AUTHOR'S ACCEPTED MANUSCRIPT

EXPLORING THE INTERPLAY BETWEEN INTELLECTUAL PROPERTY MODELS AND SUSTAINABILITY TRANSITIONS: A MULTI-LEVEL ANALYSIS

Akriti Jain[a], Anjula Gurtoo[b], Elizabeth Eppinger[c], Pratheeba Vimalnath[d], Frank Tietze[e]

[a] International Management Institute – New Delhi, India

[b] Indian Institute of Science-Bangalore, India

[c] University of Applied Sciences (HTW), Berlin

[d] University of Exeter, United Kingdom

[e] University of Cambridge, United Kingdom

DOI: 10.1002/bse.3851

To appear in: Business Strategy and The Environment

CORRESPONDING AUTHOR'S DETAILS:

Akriti Jain, Assistant Professor - Strategy & General Management Area, International Management Institute – New Delhi, India 110016. Email: akriti.jain@imi.edu

ACKNOWLEDGEMENTS

We gratefully acknowledge all valuable discussions on the topic among the team members of the project "Intellectual Models for Accelerating Sustainability Transitions (IPACST)".

For the purpose of open access, the author has applied a 'Creative Commons Attribution (CC BY) licence to any Author Accepted Manuscript version arising.

EXPLORING THE INTERPLAY BETWEEN INTELLECTUAL PROPERTY MODELS AND SUSTAINABILITY TRANSITIONS: A MULTI-LEVEL ANALYSIS

Abstract

Research on international technology transfer and partnership agreements provides a comprehensive understanding of country-level impacts of intellectual property (IP) rights on sustainability transitions. However, firm-level studies on how firms use and share their IP to support sustainability practices remains limited. The paper disentangles the relationship between firm-level IP models and sustainability practices drawing from a cross-case analysis of 28 firms offering sustainable innovations across four sectors. Analysis of firms' year-wise data collected from 854 documents (typically 1996-2021) and 58 in-depth interviews exploring linkage between IP models and sustainability practices of firms engaged in sustainable innovation provide six key findings (1) emphasis on safeguarding registered and unregistered IP assets among firms with sustainable innovations (2) widespread adoption of selectively open inbound IP models coupled with diverse IP sharing mechanisms (3) a preference for collaborative (joint) IP ownership among internally driven firms, contrasting with a tendency for exclusive in-licensing among those reacting to external pressures (4) a divergence in outbound IP models, with internally motivated firms favouring selectively open approaches and externally driven firms favoring closed IP models; (5) the adoption of fully open outbound IP models democratize sustainable innovation diffusion; (6) leveraging broadly open outbound IP models alongside closed or selectively open models balances widespread use with access control and achieves significant social sustainability. A framework is hence developed to guide technology-sharing policies and procedures. Thereby, the paper creates a platform for prescribing sustainable IP incentives for encouraging firms to share IP for wider diffusion of sustainable innovations.

Keywords

Sustainability practices; Sustainability Transition; Intellectual Property; Sustainability impact; Sustainable technology diffusion; Green Innovations

1. Introduction

Organizations worldwide are aligning their strategies and business models with the 2030 Sustainable Development Goals (SDGs) agenda to address sustainability transition (Denoncourt, 2020; Song and Yu, 2018). Sustainability transition involves long-term, co-evolutionary changes shifting production-consumption and governance subsystems from unsustainable to sustainable practices, fundamentally transforming sociotechnical systems (Bolton and Hannon, 2016; Geels, 2005; Sarasini and Linder, 2018). The transition emphases developing sustainable technologies, products, and services, focusing on circularity, decarbonization, renewable resource utilization, and inclusive work conditions (e.g., Barbieri et al., 2016; van der Waal et al., 2021).

Given the relevance of intellectual property (IP) in innovation systems and processes, and intellectual property rights (IPR) in turning inventions into tradeable assets, sustainability practices involve complex and intertwined IP-related issues. Open innovation literature has extensively explored the interplay between IP protection, innovation diffusion, and economic advancement (e.g. Manzini and Lazzarotti, 2016; Telg et al., 2023), majorly focusing on firm-level economic implications of IPRs and IP openness ((Lichtenthaler, 2010, 2008; van de Vrande et al., 2009; Vanhaverbeke et al., 2008).

The literature suggests IP protection and different degrees and modes of IP openness to facilitate innovation while providing IP owners control over its fair use and exploitation (Freel and Robson, 2017; Henkel, 2006). The literature suggests that firms prioritize inbound open innovation and often engage in intensive collaborative processes like co-designing innovation (Enkel et al., 2009; Freel and Robson, 2017). However, in the context of firms pursuing sustainable innovation and undergoing sustainability transition (involving social and environmental sustainability), the discourse remains largely nascent (Cabigiosu, 2022; Camilleri et al., 2023; Lippolis et al., 2023). While the economic implications of IPRs for open innovation have been extensively studied, the intersection with sustainable innovation development and diffusion, and sustainability transition at large remains insufficiently explored, at the firm-level but also at the industry and ecosystem level (Ockwell et al., 2010). Research focusing on the financial impacts of IP models and open innovation at the firm level ((Chesbrough and Bogers, 2014; Davari et al., 2019) needs to be complemented by an analysis of the industry and ecosystem-level effects on environmental and social sustainability associated with IP models ((West et al., 2014).

Debates surrounding IPRs in the context of sustainability transition are multifaceted (Eppinger et al., 2021). Opponents warn about IPRs preventing follow-on development and the diffusion of sustainable innovation due to monopolistic tendencies (Kanger et al., 2022; Raiser et al., 2017; Schomberg and Hankins, 2019). Proponents argue for IPRs incentivizing the development of green and environmental innovation, emphasizing the role of international technology transfer (Rai et al., 2014). However, ongoing debate within the literature on the impact of patents and other IPRs on innovation (Bessen and Meurer, 2008; Jaffe and

Lerner, 2006), patent thickets (Shapiro, 2000), and the access problems (Heller, 1998) lack consensus, highlighting the complex relationship between IP and sustainability.

To bridge the gap, the paper aims to comprehensively understand the linkages between IP models and sustainability transitions beyond traditional firm-level analysis. Sustainability transitions involve collaborative and systemic efforts across various actors, industries, and regions. Thus, our study seeks to contextualize IP models within the broader framework, recognizing their role in shaping firm-level, industry-level, and cross-industry sustainability transition practices. While previous research mainly addresses firm-level dynamics (Patil et al., 2020; Roh et al., 2021; Vimalnath et al., 2022), our study broadens the perspective to include industry and cross-industry dynamics of IP and sustainability. Specifically, by examining how firms integrate different IP models into their sustainability practices, we show the IP sharing mechanisms employed to promote the advancement of sustainable innovation throughout the innovation ecosystem.

In the paper, we ask the following questions: What types of inbound and outbound IP models do sustainable innovation firms adopt to support practices to bring sustainability transitions at firm-level, industry-level, and cross-industry levels? We define "sustainable innovation firms" as firms integrating sustainable business models (Bocken et al., 2014), offering environmentally or socially focused solutions as core value propositions. These firms can be either "born sustainable" (started with a sustainability mission focused on environmental or social solutions) or 'turned sustainable' (established firms which have gradually altered their value propositions towards sustainable "alternatives"). The term "IP model" refers to how firms manage ownership, access, and usage rights of relevant IP assets, encompassing both formal and informal IP (Vimalnath et al., 2020). The inbound and outbound degree of IP openness varies among these firms, ranging from closed to fully open IP models.

Sustainability initiatives are vital for mitigating the adverse impacts of firm activities on the environment and society (Arora et al., 2020; Thun and Zülch, 2023). Given the intertwining of sustainable technologies and business models with knowledge dissemination, selecting suitable IP models with varying degrees of openness becomes crucial for accelerating global innovation. The choice becomes particularly vital for sustainability transitions, which often require collaborative efforts across industries and countries (Chambers et al., 2013). Examples exist where firms leverage IP rights for the development and dissemination of sustainable technologies, supporting sustainability transitions. For instance, Tesla's pledge of electric vehicle patents (Rimmer, 2018); Nutriset practising differentiated licensing for IP sharing with the local community (Tietze et al., 2017); Tata Chemicals' patent openness for social sustainability in the food industry ((Eppinger et al., 2021; Jain and Gurtoo, 2021), and Coca-Cola's release of PlantBottle Technology IP to promote a circular economy (Patil et al., 2020), exemplify the strategic deployment of IP models in advancing sustainability goals.

Using a multi-case study approach (Eisenhardt, 1989), triangulating data from 58 in-depth interviews and 854 documents from secondary sources (Yin, 1994), we analysed 28 sustainable innovation firms to explore the relationship between IP models and sustainability transition. Our cross-case analysis unfolds various degrees of inbound and outbound IP openness - closed, selectively open, broadly open, and fully open IP models - and examines their alignment with firms' sustainability practices for innovation development and diffusion to create sustainability impact.

The study contributes to the innovation and sustainability transition literature by offering evidence on the strategic management of IP models and unfolding levels of inbound and outbound IP openness in a sustainable innovation context. By exploring the interplay between IP models, open innovation, and sustainability, the paper provides valuable insights for firms seeking to integrate sustainability into their IP strategies and contribute to sustainability transitions at firm-level, industry-level, and cross-industry level.

The paper is structured as follows: Section 2 describes the conceptual framework and constructs used to analyse a firm's sustainability practices, sustainability impact and IP models. Section 3 explains the research design and methodology. Section 4 describes the findings of the within and cross-case analysis. Section 5 discusses the emergent framework of IP models for sustainability transitions, and Section 6 provides conclusions, limitations, and outlines scope for future research.

2. Conceptual background

Sustainability transition research spans diverse fields such as management, political science, technology, sociology, anthropology, geography, among others. Transition ranges from actor-level (Gorissen et al., 2016; Sarasini and Linder, 2018; Schaltegger and Wagner, 2011) to system-level analyses (Geels, 2005; Heyen and Wolff, 2019). We focus on four themes relevant to our study's theoretical background – firms' sustainability practices, sustainability impact, open innovation, and IP model typology.

2.1 Firms' sustainability practices

Scholarly literature suggests firms contribute to sustainability by undertaking internal practices such as formulating sustainability mission (Jacobsen et al., 2020; Santa-Maria et al., 2021). These actions may mature to benefit external stakeholders, impacting industries and sectors (Dahlander et al., 2021; Delgado-Verde et al., 2014).

Jacobsson et al. (2020) proposed a typology categorizing firms' sustainability practices into inspiring and informing, productizing, co-creating, and system building. While the typology offers a helpful classification of firms' sustainability practices, certain limitations exist. First, the typology assumes firm practices drive change unilaterally, overlooking the bidirectional interaction with the environment (Stål et al., 2023). Second, the typology portrays a linear progression from "inspiring and informing" to "system building," neglecting the non-exclusivity of practices, and thus simultaneous engagement in multiple practices and categories (Sarasini and Linder, 2018).

In view of overcoming the above limitations and drawing from prior work (Schaltegger and Wagner, 2011), we categorize firm sustainability practices into two inclusive themes: (a) internal sustainability transition and (b) external sustainability transition. Each theme gets briefly outlined with literature references of key practices in **Figure 1**.

2.1.1.Firm's sustainability practices for internal sustainability transitions

Firms engage in sustainability practices through various initiatives like visioning strategic direction and broadening the scope of firm's activities towards sustainability (Chang et al., 2017; Foxon et al., 2015; Loorbach, 2010), leading to internal firm-level transitions. Sustainability practices for internal transition range from shop-floor bolt-in measures like installation of the pollution control, emission reduction device (Kanda et al., 2020; Parris and Kates, 2003) to policies, reporting, and corporate transformations ((Heyen and Wolff, 2019; Martek et al., 2019) through re-purposing, re-visioning and re-branding (Dyllick and Muff, 2016), similar to those of 'ecopreneurs' (Schaltegger and Wagner, 2011). Sustainability practices bringing firm-level changes enhance the firm's reputation and enterprise value (Chen et al., 2023; Hao et al., 2022).

Firms bringing internal sustainability transition may undertake sustainability practices with internal firm-level catalysts (drivers) (Hart, 1995; Chen et al., 2023; Jacobsen et al., 2020) or external sector-level catalyst (Arvidsson and Dumay, 2022; Hofman et al., 2020; Kobos et al., 2018; Kotzian, 2023). Internal catalysts include CEO's vision and commitment, and professional initiatives (Demirel and Kesidou, 2019; Thun and Zülch, 2023; Wang et al., 2022), initiating proactive sustainability practices through hiring, training, and aligning activities with SDGs (Jacobson et al., 2020; Demirel and Kesidou, 2019).

Conversely, firms undertake sustainability practices responding to external pressures such as, banning or limiting the use of specific harmful materials, or sector-specific regulations (Aghion et al., 2016; Bolton and Hannon, 2016; Frantzeskaki and Loorbach, 2010; Stern and Valero, 2021), and institutional changes like standards (Farla et al., 2010; Kohler et al., 2017), and societal shifts (Dyllick and Muff, 2016; Heyen and Wolff, 2019; Kohler et al., 2017; Xie et al., 2021; Hofman et al., 2020).

2.1.2. Firm's sustainability practices for external sustainability transitions

In exploring external sustainability transitions, literature emphasizes firm's practices driving industry-level or broader societal change (Schaltegger and Wagner, 2011). The literature shows such practices can influence sustainability practices of other actors within the same sector (Kemp, 1994; Markard and Truffer, 2008; Elkinjton, 1998) or even extend beyond to influence actors in other sectors (Bourgeois and Mima, 2003; Kohler et al., 2017; Loorbach, 2010; Schaltegger and Wagner, 2011). For instance, firms collaborate with stakeholders, advocate for sustainability standards (Jacobsen et al., 2020; Klein Woolthuis et al., 2013); Markard and Truffer, 2008; Farla et al., 2012), and form coalitions, fostering collective action within sectors through network formation and awareness campaigns ((Abraham-Dukuma, 2021; Martek et al., 2019).

Alongside, firms' sustainability practices like collaboration for market expansion through vertical or horizontal integration (Andersen and Gulbrandsen, 2020); Dyllick and Muff, 2016; Kohler et al., 2017) can influence practices in other sectors, driving cross-industry transformations (Dahlander et al., 2021; Delgado-Verde et al., 2014). Vertical integration enables a company to mobilize sustainability in multiple sectors by promoting upcycling, recycling, or other initiatives across supply chains, increasing the outreach and impact (Dyllick and Muff, 2016).

2.2 Sustainability impact

Sustainability impact refers to an organization's economic, environmental, and social effects: positive, negative, short-term, long-term, actual, potential, direct, and indirect ("G4 Sustainability Reporting Guidelines – Reporting Principles and Standard Disclosures | RESPECT," 2013). The Global Reporting Initiative (GRI) framework is widely accepted for Environmental, Social, Governance (ESG) reporting. The framework measures the sustainability impact of firms based on three pillars of sustainable development: environmental, social, and economic impacts (Thun and Zülch, 2023; Willis, 2003) ***Environment impact*** refers to the local and global environmental impact through resource use (Cavanagh et al., 2006), emission reduction (Azapagic, 2004; Azapagic and Perdan, 2000), waste management, reduce-reuse-recycle (Broniewicz, 2011), product and process efficiency, and voluntary actions to minimize the negative impact on the environment (Jain and Gurtoo, 2019). ***Social impact*** is when organizations' labour practices ensure employees' health, safety, equity & growth ("G4 Sustainability Reporting Guidelines – Reporting Principles and Standard Disclosures | RESPECT," 2013), and includes stakeholder engagement, community partnerships, and societal well-being (Jain and Gurtoo, 2021). ***Economic impact*** indicators measure the contribution from sustainable technologies in the annual profit, sales and operating cost (concerning the base year) and profit re-invested in sustainable technologies (Hao et al., 2022; Therivel et al., 2009).

2.3 Inbound and outbound open innovation

Open innovation, leveraging external sources for idea generation and commercialization, has gathered significant scholarly attention and widespread adoption by firms (Chesbrough and Appleyard, 2007). Inbound open innovation taps into external knowledge for technology development (Parida et al., 2012), encompassing networking, collaboration, R&D contracting, licensing, and IP acquisition (Cassiman and Valentini, 2016). Open-source software integration gets recognized for open innovation as well (Dahlander et al., 2021; Laursen and Salter, 2014). Inbound open innovation offers cost savings, faster development, and innovation acceleration ((Chesbrough and Garman, 2009; Davari et al., 2019).

Outbound open innovation external commercialization argues for technology and R&D capabilities ((Parida et al., 2012), and includes practices like know-how sharing, R&D activity sales, and IP transactions to generate revenue (Lichtenthaler, 2009). The IP promotes complementary knowledge development, industry standardization, and market expansion for technology and products (Grindley and Teece, 1997; Masucci et al., 2020; West and Gallagher, 2006). Collaboration embodies both inbound and outbound open innovation, facilitating knowledge exchange among stakeholders (Bogers and West, 2012).

