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The effectiveness of appropriation mechanisms for sustainable innovations from small and medium-sized enterprises

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ABSTRACT

Literature suggests that formal and informal appropriation mechanisms, such as patents and trade secrecy, play a crucial role in obtaining returns from innovation. Whether this applies to a sustainable innovation is unclear. Appropriation mechanisms could enable the commercialization of sustainable innovations, helping diffusion and societal impact, yet could clash with the principles of openness and sharing that characterize sustainable innovations. This may limit sustainable innovations' commercial success. To shed light on this debate we analyzed an original sample of sustainable innovations by Dutch small and medium-sized enterprises. We found that sustainable innovations make use of informal appropriation mechanisms, such as lead time advantage and confidentiality agreements, and that these mechanisms are positively associated with commercial success. The positive and negative views on appropriation mechanisms in a sustainable innovation context actually vary by mechanism. The results suggest that firms introducing sustainable innovations behave similarly to other small and medium-sized enterprises innovators when it comes to use of appropriation mechanisms, but the extent to which such mechanisms enable commercial success reveals important specificities. Implications for managers include the use of first-mover advantages to stay ahead of the competition. Service innovations may benefit from using confidentiality agreements. Policymakers can promote simplicity, interoperability, and right-to-repair initiatives to reduce product complexity and hence waste, thereby lowering the negative impact of complexity on commercial success. The results also contribute to the literature in which associations between innovation, sustainability and economic performance were reported for small and medium-sized enterprises.

1. Introduction

In times facing energy crises, deforestation and global warming, sustainability is becoming increasingly important for innovation research and practice. By addressing such challenges, a sustainable innovation (SI) generates returns to the innovator and society. SIs have indeed received increasing attention and interest in innovation research (Cillo et al., 2019; Díaz-García et al., 2015), while environmental and social awareness among entrepreneurs contribute to a paradigm shift from conventional non-sustainable practices toward sustainable ones (Haldar, 2019). The traditional view that SIs bring costs and burdens to a firm has been replaced by the notion that firms can leverage SIs to create value and achieve competitive advantage through sustainability (Hermundsdottir and Aspelund, 2021). However, despite evidence demonstrating the association between the innovativeness of small and medium-sized enterprises (SMEs), sustainability initiatives and economic performance (e.g., Jansson et al., 2017; Martinez-Conesa et al., 2017; Tomšič et al., 2015), the sustainability and innovation literature struggles to explain how innovators effectively capture returns from SIs (Cillo et al., 2019).

An SI is directed toward more sustainable systems of production and consumption, taking into account environmental factors like resource use and waste production, and social factors like attaining social justice and economic prosperity (Foxon and Pearson, 2008, p. 148). The principal motivations behind SI are to address grand challenges such as climate change, poverty, hunger, and social injustice (George et al., 2016). To appropriate from SI, innovators balance economic objectives of value creation and sustainability objectives. For some SIs the returns to society may be even greater than the returns to the innovator. This contrasts with appropriation strategy literature, which primarily focuses

Abbreviations: [1]Abbreviations: IPRs, intellectual property rights; SI, sustainable innovation; SME, small and medium-sized enterprise.

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on how innovators appropriate returns from their innovations and achieve commercial success (e.g., James et al., 2013; Teece, 1986). This literature suggests appropriation mechanisms – such as patents and secrecy – are key enablers of commercial success because they protect the knowledge behind the innovation (Ceccagnoli, 2009; Hall et al., 2014; Teece, 1986, 2006). Patents, for example, are associated with success indicators like market valuation of R&D (Ceccagnoli, 2009) and new product sales (Balasubramanian and Sivadasan, 2011; Hall et al., 2014), and trademarks are seen as specialized reputational assets that help innovators profit from their innovation (Teece, 1988; Flikkema et al., 2019).

However, for SIs appropriation mechanisms may play a different role, and their purpose might not even be to appropriate economic returns. Sustainability literature raises some issues in this respect: that we lack knowledge about the impact of intellectual property rights (IPRs) on SIs (Eppinger et al., 2021) and whether a sustainable SME can leverage the opportunities from IPRs (Castaldi, 2021). Performance outcomes for SIs are so far insufficiently explained (Cillo et al., 2019), and we don't know all the conditions under which SIs become successful (Hermundsdottir and Aspelund, 2021). In brief, appropriation mechanisms' relatedness to SI success is not understood. Our research question is therefore: Which appropriation mechanisms are associated with SIs' commercial success?

To answer our research question, we studied SMEs that introduced an SI, examining their use of appropriation mechanisms and hypothesizing their relation to the success of the SI. The sample of innovations was obtained by surveying two SI competitions geared to SMEs: Accenture's Blue Tulip Awards, which emphasize innovations that produce a positive sustainability impact, and the Dutch Chamber of Commerce's Innovation Top 100, fostering innovations that generate a positive impact to society and a contribution to a better world. The SME setting is relevant because SMEs play a significant role in economic growth by making up 99% of EU enterprises, half of GDP, and two-thirds of employment (European Commission, 2020, 2021). Their potential impact on sustainability is thus substantial (Patricio et al., 2018). SMEs furthermore face challenges in implementing sustainability initiatives (Barbosa et al., 2020; Nunes et al., 2019), such as cleaner production, and face economic, personnel, leadership and technical barriers to adoption, among others (see Nunes et al., 2019 for a comprehensive review of barriers). Small firms also form sustainable strategies differently than their large counterparts (Luederitz et al., 2021). By examining appropriation mechanisms in a sustainability context this study could derive managerial recommendations for SMEs on their appropriation strategy.

