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An investigation on the effect of inter-organizational collaboration on reverse logistics

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Abstract

Despite the popularity of reverse logistics in literature, the effect of different collaboration types on the likelihood to introduce reverse logistics innovations has been under-investigated. Hence, this article explores the impact of domestic collaboration with competitors, customers, suppliers, research institutions, and the breadth of collaboration on a firm's reverse logistics innovation. Four hypotheses - grounded on institutional, resource dependence, and absorptive capacity theories – are tested through generalized structural equation modelling analyses on a longitudinal sample of German firms. The results show a positive impact of vertical collaboration, horizontal collaboration, and collaboration with research institutions on the likelihood to introduce reverse logistics innovation. Instead, collaboration breadth has a negative impact on reverse logistics, an unexpected and surprising result for the innovation management literature. The article offers recommendations to practitioners as to which partners are more likely to increase the odds of introducing reverse logistics innovation and demonstrates that – to such an aim - firms should select a limited number of partners, identifying the ones that suit their needs the most.

Keywords

Reverse logistics, domestic inter-organizational collaboration, circular economy, innovation, institutional theory, resource dependence theory

1 Introduction

Reverse logistics is defined as "*a process in which a manufacturer systematically accepts previously shipped products or parts from the point for consumption for possible recycling, remanufacturing, or disposal*" (Dowlatshahi, 2000, p. 143). Unlike traditional linear logistics from producer to customer, reverse logistics refers to the reverse flow that – combined with linear logistics - determines a closed-loop supply chain (Sehnem et al., 2019). While remanufacturing and reuse operations prevail in closed-loop supply chains, recycling operations operate in open-loop systems (Rahman and Subramanian, 2012), where end-of-life products are delivered to different organizations from those that developed them originally. Reverse logistics is among the fastest-growing supply chain management research (Swanson et al., 2018). It is considered a vital component of the circular economy (Bernon et al., 2018), a restorative or regenerative view of the industrial economy by intention and design (EMF, 2013). Indeed, circular economy would not be possible without the reverse flow – enabled by reverse logistics - of end-of-life products and components essential for their recycling or regeneration.

Intuitively, introducing reverse logistics requires significant process, product, and distribution channel redesigns that imply complex interactions between the firm and the other participants in the supply and value chain (Álvarez-Gil et al., 2007). In addition, regulations increasingly induce firms to take responsibility for the packaging and products that reach their end-of-life to achieve environmental benefits. However, implementing reverse logistics can help firms to achieve not only environmental goals but also economic goals. Indeed, reverse logistics can result in economic benefits (Chileshe et al., 2016). Such benefits include savings from the reuse of low-cost inputs at a fraction of the manufacturing costs from raw materials (Lund, 1984), the recovery of the value still incorporated in the used product (Gonzalez-Torre et al., 2004), the reduced transportation and disposal costs, and the revenue generated by the sale of salvaged materials (Laefer and Manke, 2008; Leigh and Patterson, 2006).

Firms that want to innovate their logistics by re-designing their processes need to collaborate with both supply chain members (Govindan and Bouzon, 2018; Hsu et al., 2013; Janse et al., 2010; Jayaraman et al., 2008; Simpson, 2010) and non-industry partners (Bocken et al., 2014; Sahamie et al., 2013). Collaboration in reverse logistics increases market knowledge, predictability, margins (Abraham, 2011), and the firm's mastery of reverse logistics processes (Morgan et al., 2016). Collaboration may imply sharing decisions in planning and inventory management; information on market demand, in-transit items, inventory levels and other operational aspects; and visibility on the entire remanufacturing process (Cannella et al., 2016). Veleva and Bodkin (2018) underlined that circular economy relies on collaboration between accountable stakeholders, while De Angelis et al. (2018) proposed that it is enabled by "*close supply chain collaboration with partners within and beyond their immediate industrial boundaries, including suppliers, product designers & regulators*" (p. 432). The importance of collaboration was reiterated by Burger et al. (2019), who recommended working together throughout the supply chain, internally within organizations and with the public sector to increase transparency and create joint value. As well, Bernon et al. (2018) emphasized that logistics imposes inter-organizational collaboration since a firm cannot fully implement reverse logistics on its own.

Even though inter-organizational collaboration is considered essential for reverse logistics, the extant literature mainly focused on collaboration and supply chain (e.g. see the reviews Ho et al., 2019; Soosay and Hyland, 2015) and collaboration-driven innovation in the supply chain (Zimmermann et al., 2016). Instead, to the best of our knowledge, no empirical study has explored how collaboration drives reverse logistics innovation. Consistently, Chen et al. (2017) called for research on the impact of supply chain collaboration on sustainable outputs, such as eco-innovation and sustainable business models. Among the most closely related empirical studies, Olorunniwo and Li's (2010) found that collaboration is positively associated with greater satisfaction with reverse logistics operations and their profit margin. However, the authors' measure for collaboration does not inform about the typology or the variety of inter-organizational collaborations. Furthermore, the dependent variable of the study cannot predict the likelihood to introduce reverse logistics innovations. The authors themselves called for future research through longitudinal data that could identify causal relationships. Similar limitations affect other studies (Phoosawad et al., 2019; Sirisawat and Kiatcharoenpol, 2019).

The lack of quantitative research on collaboration and reverse logistics innovation is a significant gap in the literature. Even though reverse logistics is a practice dating back decades, we still know little about which collaboration channels are more fruitful for a firm to introduce reverse logistics and whether many collaborations would be better than fewer ones. Therefore, this article aims to respond to the following research question: *How inter-organizational collaboration drives reverse logistics innovation?*

Given the lack of studies on reverse logistics and collaboration, we have also built our research on the closely related literature streams of closed-loop supply chain and circular economy. On this basis, and leveraging institutional (Scott, 1995) and resource dependence (Pfeffer and Salancik, 1978) theories, we formulated the hypotheses of the study in Section 2. We tested the hypotheses by analyzing German longitudinal data (ZEW, 2018) through generalized structural equation modelling, as described in Section 3. Section 4 shows the results, and Section 5 discusses them. Finally, Section 6 offers some concluding remarks, implications for scholars and practitioners and discusses the limitations of the study.