Practices of firms bringing internal sustainability transition

- Broadened value propositions
- Using sustainable technologies as experiments
- Changing value creation and value delivery mechanism
- Change in company's vision and strategic direction
- Bolt-in measures at the shopfloor (like installation of the pollution control device; waste reduction, resource use efficiency
- Accounting returns on investments of sustainability actions
- Making policies, code of conduct, reporting, auditing

Loorbach et al., 2009; Boltona & Hannon, 2016; Foxon et al., 2015; Chang et al., 2016; Kemp, 1994; Markard & Truffer, 2008; Martek et al., 2019; Heyen & Wolff, 2019; Dyllick & Hockerts, 2002; Gorissen, et al., 2016; Vrancken and Manshoven, 2016; Sarasini & Linder, 2018; Kanda et al, 2020

Practices of firms bringing external sustainability transition

- Collaborations & Network formation
- Advocacy, coalition, and lobbying,
- Product development partnerships
- Mentoring and inspiring other firms and actors for sustainability
- Agenda and ambition of the whole sector for green energy or other sustainable solutions
- Vertical integration
- Joint ventures

Elkinjton, 1998; Elshurafa et al., 2018; Elkinjton, 1998; Allan Dahl Andersen et al., 2019; Benjamin K. Sovacool, 2015; Chang et al., 2016; Schäpke, Niko et al., 2017

Internal catalysts (drivers) of sustainability practices

- Leader's or CEO's vision and commitment to prioritize sustainability
- Sustainability-oriented initiatives by key professionals within the organisation

(Chen et al., 2023; Hart, 1995; Jacobsen et al., 2020; Demirel and Kesidou, 2019; Thun and Zülch, 20230

External catalysts (drivers) of sustainability practices

- Policy & Regulatory factors
- System infrastructure change
- Social factors (consumption pattern, customer demand)
- Competition
- External stakeholders' pressure from NGOs, civil society organizations, institutional investors and media

Arvidsson and Dumay, 2022; Kobos et al., 2018; Kohler et al., 2017; Kotzian, 2023; Martek et al., 2019; Thun and Zülch, 2023

Firm's practices influencing other actors within-sector (industry)

- Inter-firm collaboration in the same industry
- Campaigning, networking and lobbying to support sustainability policies and regulations, developing new industry standards
- mentoring/ supporting new firms in the same sector

Kemp 1994, Markard & Truffer, 2008; Elkinjton, 1998

Firm's practices influencing other actors beyond its' own or across-sector (industry)

- Inter-industry/inter-sector collaboration
- Considering 'bottom of the pyramid' as important stakeholders
- Entering another sector through routes like mergers and acquisitions, strategic partnerships and marketing alliances

Bourgeois and Mima; 2003; Köhler et al., 2019; Loorbach et al., 2009; (Schaltegger and Wagner, 2011

Figure 1. Conceptual framework of firm-level practices sustainability transition pathways *(Source: Developed by authors based on the literature)*

2.4 IP protection and degrees of openness in IP sharing: IP models typology

Firms protect their innovations through a variety of IP assets, including formal IP assets like patents, and trademarks and informal methods such as secrecy, confidential agreements, and lead time (Hall et al., 2014). Firms often rely on informal IP assets as much as they do on patents and trademarks for innovation protection (Levin et al., 1987; Stefan and Bengtsson, 2017).

We adopt (Vimalnath et al., 2020 & 2022) typology of IP models to provide a nuanced understanding of IP strategies. The framework outlines various degrees of IP openness regarding ownership, access, and commercial usage sharing across different formal and informal IP assets. These IP models apply to both inbound IP strategies - involving IP portfolio generation (inflow of IP), and outbound IP strategies - involving utilizing and leveraging IP assets, i.e., outflow of IP (Tang and Tietze, 2021).

These IP models are: (i) ***Closed IP model:*** completely restricts licensing of formal and informal IP assets for commercial exploitation, exemplified by trade secrets, like Coca cola (Prendergrast, 1993) and KFC's ((Crittenden et al., 2015; Hannah, 2005). Closed IP also includes broad patents, if not shared (Cugno and Ottoz, 2006; Klemperer, 1990), evergreening in pharmaceuticals (Granstrand and Tietze, 2015) and patent thickets (Blind et al., 2009; Shapiro, 2000). Broad patents are designed to prevent not only imitation, but also the filing of patents in related areas. In some sectors like ICT, they may form the basis for industrial standards and widespread licensing. However, in various cases, these patents are not shared and remain exclusive to their owners (Cugno & Ottoz, 2006). Another closed IP strategy creates patent thickets or walls, comprising patents not intended for use but utilized to obstruct competitors from introducing similar products. The closed inbound IP model includes IP generation via in-house R&D and IP acquisition or purchase (Hagedoorn and Wang, 2012). (ii) ***Semi-open type 1 IP model*** [referred to hereafter as ***selectively open IP model***]: involves restricted sharing of certain parts of the IP portfolio with selected actors (Granstrand, 2004). Examples are: exclusive and non-exclusive out-licensing (Beyer, 2013; Liddicoat, 2017), cross-licensing (Shapiro, 2000), and closed patent pools (van Etten 2007) (iii) ***Semi-open type 2 IP model*** [referred to hereafter as ***broadly open IP model***]: provides IP access to a wider audience, typically without monetary charges but with other non-monetary restrictions, common in the software industry (Bissell, 2009; Lindberg, 2008; Wen et al., 2016). Examples are the open-source model for Linux operating system development (West and Gallagher, 2006), royalty-free licensing, open patent pools (Ziegler et al., 2014) and patent pledges (Contreras, 2015) under fair, reasonable, and non-discriminatory (FRAND) licenses. (iv) ***Fully open IP model:*** lacks any ownership, usage, and access restrictions. Examples are expired IP rights, trade secrets if leaked, defensive publishing by filing patents or publishing in journals, knowledge repositories and reports, and publishing off-copyright media (e.g., Project Gutenberg). The model can be both inbound and outbound.

The IP models are not mutually exclusive, as firms often adopt more than one IP model at the same time for different innovations (Vimalnath et al., 2020 & 2022). IBM pledged several of software patents on a royalty free basis (Cozzi and Galli, 2014) but continued to generate revenues through royalty fees from other patents licensed for fees (Arora & Fosfuri, 2003) or the same patents from actors not from the open-source community. Initiatives like Eco-patent common (Contreras et al., 2019; Hall and Helmers, 2011) and WIPO green ("WIPO Green," 2019) embrace one or more of these IP model types, specifically focusing on sustainability.

2.5. Linkage of sustainability practices with open innovation and IP typology

To support sustainability transition, firms leverage both: formal IP assets (such as patents and trademark) and informal IP assets (such as trade secrets, data) incentivizing innovation and technology transfer (Rai et al., 2014). Sustainability practices at the firm-level, like repurposing, re-visioning, re-branding, and using sustainable materials often involve the development of green innovations. Protecting these innovations through IPRs allows firms to capitalise on their sustainability efforts, maintain competitive edge, and encourage further investments in green innovations. However, development of sustainable innovations often requires access to complementary knowledge from external sources ((Masucci et al., 2020), prompting firms to adopt IP sharing through exclusive or non-exclusive in-licensing and out-licensing, or participation in IP consortium, and other sharing mechanisms.

Sustainability practices, both at the industry and cross-industry levels, often necessitate inbound and outbound open innovation, involving the sharing of IP related to sustainable innovations ((Melander, 2018). Forming alliances and partnerships and sharing knowledge and technologies enable firms to promote sustainability practices throughout the supply chain and expand the reach and impact of sustainable innovations across sectors (Halme and Korpela, 2014). Sustainability practices thus offer opportunities for both protecting and sharing sustainability innovations. Through mechanisms like IP protection and collaboration, firms can drive internal and external sustainability transitions, ensuring ongoing development and dissemination of sustainable technologies and solutions.

The literature offers limited insight into the relationship between inbound and outbound IP models and firms' sustainability practices for sustainability transition (Cassiman and Valentini, 2016; Denoncourt, 2020). Understanding firms' adoption of these models based on their IP openness for sustainability practices remains inadequate. Roh et al. (2021) highlight the significant influence of a firm's IP protection on inbound open innovation and green product and process innovation among South Korean manufacturing firms. A bibliometric review underscores the importance of exploring "open eco-innovation" and calls for a comprehensive multi-level analysis of the interconnectedness of open innovation, IP sharing, and green innovation. Our study addresses the need by investigating how firms integrate various inbound and outbound IP models into their open innovation and sustainability practices, elucidating the IP sharing mechanisms facilitating the development and diffusion of sustainable innovation.

3 Material and methods

The study adopts a comparative, multiple-case study approach (Yin, 2012), aiming to explore commonalities and differences between case studies (**Figure 2**). The approach follows replication logic, treating each case as a separate experiment to validate or challenge evidence from others (Eisenhardt, 1989). By utilizing the case study method, the research enables a thorough exploration of context-specific factors, processes, and outcomes (Gerring, 2004), a methodology used in prior research on innovation management (Rosenbloom, 2000).

3.1. Case Identification and selection

The study focused on sustainable innovation firms, ensuring the relevance and applicability of its findings to sustainable innovations. Guided by specific criteria, such as (a) receiving sustainability-related recognition, (b) owning IP assets, and (c) adopting sustainable business models, we selected over 40 companies for the study. An advisory committee of experts validated these criteria. Out of over 40 shortlisted firms, 28 agreed to participate, ensuring the study's quality and relevance.

3.2. Data collection

Three interdisciplinary research teams, each with extensive experience in IP, sustainability, and business models, executed the data collection process. Their expertise ensured the credibility and reliability of the study's findings. Spanning from March 2020 to March 2022, primary and secondary data were gathered from 854 documents (typically spanning 1996-2021), alongside conducting 58 in-depth interviews across the 28 case study firms. Protocols and visual templates for data collection were developed from December 2019 to February 2020 to longitudinally capture information on firms' IP, sustainability impact, and business models. Annexure A, Table A.1 describes the data sources for 28 case studies, including their founding periods and analysis periods.

To address potential biases in firms' self-reported sustainability activities (Arvidsson and Dumay, 2022; Jacobsen et al., 2020), and to enhance internal validity a rigorous multi-step data collection approach was employed (Giorgi, 2002; Golafshani, 2015). As the first step, cross-referencing primary interview data with secondary archival sources developed comprehensive case histories for each firm. For instance, archival data provided year-wise records of environmental, social, and economic sustainability changes, enabling comparison with executives' interview narratives regarding sustainability priorities, motivations, and focus areas. Distinguishing between intended and realized sustainability impacts and focusing solely on supported facts ensured accuracy. Triangulating data sources—such as expert feedback, observation, archival records, and existing literature—enhances the validity and reliability of the findings (Eisenhardt, 1989). The approach also mitigates challenges like limited generalizability and bias inherent in interview-based case studies. The data collection process is detailed below.

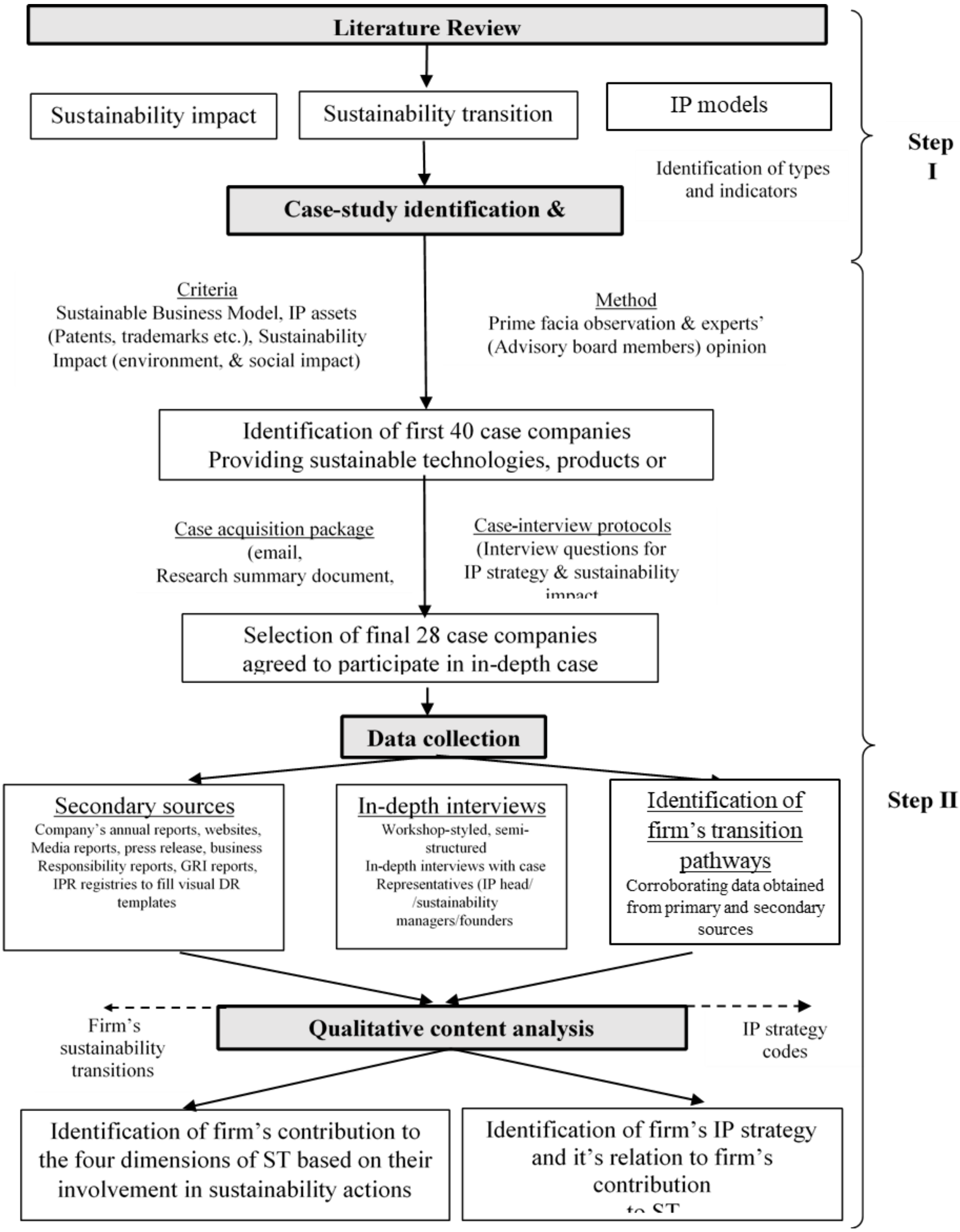


Figure 2. Flow chart of methodology (Source: developed by authors)

Step 1: Secondary sources

We collected comprehensive year-wise data covering (a) business profile, including sustainable technology launches, leadership changes, and contextual conditions; (b) IP strategy, encompassing essential IP assets and sharing mechanisms; (c) Sustainability impact across environmental, social, and economic domains, along with associated practices. IP data sources included company websites, official IP databases, news articles, media reports, press releases, and interviews with IP heads or chief technology officers. Sustainability data was gathered from annual performance reports, sustainability reports, CSR reports, and GRI reports. A total of over 854 documents were screened during desk data collection, enabling the completion of visual templates before proceeding to subsequent steps.

Step 2: Interactive workshop-styled in-depth case interviews

Semi-structured interviews, totalling 58 sessions across 28 companies, were conducted in a workshop-style format with top management. These interviews, lasting an average of 2 hours each, covered the following aspects.

IP interviews with IP and R&D heads/managers focused on crucial IP assets, challenges in accessing external sustainable technology, IP sharing strategies, and the impact of leadership changes on IP strategy.

Sustainability interviews with founders or managing directors covered long-term sustainability visions, motivations, challenges, and key practices for creating environmental, social, or economic impact.

Linkage interviews aimed to understand the relationship between IP and sustainability, exploring instances were IP either supported or hindered sustainability efforts.

3.3. Case description

The 28 case firms span four sectors[1]: manufacturing, transportation, waste management, and electricity, reflecting diverse industries. They are committed to the United Nations Sustainable Development Goals for 2030. **Figure 3** depicts the number, size (per European Union definition), and distribution of these companies across sectors and sub-sectors.

[1] https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf

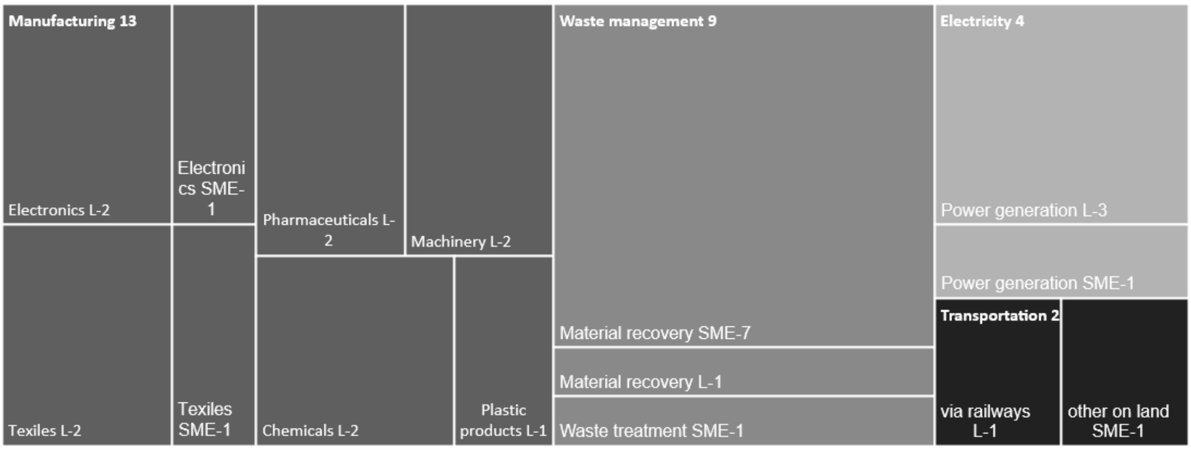


Figure 3 Number and size of case companies per sector and sub-sector

Selected companies' headquarters are located across various countries, including Australia, Denmark, Germany, India, Luxembourg, Spain, Sweden, Hungary, Italy, France, Switzerland, the Netherlands, the UK, and the USA. Their manufacturing and marketing operations extend globally, covering regions like Asia, Africa, North America, and South America. **Figure 4** illustrates the global distribution of case companies' headquarters.

