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# Adoption drivers and barriers of digital freight transport platforms—An intermodal case study

Paul Bossong<sup>1</sup> · Anne Reinhardt<sup>1</sup> · Ralf Elbert<sup>1</sup>

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## Abstract

Increasing environmental pressure urges firms to decarbonize their supply chains by reducing emissions caused by freight transport. This puts intermodal freight transport (IFT) on the agenda. IFT combines the ecological advantages of rail transport with the flexibility of road transport. However, it increases supply chain complexity by creating additional interfaces between the actors involved. This hampers efficiency and calls for automation through digital platforms. By contextualizing the Technology-Organization-Environment (TOE) framework and applying a multiple-case study approach, we aim to investigate why users opt for or against adopting IFT platforms and how adoption can be fostered. Among 30 adoption factors identified, we find that sellers of IFT services fear increased market transparency and interface standardization through platforms, while demanders of IFT services favor these attributes. We contribute to the extant literature by providing a nuanced understanding of the underlying decision rationales from the perspectives of platform users and providers and derive nine levers suitable to increase platform adoption and, hence, supply chain automation.

**Keywords** Case study research · Digital platform · Adoption decision · Intermodal freight transport · Multi-sided platforms

**JEL Classification** O33

## Introduction

The “fine-sliced”, disaggregated character of today’s global supply chains challenges firms to ensure efficient, responsive, and resilient operations (Buckley & Strange, 2015, p. 237). At the same time, firms are under pressure to reduce their environmental footprint. Transport accounts for a large share of emissions in supply chains. Shifting freight transport to more environmentally friendly transport modes (e.g., rail) is a stepping stone to mitigate the environmental footprint of supply chains, and it is an essential goal of

the EU climate policy (European Commission, 2019). This shift can be realized through intermodal freight transport (IFT). As the backbone of maritime supply chains and long inland supply chains, IFT combines the sustainability of rail-based freight transport on the long haul with the flexibility of road-based trucking on the first and last mile. It is, therefore, predestined to decrease freight transport-related emissions (Perakis & Denisis, 2008). However, additional actors are required to organize and physically conduct IFT services. Such segmentation increases supply chain complexity and commonly causes manual interaction and data exchange problems at points where information and physical goods are exchanged (see Karam et al., 2023; Kramarz et al., 2022).

Supply chain automation can tackle the challenges of IFT. By replacing or supporting “human-performed physical or informational process[es]” (Nitsche et al., 2021, p. 3), it has the potential to enable efficient communication and increase supply chain visibility despite additional interfaces and stakeholders. Particularly, digital multi-sided platforms promise to automate more sustainable yet fragmented intermodal supply chains. According to Bossong et al. (2025), two core functions of IFT platforms are currently evolving

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that are suitable to distinguish these platforms: First, platforms like the intermodal capacity broker of Rail-Flow are advertised to provide “a transparent view on available capacities in a large network of trusted carriers and rail operators” (Rail-Flow, 2024). Hence, such platforms serve as matchmakers between the demanders and sellers of IFT services. They support freight dispatchers in finding and comparing suitable IFT offerings. Second, platforms like DX Intermodal call themselves a “common data hub for the entire physical transport chain” (DX Intermodal, 2024). Such platforms digitize time-consuming manual communication (e.g., via phone and email) through standardized data exchange. Additional value-added services, ranging from data analytics to payment processing, complement these core platform functions.

However, despite their potential to tackle the inherent challenges of IFT, the prevalence of digital platforms in IFT is limited so far, and knowledge about the users’ rationales for or against adopting platforms (and potentially shifting freight volumes to IFT) is lacking in the literature. Therefore, as a complex B2B market for freight transport services, IFT is ideally suited for investigating how freight logistics as the backbone of supply chains (Lysons and Farrington 2020) can be automated through the matchmaking and data exchange functionality of digital platforms.

The extant literature has focused on digital logistics startups, in particular, so-called digital freight forwarders, entering the transport industry with digital business models for unimodal (mainly road freight) transport (e.g., Heinbach et al., 2022; Herold et al., 2023; Jain et al., 2020). The literature has, in addition, investigated the digitization of processes at specific nodes of the supply chain (e.g., terminals, ports, and airports) and has explored associated business models (Tessmann & Elbert, 2022b) as well as the adoption of platforms spatially linked to these nodes (Tessmann & Elbert, 2022a; Wallbach et al., 2019). For the IFT market, the literature recognizes the potential of digitization to reduce market entry barriers (Altuntaş Vural et al., 2020), and it has proposed early on that this market is a fertile ground for innovations in information and communication technologies and associated research (Caris et al., 2013). However, concrete studies focusing on the newly emerging digital platforms are scarce. Hence, the importance of IFT for future supply chains sets this market apart as an increasingly relevant research context. In this context, it is possible to explore the adoption of platforms without limiting the research focus to specific nodes or transport modes.

To narrow the research gap identified, this study aims to provide an in-depth understanding of IFT platform adoption as a newly emerging phenomenon. Moreover, due to the potential of IFT platforms to automate day-to-day processes (such as booking of IFT services and data exchange), to increase IFT adoption and, thus, to contribute to the decarbonization of

supply chains, this study aims to develop levers that can foster platform adoption. To achieve this twofold research objective, we understand the adoption process as a causal decision-making process of potential platform users who are influenced by their rationales (i.e., drivers and barriers of adoption). Since multi-sided platforms are commonly described as two-sided platforms in the literature, potential users can be divided into sellers and buyers (see Coleman, 2019). Therefore, it is crucial, yet neglected by the literature, to distinguish the adoption rationales of sellers (i.e., the seller of IFT services) and buyers (i.e., the demanders of IFT services). In addition, we consider the perspective of platform providers who are in a predestined position to observe and influence users’ adoption decisions. Consequently, we define the following research questions to address our research objectives:

**RQ1:** *Why* do users (i.e., sellers and demanders of IFT services) opt for or against adopting digital IFT platforms? Hence, which drivers and barriers influence their adoption decisions?

**RQ2:** *How* can IFT platform adoption be fostered? Hence, which levers exist to increase platform diffusion in the IFT industry as one cornerstone of supply chain automation?