2 Theoretical background

From a theoretical perspective, reverse logistics can be seen as an attempt to adhere to institutional prescriptions, as postulated by the institutional theory (Scott, 1995). Institutions, which include regulative, cultural-cognitive, and normative elements, impose boundaries on organizations but also support and empower them. The corresponding coercive, mimetic, and normative processes bring organizations facing the same environmental conditions to resemble the other organizations' structures and practices, i.e., isomorphism (DiMaggio and Powell, 1983). Coercive processes are determined by formal (e.g., regulation) and informal (e.g., societal expectations) pressures on organizations. Mimetic processes imply the imitation of other organizations to address uncertainty. Normative processes stem from professionalization, which is determined by formal education and professional networks that span organizations (DiMaggio and Powell, 1983). The three processes can influence organizations' strategies (Miemczyk, 2008) and may also co-occur (Mizruchi and Fein, 1999). Therefore, an organization may want to reshape its supply chain and adopt reverse logistics due to many and sometimes concurring motivations, including current or expected regulations, cultural pressures from its customer base or society, the willingness to imitate its competitors, or the technical considerations of their highly educated managers. Many studies built on institutional theory to investigate reverse logistics (Khor et al., 2016; Kumar and Putnam, 2008; Miemczyk, 2008; Ye et al., 2013) and, more in general, circular economy (de Jesus and Mendonça, 2018; Jain et al., 2020; Ranta et al., 2018; Rweyendela and Kombe, 2021). Legislation and regulation are often seen as key driving forces for reverse logistics (Kumar and Putnam, 2008; Rahman and Subramanian, 2012). While institutional forces can favour the transition towards circular economy, they may become barriers due to the lack of a conducive legal system, misaligned incentives, or rigid consumer behaviour (Brandão et al., 2020).

On the whole, the efficient use of resources – implied by the implementation of reverse logistics - can drive the approval of society and help firms be more productive (Porter and Kramer, 2006) and gain competitive advantage (Rahman and Subramanian, 2012). However, embracing reverse logistics is a very complicated task requiring a firm to retrieve the knowledge and technology it lacks outside its boundaries. The resource dependence theory (Pfeffer and Salancik, 1978) assumes that firms cannot be fully self-sufficient in terms of critical resources and need to team up with innovation partners (Vanhaverbeke and Cloodt, 2014). Therefore, an inter-organizational collaboration aimed to develop innovation (in the remainder of the manuscript, we will refer to them as "collaboration") is critical to identifying and using the missing resources and complementing those owned by the firm. Collaboration with different types of external organizations (such as universities, customers, suppliers, and competitors) can fill such gaps (Un et al., 2010) and favour mutual learning (Kumar et al., 2020). Sarkis et al. (2011) discussed that the eco-design of products and materials recovery are typical organizational resources for which firms need to establish partnerships. Notably, collaborations may only be successful when a firm can understand and integrate others' knowledge and technologies. Such a capability, which is known as absorptive capacity (Cohen and Levinthal, 1990), depends on internal R&D capabilities (Chesbrough et al., 2006), on the organization's human capital (Garcia Martinez et al., 2017), and on a certain degree of technology overlap between the partners (Dyer and Singh, 1998; Mowery et al., 1998). Absorptive capacity comprises three components: recognition, the capability to identify and assess the external sources for innovation; assimilation, the capability to analyse and assimilate external knowledge; and exploitation, the capability to apply and recombine external knowledge (Zobel, 2017). The need for conspicuous absorptive capacity is particularly relevant in reverse logistics innovation, where the firm's awareness about non-landfill disposal alternatives is vital to benefit from collaboration (Simpson, 2010).

We leverage the institutional, resource dependence, and absorptive capacity theories to formulate hypotheses regarding the possible impact of the collaboration with external organizations on the choice to reshape a firm's supply chain to allow reverse logistics. We elaborate on four collaboration archetypes, including vertical and horizontal collaboration (Ahn et al., 2017; Miemczyk, 2008; Parida et al., 2012; Reniers et al., 2010), collaboration with universities (Sjöö and Hellström, 2019; Walsh et al., 2016; Wirsich et al., 2016) and collaboration breadth (Drechsler and Natter, 2012; Greco et al., 2020).

2.1 Vertical collaboration

The literature has often studied the collaboration between a firm and its customers and suppliers, which are jointly referred to as "vertical collaboration" (Paula et al., 2019) and in most cases focuses on dyadic customer-supplier collaborations (Scholten and Schilder, 2015; Yen, 2018). From an institutional theory perspective, the pressure exerted by customers and suppliers, i.e., the market pressure, has an (informal) coercive effect on firms that can bring them to introduce environmental innovations in general and to implement reverse logistics in particular. Furthermore, since regulations may induce competing firms to an excess of isomorphism and the corresponding loss of competitive advantage, vertical collaboration may contrast this phenomenon, offering opportunities to develop capabilities and differentiate themselves from the competitors in the way they approach reverse logistics (Miemczyk, 2008).

In addition, in the view of resource dependence theory, customers and suppliers can be significant sources of critical resources. The collaboration with customers and suppliers benefits the firm by reducing the transaction costs and increasing resource and knowledge sharing (Paula et al., 2019). Indeed, collaboration with new customers and suppliers can reduce the uncertainty in the operating environment (Sarkis et al., 2011), help to fill the demand for returned products (De Angelis et al., 2018), and create value in closed-loop supply chains (Schenkel et al., 2015). Furthermore, customer and supplier may have established routines, which can maximise the frequency and intensity of their socio-technical interactions (Dyer and Singh, 1998), nurturing their absorptive capacity and, in turn, the effectiveness of their collaborations.

Collaboration with customers in reverse logistics is considered imperative (Julianelli et al., 2020; Paula et al., 2019), even though empirical studies on collaborations between firms and customers are lacking (Soosay and Hyland, 2015). On the one hand, consumers groups encourage firms to reduce waste disposal and reuse parts from an environmental and social perspective (Aitken and Harrison, 2013). On the other hand, when customers do not feel prompted to comply with reverse logistics activities, the firm can experience significant losses (Breen, 2006). Indeed, since closed-loop supply chains are likely to suffer from uncertainty regarding the rate and quality of the returns (Goltsos et al., 2019), collaboration with customers can be a critical success factor. In this vein, Gonzalez-Torre (2004) emphasized the importance of collaborating with customers to favour the usage of reusable containers in reverse logistics in the bottling sector.