Figure 4 Global distribution of case company's headquarters

3.4 Data analysis

We conducted text-based qualitative content analysis (Hsieh and Shannon, 2005) using nVIVO software. The use of software allows systematic recording, sharing, and cross-verification of notes, annotations, and codes among multidisciplinary teams (Ehrnsperger, 2019). This facilitated inter-coder reliability checks. Inductive and deductive approaches were employed to develop categorization schemes for firms' IP strategies, sustainability practices, and impact (refer to Annexure B). Using existing theoretical concepts as the main codes increased categorization reliability (Seuring and Gold, 2012).

Three research teams analysed 6-10 cases each through within- and cross-case analysis, ensuring inter-coder reliability by cross-verifying coded excerpts (Flick et al., 2004; Mayring, 2007). Using both deductive and inductive coding schemes, they iteratively generated and categorized codes, enhancing the coding system's reliability and internal validity (Seuring and Gold, 2012).

The exploratory analysis aimed to uncover correlations between IP models and sustainability practices, examining common patterns across cases. These findings were reviewed by the advisory board to ensure an impartial perspective. Annexure C, table C.1 describes the 28 case studies along with their IP models and allocation to dimensions of sustainability practices.

4. Results

Cross-case analysis identifies firms prioritizing firm-level sustainability due to internal or external drivers and firms focusing on external sustainability practices affecting within- and cross-sector transitions. Among the twenty-eight case-study firms, four cases prioritize firm-level sustainability due to internal leadership, and seven due to external factors (e.g., C#2, C#14, C#16).

Twenty-one cases prioritize external sustainability, nine of which extend sustainability across industries. Fifteen cases engage in both internal and external sustainability practices, including reduce-reuse-recycle, renewable material use, and exceeding compliance in environmental efforts. Some undertake advocacy for industry-wide transformations, reducing cost (e.g., C#2, C#7, C#14, and C#20), shaping new sustainable technology standard (C#1, C#6, C#7, C#19, and C #27), while others bring societal transformations through inter-industry innovation collaboration, and vertical/horizontal integration.

Additionally, most firms adopt a combination of various IP models. The cross-case analysis revealed several critical observations regarding the relationship between firms' IP strategies and sustainability practices:

1. All case-study firms with sustainable innovations and practices prioritize protecting and owning both formally registered and informally unregistered IP assets.

2. All case-study firms commonly adopt a selectively open-inbound IP model, employing various IP sharing mechanisms for sustainable innovations development.
3. Internally driven firms prioritize collaborative IP ownership over sole exclusivity during sustainable innovation development, while those responding to external pressures often combine internal R&D with IP acquisition, exclusive in-licensing, valuing exclusivity during collaboration.
4. Regarding sustainable innovation diffusion, internally motivated firms favour selectively open outbound IP models, employing out-licensing, cross-licensing, and know-how out-sharing, while externally driven firms opt for closed outbound IP models.
5. Four case-study firms among those bringing within- and cross-industry sustainability embrace fully open outbound IP models, democratizing the sustainable innovation diffusion, inspiring others to pursue sustainability.
6. Two case-study firms among firms bringing within- and cross-industry sustainability utilize broadly open outbound IP models alongside closed or selectively open models, balancing widespread use with access control for broader social sustainability.

4.1 Protection and ownership of formal-registered and informal-unregistered IP assets by sustainable innovation firms

In our study, all twenty-eight case-study firms bringing internal and external sustainability transition emphasize the importance of protecting and owning one or more formal-registered or unregistered and informal-unregistered IP assets (see **Figure 5**). Due to substantial investments in R&D and prototype development, firms consider IP asset protection and ownership of new components, designs, and methods as crucial.

All firms possess multiple formally registered IP assets, predominantly patents and trademarks. Ten firms further safeguard design rights through formal registration, particularly in industrial product and waste management, equipment manufacturing, textile, pharmaceuticals, and electrical vehicles. For example, C#20 designed new components and built prototypes of zero-emission EV buses, testing them on different terrain, protected by registered process and product patents, trademarks, and design rights. Formal IP protection safeguards competitive advantage in sustainable technologies and allows owners to control how their IP assets are used for sustainability.

Some firms prioritize transparency, and openness in their process innovations -such as plastic and textiles recycling processes and delivering affordable renewable energy solutions to tribal populations - do not own any formally registered IP except trademark registration. It includes C#13, that despite operating in a high patent propensity sector, i.e. consumer electronics, rely solely on trademark registration or refrain from formal IP protection. They emphasize process innovation and reject closed-door IP conversations.

Formal IP assets generated/owned by case study firms		**Informal IP assets considered as important and generated/owned by case study firms**	
Trademarks	27* cases	Unprotected tacit knowledge (technological know-how, product & process know-how, market information, financial models, design & business know-how)	23 cases
Patents	21 cases		
Copyrights	10 cases		
Design rights	9 cases	Trade-secrets to protect to protect algorithm, data, industrial know-how, product & process, formulas	13 cases
Utility model	3 cases		
Domain name	2 cases	Domain name	3 cases
Geographical indications	1 cases		

* One case company data missing (CS#26)

Figure 5. Formal and informal IP assets owned and protected by case study firm

Senior advisor of C#15 mentioned, *"IP in terms of strategies, tactics..., we don't use. [..] so many people (manufacturers) come to us saying they want to test out their technology in specific settings, and some of them have extreme IP restrictions and contract signing. We generally tend to reject much closed-door types of IP conversations. [..]" (CS#15, Senior Advisor).*

Despite differences, all firms recognize the importance of safeguarding product and process know-how, as informal IP assets, safeguarded through internal processes and systems, often preserved as trade secrets. the managing director of C#27 emphasizes the competitive advantage of maintaining know-how as a trade secret and mentioned "*maintaining industrial know-how as a trade secret offers a longer duration of protection, unlike patents that provide protection only for a limited period. Longer duration of protection promotes sustainability when the company tailors its efforts to support local industry development within its sector and hence protect the local players from competition from foreign players through prolonged competitive advantage offered by trade secrecy. [..] For all the R&D on the product, we make a choice not to file new patents for a reason again. And the only patents, we file right now is concerned [with] the industrial process and on the northern countries always to protect all partners in the field from competition from other countries." (C#27,* Managing Director*).*

In summary, while some firms opt for trademark registration and prioritize transparency in innovation, others rely on a combination of formally registered IP and trade secrecy to protect their innovations and sustain their competitive edge.

4.2. IP models for internal firm-level sustainability practices

Figure 6 and Figure 7 present the IP models adopted by case study firms prioritizing firm-level sustainability driven by internal and external catalysts respectively.

4.2.1 Selectively open inbound IP model with different sharing mechanisms by internally vs externally driven firms for sustainability

Case-study firms engaging in firm-level sustainability favour a selectively open inbound IP model. Ownership and protection of formal and informal IP assets do not hinder inbound IP openness; they instead facilitate operational freedom and security during open innovation process. For instance, C#20, an EV bus manufacturer highlights smooth access to sustainable components from suppliers despite IP restrictions: *"…the suppliers are very much part of the entire product development cycle, [..] In some cases, the IP resides with the supplier. For example, in fuel injector technology, the supplier developed the technology and supplies to different OEM's. IPR resides with the respective supplier, and through supply agreements and royalty payments, we secure our interests […] In some cases, for example, in the suspension area we developed, protected, and owned the IP on designs but got the castings and the other parts from the suppliers. Suppliers manufacture parts based on our specifications, ensuring our ownership of unique designs. (C#20, Managing Director)."*

While interestingly, firms' inclinations toward selectively open inbound IP openness remain consistent, regardless of the catalyst being internal or external, the mechanisms for IP sharing do show slight variations. Firms driven internally toward sustainability practices (Figure 6) most often opt for co-development or product-development partnerships with competitors or supply chain partners having complementary capabilities, enabling firms to (a) access external technical expertise, (b) expedite sustainable innovation timelines, and (c) involve critical ingredient suppliers in sustainable alternatives. For example, C#2 partnered to co-produce and co-own IP with research institutes and other firms to build a low-cost rice-husk-based water purifier, impacting ~2 million households through the product. Similarly, C#16 collaborates and clearly define IP ownership distribution under the contract.

Conversely, firms driven by external factors for sustainability (Figure 7) explore alternative mechanisms like exclusive in-licensing of externally owned IP (C#8, C#9, C#10) or purchasing external IP for internal development under their exclusive control and ownership. (C#11, C#22, C#23, C#24). In some cases, they also engage in co-development with the partner providing exclusive access to the externally developed IP. For instance, C#10, having limited engineering resources during the founding years, innovatively repurposed existing technology to create a premium low-energy lighting product and engaged in co-development partnership. The company *"bought in a designer; worked with manufacturing partners. [..] to innovate [..] to redeliver the original form of the bulb, but with dimmable LED technology with a much greater lifetime expectation, better performance, better* *efficiency." (C#10, Co-Founder).* Similarly, C#8 secured exclusive licensing for battery recycling, and collaborated with a university to drive IP development through innovative solutions addressing environmental challenges.

In summary, firms undergoing internal firm-level sustainability transition tend to favour selectively open inbound IP model with varying IP sharing mechanism basis internal vs. external catalysts of sustainability practices. Internally driven firms tend to prioritize factors like accelerated development time and access to external resources over exclusive IP control. While firms responding to external pressures tend to prioritize IP exclusivity, often combining closed and selectively open IP models such as in-house R&D, exclusive in-licensing of patents and trade-secrets, and IP acquisition with co-development mechanisms to further their innovation goals.

4.2.2. Selectively open vs. closed outbound IP model for internally vs externally driven firms for sustainability.

While all sustainable innovation firms adopt a selectively open inbound IP model, distinctions emerge in their outbound IP approaches based on internal versus external drivers for sustainability. Internally motivated firms (Figure 6) favor selectively open outbound IP model, including mechanisms like know-how out-sharing through non-disclosure agreements (NDAs), exclusive or non-exclusive out-licensing, and cross-licensing. For instance, C#20 co-developed an EV component with a supplier and out-licensed the design to its supplier to develop and supply the components with an exclusivity term for 10 years.

Conversely, externally driven firms (C#8, C#10, C#22, C#23, C#24, C#26) favour closed outbound IP models, prioritizing exclusivity to protect internally, co-generated IP assets or acquired IP for further development. For instance, C#10, C#11, C#24 reorient their sustainability practices, technology development towards sustainable alternatives responding to regulatory and technological changes, create new IP through incremental innovations, but do not out-license their formal IP. For instance, C#10 indicates "*what we've been cautious of is not sharing these specific designs […] because we didn't want the manufacturers just .[..] to have an easy path to produce a production model. If they did decide to copy as they would, they would end up with something very expensive that actually wouldn't really work." (C#10, Co-Founder and Creative Director).* These firms emphasize (a) exclusivity for competitive advantage during sustainability modifications, (b) freedom to operate while experimenting multiple applications of innovation (c) reduction of imitation risk. Thus, external pressure though stimulates firms to collaborate to develop sustainable innovations, does not incentivize out-sharing of sustainable IP.

CASE STUDY NO.	IP PROTECTION		IP SHARING AND OPENNESS		SELECT EXAMPLES		
	Formal IP	**Informal IP**	**In-Sharing mechanism for innovation development**	**Out-Sharing mechanism for innovation diffusion**	**Sustainability impact**	**Sustainability practices**	**IP sharing models**
C#2	Patents, Trademarks	Brand-name (well-known mark), Business & Technological Know-how	Co-development	Know-how out-sharing through NDAs	“Process of manufacturing generates a chemical waste and may have a negative impact on the environment and biodiversity. So, to tackle this issue, we developed the process of conversion of waste to cement. Which eventually became another product segment for us” (C#2)	“Before 2006, we were solely into the chemical business, Later, to become sustainable company, the top management realized the need for a specialized innovation centre.” (CS#2) “We have changed from petrochemical solvent-based products to aqua-based products. We invested for renewable-based adhesives”. (CS#14)	'"We adopted a collaborative approach [..], we developed materials, the technical support was provided by the R&D centre of another company X. [..] We partnered with company Y for the design part." (CS#2)
C#14	Patents, Trademark	Product and process Know-how	Co-development, In-licensing, & Internal R&D	Cross-licensing for selected products and processes			
C#16	Patents, Trademark, Copyrights, Design Rights	Product and process Trade-secrets	In-licensing, co-development, IP purchase, know-how in-sharing	Out-licensing			
C#20	Patents, Trademark	Brand-name (well-known mark), Business & Technological Know-how	Co-development, In-licensing	Out-licensing			

Figure 6. IP models for firms’ internally driven sustainability practices for firm-level sustainability

CASE STUDY NO.	IP PROTECTION		IP SHARING AND OPENNESS		SELECT EXAMPLES		
	Formal IP	**Informal IP**	**In-Sharing mechanism for innovation development**	**Out-Sharing mechanism for innovation diffusion**	**Sustainability impact**	**Sustainability practices**	**IP sharing models**
C#8	Patents, Trademarks	Brand-name (well-known mark), Business & technological know-how	Exclusive in-licensing from university followed by co-development	No out-sharing of formal & informal IP	“The first time when we used recycled polyester, we created a measure: number of bottles and carbon dioxide saved to produce this product. [..] the reduction of GHG emissions is also key for our company. We took the responsibility to find the best recycled PET, in terms of environmental impact." **(C#24)**	“What's driving a lot of emissions reduction is - global and local regulation, that has caused us in the last three years to spend a lot of time and investment in approving different refrigerants and what are we going to do to meet their regulatory needs” **(C#11)** “[..] the speed of innovation was accelerating, LEDs became much more competitive, much better [..]. We were only able to launch that technology in 2018 [..] we were waiting for the flexible LED filament technology to emerge and reach a critical length to allow us to create the design [..]” **(CS#10)**	“Knowhow and design rights are generally co-developed, it is a mix of external and internal activities, but fully owned by [..]we involve others to develop these and they are fully owned by us […] co-developed by external designers" **(C#24)**
C#10	Patents, Trademarks	Know-how	Co-development, Know-how in-sharing through NDAs	No out-sharing of formal & informal IP			
C#11	Patents, Trademarks	Trade secret, Know-how, data	In-house R&D, Exclusive in-licensing & IP purchase	Cross-licensing			
C#22	Utility models, Patents, Trademarks, copyrights, design rights	Trade secrets and Know-how	In-house R&D	No out-sharing of formal & informal IP			
C#23	Patents, Trademark, Design rights, copyrights	Know-how, data, trade-secrets	In-house R&D, IP purchase, Know-how in-sharing through NDAs	No out-sharing of formal & informal IP			
C#24	Patents, trademarks, design rights, copyrights, Geographical indication	Know-how, data, trade secrets	IP purchase, Know-how in-sharing through NDAs	No out-sharing of formal & informal IP			
C#26	Patents, Trademarks	Know-how, data, trade secrets	In-licensing, co-development, IP purchase, know-how in-sharing	No out-sharing of formal & informal IP			

Figure 7 IP models for firms’ externally driven sustainability practices for firm-level sustainability

In summary, we find variation in outbound IP models adopted by firms undertaking sustainability practices with internal and external catalysts. Internally driven firms favor selectively open outbound IP model, while externally driven ones prioritize exclusivity and thus closed outbound IP model, aligning with their selection of exclusivity-based sharing mechanisms of their inbound IP models.

4.3 IP models for external industry & cross-industry level sustainability practices

Figure 8 and Figure 9 present the IP models adopted by case study firms prioritizing within and cross-industry sustainability transitions.

4.3.1 Selectively open inbound IP model for within and cross-industry sustainability practices

Firms facilitating external sustainability transitions employ a selectively open inbound IP model for knowledge exchange (i.e. C#2, C#14, C#16, C#20 are common in both the categories). IP sharing mechanisms in inbound IP models of firms mirror those of internally motivated firms for sustainability practices (see **Figures 8**).

Most firms engage in product and process co-development with diverse partners including sister firms (C#2), value-chain partners (C#10, C#3), universities, and research labs (C#5, C#15, C#20). Some also utilize cross-licensing (C#7, C#20), and form technology consortiums with actors having complementary R&D capabilities (C#2, C#7), for cost-effective, and rapid sustainable technology development. For instance, C#7, stated "*...it was cost reduction not just for us but for other industry peers. We collaborate with closed peers to take these actions benefitted for all the organizations."* (CS#7, Senior Manager - Innovation & IP).