Case studies are suitable to address these “*why*” and “*how*” questions from rich, real-world data (Eisenhardt, 1989b; Yin, 2014). We, thus, selected a multiple-case study research design with three cases: IFT demanders, IFT sellers, and IFT platform providers. In a within-case analysis, we investigate how the adoption decision made by platform users (i.e., sellers and demanders of IFT services) is perceived by the users and the platform providers, respectively. To analyze the rationales behind the users’ adoption decisions (“*why*”, RQ1), we draw on the Technology-Organization-Environment (TOE) framework (Tornatzky & Fleischer, 1990) as an established theoretical lens to explain technology adoption in organizations. Selecting this theoretical lens enabled us to identify 30 factors influencing platform adoption. Moreover, we derived a set of research propositions outlining the mechanisms of how these factors impact the specific adoption decisions of sellers and demanders. A subsequent cross-case analysis compares and contrasts the adoption rationales. Such search for patterns across cases served as a basis for developing nine levers suitable to increase platform adoption (“*how*”, RQ2).

The findings for RQ1 serve as a basis for our threefold theoretical contribution: Foremost, our study is the first to investigate platform adoption in the increasingly relevant IFT context. Our study enriches the digital platform literature by systematically exploring the drivers and barriers of digital IFT platform adoption. By developing specific categories of drivers and barriers, we contextualize the TOE framework for its application in the IFT market. Thereby,

we respond to the call of Shree et al. (2021) for more industry-specific, case-based explorations of platform adoption. Second, we analyze the adoption process from the perspectives of different actors in the IFT ecosystem and interpret our findings in light of the nuanced rationales and emerging tensions between both platform user groups. Third, we contribute to the understanding of B2B platform adoption in the context of supply chain automation by stressing the prevalence of pretexts, the need for change management, and outlining further supply chain automation potential.

From a managerial perspective, our findings for RQ2 give platform providers, platform users, and political stakeholders a clear perspective on why platform adoption is lacking in IFT. The derived levers serve as “puzzle pieces” to understand why digitization is, in general, still in an early stage in IFT (see Altuntaş Vural et al., 2020) and set the ground to develop practical measures that foster platform adoption. Thereby, we show how IFT platforms can support demanders and sellers in navigating out of a principal-agent dilemma.

Our study is structured as follows: First, we provide theoretical foundations followed by our methodological approach. Next, we present our findings, structured along the within-case and cross-case analyses of the users’ and providers’ perceptions of the platform adoption decision. The subsequent discussion delineates our theoretical contribution and managerial insights before we conclude our study.

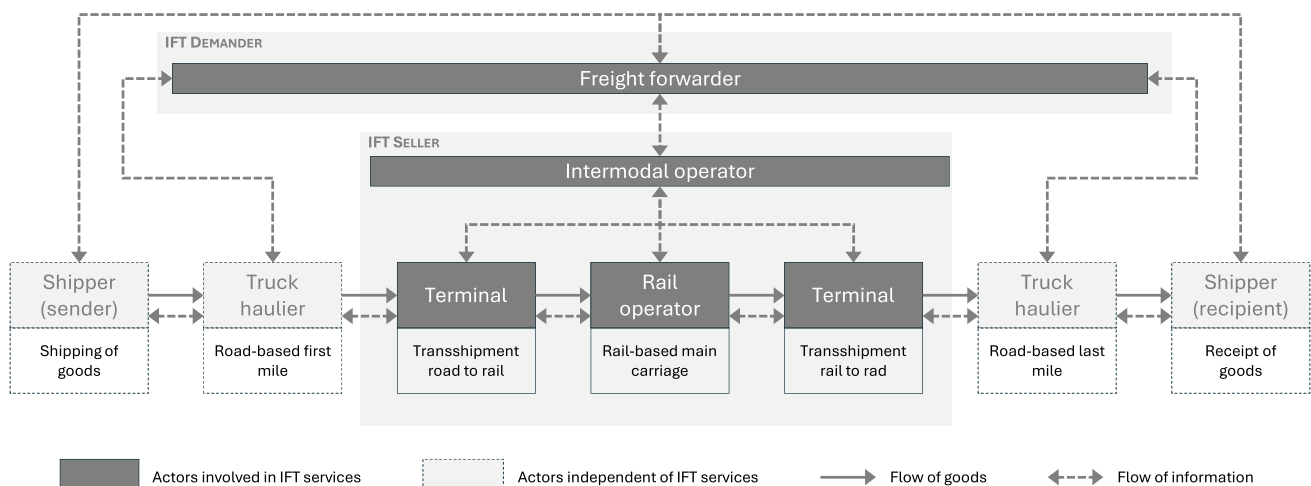
## Theoretical background

### Supply chain automation in the context of intermodal freight transport

Modern supply chains encompass a wide variety of different activities with possible applications for automation (see

Nitsche et al., 2021). Rising complexity (Klump, 2018), high competitive pressure (Capineri & Leinbach, 2006), labor shortage (Kilibarda et al., 2019), and the need to decarbonize freight transport prompt firms to automate logistics and supply chain activities. IFT can help decarbonize freight transport by combining the sustainability and efficiency of rail-based transport on the long haul with the flexibility of road-based transport on the first and last mile. However, as shown in Fig. 1, IFT leads to a high division of labor and requires the collaboration of multiple actors, resulting in many physical and informational interfaces (Faulin et al., 2019). Particularly, automating the sourcing of freight transport services and data exchange activities promises to tackle the aforementioned challenges but, surprisingly, automation (e.g., through digitization) is lacking in IFT (Altuntaş Vural et al., 2020). High complexity and missing automation lead to a low share of IFT within the European Union, with 54% of freight transport still being predominantly conducted on road versus 12% on rail (European Commission, 2023).