Collaboration with suppliers is the bottom line to reducing purchasing costs and address technical challenges (Mirkovski et al., 2016). Indeed, Janse et al. (2010) found that collaboration with suppliers was one of the key facilitators in managing reverse logistics. For instance, the collaborative re-design of the packaging in a reverse logistics perspective can bring mutual benefits to both manufacturer and supplier (Chan, 2007). Suppliers can participate in re-designing the packaging to reduce material (Simpson, 2010) and recover products or parts, which customers can buy as service parts (Toffel, 2004).

Hence, all of these considered, we hypothesize that:

Hp 1: Vertical collaboration increases the likelihood to introduce reverse logistics innovation

2.2 Horizontal collaboration

Horizontal collaboration refers to the collaboration between two or more firms at the same level in the supply chain (Paula et al., 2019). Horizontal collaboration may result in a joint-venture through a reverse logistics alliance centre (Gu et al., 2019). From the institutional theory perspective, a firm constantly compares its strategies and practices with those of its best competitors, treating them as benchmarks (Zhu and Sarkis, 2007). The resulting mimetic process takes an essential role in motivating a firm towards reverse logistics. Hsu et al. (2013) observed that many USA firms are approaching reverse logistics practices due to competitive pressures, and the same process was inducing firms from Malaysia to self-regulate. Interestingly, firms not only imitate their most successful peers, but they also imitate those organizations with which they have social ties (Galaskiewicz and Wasserman, 1989). In this vein, Miemczyk (2008) observed how horizontal collaboration could lead to isomorphic responses for product recovery, which may increase economies of scale.

The resource dependence theory reinforces the importance of horizontal collaboration since it suggests that the potential benefits deriving from collaboration may "*inhibit power imbalances even among competitors*" (Pomponi et al., 2015, p. 92). Consistently, one of the most successful firms studied by Simpson (2010) collaboratively shared information with a competitor to enhance recycling. Since some wastes are not commercially viable in small volumes, teaming-up among competitors when interacting with suppliers can open new opportunities (Simpson, 2010). Similarly, Ohnishi et al. (2012) observed that the recycling facilities that collaborated one with another rather than compete obtained better results than non-collaborating ones. Especially when the competitors share parts of the supply chain (e.g., wholesalers, logistic partners, or distributors), active collaboration among them can set standards and accelerate the implementation of reverse logistics in the industry.

Finally, from an absorptive capacity perspective, competitors have the advantage of a common knowledge base and understanding of relevant technologies, deriving from their positions in the same or similar markets, enhancing collaborative innovation (Ritala and Hurmelinna-Laukkanen, 2013). Therefore, we hypothesize:

Hp 2: Horizontal collaboration increases the likelihood to introduce reverse logistics innovation

2.3 Collaboration with universities

Universities and research institutions can shape decision-makers' professional perspective in organizations by presenting the economic and social benefits of reverse logistics both in educational settings (such as degrees, masters, and doctoral programs) and in professional settings (such as international conferences and publications). The corresponding normative processes that can act as motivators can also trigger collaborations among firms and research institutions to implement the change. Indeed, the specialized scholars on the topic often own knowledge that can help firms identify the innovations they need to enable reverse logistics innovations, making them ideal under the resource dependence theory lenses. For instance, Khan et al. (2020) observed multiple cases where firms collaborated with universities and research centres to acquire the knowledge they needed to draw value from waste. Previous studies in the supply chain management domain already offered a comprehensive view of how university-industry collaboration enhances learning (e.g. see Gibson et al., 2016), while De Marchi's research on environmental innovation (2012) confirmed the importance of collaboration with universities and other scientific agents. From an absorptive capacity perspective, Messeni Petruzzelli (2011) found that the collaborations between universities and firms active in complementary fields are particularly successful. Sahamie et al. (2013) called for interdisciplinary and transdisciplinary collaboration and identified effective different key disciplines, including those pertaining to natural sciences, engineering sciences, and management sciences.

Therefore, we hypothesize the following:

Hp 3: Collaboration with universities and research institutions increase the chances to introduce reverse logistics

2.4 Collaboration network

We discussed how the collaboration with certain types of partners is likely to affect the likelihood to adopt reverse logistics positively. Extant literature has often focused on dyadic collaborations (Huang et al., 2003; Montoya-Torres and Ortiz-Vargas, 2014; Soosay and Hyland, 2015; Xu et al., 2017), neglecting the simultaneous impact of multiple active collaborations. Collaboration networks may take various forms (Paula et al., 2019) and involve business, governmental, and even civil society actors (Ritvala and Salmi, 2010). We advance that the complexity of reverse logistics implies teaming up with several different types of partners simultaneously. From a resource dependence theory perspective, having access to multiple collaboration channels may result in greater opportunities to draw knowledge and technology from them. As posed by Ghisellini et al. (2016), the successful transition towards circular economy stems from the involvement "*of all actors of the society and their capacity to link and create suitable collaboration and exchange patterns*" (p. 11). In the same vein, Rizzi et al.'s study on extended producer responsibility (2013), which refers to the management of end-of-life products (a theme close to reverse logistics), proposed that a higher openness to collaboration among the members of the supply chain would lead to better outcomes. Multiple organizations can contribute to facilitating the implementation of reverse logistics. Bernon et al. (2018) emphasized that firms should not only aim at collaborating with the firms that can take end-of-life products away from the point of usage and then recycle them, but also with the firms that can add value through refurbishment or remanufacture operations. Similarly, Khan et al. (2020) observed the cases of four firms that successfully collaborated with multiple actors such as suppliers, research institutions, public institutions, and non-governmental organizations to recover and reuse waste.

Nevertheless, as the literature has shown in the past about the link between collaboration and the development of new products, too many partner types may disperse resources and become ineffective (Barrena-Martínez et al., 2020; Duysters and Lokshin, 2011; Greco et al., 2016). Indeed, reverse logistics may be impractical when collaboration with many partners with varying objectives is needed (Miemczyk et al., 2016). Therefore, we hypothesize the following:

Hp 4: The breadth of a collaboration network has an inverted U-shape effect on the chances to introduce reverse logistics

3 Methods

3.1 Sample

This study resorts to panel data from two waves of the German part of the Community Innovation Survey (CIS) conducted in 2015 and 2017 by the Leibniz-Zentrum für Europäische Wirtschafts (ZEW). Such secondary data are valuable to test the hypotheses of the study for several reasons.