Co-development and cross-licensing practices involve simultaneous inbound and outbound openness in IP and knowledge exchange. Co-development often leads to formal registration of IP under joint ownership (e.g., in C#2 water purification product innovation), or distributed ownership (i.e., in C#7 energy efficient wireless communication protocol) or single-firm ownership (i.e. C#20, C#5 based on contractual terms & conditions). Some firms, like C#13, opt for in-licensing to obtain necessary patented technology components. Informal-unregistered IP holders share expertise and trade secrets, fostering industry-wide cost reduction and supply enhancement for sustainable materials.

CASE STUDY NO.	IP PROTECTION		IP SHARING AND OPENNESS		SELECT EXAMPLES		
	Formal IP	**Informal IP**	**In-Sharing mechanism for innovation development**	**Out-Sharing mechanism for innovation diffusion**	**Sustainability impact**	**Sustainability practices**	**IP sharing models**
C#1	Patents, Trademarks	Know-how, Brand name	Internal R&D – no sharing	Co-branding through selective out-licensing	"We started the pilot processing facility of only 20 kgs of flakes and later extended it to 2000 kgs of flakes with minimum use of water. Generally, each Kgs of flakes processing consumes 7 litres of water, but in our process it does not take more than 2 litres of water." **(C#6)** "[Franchise] is the most complete model for the local production ... in problematic countries.: 7.2 million beneficiaries receive nutritional care from the company and its partners, it improved standard of living of employees who earned 23% more than their previous jobs] (C#27)'	"We have contributed a lot to government initiatives for improving sustainability and energy efficiency, to create specifications so that the entire sector may have much better energy balance and much less of pollution. [.] Our technical experts help government agencies to set up high energy efficiency, stringent norms and regulations [..] we are convincing our customers to focus more on sustainability" **(CS#7)** "our core product is fulfilling the nutritional needs of the population. It has rescued people from disorders like goitre caused by the iodine deficiency. Product was so effective that the Government, later, made the process compulsory to all manufacturers. " **(C#2)**	"[..] There is cross-licensing and common or shared development [..]. We collaborate with the industry peers or competitors, for IP protection [..], we have created a consortium. We cross-license our IP so that each one of us can use that IP, to develop a next-generation technology by holding hands with each other" (C#6) "We have released the (IP) on the connector, making it accessible to anyone looking to design and build EVs to further the mission of a sustainable energy ecosystem. Tearing down the IP walls and helping with engineering at an early stage will help drive a common standard [..] we will provide all the back-end support, subsystems, the design and dimension part to the company who wants to use it at a normal rate" (CS#6).
C#2	Patents, Trademarks	Brand-name (well-known mark), Business & Technological Know-how	Co-development	Know-how out-sharing through NDAs			
C#3	Patents, Trademarks, copyrights	Product and process Know-how	Co-development, In-licensing	Open-access out-sharing, defensive publication			
C#5	Patents, Trademarks, Design rights	Know-how, Trade-secrets, Databases	Co-development, IP purchase	Abandoned IP, know-how out-sharing through NDAs			
C#6	Patents, Trademarks, Design rights, copyrights	Data, Know-how, and algorithm as trade-secrets	Internal R&D, informal IP in-sharing through NDAs	Selective out-licensing, defensive publication, know-how out-sharing through NDAs, conditional open-access publication			
C#7	Patents, Trademarks, Design rights	Brand name (well-known mark), industrial Know-how and data as trade-secrets	Internal R&D, IP purchase, in-licensing, co-development, cross-licensing	Cross-licensing, know-how out-sharing through NDAs			
C#9	Patents, Trademarks	Brand-name (well-known mark), Business & Technological Know-how	Co-development, In-sharing of know-how through NDA	Informal know-how out-sharing through NDAs			
C#13	Trademarks	Product and process Know-how	Co-development, in-licensing	Open-access out-sharing			
C#14	Patents, Trademarks	Product and process Know-how	Co-development, in-licensing, cross-licensing	Cross-licensing			
C#15	Trademarks	Customer & market information, Business process, and design information Know-how, Financial Models	Co-development	Open-access publications and know-how out-sharing			
C#16	Patents, Trademarks, Design rights, copyrights	Product and process Trade-secrets	Co-development, selective in-licensing of trade-secrets	Selective out-licensing			
C#19	Trademarks	Product and process Trade-secrets	Internal R&D, co-development	Selective out-sharing of trade-secrets through NDAs			
C#20	Patents, Trademarks	Customer & market information, data, know-how, algorithms	Internal R&D, Co-development, in-licensing	Exclusive out-licensing			
C#21	Utility models, Patents, Trademarks, copyrights, design rights	Trade secrets and Know-how	Co-development, cross-licensing	Cross-licensing			
C#27	Patent, trademark, design rights, copyrights	trade-secrets - industrial Know-how and process formulas	Co-development & Internal R&D	Selective royalty-free out-licensing with some conditions, know-how out-sharing through NDAs			

Figure 8 IP models for firms' sustainability practices influencing others within the industry for sustainability

4.3.2 Selectively, broadly, and fully open outbound IP model for within and cross-industry sustainability practices

In terms of outbound IP models, firms appear to prefer selectively open approaches. First-mover firms in nascent sustainable markets often advocate for new ecosystem and technology standards, like C#6 and C#19 advising standard-setting bodies and influencing others to pursue sustainability. Likewise, C#7 supports 500 start-ups and system integrators by out-sharing trade-secret protected know-how for energy-efficient waste management. Some firms evaluate potential partner's sustainability practices before IP out-sharing; C#1 selectively co-brands and out-licenses trademarks to sustainability-focussed partner network, helping other firms achieve sustainability by reducing energy consumption, CO_2 emission, and water consumption reduction. Selectively open IP model such as IP co-development and cross-licensing arrangements helps firms such as C#20 and C#5 to vertically integrate, pooling together the IP with upstream suppliers to produce environmentally responsible upcycled material and recycled components to cater to multiple industries like telecoms, automotive, electronics, and med-tech.

Two cases, C#6 and C#27 aiming to balance widespread accessibility with the use & access control combine broadly open with selectively open outbound IP model thus bringing within and cross industry transition. For instance, C#27 grants royalty-free license for nutritional products to entrepreneurs in the global south, with the condition of contributing to the firm's R&D. Additionally, the company shares the informal IP and provides mentorship to local entrepreneurs but denies the IP access to large enterprises from developed countries to protect the small ventures from global competition. The approach promotes economic development in southern countries, by not directly establishing the factories but *"open the patents in the countries...and to let entrepreneurs build factories and to be able to do that, just put on open access" (C#27, Managing Director).* The hybrid approach benefits 10 million vulnerable populations and creates jobs in lower-middle-income countries through 12 franchisee sites.

Four firms (C#3, C #12, C#13, C#15) adopt fully open IP models (see **Figure 9)**, (e.g. open access sharing of unprotected IP, and defensive publication) inspiring sustainability adoption, and building trust with local consumers and stakeholders. C#3, C#12, and C#13, operating in chemical manufacturing with the closing resource loop business model, embrace a fully open IP model. Despite the possibility of reverse engineering, they deliberately avoid patenting products to encourage others to provide similar sustainable alternatives. Notably, C#3 & C#13 forego formal IP protection of product and process technology; opting instead for open access mechanisms to attract new players to sustainability. As the Managing Director of C#13 stated, *"So the problem is if one company does it and only one company does it, there is no benefits for the wider population."* (C#13, Managing director). C#3 openly publishes R&D collaboration outcomes, fostering partnerships and sustainability across the supply chain. C#12 refrains from formal IP protection to enable replication of sustainable alternatives to prevalent unsustainable products. Meanwhile, C#15 openly shares internally developed knowledge, promotes incubation and mentorship programs, ensuring accessibility to new knowledge from green investment projects.

Recognizing competitors as potential collaborators and stakeholders, these firms prioritize knowledge sharing to enhance traceability, and advocate repairable product designs. Moreover, these firms prioritize employment generation, respect and loyalty to stakeholders, and support for vulnerable communities, aiming to attract, and gain trust of open-source and social-sustainability oriented stakeholders.

Some firms, like C#5 and C#23, use defensive publication and abandon patents to inspire others in the industry. C#5, for instance, which provides PET bottle flaking machines abandoned a few patents and conducted many awareness campaigns on plastic recycling, leading to the entry of new players and creation of a new PET recycling industry in a developing country. Its co-founder mentioned their commitment to open innovation, prioritizing environmental concerns over IP protection. He stated *"We are more towards open innovation. [..] Sustainability and the environment is a bigger concern for us. [..] Our focus is that many people should accept this and go for it, and we should create an industry where things can be utilized more frequently [..] rather than focusing on the IP part. [..]Looking at us and at this machine (which proved to be very useful for plastic recycling), three-four new players entered the industry in 2016-2017 and started making these machines so that they can supply them to the government department or to companies who want to do the CSR activity. So, from that perspective, we have been able to create an industry where 3-4 other people now make these machines rather than only us."* (C#5, Co-Founder & Director).

Fully open outbound IP models are favored by firms in mature industries like textiles or in technology sectors like recycling, where business model innovation becomes critical for system integration or network mobilization. The approach serves as a leading strategy for inspiring others to drive change and transition towards sustainability.

CASE STUDY NO.	IP PROTECTION		IP SHARING AND OPENNESS		SELECT EXAMPLES		
	Formal IP	**Informal IP**	**In-Sharing mechanism for innovation development**	**Out-Sharing mechanism for innovation diffusion**	**Sustainability impact**	**Sustainability practices**	**IP sharing models**
C#1	Patents, Trademarks	Know-how, Brand name	Internal R&D	Co-branding through selective out-licensing	Thousands of peanut farmers and workers impacted~2000MT/year of groundnut procured from local industries impacting ~8600 persons including farmer and sorters families in Niger. About 2000MT/year impacting ~3800 persons including farmer and sorters families in Burkina Faso.(C#27) "We are contributing through two things: one we stop waste going to the dumping ground and reutilize it for energy generation. 2nd, we stop all the methane that may get excreted to environment that is again Greenhouse gas. That way this is an environmentally sustainable solution." [C#7]	"And the next step in that is to get our courier companies to adopt electric vehicles for delivery of our products. And then our manufacturing partners, how can we get them to adopt more solar? How can we get them to reduce their environmental impact? What is their environmental impact? And we go back, do intensive audits, and look at the best of practices and try and replicate that across different manufacturing" (C#17)	But small medium entrepreneurs can make something valuable for local societies. And that was the the story behind XYZ Cluster idea. And so it started with our own development, then we also used this with shoe polish production line together with know-how and that's how the idea developed. And then we started cooperation with the MNO in South Africa because we asked them to find the small businessman that will take the responsibility with. (C#30) "We have to build a partnership; we have to actually convince people to want to join this partnership" (CS#3)
C#2	Patents, Trademarks	Brand-name (well-known mark), Business & Technological Know-how	Co-development	Know-how out-sharing through NDAs without licensing			
C#3	Patents, Trademarks, copyrights	Product and process Know-how	Co-development, In-licensing	Open-access out-sharing, defensive publication			
C#5	Patents, Trademarks, Design rights	Know-how, Trade-secrets, Databases	Co-development, IP purchase	Abandoned IP, know-how out-sharing through NDAs			
C#7	Patents, Trademarks, Design rights	Brand name (well-known mark), industrial Know-how and data as trade-secrets	Internal R&D, IP purchase, in-licensing, co-development, cross-licensing	Cross-licensing, know-how out-sharing through NDAs			
C#12	Trademark, Utility model	Product and process Know-how	Co-development	Open-access out-sharing, defensive publication			
C#15	Trademarks	Customer & market information, Business process, and design information Know-how, Financial Models	Co-development	Open-access publications and know-how out-sharing			
C#16	Patents, Trademarks, Design rights, copyrights	Product and process Trade-secrets	Co-development, selective in-licensing of trade-secrets	Selective out-licensing			
C#17	Trademark, Copyright	Know-how, Trade secret on processes and algorithms	Co-development	Selective out-licensing			
C#18	Trademark	Product and process Trade-secrets	Co-development	Out-sharing of informal IP through NDAs			
C#20	Patents, Trademarks	Customer & market information, data, know-how, algorithms	Internal R&D, Co-development, in-licensing	Exclusive out-licensing			
C0#27	Patent, trademark, design rights, copyright	trade-secrets - industrial Know-how and process formulas	Co-development & Internal R&D	Selective royalty-free out-licensing with some conditions, know-how out-sharing through NDAs			
C#28	Patents, Trademark, Copyrights	Data, Know-how	In-licensing & internal development	NDAs and IP sale or out-licensing			
C#29	Patents, Trademark, domain name	Know-how	In-sharing of informal IP through NDAs	Exclusive out-licensing, and out-sharing of informal IP through NDAs			
C#30	Patents, Trademark	Business Know-how, Technical Know-how, Data, product application knowledge	Internal R&D	know-how out-sharing through NDAs			

Figure 9 IP models for firms' sustainability practices influencing others across the industry for sustainability.

5. Discussions - an emergent framework of IP strategy for sustainability transition

The study explores and provides emergent framework for the link between firms' IP models and sustainability practices for internal firm-level sustainability (Figure 10A), and external industry-, and cross-industry sustainability (Figure 10B). The argument for mission-oriented sustainability firms should open their IP for higher purposes (Eppinger et al., 2021; Jain and Gurtoo, 2021; Vimalnath et al., 2023) gets nuanced evidence by identifying IP protection, ownership and different degrees of IP openness and sharing mechanisms adopted by sustainable innovation firms.

5.1 Role of protection & ownership of IP assets for sustainability transitions

Our study emphasizes the critical role of formal and informal IP assets in facilitating innovation within sustainable firms. Notably, the emphasis on formal registration of patents, trademarks, and design rights underscores sustainable innovation firms' recognition of the competitive advantage conferred by legally protected IP assets (Vimalnath et al., 2022; Patil et al., 2020). The finding aligns with existing literature on conventional innovation, emphasizing the importance of IP rights in incentivizing firms to invest in R&D efforts (Arundel, 2001; Jain et al., 2020; Maskus and Penubarti, 1995; Teece, 1986). IP ownership and protection may not pose barriers to collaboration but facilitate the freedom to operate during open innovation processes (Chesbrough, 2003) and thus foster collaboration and technology transfer acting as a basis of trust and credibility among partnering entities ((Ferreira et al., 2020). This result aligns the literature on positive association between a firm's IP portfolio and open innovation (Lichtenthaler, 2010).

5.2 IP models for sustainability practices of firms bringing internal firm-level sustainability

Selectively open inbound IP models involving sharing mechanism like IP co-ownership or distributed ownership (see Figure 10A), enable accelerated innovation and cost reduction through shared resources and expertise (Laursen and Salter, 2014). These mechanisms support co-development and stakeholder engagement, aligning with the literature emphasizing co-designing and co-generating knowledge as an essential and deliberate practice for firms bringing firm-level sustainability (Page et al., 2016; Vimalnath et al., 2023).

When external factors drive firms' sustainability practices, firms in-source external IP for technology development through exclusive in-licensing, IP acquisition, and NDA based know-how in-sharing but adopt closed outbound IP models for technology diffusion (see Figure 10A). These firms strategically leverage external IP assets to generate new proprietary technology, reinforce their competitive advantage and drive innovation internally (Ritala et al., 2021, 2014). Closed outbound IP models may enable these companies to appropriate the returns and maximize their enterprise and reputational value (Chen et al., 2023; Hao et al., 2022) without directly enabling others to diffuse sustainable technologies.

Such hybrid IP strategies reflect a pragmatic response to market dynamics, wherein firms balance the need for exclusivity with the imperative of accessing external knowledge and technologies to address sustainability challenges (Manzhynski and Figge, 2020). The result also supports the literature on conventional technology IP strategies emphasizes the importance of IP collaborations and coopetition in a complex technological environment (Hashim et al., 2015; Hertzfeld et al., 2006; Hong et al., 2019; Zhao et al., 2019). Like other conventional firms, firms pursuing sustainability due to external pressure find combining profit-making with completely free outbound IP sharing very challenging.

5.3 IP models for sustainability practices of firms bringing external sustainability

Combining internal R&D with selectively open inbound IP model (see Figure 10B) reduces cost, and resource requirements for sustainable innovations, increasing efficiency in knowledge processes, and establishing new industry standards (Chesbrough and Appleyard, 2007; Arora et al., 2016; Henkel, 2006). In addition to building trust and loyalty among partnering firms, selectively sharing internally developed know-how and design IP with suppliers early on can provide cost and lead time advantages through exclusive supply agreements. Cross-industry in-licensing and IP cross-licensing facilitate access to unrelated knowledge, influencing sustainability across industries ((Iino et al., 2021; Eppinger et al., 2021). The result aligns with the literature emphasizing importance of early integration of suppliers in improving innovation performance (Gassmann et al., 2010), and sustainability within and across industry.