The contribution of this paper is threefold. First, we develop theoretical arguments to understand how appropriation mechanisms can work as enablers or obstacles for the commercial success of SI. This answers calls to better understand the conditions that make SIs commercially successful (Hermundsdottir and Aspelund, 2021). Second, we empirically reveal the extent to which different appropriation mechanisms support SIs' commercial success. This contributes novel evidence on the usefulness of appropriation mechanisms for SIs, a current subject of debate in the literature (Cillo et al., 2019; Corrocher and Solito, 2017; Hermundsdottir and Aspelund, 2021). Last, from a societal impact perspective this study informs policymakers about appropriation mechanism trends to help make decisions in crafting outreach and information campaigns for SMEs on such mechanisms, particularly as sustainability is becoming more pressing. The outcomes guide sustainable innovators in selecting appropriation mechanisms associated with higher chances of commercial success.

2. Theoretical framework

Appropriation mechanisms refer to formal or informal mechanisms used by companies to appropriate returns from innovation. Formal mechanisms are enshrined in law, and upon registration allow excluding others from using the right for a fixed period. Formal mechanisms include patents to register inventions and trademarks to register attributes denoting origins –brands, symbols, names. Informal mechanisms have no legal basis but emerge from an organization's strategy. They entail mechanisms such as lead time advantage, secrecy, and product complexity to hinder reverse engineering and imitation. Appropriation mechanisms contribute to appropriating the economic value of an innovation by placing barriers to imitation (Teece, 1986).

The appropriation literature is driven strongly by profiting from innovation (PFI) theory, which predicts conditions under which pioneers achieve commercial success for their innovations (Teece, 1986, 2006). Commercial success in our study entails the benefits to a firm resulting from the introduction of an innovation to the market (Flikkema, 2008; Storey and Easingwood, 1996). A central pillar of PFI is that pioneers fail on the marketplace when they lack protection for their ideas (Teece, 2006). While the role of appropriation mechanisms in SI and performance outcomes have received little attention, the conventional appropriation literature examines the association between appropriation mechanisms and various performance outcomes (e.g., Aloini et al., 2017; Ceccagnoli, 2009; Hall et al., 2014; Lee et al., 2018), showing that SMEs tend to rely on informal appropriation mechanisms rather than formal ones (Leiponen and Byma, 2009; Thomä and Bizer, 2013). Empirical evidence for appropriation mechanisms in the context of SIs is limited (though for an exception, see Vimalnath et al., 2020).

2.1. Appropriation mechanisms and SI

From a theoretical standpoint, the role of appropriation mechanisms for SIs is not clear (Eppinger et al., 2021; Hermundsdottir and Aspelund, 2021). Castaldi (2021) drew contrast between two opposing views on IPRs and SIs, but the debate should concern all appropriation mechanisms, formal and informal. A positive view argues that appropriation mechanisms work as enablers of an SI's success. Commercial success goes hand-in-hand with the ability of firms to protect their innovation and leverage it to signal sustainable leadership: they could play a key role by reducing technological and market uncertainty and enabling licensing of sustainable solutions (Eppinger et al., 2019). Here appropriation mechanisms work hand-in-hand with value creation.

A negative view argues that the very idea of value appropriation clashes with core values behind sustainability, such as sharing and openness. For example, the exclusionary nature of appropriation mechanisms might inhibit diffusion and make SIs less legitimate in the eyes of consumers and users. This may also diminish the stature of SIs as a public good that benefits society. Hence appropriation mechanisms could inhibit the value creation potential of an SI, yet sustainable innovators may have benefited from public R&D financing. This may place licensing conditions or limitations on the license holder unfavorable to the innovator. Sustainable innovators may then opt for alternative appropriation strategies such as openness, for example by collaborating, sharing knowledge, or placing it in the public domain and avoiding use of specific appropriation mechanisms. The positive and negative views provide perspectives for and against using appropriation mechanisms to attain commercial success with an SI. The next sub-sections elaborate on arguments in light of each appropriation mechanism while reflecting on extant appropriation literature.

2.1.1. Patent filing

Patents protect a technical invention and are subject to strict eligibility criteria entailing novelty, an inventive step, and susceptibility to industrial application (EPO, n.d.). They confer exclusive use of the technology for a 15-year period subject to payment of filing and management fees. Patents contribute to innovation success by blocking and delaying imitation, enabling licensing revenue, enhancing reputation by demonstrating proficiency, and attracting investment (Blind et al., 2006; Cohen et al., 2000; Pisano and Teece, 2007). From the sustainability perspective, however, patenting SIs may send contradictory signals.

Patenting may evoke reputational critiques because an attempt is made to profit from a solution meant to address sustainability challenges. Patenting may also create barriers to diffusion and hamper the use of SIs. Competitors may try to imitate patented ideas, engaging in wasteful duplication of efforts, which would have been avoided by openly sharing the innovation.

Additional arguments against patents emanate from conventional innovation literature, which suggests SMEs prefer informal appropriation mechanisms, namely lead time advantage, secrecy, and complexity over patents (e.g., Leiponen and Byma, 2009; Thomä and Bizer, 2013). SMEs particularly face financial resource constraints which affect their propensity to patent. Other reasons not to patent include novelty requirements, process timing, high filing costs, costs for maintenance and defense against infringers, and disclosure, as imitators can benefit from the public knowledge and invent around the patent, lowering the pioneer's commercial gains (Athreye and Fassio, 2020; Capponi et al., 2019; Cohen et al., 2000). While some appropriation literature highlights patents' contribution to an innovation's success, arguments are put forth from both a sustainability and an SME diverging perspective:

H1. Patent filing has no association with commercial success for SIs

2.1.2. Trademark filing

Sustainability is a property of goods and services that consumers may neither fully understand nor experience, so reputation fulfills a key function in addressing SI market failures related to strong information asymmetries. A trademark enables innovators to distinguish themselves from others and obstruct potential imitators from capitalizing on a sustainable innovator's reputation and image. A trademark can also be used to signal repositioning toward sustainability, or be out-licensed to sustainable partners. Innovators can apply their marketing capabilities and may use trademarks to legally protect a sustainable brand and build reputational assets (Castaldi, 2020).