First, Europe in general and Germany in particular have been at the forefront of the legislation on reverse logistics. Indeed, Germany imposed in 1991 the first mandatory take-back program with its "Ordinance on the Avoidance of Packaging Waste", which held the manufacturer responsible for collecting, sorting, and recycling the packaging of its products (Álvarez-Gil et al., 2007). In 1994, the European Union implemented the "Directive on Packaging and Packaging Waste", which was amended several times since then[1]. By the end of 2025, the Directive aims to recycle at least 65% of the weight of product packages. Very recently, the European Commission adopted a European Action Plan for the circular economy[2].

Second, the 2017 wave of the MIP survey specifically inquired about introducing innovation in reverse logistics while also offering other items useful to assess the drivers for this choice.

Third, although anonymised, earlier waves of the MIP survey allow following specific firm IDs, allowing the estimation of causal effects. Indeed, earlier waves also contain collaboration variables that allow testing the hypotheses of the study. Since the answers are fully anonymized, respondents have no incentive to be insincere in their answers (e.g., to make their firm appear

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[1] https://ec.europa.eu/environment/waste/packaging/legis.htm

[2] https://ec.europa.eu/environment/circular-economy/index_en.htm

"better" than it is), disabling the self-serving bias that is a known concern when analyzing a system's traits based on self-reports (Ketokivi, 2019).

3.2 Variables

3.2.1 Dependent variable

The dependent variable of the study *reverselogistics* describes the Yes/No answer to the question "*During the three years from 2014 to 2016 did your enterprise introduce any of the following innovations in logistics? Reverse logistics (reuse and return of products and materials, etc.)*".

The question appears in the "logi" group of questions in the MIP wave 2017, along with other six categories of logistics innovation (such as inventory management systems and e-procurement) and a residual "other" category. Therefore, the item unambiguously frames and targets the type of logistics innovation that is the object of our research, making the MIP survey suitable to address the research questions.

3.2.2 Collaboration independent variables

We assess the extent to which a firm collaborates with other organizations through the "ko**"** group of questions in the MIP wave 2015, which comprise 18 binary items. The questions ask whether the firm co-operated in any type of innovation activity with each of nine types of partner (firms in the same group; private customers; public customers; suppliers; competitors and firms in the same sector; consultants and commercial labs; universities and higher education institutions; government and public research institutes; private research institutes) in the years 2012-2014, distinguishing between domestic and foreign partners. We test the hypothesis of the study through 3 dummy variables and one scale *collaboration* variable that are summarized in Table 1. The *collaboration* variable is constructed in line with previous studies (e.g. Drechsler and Natter, 2012; Greco et al., 2017) as the sum of each dummy variable in the "ko" group. Hence, the variable describes the extent to which the firm has numerous active collaboration channels. We use only domestic collaboration channels since the arguments justifying the importance of collaboration with foreign organizations usually apply to firms based in countries with less stringent environmental policies (e.g. Simpson, 2010) and less developed environmental culture (e.g. Zhu and Sarkis, 2007). The literature hypothesizes that - when such firms compete in foreign countries where such policies and culture are well established - they need to adapt their operations accordingly. For instance, Miao et al. (2012) observed how Chinese manufacturers had to adapt to the European Directive on Waste Electrical and Electronic Equipment and take back used products. The authors also emphasized how foreign multinational firms exert pressure on their Chinese suppliers to achieve certifications and meet their environmental requirements. Similar considerations were discussed by Sarkis et al. (2011), with more-developed countries' regulations and normative social pressures influencing less-developed green supply chain management. Overall, we advance that these arguments are not appliable in our case, where German domestic regulation, culture, and technology related to reverse logistics are among the most advanced worldwide. Thus, it is unlikely that the collaboration with foreign partners could be crucial for the development of reverse logistics innovation in German firms, while the inclusion of foreign collaborations in our models could more likely distort the results introducing spurious relationships.

Table 1. Collaboration independent variables

Hp	**Description**	**Variable**	**Values**
1	Collaboration with public and private customers, collaboration with suppliers	*coll_vertical*	1 (Yes), 0 (No)
2	Collaboration with competitors and enterprises in the same sector	*coll_horizontal*	1 (Yes), 0 (No)
3	Collaboration with universities, public research institutions, and private research institutions	*coll_research*	1 (Yes), 0 (No)
4	Breadth of the collaboration network	*collaboration*	0-9

3.2.3 Control variables

Taking the lead from the reverse logistics drivers identified by Govindan and Bouzon (2018), we included additional control variables that could explain the introduction of a reverse logistics innovation. The variables are summarized in Table 2 and discussed below.

Some organizational innovations can lay the ground for subsequent reverse logistics innovation. The variable *organizational_innov* describes whether the firm introduced new organizational practices such as supply chain management, business re-engineering, knowledge management, lean production, and quality management. The engagement in such innovation activities can unveil the management propensity towards a change that can ultimately lead to reverse logistics implementation.

Along with organizational innovations, proper technologies enable reverse logistics that help reuse or recycle the product that reached its end-of-life. Using the variable *recycling_innov*, we verify whether the firm had introduced innovations capable of improving the recycling of a product after use, predicting the future implementation of a reverse logistics innovation for it.

We use *R&Dintensity*, a typical variable in innovation studies (e.g. Cappelli et al., 2014; Leiponen, 2012; Michelino et al., 2008), to assess the absorptive capacity of the firm, hence its capability to draw benefit from the inter-organizational collaboration and to be proactive in the introduction process of a reverse logistics innovation. Firms implementing a major change in their logistic will likely need substantial investments in research to be successful. Therefore, we measured the variable *R&Dintensity* in 2015, the first possible year in which a reverse logistics innovation was launched according to our dependent variable.

Five variables drawn from the MIP 2017 wave describe possible reasons that led the firm to implement any logistics innovation in the "*logi*" group. Therefore, even though the items pertain to the same MIP wave, they are suitable to assess causal links, which were expressly implied by the question formulations. The five variables include:

- *mot_sales_opportunities,* which describes the willingness to grasp new sales opportunities;
- *mot_firm_performance,* which describes the willingness to improve the firm's performance;
- *mot_market_pressure,* which describes how the market's informal coercive processes can impact firms' choices to engage in logistics innovation;
- *mot_cost_pressure*, which describes the role of costs in taking into account logistics innovation;
- *mot_regulation*, which refers to either the current or future impact of policymakers on the decision to engage in logistics innovation, is particularly important to consider the formal coercive processes determined by regulators.