IP co-generation and co-ownership through within- and cross-industry partnerships with diverse stakeholders like innovation consortia, local community, and advocacy groups appear to foster social sustainability through widespread sharing of sustainable innovation know-how. The practice helps in building trust in the community and encouraging fair labor practices across the industry (Arora et al., 2016; Henkel, 2006; (Alonso-Martínez, 2018; Arora et al., 2016; Henkel, 2006; Jain and Gurtoo, 2021; Vimalnath et al., 2023). Conversely, broadly, and fully open inbound IP models appear less used by sustainable innovation firms.

Broadly open outbound IP models are a recent phenomenon among sustainable innovation firms, discussed more recently in academic literature, with examples like the covid-19 patent pledge and pledges by companies like Tesla, IBM, and Toyota (Contreras et al., 2020). Broadly open outbound IP models by some case companies, incorporating open-source licensing with commercial restriction or sustainability conditions, promote inclusivity and affordability while bringing environmental and social benefits (Eppinger, 2021). These models appear to be prevalent in software industries (Henkel, 2006). Combining them with selectively open outbound IP models enables mission-oriented firms to support sustainability practices, promoting broader sectoral transitions by balancing widespread accessibility with control, thus promoting environmentally or socially sustainable innovations and practices.

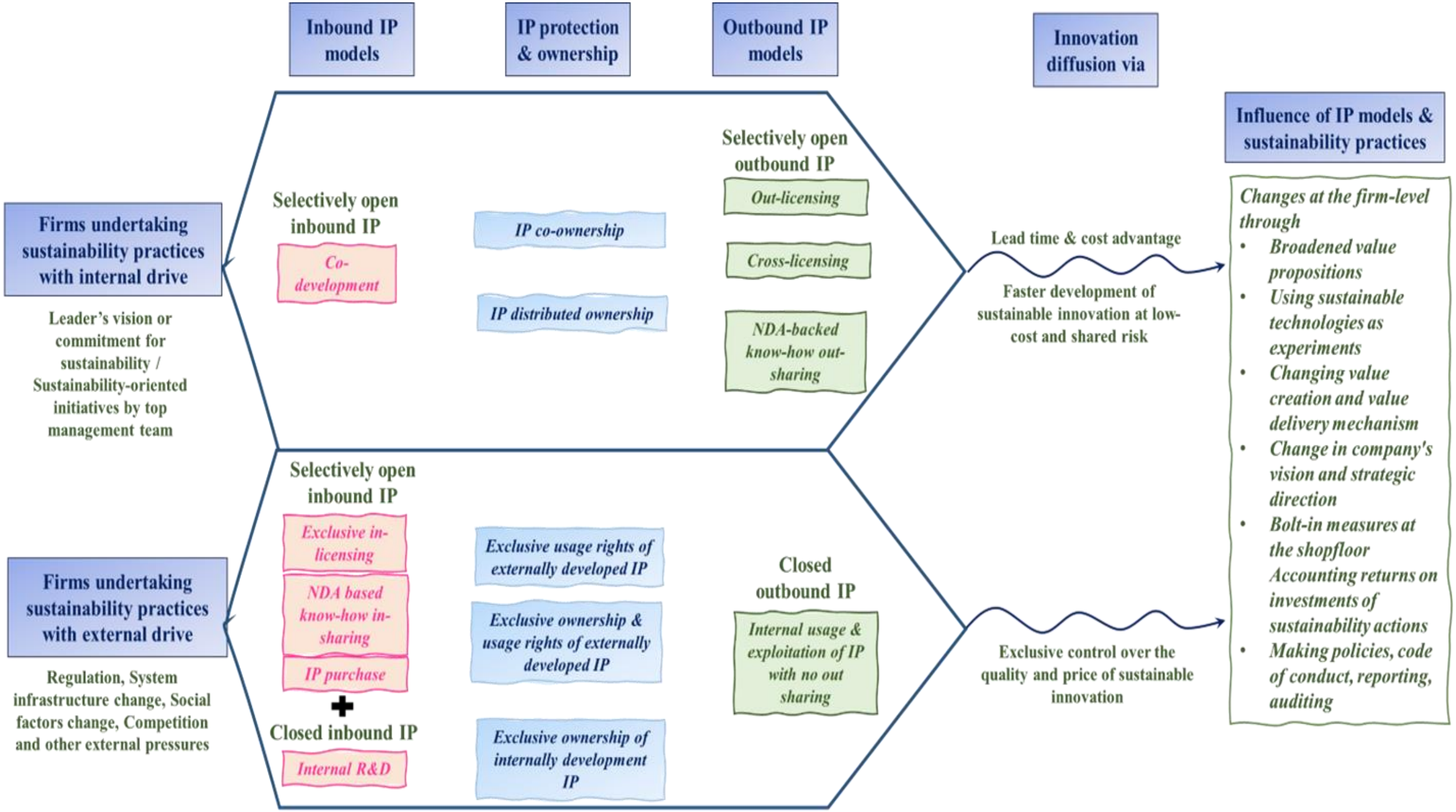


Figure 10A: An emergent framework for IP models for sustainability practices of firms bringing internal firm-level sustainability

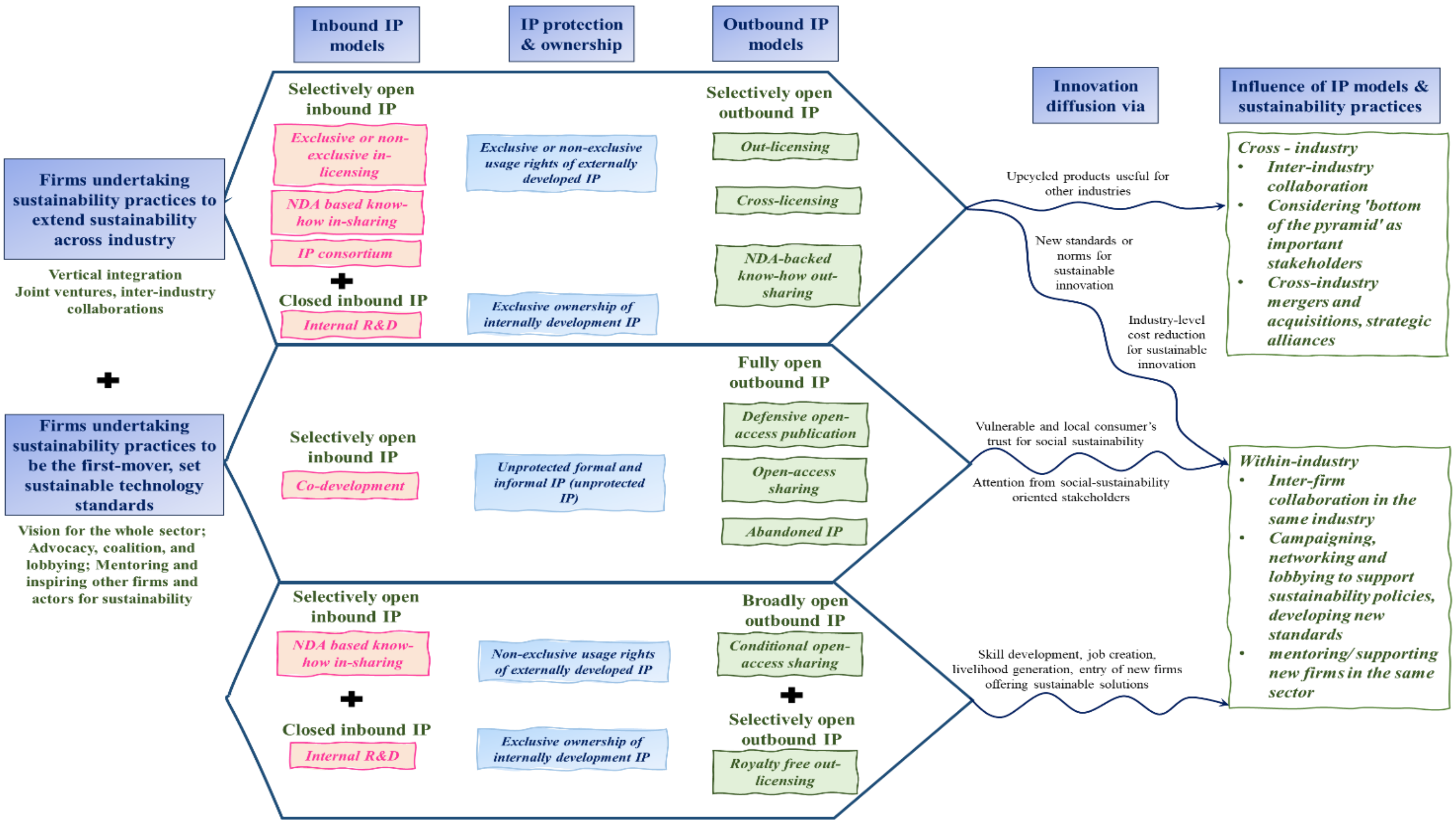


Figure 10B: An emergent framework for IP models for sustainability practices of firms bringing external sustainability

While only a limited number of firms adopt fully open outbound IP models, they support social sustainability practices. The result indicates the value and importance of protection and use of IP for any firm, particularly those developing, manufacturing, and distributing innovative products, services, and software. Some born-sustainable firms considering vulnerable communities and workers as key stakeholders, prioritize transparency and openness in process innovation, avoiding formal IP protection to encourage faster diffusion ((Dahlander and Gann, 2010).

The study challenges the perception of sustainable innovation firms being more open. The emergent framework can guide managers and policymakers to design suitable IP strategies and policies to foster a balanced approach to IP sharing.

6. Conclusions

This study explores the relationship between IP models and sustainability transitions among firms engaged in sustainable innovation. Employing a multiple-case study methodology, three interdisciplinary research teams triangulated the evidence of 28 sustainable innovation firms to examine the linkage between a firm's IP strategy, sustainability practices, and sustainability impact. The findings contribute to the fields of innovation management and sustainability.

Firstly, we show sustainable firms prioritizing the protection and ownership of both formal-registered and informal-unregistered IP assets across industries. Secondly, we identify a diversity of inbound and outbound IP models and sharing mechanism supporting firms' sustainability practices, influencing transformation on firm-, industry-, and cross-industry levels.

Our results indicate a prevalent use of selectively open inbound IP models (in-licensing, know-how in-sharing) among firms pursuing sustainability. However, specific IP sharing mechanisms adopted may vary based on internal or external factors driving sustainability practices. Firms pursuing internal changes with external drive seem to prefer exclusive in-licensing, while those pursuing sustainability without external pressures typically favor collaborative IP models like co-development and cross-licensing. Combining closed and selectively open IP models supports within-industry, and cross-industry sustainability impact.

Thirdly, selectively open out-sharing IP models when combined with broadly or fully open outbound IP models are found to facilitate industry-level and cross-industry transitions by inspiring others to engage in sustainable innovation and advocate for sustainability policies. Finally, firms adopting reactionary approaches to sustainability tend to favor closed outbound IP models, limiting their industrial or cross-industrial contribution to sustainability, highlighting a need for new policies, and incentives to encourage firms to out-share their formal and informal IP for a wider diffusion of sustainable innovations.

In the study, sustainable innovation firms appear to be more open to sharing their IP to promote sustainability practices, collaboratively striving for a higher purpose while pursuing sustainability pathways than expected from non-sustainable innovation firms. However, acknowledging study limitations, focusing solely on sustainable innovation firms may hinder the generalizability of the findings to a broader context. Future research should involve a wider range of firms for comprehensive analysis. Additionally, the study's scope does not allow us to examine specific contextual factors like technology complexity, industry maturity (Ali et al., 2021; Malhotra et al., 2019; Perruchas et al., 2020), urging further investigation. Further research on IP strategies, like open patent pools, patent pledges becomes imperative to understand how firms can be incentivized for the same. The study highlights firms, driven internally or externally toward sustainability, employ different outbound IP models and employ different sharing mechanisms under selectively open inbound IP models. Future research could quantitatively explore the linkage between firms' sustainability practices and the moderating role of different IP sharing mechanisms under both inbound and outbound IP models.

DECLARATION OF COMPETING INTEREST

The authors have no conflicts of interest.

FUNDING

This work was supported by Belmont Forum, New Opportunities for Research Funding Agency Cooperation in Europe (NORFACE) Joint Research Programme on Transformations to Sustainability, co-funded by Deutsches Zentrum für Luft- und Raumfahrt (DLR)/German Federal Ministry for Education and Research (BMBF) (Research for Sustainable Development: FONA), UK's Economics Social Science Research Council (ESRC), Global Challenge Research Funds (GCRF), VR, and the European Commission through Horizon 2020.

REFERENCES

Abraham-Dukuma, M.C., 2021. Dirty to clean energy: Exploring 'oil and gas majors transitioning'. The Extractive Industries and Society 8, 100936. https://doi.org/10.1016/j.exis.2021.100936

Aghion, P., Dechezleprêtre, A., Hémous, D., Martin, R., Van Reenen, J., 2016. Carbon Taxes, Path Dependency, and Directed Technical Change: Evidence from the Auto Industry. Journal of Political Economy 124, 1–51. https://doi.org/10.1086/684581

Alonso-Martínez, D., 2018. Social progress and international patent collaboration. Technological Forecasting and Social Change 134, 169–177. https://doi.org/10.1016/j.techfore.2018.06.001

Ali, W., Jun, W., Hussain, H., Khan, N.A., Younas, M.W., Jamil, I., 2021. Does green intellectual capital matter for green innovation adoption? Evidence from the manufacturing SMEs of Pakistan. Journal of Intellectual Capital ahead-of-print. https://doi.org/10.1108/JIC-06-2020-0204

Andersen, A.D., Gulbrandsen, M., 2020. The innovation and industry dynamics of technology phase-out in sustainability transitions: Insights from diversifying petroleum technology suppliers in Norway. Energy Research & Social Science 64, 101447. https://doi.org/10.1016/j.erss.2020.101447

Arora, A., Athreye, S., Huang, C., 2016. The paradox of openness revisited: Collaborative innovation and patenting by UK innovators. Research Policy 45, 1352–1361. https://doi.org/10.1016/j.respol.2016.03.019

Arora, P., Hora, M., Singhal, V., Subramanian, R., 2020. When do appointments of corporate sustainability executives affect shareholder value? Journal of Operations Management 66, 464–487. https://doi.org/10.1002/joom.1074

Arundel, A., 2001. The relative effectiveness of patents and secrecy for appropriation. Research Policy 30, 611–624. https://doi.org/10.1016/S0048-7333(00)00100-1

Arvidsson, S., Dumay, J., 2022. Corporate ESG reporting quantity, quality and performance: Where to now for environmental policy and practice? Business Strategy and the Environment 31, 1091–1110. https://doi.org/10.1002/bse.2937

Barbieri, N., Ghisetti, C., Gilli, M., Marin, G., Nicolli, F., 2016. A SURVEY OF THE LITERATURE ON ENVIRONMENTAL INNOVATION BASED ON MAIN PATH ANALYSIS: A SURVEY OF THE LITERATURE ON ENVIRONMENTAL INNOVATION. Journal of Economic Surveys 30, 596–623. https://doi.org/10.1111/joes.12149

Bessen, J., Meurer, M.J., 2008. Do Patents Perform Like Property? AMP 22, 8–20. https://doi.org/10.5465/amp.2008.34587991

Blind, K., Cremers, K., Mueller, E., 2009. The influence of strategic patenting on companies' patent portfolios. Research Policy 38, 428–436. https://doi.org/10.1016/j.respol.2008.12.003

Beyer, P., 2013. Developing socially responsible intellectual property licensing policies: Non-exclusive licensing initiatives in the pharmaceutical sector, in: Research Handbook On Intellectual Property Licensing. pp. 227–256. https://doi.org/10.4337/9781781005989.00018

Bissell, A.N., 2009. Permission granted: open licensing for educational resources. Open Learning: The Journal of Open, Distance and e-Learning 24, 97–106. https://doi.org/10.1080/02680510802627886

Blind, K., Cremers, K., Mueller, E., 2009. The influence of strategic patenting on companies' patent portfolios. Research Policy 38, 428–436. https://doi.org/10.1016/j.respol.2008.12.003

Bocken, N.M.P., Short, S.W., Rana, P., Evans, S., 2014. A literature and practice review to develop sustainable business model archetypes. J. Clean Prod. 65, 42–56. https://doi.org/10.1016/j.jclepro.2013.11.039

Bogers, M., West, J., 2012. Managing Distributed Innovation: Strategic Utilization of Open and User Innovation. Creativity and Innovation Management 21, 61–75. https://doi.org/10.1111/j.1467-8691.2011.00622.x

Bolton, R., Hannon, M., 2016. Governing sustainability transitions through business model innovation: Towards a systems understanding. Res. Policy 45, 1731–1742. https://doi.org/10.1016/j.respol.2016.05.003

Cabigiosu, A., 2022. Sustainable development and incumbents' open innovation strategies for a greener competence-destroying technology: The case of electric vehicles. Business Strategy and the Environment 31, 2315–2336. https://doi.org/10.1002/bse.3023

Camilleri, M.A., Troise, C., Strazzullo, S., Bresciani, S., 2023. Creating shared value through open innovation approaches: Opportunities and challenges for corporate sustainability. Business Strategy and the Environment 32, 4485–4502. https://doi.org/10.1002/bse.3377

Cassiman, B., Valentini, G., 2016. Open innovation: Are inbound and outbound knowledge flows really complementary? Strategic Management Journal 37, 1034–1046. https://doi.org/10.1002/smj.2375

Cavanagh, J.-A.E., Frame, B., Lennox, J., 2006. The Sustainability Assessment Model (SAM): Measuring Sustainable Development Performance. Australasian Journal of Environmental Management 13, 142–145. https://doi.org/10.1080/14486563.2006.9725127

Chambers, D.A., Glasgow, R.E., Stange, K.C., 2013. The dynamic sustainability framework: addressing the paradox of sustainment amid ongoing change. Implementation Sci 8, 1–11. https://doi.org/10.1186/1748-5908-8-117

Chang, R., Zuo, J., Zhao, Z., Soebarto, V., Zillante, G., Gan, X., 2017. Approaches for Transitions Towards Sustainable Development: Status Quo and Challenges. Sustain. Dev. 25, 359–371. https://doi.org/10.1002/sd.1661

Chen, Z., Hao, X., Chen, F., 2023. Green innovation and enterprise reputation value. Business Strategy and the Environment 32, 1698–1718. https://doi.org/10.1002/bse.3213

Chesbrough, H., Bogers, M., 2014. Explicating Open Innovation: Clarifying an Emerging Paradigm for Understanding Innovation.