The outreach and promotion of a sustainable brand or message may also require trademark protection to deter followers from freeriding on the innovator's branding and marketing efforts and thus their commercial success. Without a trademark, advertising risks taking on characteristics of public goods because all innovators benefit equally from advertisement (Llerena and Millot, 2020). The underlying reason to trademark could be to build brand equity, protect IP, or signal strategic change (Flikkema et al., 2014). These reasons could also apply to SIs. Appropriation literature also highlights trademarks' role as a specialized reputational asset that helps companies profit from innovation (Teece, 1988). Innovators can use these reputational and image-building assets to differentiate their SI from competing innovations (Delmas and Colgan, 2019). Accordingly:

H2. Trademark filing is positively associated with commercial success for SIs

2.1.3. Secrecy and confidentiality agreements

An innovator may designate knowledge as a secret to protect their innovation. Secrecy can function perpetually in contrast to patents, yet the protected status is lost once the secret material is made public (Hannah, 2006). Secrecy can be implemented through access restrictions or by structuring the R&D organization into different units so no single unit has a complete understanding of the technology (Hall et al., 2014; Hannah, 2006). Confidentiality agreements or non-disclosure agreements can also be implemented (Hannah, 2006) and used to protect a secret plus create a barrier to imitation by controlling knowledge. Followers and imitators are thus deprived from exclusive knowledge that contributes to an innovation's commercial success. The appropriation literature shows SMEs prefer using informal appropriation mechanisms such as secrecy instead of patents (Leiponen and Byma, 2009; Thomä and Bizer, 2013). Secrecy through access restrictions or written confidentiality agreements can protect tacit SI knowledge and prevent and delay discovery of competitive advantage by others. Written agreements could also enable contracting out of SI knowledge that was not or could not have been patented, enabling the innovator to obtain revenue and benefit from the success of their innovation. Also, secrecy and confidentiality agreements are not as publicly visible as patents or trademarks because they are not registered and may thus face a lower risk of being perceived as obstructing SI diffusion. We therefore expect the following:

H3. Secrecy is positively associated with commercial success for SIs

H4. Confidentiality agreements are positively associated with commercial success for SIs

2.1.4. Lead time advantage

Lead time or first-mover advantage refers to the ability of pioneering firms to earn profit from their innovation by being the first to introduce it to the market (Lieberman and Montgomery, 1988). Innovators can use an early mover strategy to show sustainable leadership. To their detriment, later entrants may have to put more effort into outreach and attracting customers away from the first mover. A head start with environmental standards and certifications (e.g., ISO 14001) or labels (e.g., ISO 14020 series, EU Ecolabel) could also add a barrier and slow potential imitators from obtaining certifications and labels, which is time-consuming. Appropriation literature identifies SME innovators' strong preference for lead time advantage as the most effective or important appropriation mechanism in various settings (e.g., Cohen et al., 2000; Leiponen and Byma, 2009; Thomä and Bizer, 2013). A collaborative innovation environment may erode the effectiveness of secrecy. As many SIs require collaboration, first-mover advantage may be more effective to appropriate value from an SI (Leiponen and Byma, 2009). Lieberman and Montgomery (1988) demonstrate how certain enabling conditions of first-mover advantage – e.g., technological superiority, pre-emption by possession, access to scarce complementary assets, increasing switching costs – ensure commercial success. This leads us to hypothesize that:

H5. Lead time advantage is positively associated with commercial success for SIs

2.1.5. Complexity

An innovator may opt for complexity by inserting attributes that increase and hinder the ability to understand how an innovation creates an outcome (McEvily and Chakravarthy, 2002), deterring the extent and speed of imitation and reverse engineering. For example, high-tech products can be supplemented with obfuscation and anti-tampering mechanisms that can destroy circuitry to prevent reverse engineering (Henry and Ruiz-Aliseda, 2012). However, complexity introduces uncertainties, risks, and feedback loops, plus increases challenges with coordination and project management (Hobday, 1998). James et al. (2013) suggest that implementing complexity requires many resources. Complexity from excessive configurations of product and service offerings can also adversely impact firm performance (Gottfredson and Aspinall, 2005), and questions exist on whether complexity is even a feasible appropriation mechanism (Cohen et al., 2000). For SIs, complexity appears incompatible with sustainability objectives because it introduces steps contrary to optimal use of resources by over-manufacturing an innovation in order to obfuscate it, introducing inefficiencies, and potentially hindering repair and reuse options crucial to a circular economy. Complexity may also elicit a reputational critique by sustainable competitors or activists, and encumber application for a "green" or "sustainable" certification. Complexity runs against consumer expectations too, as complexity of repair decreases likelihood of recommendation (Sabbaghi et al., 2016). Overall, complexity seems to come with risks and costs that potentially reduce the returns from an SI. Hence, we propose that:

H6. Complexity is negatively associated with commercial success for SIs.

A conceptual framework illustrating the hypotheses and proposed associations is presented in Fig. 1.