Table 2. Description of the control variables of the study

Variable	**Item**	**Source**	**Ref. years**
organizational_innov	Did your enterprise introduce new business practices for organizing procedures? (Y/N)	MIP2015	2012-2014
recycling_innov	Did your enterprise introduce innovations that had any of the following environmental benefits? Improved recycling of product after use? (No, Yes insignificant, Yes significant)	MIP2015	2012-2014
R&Dintensity	Total R&D expenditure as a share of turnover * 100	MIP2017	2015

mot_sales_opportunities	Motivations for logistics innovation: Opening of new sales opportunities (High, Medium, Low, No)	MIP2017	2014-2016
mot_firm_performance	Motivations for logistics innovation: Improvement of firm performance (High, Medium, Low, No)	MIP2017	2014-2016
mot_market_pressure	Motivations for logistics innovation: Respond to market pressures (High, Medium, Low, No)	MIP2017	2014-2016
mot_cost_pressure	Motivations for logistics innovation: Respond to cost pressures (High, Medium, Low, No)	MIP2017	2014-2016
mot_regulation	Motivations for logistics innovation: Respond to existing or forthcoming regulatory provisions (High, Medium, Low, No)	MIP2017	2014-2016
reputation	How important were the following factors in driving your enterprise's decisions to introduce environmental innovations? Improving your enterprise's reputation (High, Medium, Low, Not relevant)	MIP2015	2012-2014
size	Three classes of size: <50 employees, 50-249 employees, >=250 employees	MIP2017	2015
sector	Four classes of aggregate economic sectors: 1. Research-intensive industry, 2. Other industry, 3. Knowledge-intensive services, 4. Other services (see ZEW, 2019).	MIP2017	2017

We assess the sensitivity of a firm's management towards social pressure - a characteristic that is likely to be part of the corporate culture - through the variable *reputation*, which verifies whether the willingness to improve the firm's reputation drove its choice to introduce environmental innovations in the years 2012-2014. Indeed, we advance that a firm that introduced environmental innovations due to reputation aspects is more likely to be sensible to the social drivers of reverse logistics.

Additional control variables include the firm's *size* and *sector*.

3.3 Methodology

We estimate the impact of our independent variables employing generalized structural equation modelling. The versatility of structural equation modelling determined its widespread success in the literature, specifically in studies on reverse logistics (Couto et al., 2016; Hsu et al., 2016). While structural equation modelling uses continuous responses and linear regression models, generalized structural equation modelling allows for binary responses (as well as ordinal, count, and multinomial). Hence, generalized structural equation modelling suits the binary dependent variable of the study and also allows multilevel analysis, which allows considering the random effects determined by a firm's sector. We use a logit model in the generalized structural equation modelling.

As displayed in Figure 1, the main model (depicted with black arrows) describes the impact of the collaboration independent variables and of the control variables on *reverselogistics* at the firm level (grey background). We resort to multilevel modelling, which is suitable for hierarchical data structure where elementary units at level 1 (in our case, firms) are nested in clusters at level 2 (in our case, sector classes). Multilevel modelling allows controlling for unobserved heterogeneity at different levels, inducing dependence among all firms in the same sector (Rabe-Hesketh et al., 2004). To this aim, we use a latent control variable that varies at the *sector* level, adding a random effect for the *sector* to both *reverselogistics* and collaboration behaviour (describing four additional models, grey arrows). The descriptive statistics of the variables are displayed in Table 3. All the variance inflation factors fall below the conventional threshold of 10 (mean 2.5, maximum 8.49) that would suggest the risk of multicollinearity among the independent variables (Baum, 2006).

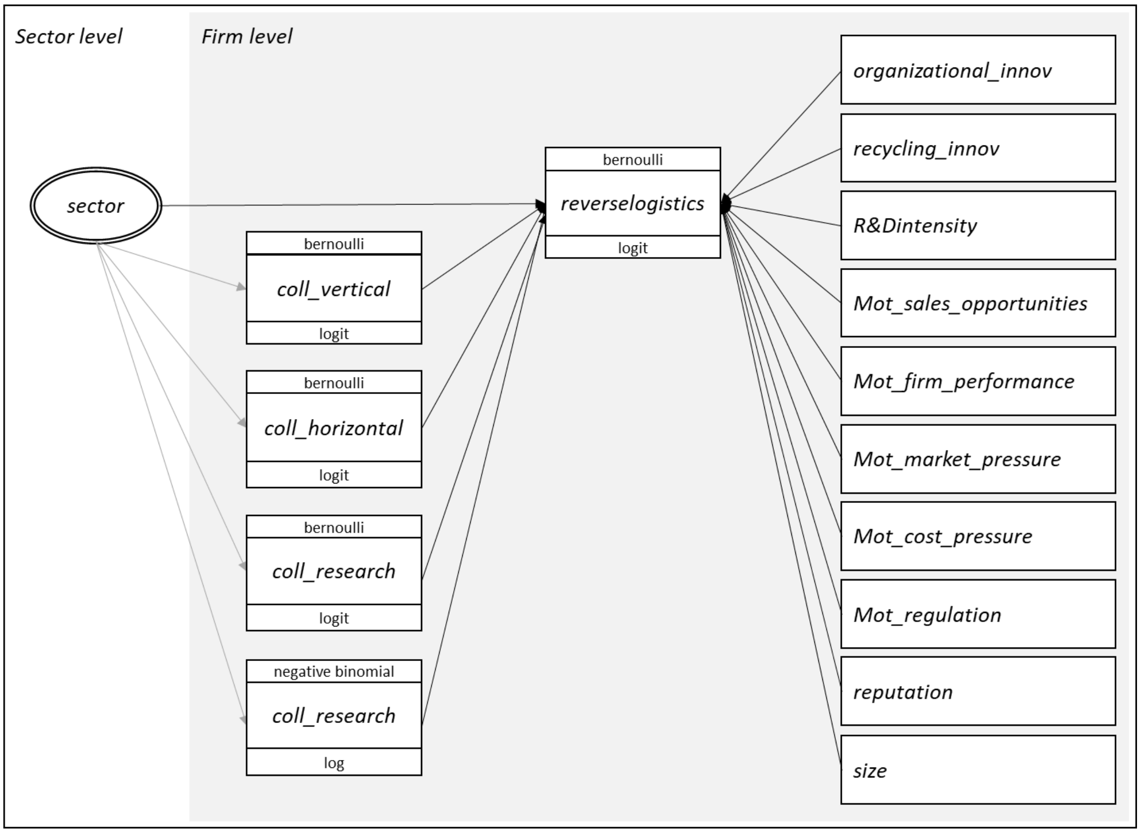

Figure 1. Generalized structural equation model

Table 3. Descriptive statistics of the sample included in the main regression and in the additional models