Figure 1 presents an overview of the actors typically involved in IFT: Shippers usually outsource their logistics function. Their choice of transport providers (i.e., freight forwarders) and associated modes of transport is decisive for supply chain emissions resulting from transport (Ellram et al., 2022). Freight forwarders organize the transport of shippers’ goods by consolidating multiple shipments and purchasing adequate transport services like IFT (Reis & Macário, 2019). While freight forwarders might conduct the truck-based first and last mile with their own truck fleets, they commonly purchase IFT services from intermodal operators. Intermodal operators, in turn, organize transshipments and rail transport carried out by terminal and rail operators. Hence, as depicted in Fig. 1, freight forwarders can be considered the demanders of IFT services, while terminal operators, rail operators, and intermodal operators are the



**Fig. 1** Intermodal freight transport (IFT) flow of goods and information (without digital platform)

sellers of IFT services (Woxenius & Bärthel, 2008). Even though there has been a consolidation trend in the freight forwarder industry in recent years, the demander side is still fragmented, with small, regionally focused freight forwarders dominating the industry (Reis & Macário, 2019). In contrast, the seller landscape is characterized by large IFT service providers exhibiting an oligopolistic market structure (Monios, 2018).

A common communication standard among the actors in IFT is missing, and communication is often formless and paper- or email-based, as examples from the freight forwarder industry show (Heinbach et al., 2022). Moreover, a lack of transparency (e.g., on prices and services offered), which results from the fragmented actor landscape and missing digitization (Herold et al., 2023), hinders the sourcing process of freight service demanders and the selling process of freight service sellers, respectively. Digital platforms are promising tools to automate non-physical but labor-intensive standard processes (such as booking, monitoring, and administering freight transports) and enable efficient resource allocation (Patrucco et al., 2024). This automation potential suggests that digital platforms acting as intermediaries between the seller and demander side (see Fig. 2) would be highly beneficial for increasing efficiency, reducing costs, and decarbonizing freight transport. As digitization in general and platform adoption specifically are lacking in the IFT industry (Altuntaş Vural et al., 2020), an understanding of the factors influencing platform adoption in IFT is essential to tap into further automation potential.

### Adoption theory for digital platforms as a theoretical lens

Digital platforms combine different digital technologies (Hein et al., 2020), which is why technology adoption and diffusion theories are frequently used to study platform adoption (Shree et al., 2021). These theories can take an individual perspective (e.g., on the employee level) and an overarching perspective on the organizational level (Hillmer, 2009).

For individuals, the Theory of Reasoned Action (TRA) explains human behavior through the influence of two factors: attitude toward behavior and subjective norm (Ajzen & Fishbein, 1980; Fishbein & Ajzen, 1975). While the attitude describes the individual's belief in what the consequences of an intended action are, subjective norms represent the "perceived social pressure to perform [...] the behavior" (Ajzen et al., 2014, p. 5). With perceived behavioral control as an additional factor, Ajzen (1991) developed the Theory of Planned Behavior (TPB), which accounts for the perceived ability of individuals to perform an action. The TPB has been extended to the Reasoned Action Approach (RAA) by identifying background factors and beliefs as antecedents of

the influencing factors from the TPB (Fishbein, 2010). With a stronger focus on technology, the Technology Acceptance Model (TAM) assumes that the actual use of technology is mainly driven by the technology's perceived usefulness and perceived ease of use, which influence potential users' attitude toward using as well as their behavioral intention to use technology (Davis, 1985, 1989). The framework has been applied in many empirical studies and has been extended multiple times by several factors, leading to TAM2, TAM3, and—by combining it with other frameworks such as TRA and TPB—to UTAUT (Unified Theory of Acceptance and Use of Technology, Venkatesh & Davis, 2003).

To not only account for individual adoption behavior, Tornatzky and Fleischer (1990) proposed a framework suitable to describe an organization's "context in which innovation takes place" (Tornatzky & Fleischer, 1990, p. 151). Their framework comprises three interdependent dimensions: Technology, Organization, and Environment (TOE). The technological context describes the characteristics and availability of internal and external technologies that influence the organization's adoption decision. The organizational context accounts for internal characteristics such as firm size, available resources, and linkages, whereas the environmental context connects the adoption process to the market and industry as well as to the regulatory scope (Tornatzky & Fleischer, 1990).

### The state of the literature on drivers and barriers of digital platform adoption

Literature investigating the adoption of digital freight transport platforms is scarce and limited to specific platform types (e.g., maritime container booking platforms; see Zeng et al., 2020, 2021) or platforms for particular nodes within supply chains (e.g., air cargo hubs; see Wallbach et al., 2018, 2019). In the broader supply chain context, the adoption of physical internet networks (Plasch et al., 2021) and sourcing platforms for manufacturing firms (Garcia et al., 2019; Marzi et al., 2023) have been investigated. In non-supply chain B2B contexts, recent studies focused on platform adoption for the metal industry (Rohn et al., 2021), for digital document exchange in B2B projects like construction work (Loux et al., 2020), e-invoicing platforms (Penttinen et al., 2018), or e-commerce platforms (Hamad et al., 2018; Najmul Islam et al., 2020).

To gain an overview of recent literature that investigates factors influencing the adoption or diffusion of B2B platforms, we systematically screened the databases Web of Science and EBSCOhost and complemented this search with a snowballing approach. We deliberately excluded literature from the B2C context and focused on peer-reviewed journals with a high reputation (Q1 of Scimago Journal Rank) and established conference proceedings. Due to the novelty of emerging platforms in

**Table 1** Overview of factors influencing platform adoption and respective theoretical lens, identified from the literature

Study	Marzi et al., 2023*	Plasch et al., 2021*	Rohn et al., 2021	Zeng et al., 2021*	Loux et al., 2020	Najmul Islam et al., 2020	Zeng et al., 2020*	Garcia et al., 2019*	Wallbach et al., 2019*	Hamad et al., 2018	Penttinen et al., 2018	Wallbach et al., 2018*
Theoretical lens	SNT, DOI, TOE	RBV, ROT	-	-	-	CSLC	TOE	DOI	-	TOE	Multiple (e.g., TCT)	TOE
<b>Category</b>	<b>Factors</b>											
Economic factors	Adoption cost (-); assimilation costs (-); cost (-/?); total cost (+)	•			•	•	•	•		•		
Inter-organizational dynamics	Blaming other actors (-); community idea (-); conflict of interest (-); contractual relationship (-); leading organization pressure (+); mimetic pressure (+); trading partner pressure (+)			•				•	•			•
Management support	Management commitment (+); strategic alignment (+); top management support (+/-)	•		•		•	•		•	•		•
Market and industry conditions	Being a central firm in the SC network/position in the tier structure (+); belonging to a cluster or community with early adopters (+); business partner pressure (?); coercive pressure (+); competitive pressure (+); cost pressure (+); demand uncertainty (?); environmental performance (+); industrial characteristics (-); institutional environment (-); logistics resource access/expansion (+); place in the tier structure (-); supply network flexibility (+)	•				•	•	•		•		
Network and resource access	Fluid partnering (+); innovation and business model development strategy (+); know-how access (+); network and/or market expansion and internationalization (+)	•										
Organizational structure and culture	Adoption fatigue (-); external processes (-); firm size (-); implementation of workarounds (-); integration and collaborative business strategy (+); internal processes (-); organizational readiness (?); ownership structure (-); process dynamics (-); promotion and sensitization of digital transformation (+); qualified workforce (+); spirit of innovation (+); start-up culture (+)	•	•			•	•		•	•		•
Platform benefits	Benefits (+); communication of functionalities (-); efficiency and security (+); flexibility requirements (+); functionalities (-); recognized potential of the system (+); relative advantage (+/?); strategic benefits (+); usefulness (?); value capture (-); value creation (-); value delivery (-)	•	•			•	•	•	•	•		•