3. Methods

3.1. Sample of innovations

Innovations entered into sustainability-themed innovation awards provide a sample of new products and services developed with a commitment to sustainability and addressing grand societal challenges. Innovation award contests are time-limited, calling on a target group to put forth an innovative solution to a task or problem (Adamczyk et al., 2012). Our sample comes from two SI competitions held in the Netherlands: the Blue Tulip Awards and the Innovation Top 100. The Blue Tulip Awards welcome innovations addressing grand societal challenges that improve and reshape how society lives and works. The innovations must meet entry criteria which include a positive sustainability impact on areas such as climate and energy, consumption and production, and food and water. Entries to the Innovation Top 100 must demonstrate a positive impact on society and a contribution to a better world in order to reach the ranked top-100 list. Products entered into these two competitions include water-heating devices using solar energy, soap made from residual organic waste, and oil spill cleanup equipment. Services include platforms to outsource unused courier capacity and software to enhance existing audio devices to assist persons with poor hearing.

An innovator may have participated multiple times over several years; in such cases we removed duplicate entries and asked the innovator to complete the survey for their most recent innovation. The Blue Tulip Awards received 2147 submissions in 2016–2018, with 329 responses (15.3% response rate). The Innovations Top 100 received 912 unique innovations from the years 2009–2019, with 215 responses (23.6% response rate). Potential respondents were approached by e-mail and phone to reach the person most knowledgeable with the innovation.

3.2. Key variables

This section describes the dependent, independent, control, and demographic variables. Table 1 includes all variables in the study by category, full name, data type, and description. The survey is presented in Appendix A (in the Supplementary material).

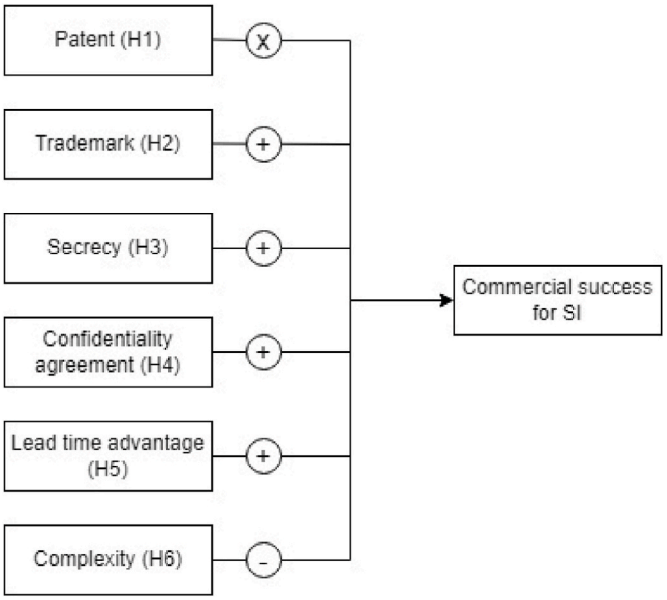

Fig. 1. Conceptual framework.

Table 1
List of key variables and their measurement.

Variable	Type of data	Description (if applicable)
Demographics		
Startup dummy	Nominal; binary	Was the firm a startup (<2 years old)
B2B	Nominal; binary	Business-to-business sales focus
B2C	Nominal; binary	Business-to-consumer sales focus
B2NP	Nominal; binary	Business-to-non-profit sales focus
Industry	Nominal; categorical	Self-reported industry based on 48 ISIC categories
Dependent variable		
Commercial success	Continuous	Innovator's evaluation of commercial success as a result of the innovation
Appropriation mechanisms		
Patent filed	Nominal; binary	Whether the innovator implemented any of the appropriation mechanisms
Trademark filed	Nominal; binary	
Secrecy	Nominal; binary	
Confidentiality agreement	Nominal; binary	
Lead time advantage	Nominal; binary	
Complexity	Nominal; binary	
Complementary assets		
Ability to upscale production	Nominal; binary	Whether the innovator possesses any of the complementary assets
Control over distribution channels	Nominal; binary	
Complementary Sales and Services	Nominal; binary	
Competitive Manufacturing	Nominal; binary	
Marketing	Nominal; binary	
Complementary asset rating		
Manufacturing rating	Ordinal; Likert scale	Extent to which the respondent agrees on whether the complementary asset is superior to those of competitors
Distribution rating	Ordinal; Likert scale	
Marketing rating	Ordinal; Likert scale	
Experience with IPRs		
Patent experience	Ordinal; Likert scale	Extent to which the respondent's firm is experienced with patents and trademarks
Trademark experience	Ordinal; Likert scale	
Innovator taxonomy	***Abbreviation***	***Industry examples***
Scale-intensive	SI	Assembly, consumer durables, automotive, food, bulk materials (steel, glass)
Science-based	SB	Chemicals, pharmaceuticals, electrical
Specialized supplier	SS	Machinery, specialized instruments (mechanical and instrument engineering)
Supplier-dominated	SD	Traditional manufacturing, agriculture, housing
Information networks	IN	Finance, insurance, communications
Specialized suppliers and science-based services	KIBS	Software, specialized business services
Physical networks	PN	Transportation, wholesale
Supplier-dominated services	SDS	Personal services (restaurants, laundry), public services (health, education)

Note: Likert scale questions are assessed on a 5-point scale (from strongly disagree to strongly agree).

3.2.1. Dependent variable

We used the eight items from the *enhanced possibilities from new service performance* scale developed by Flikkema (2008), based on new product performance indicators by Storey and Easingwood (1996). The items on our scale measure the benefits to a firm resulting from introducing a new product or service to the market. Since the questions were adapted to account for both new products and services, we validated the scale with an exploratory factor analysis. The Kaiser-Meyer Olkin measure of sampling adequacy indicated that the items were factorable (KMO = 0.820) and Bartlett's test of sphericity was significant ($p = .00$). The eight questions relating to performance success outcomes were analyzed using a principal components analysis with direct oblimin (oblique) rotation. The analysis resulted in one factor explaining 48.926% of the variance. Table 2 presents the items along with their loading on the single factor. The construct ($\alpha = 0.85$, based on our sample) is measured on a 5-point Likert scale assessing the extent to which respondents agree with eight statements about the innovation's success. Because of the favorable validity and reliability analyses, the mean of the eight items was used as the dependent variable.