	Main model			**Additional models**				
	Obs	Mean	St.Dev.	Obs	Mean	St.Dev.	Min	Max
reverselogistics	352	0.14	0.352				0	1
coll_vertical	352	0.11	0.318	2,410	0.07	0.257	0	1
coll_horizontal	352	0.01	0.119	2,410	0.02	0.134	0	1
coll_research	352	0.18	0.384	2,410	0.11	0.308	0	1
collaboration	352	0.55	1.193	2,410	0.34	1.031	0	9
organizational_innov	352	0.38	0.487				0	1
recycling_innov	352	0.45	0.703				0	2
R&Dintensity	352	1.84	3.776				0	0.15

mot_sales_opportunities	352	1.14	1.109				0	3
mot_firm_performance	352	1.63	1.102				0	3
mot_market_pressure	352	1.38	1.095				0	3
mot_cost_pressure	352	1.51	1.073				0	3
mot_regulation	352	1.04	1.057				0	3
reputation	352	0.93	1.040				0	3
size	352	1.59	0.707				1	3
sector	352	2.18	0.986	2,410	2.41	0.952	1	4

4 Results

Table 4 shows the generalized structural equation modelling results used to estimate the impact of the independent variables on *reverselogistics*. Model 0 is the baseline, while Model 1 describes the full model with the collaboration independent variables to test Hp.1, Hp.2, and Hp.3, without the squared term for *collaboration.* Model 1 is statistically better than Model 0 according to the AIC values (p=0.067), supporting the introduction of the variables. Model 2 also includes the squared term for collaboration to test the inverted U-shaped relationship hypothesized in Hp. 4. However, Model 2 is no better than Model 1 in terms of AIC value (p=0.61), which suggests focusing on the more parsimonious Model 1. As a robustness check, we verified that the results stand even using Probit models instead of Logit ones in the generalized structural equation modelling. Furthermore, since the prevalence of zero values in *reverselogistics* may lead to underestimated probabilities of Y=1, we re-estimated our main model using the rare events logit (RElogit) model proposed by King and Zeng (2001), obtaining comparable results (not included for the sake of brevity).

The results support Hp 1, which advanced that firms active in vertical collaboration are more likely to implement reverse logistics innovation. Indeed, the *coll_vertical* odds ratio in Model 1 suggests that vertical collaboration increases the odds of introducing a reverse logistics innovation in the following three years by 76% (all other factors being equal). The results are even stronger in support of Hp 2, which focused on the importance of horizontal collaboration as an enabler of reverse logistics. The odds ratio suggests that firms collaborating horizontally are nine times more likely to introduce a reverse logistics innovation. The result is particularly surprising if we consider the paucity of horizontal collaborations in our sample (as shown in Table 3). In support of Hp 3, collaborating with research institutions makes it four times more likely to introduce a reverse logistics innovation.

Instead, somewhat surprisingly, the results do not support our Hp 4, which advanced the breadth of a collaboration network to have an inverted U-shape effect on the chances to introduce reverse logistics. On the contrary, our results suggest that as the number of collaboration channels increases, the odds of introducing reverse logistics innovation decrease. Such a result may have been influenced by the relatively small number of multiple (>3) collaborations in our sample (17 cases, or 4.82%).

Among the other statistically significant controls, we found that introducing an incremental innovation in recycling in the near past can predict the subsequent introduction of a reverse logistics one, whereas having introduced a radical innovation in recycling is not. An interpretation for this result could be that a radical innovation in recycling is more likely to trigger an immediate reverse logistics innovation than one that takes place up to three years later. Unfortunately, the variable on recycling innovation is not available for 2014-2016; thus, this interpretation cannot be empirically tested.

Among the key motivations leading to logistics innovation, those that have a significant and positive impact on *reverse logistics* include the willingness to improve the firm's performance (*mot_firm_performance*), the need to respond to cost pressure (*mot_cost_pressure*), as well as the need to adapt to regulations (*mot_regulation*). The positive impact stands at any level of importance for the three variables, except for a high-cost pressure level, which is not statistically significant. The latter result suggests that reverse logistic innovation is an option to the firm when cost pressure is high, but not necessarily the one that stands among the other possible logistic innovations.

The reputational drivers of environmental innovations are not likely to enhance reverse logistics. On the contrary, a high level of attention towards reputation reduced the probability to introduce reverse logistics. This result may suggest that firms with a high focus on reputation are more likely to implement different and possibly more easily communicable actions to address their environmental footprint. However, another interpretation could be that such firms already were equipped with processes allowing reverse logistics, and therefore do not need to innovate them any further.

Table 4. Results of Generalised Structural Equation Modelling on Reverse Logistics Innovation (reverselogistics)