Table 1 (continued)

Study	Marzi et al., 2023*	Plasch et al., 2021*	Rohn et al., 2021	Zeng et al., 2021*	Loux et al., 2020	Najmul Islam et al., 2020	Zeng et al., 2020*	Garcia et al., 2019*	Wallbach et al., 2019*	Hamad et al., 2018	Penttinen et al., 2018	Wallbach et al., 2018*
Platform governance			•						•			•
Platform reach and reputation		•						•			•	
Regulatory environment		•		•			•	•	•	•		•
System characteristics		•							•			•
Trust and confidentiality		•	•				•					
Usability				•			•	•	•	•	•	•

\*Supply chain-related studies; *CSLC*: Customer Service Life Cycle framework; *DOI*: Diffusion of Innovations; *RBV*: Resource-based view; *ROT*: Resource Orchestration Theory; *SNT*: Social Network Theory; *TCT*: Transaction Cost Theory; *TOE*: Technology – Organization – Environment; +: positive impact; –: negative impact; ~: impact depending on settings; ? : unclear/no impact

the IFT sector, we narrowed down the scope to literature published over the last 6 years. By screening the titles, abstracts, and full studies, we ensured they aligned with our research objective. Our review yielded seven studies focusing on platforms in the supply chain context (denoted with an asterisk in Table 1) and five studies analyzing platform adoption in the broader B2B context. Most of these studies obtain a theoretical lens based on existing adoption theory, frequently TOE. However, as demonstrated in Table 1, a consistent terminology of factors influencing digital platform adoption is missing in B2B contexts. We were able to extract 88 different notions of factors which frequently describe similar phenomena. Table 1 lists these factors and indicates whether we found a positive (+), negative (−), or setting-dependent (~) adoption impact or if a clear impact cannot be identified (?). For factors that have been named by multiple sources, multiple impact indicators are reported (e.g., high complexity is found by Garcia et al. (2019) to have a negative impact, while Hamad et al. (2018) find a setting-dependent impact). By intuitively clustering the 88 factors into 13 aggregated categories, Table 1 reveals that there are categories that have been identified and analyzed frequently in previous research: *Clear platform benefits*, *easy usability*, and an *organizational structure and culture* that nurtures the usage of digital platforms have often been identified as adoption drivers, whereas a *lack of management support* is underpinned as a major barrier of platform adoption. The *regulatory environment*, in turn, is found to have an ambiguous impact: While the enforcement of platform utilization by the government (e.g., for tax- and customs-related processes) can increase adoption (Zeng et al., 2020), it can also urge users to avoid specific platforms (Zeng et al., 2021).

The reviewed literature shows that there is neither a consistent terminology nor consistent findings on the influence of various factors on the adoption decision. This observation suggests that a context-specific analysis for IFT is required. In addition, it is conspicuous that previous research has neglected the (potentially) varying impact of the adoption factors depending on different platform user groups. In line with the call of Shree et al. (2021), we aim to contribute to the research body with a case-based analysis of platform adoption in IFT as a yet unexplored industrial setting.

## Methodology

### Research design

To gain a deep understanding of the drivers and barriers for platform adoption, we chose a multiple-case study research design. Case studies are suitable for exploring new phenomena (see Voss et al., 2002) like emerging IFT platforms. With IFT sellers and demanders as the users of these platforms and platform providers as the

intermediaries between them, we selected three distinct cases that enabled us to navigate within the established TOE framework (see Fig. 2). We followed the methodological guidance of Eisenhardt (1989b) for our case study design, which is suitable for theory-building and theory-elaboration purposes (see Ridder, 2017). In the process of theory elaboration, we adjusted and refined the underlying dimensions of the TOE framework to the IFT context. Such a process of “theoretical contextualization” (Craighead et al., 2016, p. 242) is typical for the development of middle range theory (MRT). In doing so, our study tailors our theoretical lens to the IFT context without relying on a “traditional one size fits all” approach (Soltani et al., 2014, p. 1015). Instead, it provides in-depth insights into users’ complex inner causal mechanisms behind their IFT platform adoption decisions.

