0.0002 (0.008)	−0.0002 (0.008)
Competitive intensity	−0.056* (0.028)	−0.057* (0.028)	−0.059* (0.028)	−0.062* (0.028)	−0.015 (0.019)	−0.015 (0.019)	−0.011 (0.019)	−0.013 (0.019)
Market turbulence	0.026 (0.016)	0.024 (0.016)	0.024 (0.016)	0.027 (0.016)	0.037** (0.012)	0.035** (0.012)	0.035** (0.012)	0.038** (0.012)
Regular innovation assets	0.080 (0.103)	0.074 (0.100)	0.079 (0.100)	0.048 (0.097)	0.145 (0.103)	0.142 (0.101)	0.129 (0.100)	0.100 (0.098)
Regular innovation scope	−0.138 (0.079)	−0.097 (0.079)	−0.075 (0.082)	−0.075 (0.081)	0.328*** (0.064)	0.345*** (0.065)	0.289*** (0.063)	0.288*** (0.061)
EIA total	−0.159* (0.072)	−0.210** (0.074)	−0.210** (0.074)	−0.344*** (0.099)	−0.078 (0.041)	−0.108** (0.041)	−0.109** (0.041)	−0.235*** (0.048)
EIA relative	0.006 (0.009)	−0.002 (0.010)	−0.003 (0.010)	0.004 (0.010)	0.005 (0.004)	−0.002 (0.006)	−0.001 (0.006)	0.005 (0.006)
Independent variables								
EIA depth		0.099** (0.034)	0.092** (0.035)	0.107** (0.037)		0.060* (0.025)	0.077** (0.026)	0.091*** (0.025)
EIA breadth		−0.041 (0.025)	0.008 (0.050)	0.068 (0.053)		−0.014 (0.017)	−0.139*** (0.034)	−0.083* (0.034)

(Continues)

TABLE 8 | (Continued)

	Dependent variable: ABP ($t+1$)				Dependent variable: VBP ($t+1$)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EIA breadth^2			−0.065 (0.072)	−0.079 (0.072)			0.164*** (0.046)	0.151*** (0.045)
Interaction effect								
EIA depth × EIA breadth				0.154** (0.060)				0.144*** (0.031)
Wald-χ^2	569.75	585.51	586.58	605.61	649.77	662.92	684.54	729.75
Observations	3400	3400	3400	3400	3400	3400	3400	3400
R^2	0.158	0.162	0.162	0.166	0.176	0.179	0.184	0.194
Adjusted R^2	0.058	0.062	0.062	0.067	0.079	0.082	0.087	0.097
F statistic	51.796***	45.039***	41.899***	40.375***	59.070***	50.994***	48.896***	48.650***

Note: This table reports standardized coefficients; robust standard errors are in parentheses.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

TABLE 9 | 2SLS IV regression of the effects of EIA depth and breadth on accounting- and value-based performance.

	Dependent variable: ABP ($t+1$)	Dependent variable: VBP ($t+1$)
	(1)	(2)
Control variables		
Prior financial performance	0.747*** (0.078)	0.468*** (0.076)
Firm size (log)	−0.033 (0.044)	0.120* (0.048)
R&D intensity	0.002 (0.002)	−0.003 (0.002)
Leverage	0.013 (0.015)	0.032** (0.013)
Capital intensity	−0.079* (0.032)	0.038** (0.014)
Competitive intensity	−0.027 (0.028)	−0.007 (0.023)
Market turbulence	0.015 (0.014)	0.007 (0.012)
Regular innovation assets	0.067 (0.083)	0.264 (0.161)
Regular innovation scope	0.052 (0.088)	0.612*** (0.136)
EIA total	−0.292*** (0.089)	−0.232*** (0.059)
EIA relative	0.002 (0.010)	0.016* (0.006)
Independent variables		
EIA depth	0.095** (0.035)	0.064 (0.033)
EIA breadth	0.185*** (0.055)	−0.112* (0.051)
EIA breadth^2	−0.232** (0.072)	0.133* (0.065)
Interaction effect		
EIA depth x EIA breadth	0.150** (0.051)	0.151*** (0.043)
Wald-χ^2	1296.94	1769.45
Observations	3400	3400
R^2	0.299	0.368
Adjusted R^2	0.216	0.293
F statistic	1296.947***	1769.457***

Note: This table reports standardized coefficients; robust standard errors are in parentheses.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

other regions might react differently to certain portfolio structures. Moreover, large firms usually have access to substantial resources, which allows for different strategic approaches than those of smaller firms. Their complex organizational structures further differentiate them from smaller firms, potentially leading to different strategic decisions. Future studies should investigate whether the effects of EIA depth and breadth vary in

other regions or in the context of smaller firms such as small and medium-sized enterprises.

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Conflicts of Interest

The authors declare no conflicts of interest.

Endnotes

[1] www.patentsview.org

[2] For robustness, we also estimated random-effects models for both outcome variables and compared the results with those of the fixed-effects regression. The random-effects models showed the same significant effects as the fixed-effects models, with coefficients that were consistent in magnitude and direction. This supports the stability of our fixed-effects estimates.

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