3.2.2. Independent, control, and demographic variables

The independent variables indicate whether a patent or trademark was filed[1] and whether any of the informal appropriation mechanisms (secrecy, confidentiality agreements, lead time advantage, complexity) were used for the specific innovation. We opted to control startup status, sales orientation and industry, patent and trademark experience, and strength of complementary assets. Patent and trademark experience are used as a proxy to control for organizational experience. Less experienced firms, such as startups, may face liabilities of newness (Freeman and Engel, 2007; Stinchcombe, 1965), which could pose challenges for an innovator to network, acquire, or access complementary assets and file patents due to costs. We control for complementary assets, as possession thereof can facilitate the successful commercial exploitation of an innovation (Teece, 1986). To gain additional descriptive contrasts, we applied Pavitt's (1984) innovator taxonomy augmented by Miozzo and Soete (2001) to account for service industries. The taxonomy categorizes industries by innovative activity and patterns of technological change.

Table 2
Exploratory factor analysis for commercial success construct.

	Factor 1:Commercial success
It is a market success	.746
Brought in new customers	.748
Improved loyalty of existing customers	.632
Acts as a platform to introduce new products/services	.673
Enabled access to a new market	.647
Improved profitability of existing products and services	.609
Has contributed positively to the repositioning of my/our organization	.756
Contributes positively to the profitability of my/our organization	.764
Eigenvalue	3.914
Total variance	48.926
KMO Sampling Adequacy	.820
Bartlett's test	
Approx. Chi-square	961.865
Df	28
Sig.	.000

[1] The survey also measured formal mechanisms such as design rights, copyrights, and plant variety rights. However, these were used by very few respondents. We focus our empirical analysis on patents and trademarks as the most used IPRs.

3.3. Statistical methods

The analysis covers descriptive statistics, correlations, and linear regressions. An available case analysis method was applied to handling missing data. A response was excluded when a relevant variable for an analysis in question was missing. Missing data in the survey manifested itself mainly as dropping out at a certain sequential point in the survey, as the surveying platform required a completed response before moving to these questions. Survey responses under 26% completion were not included in the analyses, as they did not complete basic demographic questions. We did not remove outliers because all questions used were dichotomous, categorical, or scaled, and because we considered outlying responses as legitimate.

4. Results

4.1. Descriptive statistics

Table 3 shows propensities to apply formal and informal appropriation mechanisms by demographics. The outermost columns and rows indicate the mean commercial success rating. The top appropriation mechanisms used for SIs are complexity (49.6%), confidentiality agreements (46.9%), and patents (41.6%). This aligns with appropriation literature, indicating that smaller firms prefer informal appropriation mechanisms or view them as more important than formal ones (e.g., Cohen et al., 2000; Gallié and Legros, 2012; Thomä and Bizer, 2013). It also suggests that sustainable innovators follow appropriation strategies similar to those of non-SI innovators.

The correlation matrix (Table 4) shows that confidentiality agreements and lead time advantage are significantly and positively correlated with the commercial success of an innovation, corresponding again with appropriation literature, which suggests a preference among SMEs for informal appropriation mechanisms (e.g., Leiponen and Byma, 2009; Thomä and Bizer, 2013). The complementary asset ratings (for manufacturing, distribution, and marketing) are significantly and positively associated with commercial success, conforming with a proposition in PFI that complementary assets are important for the successful commercialization of an innovation (Teece, 1986, 1988). The result suggests complementary assets are also important to sustainable innovators in appropriating returns from an innovation.

4.2. Results of regression analyses

We applied a multivariate linear regression to test the association between the independent variables and commercial success. Model 1 in Table 5 examines the control variables: firm age, market scope, patent and trademark experience, and complementary asset (strength). Model 2 analyzes the entire sample, models 3 and 4 cover manufacturing and service industries subsamples to add context to the results. Multicollinearity was not an issue as the variables range from no to moderate correlations (Table 4). Variance inflation factors did not exceed 2.733 and tolerances remained above 0.366 in our sample for all variables included in the regression models. Our data also met the assumption of non-zero variances.

In models 2 through 4 no significant relationship exists between patent, trademark filing, or secrecy and commercial success. The result aligns with SME literature, indicating that SMEs encounter difficulties with successfully deploying patents; however, the non-significant result for trademarks is incongruent with trademark literature, which demonstrated that SME innovators successfully leverage trademarks to build their presence in the market (e.g., Flikkema et al., 2014). In model 4 we do find a significant and positive association between confidentiality agreements and commercial success for innovations from service industries ($B = 0.229$, $p = .03$). The outcome suggests that, as posited in the theoretical framework, secrecy and confidentiality agreements should be seen as separate mechanisms. A positive and significant

Table 3
Propensity to apply formal and informal appropriation mechanisms (percentage of firms, by demographics).