Chesbrough, H.W., Appleyard, M.M., 2007. Open Innovation and Strategy. California Management Review 50, 57–76. https://doi.org/10.2307/41166416

Chesbrough, H.W., Garman, A.R., 2009. How open innovation can help you cope in lean times. Harv Bus Rev 87, 68–76, 128.

Contreras, J.L., 2015. Patent Pledges: Between the Public Domain and Market Exclusivity. Mich. St. L. Rev. 787.

Contreras, J.L., Eisen, M., Ganz, A., Lemley, M., Molloy, J., Peters, D.M., Tietze, F., 2020. Pledging intellectual property for COVID-19. Nat Biotechnol 38, 1146–1149. https://doi.org/10.1038/s41587-020-0682-1

Contreras, J.L., Hall, B.H., Helmers, C., 2019. Pledging patents for the public good: Rise and fall of the eco-patent commons 40.

Costantini, V., Crespi, F., Martini, C., Pennacchio, L., 2015. Demand-pull and technology-push public support for eco-innovation: The case of the biofuels sector. Research Policy 44, 577–595. https://doi.org/10.1016/j.respol.2014.12.011

Cozzi, G., Galli, S., 2014. Sequential R&D and blocking patents in the dynamics of growth. J Econ Growth 19, 183–219. https://doi.org/10.1007/s10887-013-9101-5

Crittenden, W.F., Crittenden, V.L., Pierpont, A., 2015. Trade secrets: Managerial guidance for competitive advantage. Business Horizons, SPECIAL ISSUE: THE MAGIC OF SECRETS 58, 607–613. https://doi.org/10.1016/j.bushor.2015.06.004

Cugno, F., Ottoz, E., 2006. Trade Secret vs. Broad Patent: The Role of Licensing. Review of Law & Economics 2, 209–221. https://doi.org/10.2202/1555-5879.1069

Dahlander, L., Gann, D.M., 2010. How open is innovation? Research Policy 39, 699–709. https://doi.org/10.1016/j.respol.2010.01.013

Dahlander, L., Gann, D.M., Wallin, M.W., 2021. How open is innovation? A retrospective and ideas forward. Research Policy 50, 104218. https://doi.org/10.1016/j.respol.2021.104218

Davari, A., Emami, A., Seyedi, S., 2019. Investigating the Effect of Inbound and Outbound Open Innovation on Discovery and Exploiting of Entrepreneurial Opportunities, in: Rexhepi, G., Hisrich, R.D., Ramadani, V. (Eds.), Open Innovation and Entrepreneurship: Impetus of Growth and Competitive Advantages. Springer International Publishing, Cham, pp. 51–66. https://doi.org/10.1007/978-3-030-16912-1_4

Delgado-Verde, M., Amores-Salvadó, J., Castro, G.M., Navas-López, J.E., 2014. Green intellectual capital and environmental product innovation: the mediating role of green social capital. Knowledge Management Research & Practice 12, 261–275. https://doi.org/10.1057/kmrp.2014.1

Demirel, P., Kesidou, E., 2019. Sustainability-oriented capabilities for eco-innovation: Meeting the regulatory, technology, and market demands. Business Strategy and the Environment 28, 847–857. https://doi.org/10.1002/bse.2286

Denoncourt, J., 2020. Companies and UN 2030 Sustainable Development Goal 9 Industry, Innovation and Infrastructure. Journal of Corporate Law Studies 20, 199–235. https://doi.org/10.1080/14735970.2019.1652027

Dyllick, T., Muff, K., 2016. Clarifying the Meaning of Sustainable Business: Introducing a Typology From Business-as-Usual to True Business Sustainability. Organization & Environment 29, 156–174. https://doi.org/10.1177/1086026615575176

Eisenhardt, K.M., 1989. Building Theories from Case Study Research. AMR 14, 532–550. https://doi.org/10.5465/amr.1989.4308385

Enkel, E., Gassmann, O., Chesbrough, H., 2009. Open R&D and open innovation: exploring the phenomenon. R&D Management 39, 311–316. https://doi.org/10.1111/j.1467-9310.2009.00570.x

Eppinger, E., 2021. How Open Innovation Practices Deliver Societal Benefits. Sustainability 13, 1431. https://doi.org/10.3390/su13031431

Eppinger, E., Jain, A., Vimalnath, P., Gurtoo, A., Tietze, F., Hernandez Chea, R., 2021. Sustainability transitions in manufacturing: the role of intellectual property. Current Opinion in Environmental Sustainability 49, 118–126. https://doi.org/10.1016/j.cosust.2021.03.018

Farla, J., Alkemade, F., Suurs, R.A.A., 2010. Analysis of barriers in the transition toward sustainable mobility in the Netherlands. Technological Forecasting and Social Change, Issue includes a Special Section on "Infrastructures and Transitions" 77, 1260–1269. https://doi.org/10.1016/j.techfore.2010.03.014

Ferreira, J.J.M., Fernandes, C.I., Ferreira, F.A.F., 2020. Technology transfer, climate change mitigation, and environmental patent impact on sustainability and economic growth: A comparison of European countries. Technological Forecasting and Social Change 150, 119770. https://doi.org/10.1016/j.techfore.2019.119770

Foxon, T.J., Bale, C.S.E., Busch, J., Bush, R., Hall, S., Roelich, K., 2015. Low carbon infrastructure investment: extending business models for sustainability. Infrastruct. Complex 2, 4. https://doi.org/10.1186/s40551-015-0009-4

Frantzeskaki, N., Loorbach, D., 2010. Towards governing infrasystem transitions: Reinforcing lock-in or facilitating change? Technological Forecasting and Social Change, Issue includes a Special Section on "Infrastructures and Transitions" 77, 1292–1301. https://doi.org/10.1016/j.techfore.2010.05.004

Freel, M., Robson, P.J., 2017. Appropriation strategies and open innovation in SMEs. International Small Business Journal 35, 578–596. https://doi.org/10.1177/0266242616654957

Gassmann, O., Enkel, E., Chesbrough, H., 2010. The future of open innovation: The future of open innovation. R&D Management 40, 213–221. https://doi.org/10.1111/j.1467-9310.2010.00605.x

G4 Sustainability Reporting Guidelines – Reporting Principles and Standard Disclosures | RESPECT, n.d. URL https://respect.international/g4-sustainability-reporting-guidelines-reporting-principles-and-standard-disclosures/ (accessed 6.26.22).

Geels, F.W., 2005. Technological Transitions and System Innovations: A Co-evolutionary and Socio-technical Analysis. Edward Elgar Publishing.

Gerring, J., 2004. What Is a Case Study and What Is It Good for? American Political Science Review 98, 341–354. https://doi.org/10.1017/S0003055404001182

Gorissen, L., Vrancken, K., Manshoven, S., 2016. Transition Thinking and Business Model Innovation–Towards a Transformative Business Model and New Role for the Reuse Centers of Limburg, Belgium. Sustainability 8, 112. https://doi.org/10.3390/su8020112

Giorgi, A., 2002. The Question of Validity in Qualitative Research. Journal of Phenomenological Psychology 33, 1–18. https://doi.org/10.1163/156916202320900392

Golafshani, N., 2015. Understanding Reliability and Validity in Qualitative Research. TQR. https://doi.org/10.46743/2160-3715/2003.1870

Granstrand, O., 2004. The economics and management of technology trade: towards a pro-licensing era? International Journal of Technology Management 27, 209–240.

Granstrand, O., Tietze, F., 2015. IP strategies and policies for and against evergreening. University of Cambridge Centre for Technology Management Working Paper Series.

Hall, B., Helmers, C., 2011. Innovation and Diffusion of Clean/Green Technology: Can Patent Commons Help? (No. w16920). National Bureau of Economic Research, Cambridge, MA. https://doi.org/10.3386/w16920

Hall, B. H., & Sena, V. (2017). Appropriability mechanisms, innovation, and productivity: evidence from the UK. Economics of Innovation and New Technology, 26(1-2), 42-62.

Halme, M., Korpela, M., 2014. Responsible Innovation Toward Sustainable Development in Small and Medium-Sized Enterprises: a Resource Perspective. Business Strategy and the Environment 23, 547–566. https://doi.org/10.1002/bse.1801

Hannah, D.R., 2005. Should I Keep a Secret? The Effects of Trade Secret Protection Procedures on Employees' Obligations to Protect Trade Secrets. Organization Science 16, 71–84. https://doi.org/10.1287/orsc.1040.0113

Hao, X., Chen, F., Chen, Z., 2022. Does green innovation increase enterprise value? Business Strategy and the Environment 31, 1232–1247. https://doi.org/10.1002/bse.2952

Hart, S.L., 1995. A Natural-Resource-Based View of the Firm. The Academy of Management Review 20, 986–1014. https://doi.org/10.2307/258963

Hashim, R., Bock, A.J., Cooper, S., 2015. The Relationship between Absorptive Capacity and Green Innovation. International Journal of Industrial and Manufacturing Engineering 9, 1065–1072.

Heller, M.A., 1998. The Tragedy of the Anticommons: Property in the Transition from Marx to Markets. Harvard Law Review 111, 621–688. https://doi.org/10.2307/1342203

Henkel, J., 2006. Selective revealing in open innovation processes: The case of embedded Linux. Research Policy 35, 953–969. https://doi.org/10.1016/j.respol.2006.04.010

Hertzfeld, H.R., Link, A.N., Vonortas, N.S., 2006. Intellectual property protection mechanisms in research partnerships. Research Policy, Property and the pursuit of knowledge: IPR issues affecting scientific research 35, 825–838. https://doi.org/10.1016/j.respol.2006.04.006

Heyen, D.A., Wolff, F., 2019. Drivers and barriers of sustainability transformations: A comparison of the "Energiewende" and the attempted transformation to organic agriculture in Germany. GAIA - Ecological Perspectives for Science and Society 28, 226–232. https://doi.org/10.14512/gaia.28.S1.9

Hofman, P.S., Blome, C., Schleper, M.C., Subramanian, N., 2020. Supply chain collaboration and eco-innovations: An institutional perspective from China. Business Strategy and the Environment 29, 2734–2754. https://doi.org/10.1002/bse.2532

Hong, J., Zheng, R., Deng, H., Zhou, Y., 2019. Green supply chain collaborative innovation, absorptive capacity and innovation performance: Evidence from China. Journal of Cleaner Production 241, 118377. https://doi.org/10.1016/j.jclepro.2019.118377

Iino, T., Inoue, H., Saito, Y.U., Todo, Y., 2021. How does the global network of research collaboration affect the quality of innovation? JER 72, 5–48. https://doi.org/10.1007/s42973-020-00042-y

Jacobsen, S.S., Korsgaard, S., Günzel-Jensen, F., 2020. Towards a Typology of Sustainability Practices: A Study of the Potentials and Challenges of Sustainable Practices at the Firm Level. Sustainability 12, 5166. https://doi.org/10.3390/su12125166

Jaffe, A.B., Lerner, J., 2006. Innovation and Its Discontents. Capitalism and Society 1. https://doi.org/10.2202/1932-0213.1006

Jain, A., Gurtoo, A., 2021. Can the restrictive boundaries of intellectual property create a larger social impact? CURRENT SCIENCE 120, 3.

Jain, A., Gurtoo, A., 2019. E-Waste and Sustainability: Impact Assessment Indicators (SSRN Scholarly Paper No. ID 3628670). Social Science Research Network, Rochester, NY. https://doi.org/10.2139/ssrn.3628670

Kanda, W., Kuisma, M., Kivimaa, P., Hjelm, O., 2020. Conceptualising the systemic activities of intermediaries in sustainability transitions. Environmental Innovation and Societal Transitions 36, 449–465. https://doi.org/10.1016/j.eist.2020.01.002

Kanger, L., Tinits, P., Pahker, A.-K., Orru, K., Tiwari, A.K., Sillak, S., Šeļa, A., Vaik, K., 2022. Deep Transitions: Towards a comprehensive framework for mapping major continuities and ruptures in industrial modernity. Global Environmental Change 72, 102447. https://doi.org/10.1016/j.gloenvcha.2021.102447

Klein Woolthuis, R., Hooimeijer, F., Bossink, B., Mulder, G., Brouwer, J., 2013. Institutional entrepreneurship in sustainable urban development: Dutch successes as inspiration for transformation. Journal of Cleaner Production, Special Issue: Advancing sustainable urban transformation 50, 91–100. https://doi.org/10.1016/j.jclepro.2012.11.031

Klemperer, P., 1990. How Broad Should the Scope of Patent Protection Be? The RAND Journal of Economics 21, 113–130. https://doi.org/10.2307/2555498

Kobos, P.H., Malczynski, L.A., Walker, L.T.N., Borns, D.J., Klise, G.T., 2018. Timing is everything: A technology transition framework for regulatory and market readiness levels. Technological Forecasting and Social Change 137, 211–225. https://doi.org/10.1016/j.techfore.2018.07.052

Kohler, J., de Haan, F., Holtz, G., 2017. Modelling Sustainability Transitions: An Assessment of Approaches and Challenges. Journal of Artificial Societies and Social Simulation 21. https://doi.org/10.18564/jasss.3629

Kotzian, P., 2023. Firms' sustainability engagement and sustainability-related controversies. Business Strategy and the Environment 33, 1610–1625. https://doi.org/10.1002/bse.3562

Laursen, K., Salter, A.J., 2014. The paradox of openness: Appropriability, external search and collaboration. Research Policy 43, 867–878. https://doi.org/10.1016/j.respol.2013.10.004

Levin, R.C., Klevorick, A.K., Nelson, R.R., Winter, S.G., Gilbert, R., Griliches, Z., 1987. Appropriating the Returns from Industrial Research and Development. Brookings Papers on Economic Activity 1987, 783–831. https://doi.org/10.2307/2534454

Lichtenthaler, U., 2010. Intellectual property and open innovation: an empirical analysis. International Journal of Technology Management 52, 372–391. https://doi.org/10.1504/IJTM.2010.035981

Lichtenthaler, U., 2009. Outbound open innovation and its effect on firm performance: examining environmental influences. R&D Management 39, 317–330. https://doi.org/10.1111/j.1467-9310.2009.00561.x

Lichtenthaler, U., 2008. Open Innovation in Practice: An Analysis of Strategic Approaches to Technology Transactions. IEEE Transactions on Engineering Management 55, 148–157. https://doi.org/10.1109/TEM.2007.912932

Lippolis, S., Ruggieri, A., Leopizzi, R., 2023. Open Innovation for sustainable transition: The case of Enel "Open Power." Business Strategy and the Environment 32, 4202–4216. https://doi.org/10.1002/bse.3361

Loorbach, D., 2010. Transition Management for Sustainable Development: A Prescriptive, Complexity-Based Governance Framework. Governance 23, 161–183. https://doi.org/10.1111/j.1468-0491.2009.01471.x

Lindberg, V., 2008. Intellectual property and open source: A practical guide to protecting code. O'Reilly Media, Inc.