	Model 0 - Baseline			Model 1			Model 2		
	odds ratio	*coeff (SE)*	*p*	*odds ratio*	*coeff (SE)*	*p*	*odds ratio*	*coeff (SE)*	*p*
coll_vertical				1.76***	0.57 (0.122)	0.000	1.48***	0.39 (0.106)	0.000
coll_horizontal				9.97*	2.3 (0.945)	0.015	13.98†	2.64 (1.402)	0.060
coll_research				5.01***	1.61 (0.285)	0.000	2.6	0.96 (0.600)	0.111
collaboration				0.53***	-0.64 (0.074)	0.000	1.12	0.11 (0.451)	0.803
collaboration²							0.86*	-0.15 (0.060)	0.015
organizational_innov	0.68	-0.38 (0.337)	0.253	0.71	-0.34 (0.345)	0.330	0.73	-0.31 (0.334)	0.348
recycling_innov									
minor importance	2.33*	0.85 (0.352)	0.016	2.54*	0.93 (0.380)	0.014	2.57*	0.94 (0.436)	0.031
important	1.14	0.13 (0.613)	0.828	1.23	0.21 (0.706)	0.771	1.22	0.2 (0.711)	0.784
R&D intensity	1.05	0.05 (0.036)	0.158	1.04	0.04 (0.036)	0.271	1.04	0.04 (0.035)	0.292
mot_sales_opportunities									
low	1.03	0.03 (0.286)	0.926	1.08	0.08 (0.297)	0.795	1.1	0.1 (0.277)	0.718
medium	0.68	-0.39 (0.707)	0.581	0.69	-0.38 (0.722)	0.601	0.68	-0.39 (0.673)	0.566
high	0.49	-0.71 (0.767)	0.353	0.42	-0.88 (0.758)	0.247	0.42	-0.87 (0.758)	0.251
mot_firm_performance									
low	5.08*	1.62 (0.814)	0.046	5.40†	1.69 (0.865)	0.051	5.33*	1.67 (0.853)	0.050
medium	6.57**	1.88 (0.613)	0.002	6.49**	1.87 (0.689)	0.007	6.46**	1.87 (0.658)	0.005
high	4.91*	1.59 (0.654)	0.015	4.79*	1.57 (0.66)	0.018	4.75*	1.56 (0.665)	0.019
mot_market_pressure									
low	0.25	-1.38 (0.977)	0.158	0.26	-1.33 (0.878)	0.129	0.25	-1.37 (0.853)	0.107
medium	1.05	0.05 (0.271)	0.864	1.01	0.01 (0.171)	0.938	0.93	-0.07 (0.200)	0.735
high	1.53	0.42 (0.903)	0.639	1.42	0.35 (0.788)	0.655	1.44	0.37 (0.867)	0.673
mot_cost_pressure									
low	2.61***	0.96 (0.274)	0.000	2.42***	0.88 (0.231)	0.000	2.37***	0.86 (0.232)	0.000
medium	2.95***	1.08 (0.157)	0.000	3.02***	1.11 (0.115)	0.000	3.06***	1.12 (0.108)	0.000

high	1.49	0.4 (0.57)	0.482	1.62	0.48 (0.579)	0.404	1.53	0.43 (0.582)	0.464
mot_regulation									
low	1.89*	0.64 (0.281)	0.023	1.98*	0.69 (0.346)	0.048	1.98*	0.68 (0.344)	0.047
medium	3.5***	1.25 (0.212)	0.000	3.94***	1.37 (0.245)	0.000	4.02***	1.39 (0.252)	0.000
high	2.57	0.95 (0.576)	0.101	3.16†	1.15 (0.651)	0.077	3.22†	1.17 (0.616)	0.058
reputation									
minor importance	0.62	-0.47 (0.458)	0.302	0.64	-0.44 (0.462)	0.336	0.63	-0.47 (0.424)	0.268
middle importance	1.13	0.12 (0.27)	0.657	1.15	0.14 (0.276)	0.603	1.16	0.15 (0.299)	0.617
highly important	0.36†	-1.02 (0.541)	0.060	0.41*	-0.88 (0.444)	0.047	0.4†	-0.91 (0.482)	0.06
size									
50-249	1.12	0.11 (0.69)	0.868	1.08	0.08 (0.715)	0.916	1.11	0.11 (0.706)	0.878
>=250	0.49	-0.72 (0.708)	0.312	0.43	-0.85 (0.679)	0.213	0.46	-0.77 (0.692)	0.267
sector		1 (constrained)			1 (constrained)			1 (constrained)	
Obs. (main model)		352			352			352	
AIC		10489.6			10484.2	0.067†		10483.2	0.61
% of correct predictions		86.1%			86.9%			86.4%	

Notes: robust standard errors in parentheses; *** p<0.001; **p<0.01; *p<0.05; † p<0.1

5 Discussions

The literature has discussed how firms operating in a supply chain can embrace the circular economy and create shared value (Genovese et al., 2017) and how supply chain leadership and governance mechanisms can improve performance (Mokhtar et al., 2019). However, the impact of inter-organizational collaboration on circular economy processes, such as reverse logistics, has been under-researched.

The German context of our study plays an important role in enabling the interpretation of the results from an institutional theory perspective (Scott, 1995). Indeed, different contexts are likely to trigger different institutional forces. For instance, in their research on reverse logistics in Malaysia, Khor et al. (2016) focused on coercive institutional forces only, excluding the existence of mimetic and normative ones. Indeed, they argued that very few firms in their context committed to product reprocessing, while their consumers were not exerting pressure on them towards more environmental-friendly behaviour. We discussed earlier in the article how Germany is among the most advanced nations in adopting reverse logistics, which – differently from Khor et al.'s study - is likely to activate all the institutional forces. Hence, taking an institutional theory perspective, our results support the importance of coercive, mimetic, and normative processes as enablers for reverse logistics innovation. Both the informal coercive processes underlying vertical and horizontal collaboration and the formal coercive processes implied by regulations positively impact the likelihood of introducing reverse logistics innovation. The same effect can result from the mimetic processes in horizontal collaborations (Zhu and Sarkis, 2007). Lastly, also the normative processes that stem from the professionalization provided by universities and research institutions are likely to be drivers for reverse logistics innovation. These conclusions resonate with Ye et al.'s study (2013) on the positive impact of institutional pressures on top managers' favourable attitude towards the implementation of reverse logistics, which in turn increases the likelihood of product recovery initiatives. As mentioned before, German regulation proved its importance as a coercive institutional driver of reverse logistics, consistently with other studies (Khor et al., 2016). While our study focused on reverse logistics and collaborations at the national level, implying the institutional proximity of the involved subjects (Veyssière et al., 2021), the emergence of global supply chains sets a new goal for future research grounded in the institutional theory. On the one hand, as posed by Sarkis et al. (2011), who cite (Daniels and Perez, 2007), mimetism can encourage cross-national collaboration among firms operating in the same supply chain. On the other hand, coercive institutional forces may hinder reverse logistics across nations when policies between different countries are inconsistent, a barrier true, more in general, for circular economy (Grafström and Aasma, 2021).

In terms of resource dependence theory (Pfeffer and Salancik, 1978), all of the three types of collaboration that positively influence reverse logistics innovation are likely to enrich the set of resources a firm can leverage to introduce reverse logistics innovation. Suppliers can help to overcome the technical issues (Mirkovski et al., 2016), competitors may share knowledge to set standards (Ohnishi et al., 2012), while research institutions can offer information on the latest technologies or on the ones that are more suitable for the firm (Khan et al., 2020). Since vertical and horizontal collaboration imply an overlap in the partners' knowledge base, our results add to the stream of literature based on the absorptive capacity theory that studies whether collaboration is more effective when overlap in the competencies is present (Kim and Inkpen, 2005; Nagati and Rebolledo, 2012; Nooteboom et al., 2007).