	N	Patent	Trademark	No formal appropriation	Secrecy	Confidentiality agreement	Complexity	Lead time advantage	No informal appropriation	Commercial success (*M*)
Startup	115	38.6	36.4	21.6	21.0	40.7	45.7	32.1	17.3	*3.64*
B2B	103	43.7	35.0	23.5	31.0	51.5	53.8	37.3	14.9	*3.83*
B2C	176	41.5	39.3	25.9	22.4	35.2	37.6	32.8	23.2	*3.59*
B2NG	91	22.9	30.0	37.1	30.6	41.9	48.4	43.5	16.1	*3.87*
Manufacturing industry	209	56.1	39.8	17.5	35.6	50.0	53.8	35.6	14.4	*3.66*
SI	73	45.3	43.8	21.9	30.5	45.8	50.8	33.9	11.9	*3.55*
SB	59	59.3	46.3	14.8	41.5	66.0	69.8	49.1	11.3	*3.77*
SS	32	70.4	29.6	22.2	44.4	55.6	51.9	33.3	11.1	*3.91*
SD	56	59.0	35.9	15.4	30.3	36.4	54.5	30.3	21.2	*3.54*
Service industry	310	32.9	30.5	28.9	24.5	45.4	48.0	37.1	16.2	*3.84*
IN	121	25.0	31.3	28.1	28.1	48.3	51.7	42.7	7.9	*3.92*
KIBS	55	43.8	29.2	33.3	34.8	56.5	47.8	30.4	19.6	*3.83*
PN	43	38.2	35.3	26.5	21.9	37.5	59.4	31.3	18.8	*3.90*
SDS	62	31.4	33.3	31.4	18.4	44.9	57.1	51.0	8.2	*3.75*
SME (<250 FTE)	501	41.6	34.2	24.4	28.4	46.9	49.6	35.9	15.8	*3.76*
1 FTE	36	26.9	26.9	38.5	8.3	20.8	41.7	12.5	37.5	*3.45*
Micro (2–10 FTE)	281	43.2	33.8	23.1	29.4	47.5	48.0	39.8	15.4	*3.73*
Small (10–50 FTE)	147	42.5	39.8	23.0	30.7	53.5	56.4	36.6	12.9	*3.92*
Medium (50–250 FTE)	37	39.3	21.4	28.6	29.6	40.7	44.4	22.2	11.1	*3.71*
Entire sample	**501**	**41.6**	**34.2**	**24.4**	**28.4**	**46.9**	**49.6**	**35.9**	**15.8**	***3.76***
Commercial success (*M*)	*3.76*	*3.84*	*3.81*	*3.73*	*3.78*	*3.87*	*3.78*	*3.89*	*3.48*	

Table 4
Correlation analysis.

		M	*SD*	1	2	3	4	5	6	7	8	9
1	Commercial success	3.76	0.71									
2	Patent filed	0.42	0.49	.09								
3	Trademark filed	0.34	0.48	.05	.11*							
4	Secrecy	0.28	0.45	.02	.17**	.07						
5	Confidentiality agreement	0.47	0.50	.16**	.26**	.10	.44**					
6	Lead time advantage	0.36	0.48	.15**	.00	.05	.15**	.18**				
7	Complexity	0.50	0.50	.03	.12*	.14**	.22**	.25**	.29**			
8	Manufacturing rating	3.30	1.12	.29**	.06	−.06	.07	.19**	.01	.12*		
9	Distribution rating	3.00	0.99	.18**	−.05	−.01	−.04	−.03	.07	−.02	.37**	
10	Marketing rating	3.04	1.05	.16**	−.01	.05	−.05	−.01	.01	−.01	.13*	.38**

Note: * Significant at the 0.05 level (2-tailed). ** Significant at the 0.01 level (2-tailed).

association is found for lead time advantage in model 2 ($B = 0.210$, $p = .01$) and for service industries in model 4 ($B = 0.209$, $p = .04$), corresponding with SME literature indicating that lead time advantage is important for SMEs (Leiponen and Byma, 2009; Thomä and Bizer, 2013). We also found a negatively significant association between complexity and commercial success in model 3 only for manufacturing ($B = -0.260$, $p = .04$), suggesting the mechanism is detrimental to SIs' commercial success. The results of the hypotheses' testing are summarized in Table 6.

All models also indicate a positive and significant association between manufacturing capabilities and commercial success, yet for distribution capabilities the association is not significant. For marketing the association is only significant for manufacturing. The contribution of manufacturing capabilities to commercial success for innovations from service industries might indicate the presence of product-service solutions or other servitization strategies to exploit the innovation (e.g., Brax and Visintin, 2017). Overall, the adjusted R-squared figures in our models suggest the examined variables play a modest role in the variance explaining commercial success. The highest explained variance emerged for the model with innovations from manufacturing industries ($R^2_{Adj} = 0.168$), while those for service industries scored lowest ($R^2_{Adj} = 0.106$). This conforms with appropriation literature, indicating that not only formal and informal appropriation mechanisms and complementary assets but also other constructs not measured in this study like the dominant design and market know-how could likewise account for commercial success (Teece, 1986, 2006).

5. Discussion and conclusions

This study analyzed the association between appropriation mechanisms applied to SIs with commercial success. We addressed questions from sustainability literature on whether SIs can benefit from value appropriation mechanisms (Cillo et al., 2019; Corrocher and Solito, 2017; Hermundsdottir and Aspelund, 2021), and found that while SIs are similar to non-SIs from SMEs in terms of appropriation mechanism usage, their association with commercial success reveals unique insights. Our results also augment the SME sustainability literature which demonstrated associations between innovativeness, sustainability and economic performance for SMEs (e.g., Jansson et al., 2017; Martinez-Conesa et al., 2017; Tomšič et al., 2015) by showing how appropriation mechanisms explain commercial success of a SI, which could also contribute to overall firm performance. Reflecting on the theoretical framework, results suggest that positive and negative views on IPRs and SIs (Castaldi, 2021) actually vary by appropriation mechanism. Conforming with the positive view on appropriation mechanisms and SI, informal mechanisms such as lead time advantage and confidentiality agreements appear to enable SI success, and lead time advantage is an important mechanism to achieve commercial success (Leiponen and

Table 5
Results of regressions.