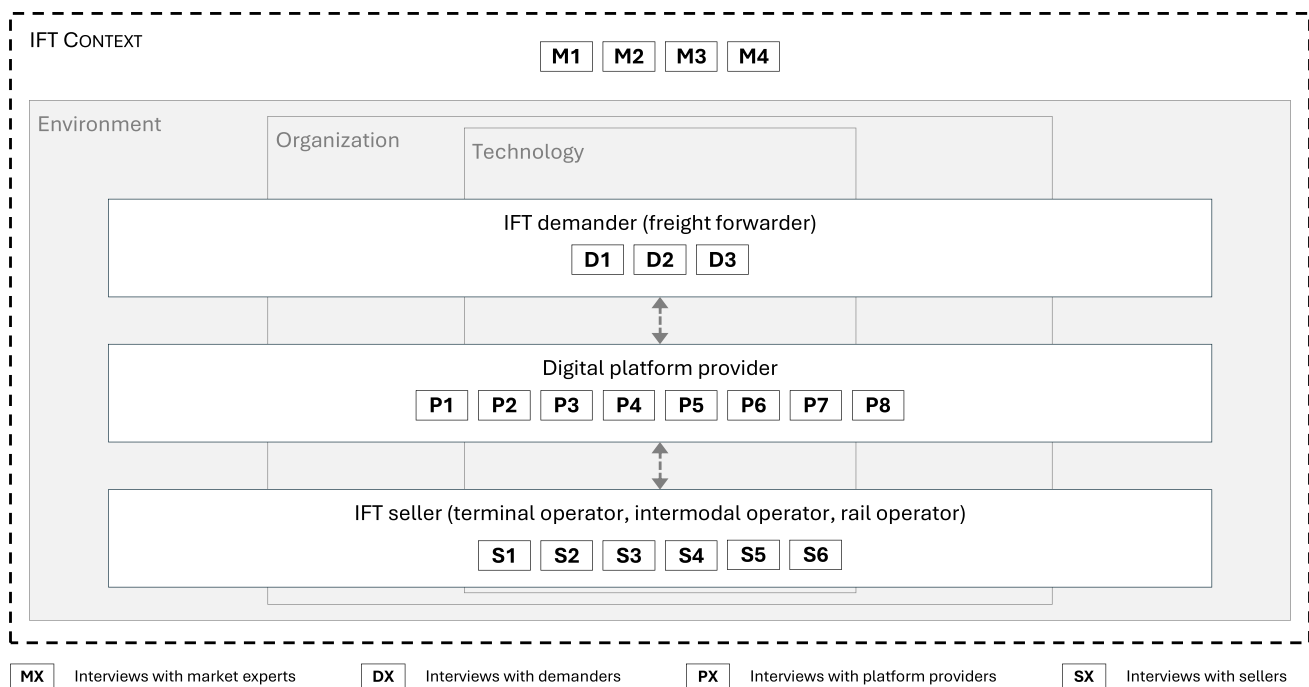
We chose the TOE framework (Tornatzky & Fleischer, 1990) as a suitable grand theory for our MRT approach for several reasons: First, numerous empirical studies have used, modified, and enhanced the TOE framework to study the adoption of platforms in similar contexts, including the supply chain context (e.g., Marzi et al., 2023; Wallbach et al., 2018; Zeng et al., 2020). Second, adoption theories like the TAM focus on individual adoption behavior and neglect the organizational level (Lippert & Govindarajulu, 2006; Lyytinen & Damsgaard, 2001). The IFT platform adoption decision and the decision to enter the IFT market, however, are made on the firm level (e.g., freight forwarder firms) and not on the level of individuals (e.g., freight dispatchers). Third, IFT actors operate in a complex B2B market, which serves as their environment and is considered by the TOE framework. Hence, the TOE framework is well suited to structure and strengthen the understanding of platform adoption by organizations in the IFT industry, leading to the overall research design presented in Fig. 2.

### Sample selection

We deliberately chose the three cases of platform providers, sellers, and demanders by using a theoretical replication logic (see Barratt et al., 2011; Voss et al., 2002). In doing so, we selected the cases based on our expectation that they reveal distinct perceptions of the platform adoption decision and provide us with a nuanced and comprehensive understanding of the different rationales influencing the decision.

We defined the decision to adopt or not adopt an IFT platform as the embedded *unit of analysis* of our cases. Sellers and demanders make the adoption decision, while platform providers observe the decision and can influence it. Since such a decision with its underlying causal mechanisms is an abstract construct, it was necessary to rely on concrete *units*





**Fig. 2** Overview of research design and assignment of interviews to the three cases and the IFT context, embedded in the TOE framework based on Tornatzky and Fleischer (1990)

of data collection for building a sample. Considering digital platforms as intermediaries positioned between IFT sellers and demanders (see Fig. 2), we focused on freight forwarders as units of data collection for the demander case, on terminal, rail, and intermodal operators for the seller case, and on platform providers for the provider case. Moreover, to support our MRT approach with insights into the specifics of the IFT context, we decided to add the perspectives of IFT market experts to our sample. As consultancies or associations, these actors can share viewpoints on market dynamics and reflect on the actors' adoption decisions from a neutral standpoint.

We used multiple sources to identify firms from the outlined groups: online searches, reports from publicly funded research projects, attendance at relevant conferences, and we used a snowballing approach to follow up on references from our interviewees (see Small, 2009). In an iterative and overlapping data collection and analysis process, we stopped searching for additional firms for our sample when we reached theoretical saturation (Eisenhardt, 1989b), meaning no further adoption drivers or barriers were identified and a sufficient understanding of the three cases was established.

In sum, our final sample consists of 21 firms, as shown in Appendix 1. Direct insights into the seller case are gained from two intermodal operators, two terminal operators, and two rail operators, all long-established in the IFT market. The demander side is represented by three freight forwarders; two of them are active in intermodal transport (as active

platform users), while one has so far intentionally refrained from entering the IFT market and using IFT platforms but is familiar with them. Even though the freight forwarder landscape consists of many small firms (recall the “[Theoretical background](#)” section), our sample also contains large freight forwarder firms (see Appendix 1). This is because IFT suffers from knowledge gaps (Gleser & Elbert, 2024). Specifically, small freight forwarders are often not familiar with IFT (see Truschkin et al., 2014) and are, therefore, not yet in a position to reflect on IFT platform adoption. In addition to the nine sellers and demanders, eight firms from our sample are platform providers. These firms operate in the digital sector (e.g., software development and data management), have recently been founded, and have a start-up status in the IFT market. They cover the whole spectrum of the currently emerging digital services for IFT, from versatile marketplaces for easy IFT booking to pure data exchange for efficient IFT operations (see Bossong et al., 2025). Finally, four IFT market experts round off our sample. They provide IFT-specific market know-how and valuable insights from their experience with firms that have opted for or against using digital IFT platforms.

All 21 firms are located in Germany. Due to Germany's importance for the European transport industry as a transit country and the growing number of IFT platforms launched by German firms, the country provides a unique position to investigate platform adoption. In 2023, 59% of the goods transported in Germany with rail-based IFT were either

transiting Germany or had their origin or destination outside of Germany (Destatis, 2024). This is why some of the firms in our sample were also able to share experiences with non-German actors (particularly from Western Europe).