Our findings supported most of the hypotheses of the study, including the positive effect on reverse logistics innovation of vertical and horizontal collaboration, as well as of the collaboration with research institutions. However, the breadth of the collaboration network was negatively associated with the dependent variable. The result was unexpected since the vast literature that studied the impact of collaboration breadth on innovation (i.e., not specifically reverse logistics innovation) generally found positive (e.g., Ahn et al., 2015; Christensen et al., 2019; Ebersberger et al., 2012) or inverted U-shaped effects (e.g., Greco et al., 2016; Kobarg et al., 2019; Laursen and Salter, 2006). The finding suggests that collaboration is not a panacea for all ills. Indeed, the results of collaboration may also be disappointing (Pomponi et al., 2015). Bönte and Dienes (2013) studied the impact of a 'cooperation strategy' on environmental process innovations that reduced materials or energy per unit and found that such a strategy was not significantly better than an internally oriented 'in-house' strategy. Several factors such as asymmetric power, transaction costs (Abbasi and Nilsson, 2012), or lack of trust (Pomponi et al., 2015) can hamper collaboration in a supply chain. Hence, firms should select their partners with great care, preferring a few trusted partners to a variety of them. This recommendation is in line with González-Moreno et al.'s recent findings on food firms' eco-innovation propensity (2019). Indeed, the authors emphasized that deep, frequent and intense relationships with stakeholders nurture process eco-innovations. Furthermore, Mokhtar et al. (2019) emphasized that trust positively mediates the relationship between supply chain transformational leadership and reverse supply chain performance.

This study also offered the occasion to investigate other possible drivers for reverse logistics innovation. Indeed, the likelihood to introduce reverse logistics innovation was significantly increased by the willingness to improve the firm's performance and – to a lesser extent – reduce its costs. The result suggests that firms are confident in the future outcome deriving from reverse logistics, even though the implementation of circular economy in supply chains may be challenging from an economic point of view (Genovese et al., 2017), and firms are often concerned about cannibalisation risk (Atasu et al., 2010). Notably, German firms' positive attitude towards circular economy initiatives may have played an important role in shaping these perspectives. Even though we cannot exclude some external influence on the abovementioned two motivations (e.g., the influence exerted by scholarly studies on the economic benefits of reverse logistics or collaboration with peers that have experienced improved performance thanks to reverse logistics), their self-centred nature is particularly interesting, especially when compared with the lack of statistical significance obtained by the variables *mot_sales_opportunities* and *mot_market_pressure*. Indeed, the latter result suggests that firms do not feel that competitive pressure (i.e., informal coercive institutional processes) leads them towards reverse logistics as opposed to the self-centred willingness to improve their performance. Finally, the insignificant result of R&D intensity, a variable we associated with absorptive capacity, is another surprising result. Given the absence of studies focused on the relationship between reverse logistics and R&D intensity (or, more generally, absorptive capacity), we encourage future research on this topic.

6 Conclusions and Future Developments

We analyzed the impact of inter-organizational collaboration on the likelihood to introduce reverse logistics innovation. The results have implications for theory and practitioners.

6.1 Implications for theory

This study is among the first ones to discuss how collaboration drives reverse logistics innovation. We found that collaboration with customers and suppliers, collaboration with competitors, and collaboration with research institutions increase the likelihood to introduce reverse logistics. A comparative pre-eminence of collaboration with competitors with respect to the other two channels emphasized the importance of co-opetition in a closed-loop supply chain. Furthermore, we found that the breadth of collaboration negatively impacts reverse logistics innovation, which is a surprising result for innovation management literature. Future research should identify the key differences between reverse logistics innovation and other innovation types to understand what makes collaboration breadth detrimental in this case.

The study offers new evidence supporting the role of resource dependence theory and institutional processes. Indeed, the positive impact of collaborations on reverse logistics innovation suggests that the firms under investigation benefited from their partners' resources. Furthermore, the close interaction implied by collaboration is likely to activate the informal coercive processes underlying both vertical and horizontal collaboration; the mimetic processes in horizontal collaborations; and the normative processes that can stem from the collaboration with universities and research institutions. The formal coercive processes implied by regulations, whose positive impact on reverse logistics innovation was confirmed, complete the picture. In this vein, another implication for theory stems from the fact that the interviewees were more motivated to implement logistics innovation by the willingness to improve performance and the necessity to cope with regulations rather than by market pressure. Future research could further study these motivations through in-depth interviews.

Furthermore, as Doering et al. (2020) posed, longitudinal studies in the supply chain management domain are uncommon despite their value, making this contribution particularly valuable from a methodological perspective since it allows causal inferences.

6.2 Implications for practice

Our results offer insights for managers willing to introduce reverse logistics innovation. They should select a limited number of partners, identifying the ones that suit their firms' needs the most. The literature has discussed how vertical collaboration can be valuable to overcome technological challenges. Competitors can facilitate the introduction of reverse logistics innovation – particularly when their supply chains overlap – while research institutions can transfer their knowledge on the latest technologies and business models. Since this article demonstrated that collaborating with each of these partner types has a positive impact on reverse logistics innovation, we recommend a careful analysis of the firms' needs to identify which can contribute the most to the successful implementation of reverse logistics.

6.3 Limitations

This article is limited in that it analyzed a sample of German firms. Indeed, the context of the study is very advanced concerning environmental innovation in general and reverse logistics innovation in particular, and the results may not be extended to other countries. Furthermore, this study did not formulate and test hypotheses on collaboration with foreign organizations since regulations and customer expectations in our sample were among the more demanding on the global scale. Hence, the results do not necessarily hold for global supply chains or international collaborations. Given the lack of empirical evidence on the topic, we encourage future research. Another limitation is caused by binary collaboration variables, which impede a more thorough understanding of the nature, cardinality, and importance of such collaborations. Furthermore, the collaboration variables refer to innovation activities in general, not specifically focused on reverse logistics. Since our dataset does not include more detailed collaboration variables, we encourage future research to complement and enrich our findings. Finally, the items referring to the motivations for innovation in logistics, which we used as control variables, are based on the interviewees' perceptions. The accuracy of such perceptions could have been biased since interviewees could have underestimated the importance of informal coercive institutional processes. Indeed, managers are typically more focused on their firms' performance and the constraints they must comply with, such as regulations (another important driver of reverse logistics innovation, as mentioned before).

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