	M1 - Control variables entire sample			M2 – Entire sample			M3 - Manufacturing			M4 - Services		
	B	*S.E.*	*p*	*B*	*S.E.*	*p*	*B*	*S.E.*	*p*	*B*	*S.E.*	*p*
Appropriation mechanism												
Patent filed				0.159	0.111	.155	0.210	0.162	.198	0.085	0.150	.571
Trademark filed				0.033	0.090	.713	0.142	0.154	.361	−0.013	0.110	.906
Secrecy				−0.075	0.093	.418	0.037	0.154	.811	−0.126	0.115	.272
Confidentiality agreement				0.090	0.090	.315	−0.164	0.167	.330	0.229	0.105	**.030**
Lead time advantage				0.210	0.082	**.011**	0.260	0.134	.054	0.209	0.103	**.043**
Complexity				−0.148	0.081	.068	−0.260	0.128	**.044**	−0.073	0.103	.481
Control variables												
Startup dummy	−0.112	0.089	.209	−0.101	0.089	.254	−0.125	0.155	.422	−0.018	0.106	.865
B2B	0.161	0.107	.133	0.163	0.107	.127	0.304	0.185	.103	0.036	0.129	.781
B2C	−0.167	0.090	.064	−0.177	0.090	**.050**	−0.132	0.151	.386	−0.168	0.108	.120
Patent experience	0.014	0.028	.631	−0.023	0.041	.577	0.018	0.064	.781	0.013	0.053	.799
Trademark experience	0.038	0.034	.269	0.039	0.039	.322	0.016	0.065	.806	0.037	0.049	.453
Complementary asset use												
Ability to upscale production	−0.077	0.079	.336	−0.091	0.079	.253	−0.036	0.130	.779	−0.157	0.098	.111
Control over distribution channels	0.088	0.096	.359	0.098	0.097	.313	0.125	0.161	.438	0.095	0.118	.423
Complementary sales and services	0.171	0.089	.055	0.162	0.089	.071	0.043	0.159	.786	0.171	0.106	.110
Competitive manufacturing	0.023	0.117	.842	0.018	0.116	.874	0.170	0.175	.333	−0.103	0.154	.503
Marketing	0.060	0.080	.450	0.073	0.080	.363	−0.050	0.137	.717	0.127	0.098	.200
Complementary asset ratings												
Manufacturing rating	0.133	0.038	**.000**	0.140	0.038	**.000**	0.151	0.065	**.021**	0.120	0.046	**.009**
Distribution rating	0.026	0.044	.562	0.020	0.044	.646	−0.059	0.089	.504	0.007	0.050	.886
Marketing rating	0.068	0.040	.091	0.069	0.040	.086	0.155	0.073	**.034**	0.046	0.048	.333
(Constant)	2.794	0.187	.000	2.778	0.188	.000	2.514	0.294	.000	2.968	0.243	.000
Adjusted R2		.131			.149			.168			.106	
F		4.702			3.944			2.433			2.239	
p		<.001			<.001			<.005			<.005	
df (regression)		13			19			19			19	
df (residual error)		306			300			116			179	
N		319			319			135			198	

Table 6
Summary of results.

Appropriation mechanism	Hypothesis result	Direction
Formal		
Patents (H1)	Supported	No association
Trademarks (H2)	Not supported	No association
Informal		
Secrecy (H3)	Not supported	No association
Confidentiality agreement (H4)	Supported (only for service)	+
Lead time advantage (H5)	Supported	+
Complexity (H6)	Supported (only for manufacturing)	–

Byma, 2009; Thomä and Bizer, 2013). Conversely, complexity runs contrary to SI success and clashes with sustainability for the reasons described in the theoretical framework and below, aligning with the negative view of appropriation and sustainability. However, strategic and resource constraints faced by SMEs may lead to challenges with appropriating returns using formal appropriation mechanisms, similarly as for non-SI innovators. Their place on the positive or negative view may have to be evaluated by future research on innovators' motivations to apply them to SIs.

5.1. Key results

The principal implication of this study is that SIs are similar to non-SIs in terms of appropriation, except for complexity. SMEs producing SIs could be making similar considerations or facing similar strategic challenges with appropriation mechanisms as non-sustainable innovators. Strategic concerns could be why formal appropriation mechanisms have no association with commercial success: for example, patents can be costly, elicit a reputational critique, or obstruct diffusion-driven success. Patents could also be unimportant for smaller firms (Arundel, 2001; Balasubramanian and Sivadasan, 2011). The non-significant outcome for trademarks could be explained by the innovation-level study, as trademarks might be more important for the firm name than for the SI. To emphasize sustainability an eco-mark or ISO certification might be sufficient for an SI. Patents and trademarks could also be used to position the firm as a sustainable investment target for large multinational enterprises (e.g., see Moore and Manring, 2009 for SME strategies for using sustainability to achieve competitive advantage), or to attract venture capital funding (Zhou et al., 2016) rather than to ensure the commercial success of the SI.

Similar strategic considerations could prevent the effective application of secrecy to SIs. For example, secrecy might create obstacles to efficiency inside the organization, elicit a reputational critique by potential users and sustainability activists, or similarly to patents slow the diffusion of an SI. Secrecy could thus be less important than patents or lead time advantage for small innovating firms (Leiponen and Byma, 2009). Potentially incommensurable strategic rationales might be used when applying product complexity to SIs. The negative result for complexity suggests its implementation reflects over-manufacturing, inefficiencies, and wasteful mechanisms leading to decreased economic gains, which is perplexing considering the high propensity to apply complexity. This is discussed in the managerial and policy implications.