## Data collection

Our main sources for collecting data on platform adoption decisions were in-depth interviews, which we triangulated with publicly available data from web searches (i.e., information provided by firm websites, reports, news websites, etc.). This triangulation supported us in building a broader knowledge of the firms and their general relation to IFT.

We conducted one in-depth interview in each of the 21 firms (lasting on average 51 min; see Appendix 1). Figure 2 illustrates how the interviews contributed to building an understanding of the three cases. Prior to the interviews, we prepared a semi-structured interview guide focused on our two research questions (see Appendix 2). We conducted the first four interviews as a pilot study and slightly adjusted the interview guide after each of them to address our unit of analysis more precisely. Afterward, we kept the interview guide flexible to consider the specific positions and perspectives of the different firm types (i.e., sellers, demanders, platform providers, and market experts). The interviews took place between June 2023 and June 2024. All interviews except one telephone interview were conducted as video interviews. We carefully selected interviewees from middle- and high-management positions (see Appendix 1 for their job positions). This approach enabled us to gain strategic viewpoints into platform adoption and reflective views on the operative challenges when using IFT platforms in day-to-day business.

## Data analysis

Our interviews were recorded and transcribed. The interviewees received the transcripts for content verification and to address follow-up questions. An overlapping data collection and analysis process, as common in case study research (Barratt et al., 2011), enabled us to observe how rationales (drivers and barriers) and linkages between them emerged, were adjusted, and stabilized in our findings. One of the authors was responsible for coding all interviews, while the author team discussed exemplary and critical codes to build a shared understanding of platform adoption. Coding was conducted using MAXQDA and by borrowing the concepts of open, axial, and selective coding from grounded theory (see Corbin & Strauss, 2015).

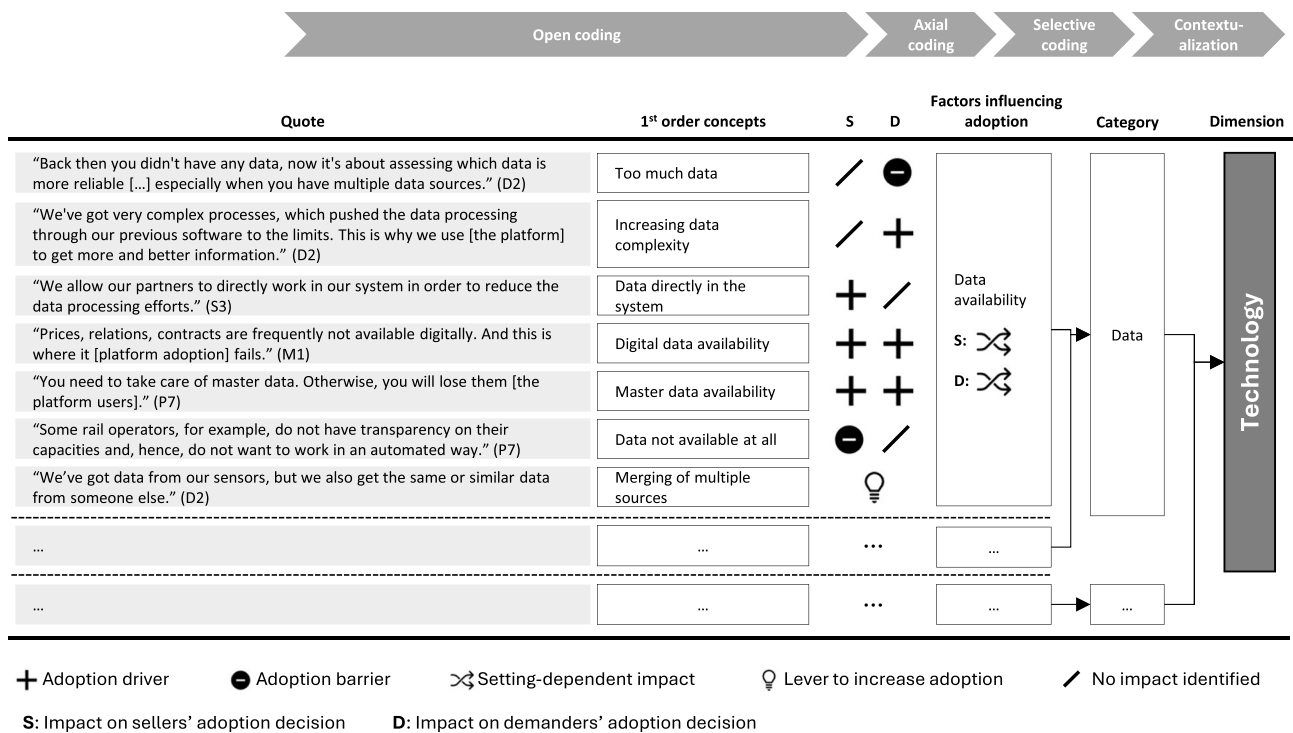
We followed the approach of Eisenhardt (1989b) of analyzing multiple-case studies in a within-case and cross-case analysis. In three within-case analyses, we investigated the drivers and barriers of platform adoption, while the

cross-case analysis allowed us to contrast these factors to identify shared and conflicting interests between the actors involved. Based on these findings, we derived levers that are suitable to foster platform adoption.

For each case, we developed a similar data structure, starting on the level of single sentences in our raw interview data to identify first-order concepts (open coding). This step of analysis is shown exemplarily in a consolidated view in Fig. 3. As the columns “S” and “D” display, first-order concepts were tagged to keep track of whether the concept positively (driver) or negatively (barrier) influences the adoption decision of sellers or demanders (symbols: “+”, “−”, “/”). Where applicable (e.g., for overarching observations by platform providers and market experts), concepts were tagged for both user groups. In the process of open coding, we also identified concepts that serve as a basis for the cross-case analysis, hence, to derive levers that increase adoption. We tagged these concepts accordingly (bulb symbol). Following the Straussian school of grounded theory, solitary and multiple occurrences in the data (Howard-Payne, 2016) were used to derive concepts. In the second step (axial coding), we inductively subsumed first-order concepts under sub-categories (i.e., factors influencing adoption), and we consolidated the adoption influence further: The example in Fig. 3 shows that three concepts are adoption drivers and one concept is a barrier for sellers and demanders, respectively. This is why we consolidated the adoption impact of data availability as a setting-dependent factor for both user groups (arrow symbol). In the third step (selective coding), we grouped the factors into categories, which we, in the final step, contextualized within the original TOE framework. In doing so, we applied a bottom-up MRT approach similar to Craighead et al. (2016). Note that, following the guidance of Mello et al. (2021), we conducted our literature review (see the “Theoretical background” section) after the third step of our data analysis process to ensure that our findings are grounded in data and not driven by the existing literature. For the final step, the contextualization, the literature review served as a foundation to harmonize the wording and allocation of the identified factors within the TOE framework, where applicable. Overall, the four-step analysis was a learning process (see Åhlström, 2007) of successively moving from our raw data to the TOE framework, the refinement of this theoretical lens for the IFT context, and the identification of levers suitable to increase platform adoption.