Manzhynski, S., Figge, F., 2020. Coopetition for sustainability: Between organizational benefit and societal good. Business Strategy and the Environment 29, 827–837. https://doi.org/10.1002/bse.2400

Manzini, R., Lazzarotti, V., 2016. Intellectual property protection mechanisms in collaborative new product development. R&D Management 46, 579–595. https://doi.org/10.1111/radm.12126

Markard, J., Raven, R., Truffer, B., 2012. Sustainability transitions: An emerging field of research and its prospects. Research Policy, Special Section on Sustainability Transitions 41, 955–967. https://doi.org/10.1016/j.respol.2012.02.013

Markard, J., Truffer, B., 2008. Actor-oriented analysis of innovation systems: exploring micro–meso level linkages in the case of stationary fuel cells. Technology Analysis & Strategic Management 20, 443–464. https://doi.org/10.1080/09537320802141429

Martek, I., Hosseini, M.R., Shrestha, A., Edwards, D.J., Durdyev, S., 2019. Barriers inhibiting the transition to sustainability within the Australian construction industry: An investigation of technical and social interactions. Journal of Cleaner Production 211, 281–292. https://doi.org/10.1016/j.jclepro.2018.11.166

Maskus, K.E., Penubarti, M., 1995. How trade-related are intellectual property rights? Journal of International Economics 39, 227–248. https://doi.org/10.1016/0022-1996(95)01377-8

Masucci, M., Brusoni, S., Cennamo, C., 2020. Removing bottlenecks in business ecosystems: The strategic role of outbound open innovation. Research Policy 49, 103823. https://doi.org/10.1016/j.respol.2019.103823

Melander, L., 2018. Customer and Supplier Collaboration in Green Product Innovation: External and Internal Capabilities. Business Strategy and the Environment 27, 677–693. https://doi.org/10.1002/bse.2024

Ockwell, D.G., Haum, R., Mallett, A., Watson, J., 2010. Intellectual property rights and low carbon technology transfer: Conflicting discourses of diffusion and development. Global Environmental Change, 20th Anniversary Special Issue 20, 729–738. https://doi.org/10.1016/j.gloenvcha.2010.04.009

Page, G.G., Wise, R.M., Lindenfeld, L., Moug, P., Hodgson, A., Wyborn, C., Fazey, I., 2016. Co-designing transformation research: lessons learned from research on deliberate practices for transformation. Current Opinion in Environmental Sustainability, Sustainability challenges 20, 86–92. https://doi.org/10.1016/j.cosust.2016.09.001

Parida, V., Westerberg, M., Frishammar, J., 2012. Inbound Open Innovation Activities in High-Tech SMEs: The Impact on Innovation Performance. Journal of Small Business Management 50, 283–309. https://doi.org/10.1111/j.1540-627X.2012.00354.x

Parris, T.M., Kates, R.W., 2003. Characterizing a sustainability transition: Goals, targets, trends, and driving forces. Proceedings of the National Academy of Sciences 100, 8068–8073. https://doi.org/10.1073/pnas.1231336100

Patil, R., Jain, A., Gurtoo, A., 2020. Sustainability Transition in Established Corporations: Role of Technological Innovation (SSRN Scholarly Paper No. ID 3635658). Social Science Research Network, Rochester, NY.

Perruchas, F., Consoli, D., Barbieri, N., 2020. Specialisation, diversification and the ladder of green technology development. Research Policy 49, 103922. https://doi.org/10.1016/j.respol.2020.103922

Pettigrew, A.M., 1990. Longitudinal Field Research on Change: Theory and Practice. Organization Science 1, 267–292. https://doi.org/10.1287/orsc.1.3.267

Prendergrast, M., 1993. For God, Country, and Coca-Cola: The Unauthorized History of the Great American Soft Drink and the Company That Makes It. New York: Scribner.

Rai, V., Schultz, K., Funkhouser, E., 2014. International low carbon technology transfer: Do intellectual property regimes matter? Global Environmental Change 24, 60–74. https://doi.org/10.1016/j.gloenvcha.2013.10.004

Raiser, K., Naims, H., Bruhn, T., 2017. Corporatization of the climate? Innovation, intellectual property rights, and patents for climate change mitigation. Energy Research & Social Science 27, 1–8. https://doi.org/10.1016/j.erss.2017.01.020

Rimmer, M., 2018. Elon Musk's Open Innovation: Tesla, Intellectual Property, and Climate Change, in: Rimmer, M. (Ed.), Intellectual Property and Clean Energy. Springer Singapore, Singapore, pp. 515–551. https://doi.org/10.1007/978-981-13-2155-9_19

Ritala, P., Albareda, L., Bocken, N., 2021. Value creation and appropriation in economic, social, and environmental domains: Recognizing and resolving the institutionalized asymmetries. Journal of Cleaner Production 290, 125796. https://doi.org/10.1016/j.jclepro.2021.125796

Ritala, P., Golnam, A., Wegmann, A., 2014. Coopetition-based business models: The case of Amazon.com. Industrial Marketing Management, Special Issue on Co-opetition Cooperation and Competition 43, 236–249. https://doi.org/10.1016/j.indmarman.2013.11.005

Roh, T., Lee, K., Yang, J.Y., 2021. How do intellectual property rights and government support drive a firm's green innovation? The mediating role of open innovation. Journal of Cleaner Production 317, N.PAG-N.PAG. https://doi.org/10.1016/j.jclepro.2021.128422

Rosenbloom, R.S., 2000. Leadership, Capabilities, and Technological Change: The Transformation of NCR in the Electronic Era. Strategic Management Journal 21, 1083–1103. https://doi.org/10.1002/1097-0266(200010/11)21:10/11<1083::AID-SMJ127>3.0.CO;2-4

Santa-Maria, T., Vermeulen, W.J.V., Baumgartner, R.J., 2021. Framing and assessing the emergent field of business model innovation for the circular economy: A combined literature review and multiple case study approach. Sustainable Production and Consumption 26, 872–891. https://doi.org/10.1016/j.spc.2020.12.037

Sarasini, S., Linder, M., 2018. Integrating a business model perspective into transition theory: The example of new mobility services. Environ. Innov. Soc. Trans. 27, 16–31. https://doi.org/10.1016/j.eist.2017.09.004

Schaltegger, S., Wagner, M., 2011. Sustainable entrepreneurship and sustainability innovation: categories and interactions. Business Strategy and the Environment 20, 222–237. https://doi.org/10.1002/bse.682

Schomberg, R. von, Hankins, J., 2019. International Handbook on Responsible Innovation: A Global Resource. Edward Elgar Publishing.

Shapiro, C., 2000. Navigating the patent thicket: Cross licenses, patent pools, and standard setting. Innovation policy and the economy 1, 119–150.

Seuring, S., Gold, S., 2012. Conducting content-analysis based literature reviews in supply chain management. Supply Chain Management: An International Journal 17, 544–555. https://doi.org/10.1108/13598541211258609

Song, W., Yu, H., 2018. Green Innovation Strategy and Green Innovation: The Roles of Green Creativity and Green Organizational Identity. Corporate Social Responsibility and Environmental Management 25, 135–150. https://doi.org/10.1002/csr.1445

Stål, H.I., Riumkin, I., Bengtsson, M., 2023. Business models for sustainability and firms' external relationships—A systematic literature review with propositions and research agenda. Business Strategy and the Environment 32, 3887–3901. https://doi.org/10.1002/bse.3343

Stefan, I., Bengtsson, L., 2017. Unravelling appropriability mechanisms and openness depth effects on firm performance across stages in the innovation process. Technological Forecasting and Social Change 120, 252–260. https://doi.org/10.1016/j.techfore.2017.03.014

Stern, N., Valero, A., 2021. Innovation, growth and the transition to net-zero emissions. Research Policy 50, 104293. https://doi.org/10.1016/j.respol.2021.104293

Tang, A., Tietze, F., 2021. Intellectual Property Strategy Trajectory: A New Visualisation Approach (Working Paper). https://doi.org/10.17863/CAM.75500

Teece, D.J., 1986. Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. Research Policy 15, 285–305. https://doi.org/10.1016/0048-7333(86)90027-2

Telg, N., Lokshin, B., Letterie, W., 2023. How formal and informal intellectual property protection matters for firms' decision to engage in coopetition: The role of environmental dynamism and competition intensity. Technovation 124, 102751. https://doi.org/10.1016/j.technovation.2023.102751

Therivel, R., Christian, G., Craig, C., Grinham, R., Mackins, D., Smith, J., Sneller, T., Turner, R., Walker, D., Yamane, M., 2009. Sustainability-focused impact assessment: English experiences. Impact Assessment and Project Appraisal 27, 155–168. https://doi.org/10.3152/146155109X438733

Thun, T.W., Zülch, H., 2023. The effect of chief sustainability officers on sustainability reporting—A management perspective. Business Strategy and the Environment 32, 2093–2110. https://doi.org/10.1002/bse.3238

Tietze, F., Eppinger, E., Sternkopf, J., Vimalnath, P., 2017. IP strategies for sustainability, in: 2017 IEEE Technology & Engineering Management Conference (TEMSCON). Presented at the 2017 IEEE Technology & Engineering Management Conference (TEMSCON), IEEE, Santa Clara, CA, USA, pp. 173–178. https://doi.org/10.1109/TEMSCON.2017.7998373

Turnheim, B., Berkhout, F., Geels, F., Hof, A., McMeekin, A., Nykvist, B., van Vuuren, D., 2015. Evaluating sustainability transitions pathways: Bridging analytical approaches to address governance challenges. Global Environmental Change 35, 239–253. https://doi.org/10.1016/j.gloenvcha.2015.08.010

van de Vrande, V., de Jong, J.P.J., Vanhaverbeke, W., de Rochemont, M., 2009. Open innovation in SMEs: Trends, motives and management challenges. Technovation 29, 423–437. https://doi.org/10.1016/j.technovation.2008.10.001

van der Waal, J.W.H., Thijssens, T., Maas, K., 2021. The innovative contribution of multinational enterprises to the Sustainable Development Goals. Journal of Cleaner Production 285, 125319. https://doi.org/10.1016/j.jclepro.2020.125319

Vanhaverbeke, W., Vrande, V., Chesbrough, H., 2008. Understanding the Advantages of Open Innovation Practices in Corporate Venturing in Terms of Real Options. Creativity and Innovation Management 17, 251–258. https://doi.org/10.1111/j.1467-8691.2008.00499.x

Vimalnath, P., Tietze, F., Eppinger, E., Jain, A., Gurtoo, A., Elsen, M., 2023. Responsible intellectual property strategy for sustainability transition - An exploratory study. World Patent Information 73, 102195. https://doi.org/10.1016/j.wpi.2023.102195

Vimalnath, P., Tietze, F., Eppinger, E., Sternkopf, J., 2020. Closed, Semi-Open, or Fully-Open? Towards an Intellectual Property Strategy Typology. Proceedings 2020, 22070. https://doi.org/10.5465/AMBPP.2020.22070abstract

Vimalnath, P., Tietze, F., Jain, A., Gurtoo, A., Eppinger, E., Elsen, M., 2022. Intellectual property strategies for green innovations - An analysis of the European Inventor Awards. Journal of Cleaner Production 377, 134325. https://doi.org/10.1016/j.jclepro.2022.134325

Wang, Y., Qiu, Y., Luo, Y., 2022. CEO foreign experience and corporate sustainable development: Evidence from China. Business Strategy and the Environment 31, 2036–2051. https://doi.org/10.1002/bse.3006

West, J., Salter, A., Vanhaverbeke, W., Chesbrough, H., 2014. Open innovation: The next decade. Research Policy, Open Innovation: New Insights and Evidence 43, 805–811. https://doi.org/10.1016/j.respol.2014.03.001

West, J., Gallagher, S., 2006. Challenges of open innovation: the paradox of firm investment in open-source software. R and D Management 36, 319–331. https://doi.org/10.1111/j.1467-9310.2006.00436.x

Willis, A., 2003. The Role of the Global Reporting Initiative's Sustainability Reporting Guidelines in the Social Screening of Investments. Journal of Business Ethics 43, 233–237. https://doi.org/10.1023/A:1022958618391

WIPO Green [WWW Document], n.d. URL https://www3.wipo.int/wipogreen/en/

Xie, J., Lv, T., Tong, P., Li, X., Lu, Y., Sajid, M.J., Lv, Q., 2021. How Does the Efficiency of Value Realization on a Platform Influence Sustainability Transition? A Case of the Power Industry in China. Front. Energy Res. 8, 616124. https://doi.org/10.3389/fenrg.2020.616124

Yin, R.K., 1994. Discovering the Future of the Case Study. Method in Evaluation Research. Evaluation Practice 15, 283–290. https://doi.org/10.1177/109821409401500309

Zhao, S., Jiang, Y., Wang, S., 2019. Innovation stages, knowledge spillover, and green economy development: moderating role of absorptive capacity and environmental regulation. Environ Sci Pollut Res 26, 25312–25325. https://doi.org/10.1007/s11356-019-05777-9

Ziegler, N., Gassmann, O., Friesike, S., 2014. Why do firms give away their patents for free? World Patent Information 37, 19–25.

ANNEXURES

Annexure A. Methodology tables

Table A.1. Description of sources for the data collection

S. no	Case code	Founding period range	Periods analysed	# Documents for desk research	Executives interviewed	# interview rounds	Duration of each round of interview [in minutes]
1	C#1	1995-2000	1996-2020	34	[1] IP general counsel [2] Sustainability Head	3	[1] 110 [2] 120 [3] 90
2	C#2	1935-1940	1996-2019	20	[1] R&D Head [2] IP manager	2	[1] 90 [2] 180
3	C#3	2010-2015	2008-2020	42	[1] Sustainability Manager and R&D director and R&D Manager [2] IP manager and R&D Manager [3] Director [4] IP Manager and R&D director	2	[1] 75 [2] 70 [3] 45 [4] 90
4	C#5	2010-2015	2011-2020	31[i]	[1] Founder [2] Co-Founder and MD	2	[1] 90 [2] 90
5	C#6	2010-2015	2012-2020	39	[1] IP Head	3	[1] 120 [2] 120 [3] 90
6	C#7	1995-2000	1996 - 2020	57	[1] Senior Manager – IP and Innovation	2	[1] 120 [2] 60
7	C#8	2010-2015	2014-2020	13	[1] Chief Executive Officer [2] Chief Technology Officer	2	[1] 150 [2] 100
8	C#9	2010-2015	2013-2020	31[ii]	[1] Managing Director [2] Chief Technology Officer [3] Chief Financial Officer (now Chief Operating Officer)	4	[1] 75 [2] 55 [3] 65 [4] 90
9	C#10	2010-2015	2010-2020	30[iii]	[1] Co-Founder and Creative Director	4	[1] 105 [2] 70 [3] 30 [4] 90
10	C#11	1890-1895	2011-2020	61[iv]	[1] Director, Growth & Business Transformation [2] Vice President of Research [3] Director of Solution Strategy [4] Director of Strategic Marketing	4	[1] 50 [2] 70 [3] 80 [4] 40
11	C#12	1975-1980	1977-2020	31	[1] Managing director	1	[1] 120
12	C#13	2010-2015	2014-2020	27	[1] Co-founder and managing director [2] Co-founder and managing director	2	[1] 90 [2] 60
13	C#14	1985-1990	1983-2020	32	[1] R&D director	1	[1] 110
14	C#15	1995-2000	1996-2020	28	[1] Senior Advisor	1	[1] 120

15	C#16	1935-1940	1980-2020	43	[1] Sustainability manager and business unit manager	1	[1] 130
16	C#17	2005-2010	2006-2020	28	[1] Founder and managing director	1	[1] 115
17	C#18	2010-2015	2015-2020	34	[1] Co-founder and managing director	1	[1] 125
18	C#19	1945-1950	1980-2020	47	[1] R&D director	1	[1] 120
19	C#20	1945-1950	2006-2020	59	[1] Vice President – E-Mobility solutions [2] Vice president - corporate strategy [3] Assistant General Manager – Engine innovation [4] Assistant Manager – Supplier quality assurance	2	[1] 60 [2] 120
20	C#21	2010-2015	2012-2021	10	[1] Founder, CTO	2	[1] 100 [2] 100
21	C#22	2005-2010	2007-2021	15	[1] CEO – Chief Executive Officer [2] Chief Marketing Officer [3] Project Manager	2	[1] 80 [2] 40
22	C#23	2010-2015	2012-2021	10	[1] Vice President – Intellectual Property	2	[1] 80 [2] 60
23	C#24	1985-1990	1987-2021	270	[1] CEO– Chief Executive Officer	2	[1] 150 [2] 120
24	C#26	1930-1935	2015-2020	34	[1] Director of Technological Innovation Processes [2] IP Manager [3] Sustainability Manager [4] CEO office representatives	4	[1] 50 [2] 90 [3] 110 [4] 90
25	C#27	1985-1990	2011-2020	25 [v]	[1] Managing Director (the core person behind the company's IP strategy)	2	[1] 115 [2] 75
26	C#28	2010-2015	2011-2020	13	[1] Founder and Chief Executive Officer [2] Technical Director [3] IP Analyst	2	[1] 135 [2] 60
27	C#29	2005-2010	2010-2020	9	[1] Founder	2	[1] 90 [2] 70
28	C#30	2000-2005	2011-2021	24[vi]	[1] Founder and Chief Executive Officer, [2] Business Development Manager, [3] Sustainability and Business Development Manager,	1	[1] 165

[i]22 from the public domain + 9 provided by the company; [ii] 28 from the public domain + 3 provided by the company; [iii]29 from the public domain + 1 provided by the company; [iv]51 from the public domain + 10 provided by the company; [v]21 from the public domain + 3 provided by the company; [vi]23 from the public domain + 2 provided by the company.