Strategic motives to apply lead time advantage and confidentiality agreements could also apply to SIs. The positive outcome for lead time advantage suggests sustainable innovators engage in sustainable leadership to rapidly innovate in order to stay ahead of competition. Being first to access or acquire needed complementary assets or to place buyer switching costs on customers could be ways to stay ahead (Lieberman and Montgomery, 1988). The result also aligns with appropriation literature, where SMEs find the strategy highly important (Thomä and Bizer, 2013). For sustainable service innovations, confidentiality agreements may be a substitute for patents, preventing or delaying

imitation, or enabling knowledge transfer and collaboration for sustainable service innovations, thereby ensuring returns from the SI.

5.2. Implications for future research

The results discussed above contribute to the understanding of the association between appropriation mechanisms for SIs and commercial success. We see several opportunities for further research. First, our dependent variable captures only commercial success, which is subjective as it denotes benefits from having introduced an innovation. Objective financial indicators, such as establishing a worthwhile profit or market, sales growth (or decline), or turnover after a year could be measured in future studies. Other research could also consider including sustainability performance variables, examining to what extent appropriation mechanisms are associated with sustainability performance, and revealing whether they help or hinder sustainability outcomes.

Second, our study leveraged innovation awards as salient sources of innovation-level data. SMEs that opted not to enter their SI in a competition may exhibit different characteristics than those who did; the effect of self-selection cannot be ruled out. This could inspire others to replicate studies on SIs in other contexts. The innovation level of this study presents results that need to be carefully interpreted when comparing to firm-level studies. This is because appropriation mechanisms could also be used for non-innovative purposes at the firm level. For example, trademarks could be filed for brand modernization purposes and patents could be filed for defensive blocking purposes.

Third, further research could investigate the external validity of these results for countries with different institutional and cultural contexts. National policies and regulations could create market conditions that impact the ability to profit from an innovation, so innovators may adjust strategies and business models to match these conditions. The results may also be different for countries where market formation processes for sustainable products and services are still developing. National culture may likewise play a role, as demonstrated by Delerue and Lejeune (2011), where the importance of secrecy varies across cultures.

Fourth, through a qualitative design future research could examine the motivations for sustainable innovators to use or not use formal or informal appropriation mechanisms. Policymakers and researchers are likely to benefit from a better understanding of these motives, which could help craft more suitable IPRs policy and support programs for SMEs engaging in SIs.

Last, the outcome on secrecy and confidentiality agreements presents opportunities for developing the appropriation literature. Our result highlights a potential incommensurability in the appropriation literature, as secrecy is handled as an all-inclusive mechanism. To measure secrecy accurately, research should determine whether its components (e.g., confidentiality agreements, access policies and restrictions, non-disclosure agreements) should be measured separately rather than through an umbrella term of secrecy.

5.3. Implications for sustainable management and policy

For SMEs engaging in SI, three implications arise from considering whether to use appropriation mechanisms. First, innovators may face the same patenting challenges as with non-SIs, such as costs, disclosure, timing, and novelty thresholds. Managers should carefully consider whether a patent is prudent for their innovation or whether informal mechanisms – such as lead time advantage or confidentiality agreements – are more beneficial. While not associated with commercial success, a trademark could still help protect the firm name (and the innovation) against infringement or imitation. Second, the negative performance outcome from complexity may be explained by inefficiencies, over-manufacturing, waste, and potentially introducing barriers to repairing, reusing, and upgrading the innovation. However, complexity might not be a deliberate choice as some innovations such as specialized electronics and machinery are inherently complex. SMEs may nonetheless strive to avoid complexity and leverage lead time advantage instead. Third, our study does not determine the suitability of appropriation mechanisms for SI – rather, we identified usage patterns and their association with commercial success. To understand whether and how appropriation mechanisms are used for sustainability purposes or targets, the motives to use or not use appropriation mechanisms on SIs could be studied through qualitative methods.

From a sustainability policy perspective, further educational outreach for manufacturing innovators may be necessary when it comes to complexity of design. Policymakers could further promote interoperability, simplicity, and adherence to standards as repair and product life extension activities and legislation become more prominent (Svensson-Hoglund et al., 2021). Recycling through ease of dismantling, reuse, and other circular economy initiatives should be encouraged, and restrictive repair policies and practices discouraged. Regulations could also be examined so they do not unintentionally encourage complexity.

6. Conclusion

Against a research background showing that appropriation mechanisms' place in SIs and their link to SI performance outcomes are currently not understood (Castaldi, 2021; Cillo et al., 2019; Eppinger et al., 2021; Hermundsdottir and Aspelund, 2021), this study analyzed the extent to which formal and informal appropriation mechanisms are similarly relevant for SI performance outcomes. In this respect we add further understanding to the relationships between innovation, sustainability and economic performance and found that SIs are similar, but not identical, to non-sustainable innovations by SMEs. Formal appropriation mechanisms like patents and trademarks neither help nor hinder a performance outcome, but informal mechanisms are important. Lead time advantage for all innovations and confidentiality agreements for innovations from service industries were associated with positive performance outcomes, suggesting these mechanisms enable SI success – in line with the positive view on appropriation mechanisms in an SI context. However, product complexity is associated with a negative performance outcome for SIs from manufacturing industries, contrasting with non-SI appropriation literature. Complexity may introduce inefficiencies and hinder repair and reuse options crucial to a circular economy, aligning with the negative view on appropriation in the context of SIs.

CRediT authorship contribution statement

Pablo Morales: Methodology, Formal analysis, Writing – original draft, Visualization, Project administration, Validation. **Meindert Flikkema:** Resources, Writing – review & editing. **Carolina Castaldi:** Conceptualization, Writing – review & editing. **Ard-Pieter de Man:** Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could appear to have influenced the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2022.133921.

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