## Quality measures

To ensure quality, we rigorously followed our case study design and ensured construct validity, internal validity, external validity, and reliability (see Gibbert et al., 2008). *Construct validity* requires that a clear “chain of evidence” is maintained (Yin, 2014, p. 41), which we ensured by



**Fig. 3** Exemplary identification of factors influencing the adoption decision and levers increasing adoption based on interview data

using multiple sources of evidence (particularly multiple interviews per case, triangulated with publicly available data) and building our results on a transparent and reflective process (e.g., reviewing transcripts in multiple rounds, verifying content with interviewees, and discussing codes among the authors). In addition, we organized workshops with representatives from platform providers, IFT sellers, and market experts in February, June, and September 2024 to validate and discuss our findings. *Internal validity* is concerned with establishing causal relationships (Voss et al., 2002). It requires a clearly communicated research framework (Yin, 2014), which we ensured by setting our focus on the IFT platform adoption decision from three perspectives and relying on the TOE framework. Moreover, we discuss our findings in light of existing literature and, thereby, achieve internal validity by pattern-matching (Eisenhardt, 1989b). *External validity* and, hence, the analytical generalization of results (Gibbert et al., 2008) are maintained by clarifying why we selected the three cases (using replication logic) and the specific research context of IFT in Germany. Our MRT approach assists us in revealing how far our findings are transferable to platform adoption in other (B2B) contexts. *Reliability* is concerned with the repeatability of the study (Yin, 2014), which we ensured through a semi-structured interview guide and a standardized, transparent coding process.

## Findings

### Within-case analysis: Factors influencing the platform adoption decision

The within-case analysis enabled us to identify 30 factors that influence platform adoption from the perspective of IFT sellers, demanders, and platform providers. From these perspectives, we built an understanding of how the identified factors influence the adoption decision of the two platform user groups (i.e., IFT sellers and demanders). Figure 4 provides an indication of whether each identified factor is a driver (plus symbol), a barrier (minus symbol), or if the impact on platform adoption is dependent on the setting (arrow symbol).

Appendix 3 in the supplementary material available online underlines the characterization of the three cases by providing additional quote-based evidence for the identified factors. The characterization, structured along our contextualized TOE framework, starts with the overarching perspective of platform providers on the adoption decision before it highlights specifics from the perspectives of the two platform user groups.

#### The platform provider perspective

**Technology** Throughout our interviews, IFT platform providers strongly highlighted the *benefits* they see for their

Factors influencing adoption	S	D	Lever	Category	Dimension
Increased operational efficiency	+	+		Benefits	Technology
Increased operational quality	+	+			
Enlarged sales and sourcing channel	+	+			
Increased transparency on prices and offerings	⊖	+	L1		
Intuitive implementation and user interface	+	+		Usability	
Platform reliability & availability	+	+			
Data availability	↯	↯		Data	
Data quality & accuracy	+	+			
Interface standardization	⊖	+	L2		
Data security & privacy	+	+			
Platform neutrality	↯	+	L3	Platform governance	
Unclear liability for mistakes/downtime/damage	⊖	⊖			
High price of IFT services offered on platform	+	⊖	L4	Cost / Price	
High costs for platform implementation and use	⊖	⊖			
Platform awareness & knowledge	+	+		Firm resources	Organization
IT capabilities	+	+			
Slack resources	+	+	L5		
Firm size (adopting firm)	↯	+		Firm background	
Availability of digitization strategy	+	+			
IFT experience	↯	↯			
Management support	+	+		Personnel	
Pretexts	⊖	⊖	L6		
IFT characteristics	↯	↯		Market conditions	Environment
Cost pressure	+	+			
Labor shortage	+	+			
Good references	+	+		Peers / Stakeholders	
Partner integration	+	+			
Firm size (platform provider)	↯	+	L7		
Operational regulation	↯	↯	L8	Regulations	
Environmental regulation	+	+	L9		
<div><div>+</div> Adoption driver</div> <div><div>⊖</div> Adoption barrier</div> <div><div>↯</div> Setting-dependent impact</div>					
<div><div>S</div> Impact on sellers' adoption decision</div> <div><div>D</div> Impact on demanders' adoption decision</div>					

+ Adoption driver    ⊖ Adoption barrier    ⊗ Setting-dependent impact

S: Impact on sellers' adoption decision    D: Impact on demanders' adoption decision

**Fig. 4** Contextualized TOE framework with factors influencing the adoption decision of sellers and demanders and associated levers to foster adoption

users. From their perspective, increased automation and digitization of freight dispatching and monitoring result in increased operational efficiency, quality, and consequently cost savings since these benefits reduce manual communication with numerous IFT actors. These are key drivers for platform adoption: “Users want to work in one system [...] showing all information concerning a transport end-to-end in a dashboard” (P2). As two platform providers recalled from discussions with their users, dispatchers appreciate not having to “mindlessly fill in data fields” (P1) anymore and that they can use resources, which are released through process automation, beneficially to “communicate with their customers in a targeted manner” (P6).

To fully take advantage of these benefits, high *usability* through simple integration into existing IT systems and a straightforward user interface are imperative for IFT platform adoption of both user groups. At the same time, ensuring such integrability poses a challenge to platform providers since “it is hard to convince dispatchers to use a platform in their day-to-day business if it is not 100% tailored to their processes” (P5). To increase usability and, hence, IFT platform adoption, platform providers aim to establish platforms with the reputation of running reliably and with high availability.