Annexure B. Methodology Figures

Figure B.1 Code categorization scheme of firm's IP strategy

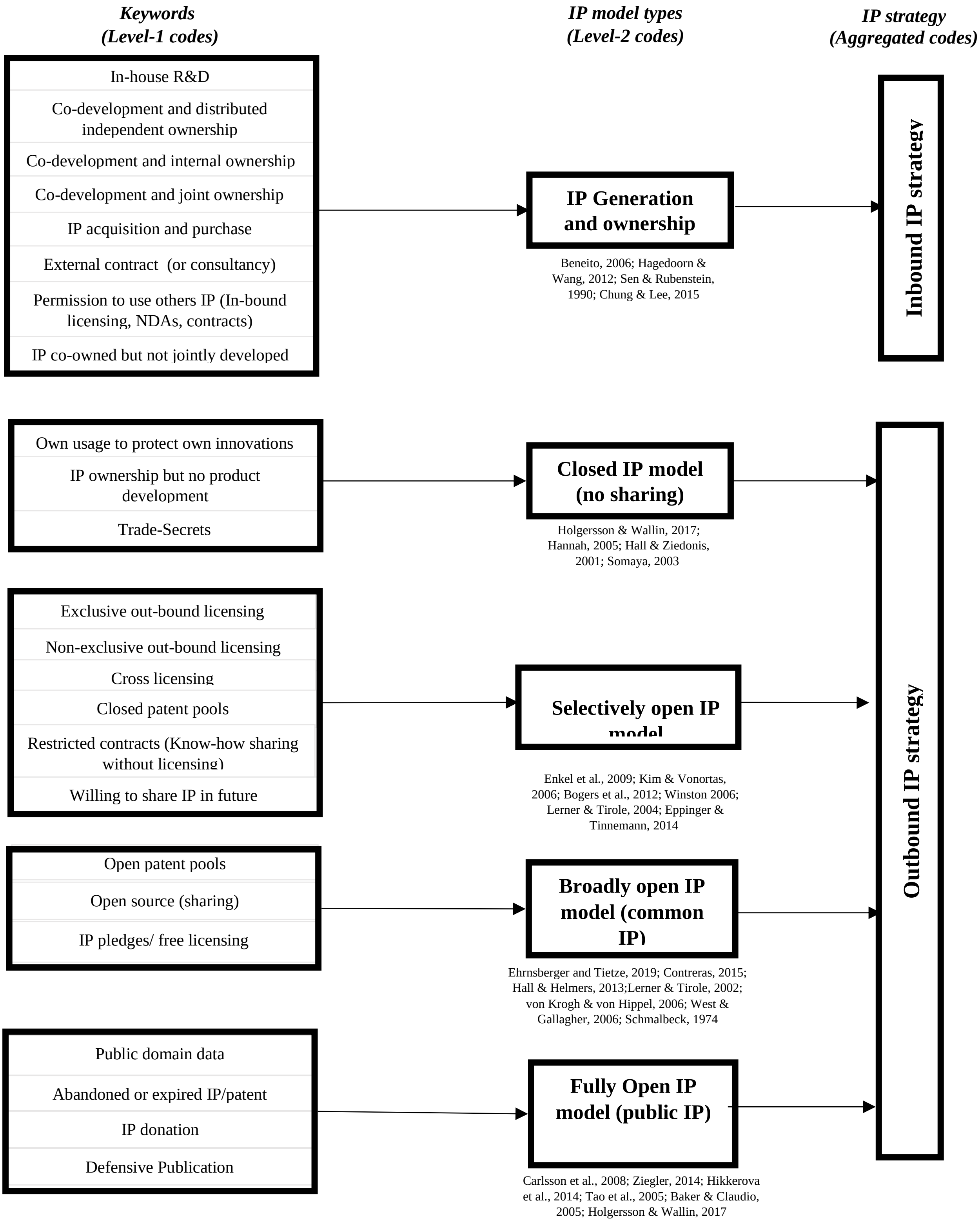
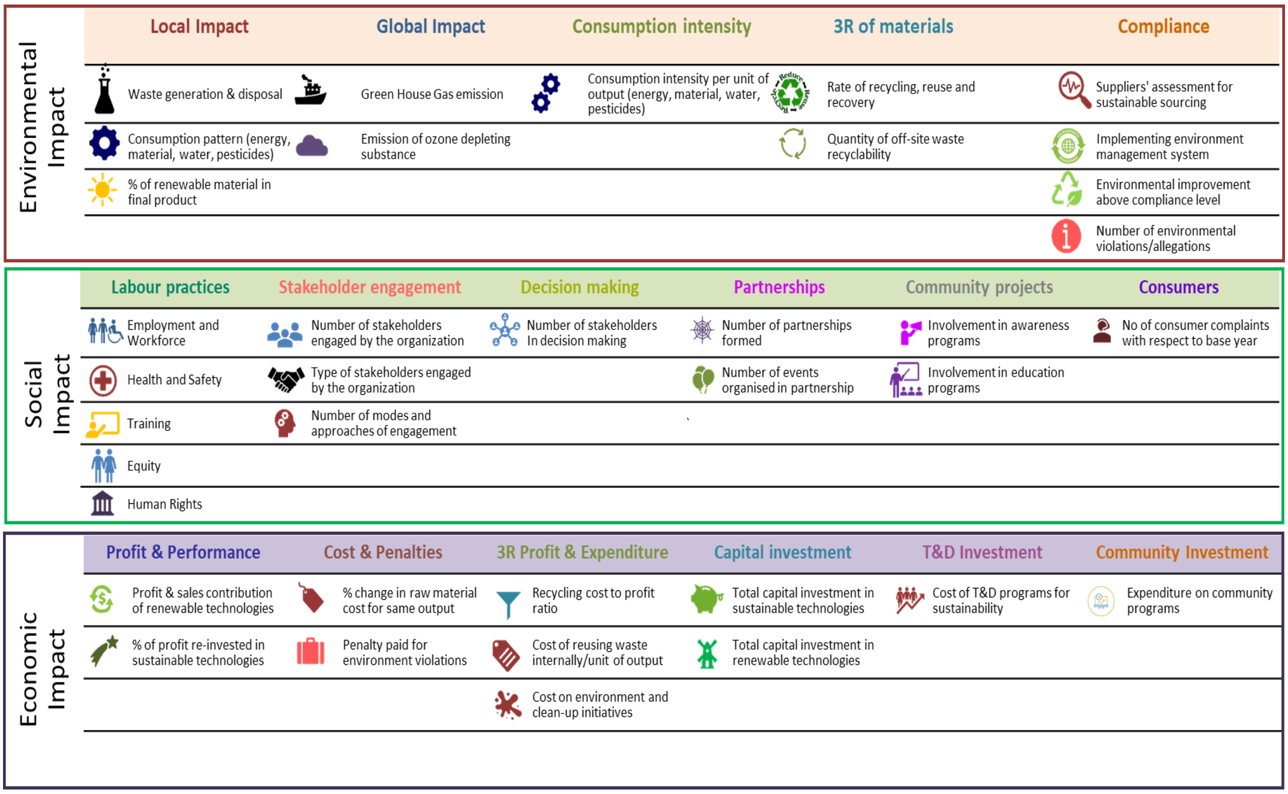


Table B.2. Code categorization scheme of firms' sustainability practices

Dimensions (Aggregated code)	Indicators (Level 2 sub-codes)	Keywords identified from literature (Level-1 codes)	References
Firms' internally driven practices bringing firm-level sustainability	**Broadened value propositions with internal drive**	Leader's or CEO's vision and commitment to prioritize sustainability	Loorbach et al., 2009; Bolton & Hannon, 2016; Foxon et al., 2015; Chang et al., 2016; Hart, 1995
		Sustainability-oriented initiatives by key professionals within the organisation	
		Training to employees for sustainability practices, product, or service	
		Hiring sustainability specialist and staff	
		Developing sustainability work policies, code of conduct, reporting and auditing	
		Accounting returns on investments of sustainability actions	
		Broadening the context and scope of firms' activity to provide green and sustainable solutions to the customer	
	Re-visioning, Re-purposing, & Re-branding	Change in company's direction and revising their goals and aims towards sustainability	Kemp, 1994; Markard & Truffer, 2008; Martek et al., 2019; Heyen & Wolff, 2019
		Change in business model or value creation or delivery logic	
	Small sustainability modifications	Taking small steps or modifications towards sustainability	Dyllick & Hockerts, 2002; Gorissen, Chang et al., 2016; Vrancken and Manshoven, 2016; Sarasini & Linder, 2018; Kanda et al, 2020
		Installation of pollution control devices	
		Use of more environmentally benign materials	
		Giving "medium" or similar priority to renewable technology than to other technologies	
		Modify the service/product towards environmental or social sustainability	
		Increase in energy, water, and resource efficiency per value creation	
		Reduction in waste created per unit of value generated	
External catalysts (drivers) making firms to undertake sustainability practices	**Policy & Regulatory factors**	Introducing sustainability related changes as a response to change in government's policy, fundings, subsidies; incentives, capital grants, loans, exemptions or other policy or regulatory support for adoption of new and sustainable technologies	Kim, 2003; Loorbach & Rotman, 2009; Loorbach et al., 2009; Farla et al., 2012; Kobos et al., 2018; Markard, 2018; Köhler et al, 2019; Elshurafa et al., 2018; Lieberherr, Truffer 2014; Wainsteina &. Bumpus, 2016
		Bring about sustainability as response to change in sectoral norms and standards?	
		Interaction with (or making use of any) government programs/funds or support in any way for modification/move towards sustainability	
	Social factors (consumption pattern. Demand, social beliefs)	Sustainability in response to change in demand of customers, or consumption pattern, civil society and social movements.	
	Technological factors (complementary technology & capabilities)	Sustainability related changes due to obsoleteness of the technology company were using, or introduction of new complementary technology of the core sustainable technology	
	Competition	Sustainability due to pressure from external forces (competitors) to go sustainable.	
Firm's sustainability practices influencing other actors within-sector (industry)	**Inter-firm collaborations in same industry**	Collaborate (to build or use an IP) with a company from the same sector	Martin E. Wainsteina,Adam G. Bumpus, 2016; Bolton & Hannon, 2016; Elshurafa et al., 2018; Elkinjton, 1998; Allan Dahl Andersen et al., 2019; Benjamin K. Sovacool, 2015; Chang et al., 2016
		Collaborate with academic or research institute	
		Company reaches out to its' suppliers to make sustainable choices	
	Advocacy, coalitions, lobbying	Company did advocacy or join an advocacy group to push sustainability agenda	
		Company pushing sustainability agenda and ambition of whole sector	
		Convincing civil servants, environmentalist, governments offices about the benefits/necessity of regulations for green energy or other sustainable solutions	
	leading strategy' inspiring others for sustainability	Company is the first mover in the sector to do the social or environmental sustainability initiatives	
		Pronounced public statements and intense awareness campaigns to induce and give signal to other players to take risks and change their strategies and pursue sustainability	

		Fuelling/Mentoring/financing/supporting new firms/venture/startups that provide sustainable solutions in the same sector	
		The company's IP generate recycling or reuse program within or with other company?	
Firm's sustainability practices influencing other actors across-sector (industry)	**Inter-industry/inter-sector collaboration**	Collaborate to CO-CREATE IP with a company from another sector	Geels & Scot, 2007; Kemp, Loorbach & Rotman, 2009; Farla et al., 2012; Köhler et al, 2019; Schäpke, Niko et al., 2017; Elshurafa et al.,2018
		Collaborate to CO-CREATE with a company from another sector – lead to increase in market access	
		Collaborate to CO-CREATE with a company from another sector – lead to increase in NEW market access	
		Collaborate to OUT-SHARE the IP with another company from another sector	
		Collaborate to OUT-SHARE the IP with another company from another sector – lead to increase in market access?	
		Collaborate to OUT-SHARE the IP with another company from another sector – lead to access to NEW market?	
	Vertical/horizontal integration	Share (out or in) IP with a supplier/distributor kind of company (vertical)	Kemp 1994; Bourgeois and Mima 2003; Allan Dahl Andersen et al., 2019
		Share (out or in) IP for a business operating at the same level as them (horizontal)	
		Sharing of IP lead to any innovation – in practice of doing business	
		Sharing of IP lead to any innovation – in product	
		Sharing of IP lead to any innovation – in service	

Figure B.3 Indicators to identify firm's sustainability impact [code categorization scheme for sustainability impact]



Annexure C – Case description

Table C.1 –Description of 28 case studies

S. No.	Case study code	Industry sector (division) and sub-sector (group)*	Technology	Country Headquarter	Firm's size**	Inbound IP openness ***	Outbound IP openness	Sustainability practices****
1	#1	Electricity (35) - Electric power generation (351)	Renewable energy generation and distribution	UK	L	Closed	SO	Within industry influencer + Cross industry influencer
2	#2	Manufacturing (21) - Manufacture of pharmaceutical, etc. (210)	Water purification, heal and nutrition consumer products, green tyres	India	L	SO	SO	Firm-level – ID + Within industry influencer + Cross industry influencer
3	#3	Manufacturing (26) - Manufacture of consumer electronics (264)	Consumer electronics, hardware, and software construction	The Netherlands	L	SO	FO	Within industry influencer + Cross industry influencer
4	#5	Water supply, waste management (38) - Materials recovery (383)	PET bottles flaking machine and recycling process	India	SME	SO	SO+FO	Within industry influencer + Cross industry influencer
5	#6	Transportation (49) – other land transport (492)	IoT based smart electric two-wheeler	India	SME	Closed + SO	SO+BO	Within industry influencer
6	#7	Manufacturing (28) – Manufacture of general-purpose machinery (281)	Energy-efficient industrial automation products	U.S.	L	Closed + SO	SO	Within industry influencer + Cross industry influencer
7	#8	Water supply, waste management (38) - Materials recovery (383)	Battery recycling	UK	SME	SO	Closed	Firm-level - ED
8	#9	Water supply, waste management (38) - Materials recovery (383)	Biomass recycling	UK	SME	SO	SO	Within industry influencer
9	#10	Manufacturing (26) - Manufacture of consumer electronics (264)	Premium, energy efficient lighting	UK	SME	SO	Closed	Firm-level - ED
10	#11	Manufacturing (28) – Manufacture of general-purpose machinery (281)	Cold chain refrigeration	U.S.	L	SO	SO	Firm-level - ED
11	#12	Manufacturing (20) – Manufacture of chemicals	Chemical manufacturing	Germany	L	SO	FO	Cross industry influencer
12	#13	Manufacturing (26) - Manufacture of consumer electronics (264)	Consumer electronics, hardware and software construction	Germany	L	SO	FO	Within industry influencer + Cross industry influencer
13	#14	Manufacturing (20) – Manufacture of chemicals	Chemical manufacturing	Germany	L	SO	SO	Firm-level – ID + Within industry influencer
14	#15	Electricity (35) - Electric power generation (351)	Renewable energy solutions	India	L	FO	FO	Within industry influencer + Cross industry influencer
15	#16	Manufacturing (13) – Manufacture of Textiles	Textile manufacturing, dying, coating, & recycling	Denmark	L	SO	SO	Firm-level – ID +

								Within industry influencer + Cross industry influencer
16	#17	Manufacturing (22) – Manufacture of plastic products (222)	Biodegradable packaging solutions and software	Australia	L	SO	SO	Cross industry influencer
17	#18	Water supply, waste management (38) - Materials recovery (383)	Textile recycling	U.S.	L	SO	SO	Cross industry influencer
18	#19	Manufacturing (13) – Manufacture of Textiles	Textile manufacturing and recycling technologies	The Netherlands	L	Closed + SO	SO	Within industry influencer
19	#20	Transportation (49) – Other land transport (492)	Heavy locomotive electric vehicles	India	L	Closed + SO	SO	Firm-level – ID + Within industry influencer + Cross industry influencer
20	#21	Water supply, waste Management (38) – Waste treatment and disposal (382)	Wastewater treatment & recycling	Hungary	SME	SO	SO	Within industry influencer
21	#22	Electricity (35) - Electric power generation (351)	Renewable energy generation	Sweden	SME	Closed	Closed	Firm-level - ED
22	#23	Water supply, waste management (38) - Materials recovery (383)	IoT based smart water purification	Sweden	SME	SO	Closed	ED – firm-level
23	#24	Manufacturing (13) – Manufacture of Textiles	Textile manufacturing & recycling	Italy	SME	SO	Closed	ED – firm-level
24	#26	Electricity (35) - Electric power generation (351)	Renewable energy generation	Spain	L	SO	Closed	ED – firm-level
25	#27	Manufacturing (21) – Manufacture of pharmaceuticals (210)	Therapeutic nutritional solution provider	France	L	SO	SO + BO	Within industry influencer + Cross industry influencer
26	#28	Water supply, waste management (38) - Materials recovery (383)	Modular plastic recycling process technology	U.S.	SME	SO	SO	Cross industry influencer
27	#29	Water supply, waste management (38) - Materials recovery (383)	Carbon recycling	Switzerland	SME	SO	SO	Cross industry influencer
28	#30	Water supply, waste management (38) - Materials recovery (383)	Plastic recycling	Luxembourg	SME	Closed	SO	Cross industry influencer

*Definition of sector and sub-sector as per UN STAT https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf

****** Definition of micro, small and medium enterprises (SME), and Large (L) enterprises as per the EU: https://ec.europa.eu/growth/smes/sme-definition_en;

*** Closed/Selectively open (SO)/Broadly open (BO)/Fully open (FO)

**** internally driven sustainability practices for firm-level sustainability (ID – firm-level)/ Externally driven sustainability practices for firm-level sustainability (ED – firm-level)/ sustainability practices influencing others within the industry for sustainability (Within industry influencer)/ sustainability practices influencing others across the industry for sustainability (Cross-industry influencer)