By standardizing interfaces, some IFT platforms focus on facilitating *data* exchange. Despite standardization attempts, platform providers find it difficult to “get the data in the right format out of the [users’] systems [and] even more difficult to have someone on the other side who can process this data” (P3). Thus, they see a lack of data availability and quality in IFT as a general barrier for platform adoption. Standardized interfaces can simplify data exchange with demanders but conflict with platform-like systems that large IFT sellers launch. These sellers make it mandatory for their customers to use such systems, thus thwarting standardization and the adoption of third-party platforms. In addition, platform providers perceive that users are worried about privacy and data security, which is why platform users require “an order that is placed through the platform [to be] treated confidentially” (P6).

To further increase trust, some platform providers establish independent *platform governance* by being forced to neutrality through their corporate charter. They expect this neutrality to increase platform adoption, although one platform provider noted that “very few [users] doubt neutrality” (P3).

**Prop. 1:** The more intuitive, reliable, and independent (in terms of neutrality) a platform is in facilitating and automating communication between IFT actors, the higher platform adoption of sellers and demanders will be. Interface standardization can further boost adoption on the demander side, although it hampers adoption on the seller side.

**Organization** Platform provider interviewees highlighted that most firms in the logistics industry, especially in the IFT context, exhibit a low degree of digitization. On the one hand, this observation is partially due to lacking IT capabilities. On the other hand, platform adoption requires significant *slack firm resources*, which are often restricted due to being tied up in day-to-day business: “When you want to introduce new things, you hear, ‘I have already got enough to do’” (P2). This finding aligns with the original TOE framework, in which “slack resources” are a key adoption factor (Tornatzky & Fleischer, 1990).

In addition to its resources, a *firm’s background* influences platform adoption. Potential IFT platform users are commonly not aware of platforms and their benefits, as one platform provider emphasized: “The thought that things could be even better has not yet sunk in because they [the potential users] manage their current day-to-day business quite well” (P1). Moreover, according to our interviewees, firms in the IFT industry often miss a dedicated digitization strategy. This lack of strategy leads to a behavior that can be compared to the “late majority” or “laggards” archetypes described by Rogers (2003) in the context of the DOI (Diffusion of Innovations) theory. It is expressed by erratic adoption behavior: “There are parties who think, ‘We need to do something. Now.’ But they do not really have in their mind what they want to do.” (P4).

Platform providers further indicated that the firm’s *personnel* play a crucial role in the adoption decision. Specifically, management support is a critical factor for platform adoption. This factor is observable for both, sellers and demanders, and in line with previous research (e.g., Plasch et al., 2021; Wallbach et al., 2018, 2019; Zeng et al., 2020, 2021). A lack of management support stems not only from the fear of disturbing day-to-day operations or the lack of awareness of platform benefits. An additional barrier is the existence of—sometimes irrational—pretexts. Our interviewees observed employees on an operational and managerial level with a conservative mindset who categorically refuse digitization: “Sometimes there are no rational reasons; it is just a matter of gut feeling” (P4). In this vein, managers and dispatchers use special cases of platform malfunction to generalize platform immaturity or refuse software that is not tailored entirely to their needs.

**Prop. 2:** The fewer slack resources, management support, and digitization strategies a firm has, the lower platform adoption of sellers and demanders will be. Pretexts against digitization (as a result of rather conservative firms in the IFT industry) lead to a fundamental rejection of digital tools and further hamper adoption.

**Environment** Similar to the original TOE framework (Tornatzky & Fleischer, 1990), our interviews with platform providers suggest that *market conditions* are essential when making adoption decisions. These market conditions are driven by the characteristics of the IFT market itself. The large number of actors involved creates challenges when handling exceptional cases (e.g., customs and dangerous goods) and frequently requires actors to adapt their IT systems to the systems or interfaces of other actors: “In the IFT chain, there are sometimes up to eight actors, each of them having different interfaces or their own software” (P4). On the one hand, this fragmentation can drive the adoption of platforms aiming to standardize and reduce the number of interfaces. On the other hand, it can hinder the adoption of platforms if they cannot be easily integrated into existing systems.

Given these IFT characteristics, IFT platforms need a strong relationship among their *peers and stakeholders*. Since platforms benefit from a good reputation, they seek partnerships as one platform provider, who is part of an industry association, described: “We have the advantage that the association members are incentivized to use our platform” (P7). Such collaborative efforts increase platform reputation and enhance trust. Our observation aligns with the findings by Penttinen et al. (2018), who identify platform reputation as a vital adoption driver.

Furthermore, platform providers see IFT-related *regulations* as a chance for growing platform adoption since there are, for example, regulations that “require digitization of customs” (P8) and consequently drive adoption. Environmental regulations emerged in our interviews as a pure adoption driver since they foster a shift toward more sustainable transport modes like IFT and, in doing so, broaden the pool of potential IFT platform users. Vice versa, a missing environmental framework can have adverse effects: “We can have the best platforms. If the [environmental] framework is not right, it will not work” (P2).

**Prop. 3:** The more partners are integrated into the platform, the better the platform’s reputation, and the stronger the regulatory support for IFT, the higher platform adoption of sellers and demanders will be. The fragmentation of the IFT landscape can be an opportunity to connect actors digitally, thereby increasing platform adoption.

### The demander perspective

**Technology** IFT demanders agreed in our interviews with platform providers that the *benefits* of a platform reflect important adoption drivers. Through digitization and automation of processes, transport order details can be

exchanged quickly with reduced error rate. Typos, for example, have posed a significant threat to freight forwarders: “In the past, we had a couple of employees [i.e., dispatchers] who have manually typed in waybills. There have been fatal typos [...], which resulted in a completely wrong location” (D1). Especially for freight forwarders with little or no IFT knowledge, digital platforms, particularly matchmaking platforms, serve as tools to source IFT services easily and to gain knowledge about IFT (e.g., required technical equipment and certifications). Moreover, as one market expert highlighted, IFT demanders consider the transparency created through platforms a major adoption driver, enabling them to “get a comparison of prices and services offered by multiple IFT service providers” (M1).

The sufficient availability of *data* is another adoption prerequisite for demanders. Surprisingly, our interviews revealed that demanders have a saturation point at which more data does not lead to increased IFT platform adoption since more data also requires “assessing which data is more reliable [...] especially when you have multiple data sources” (D2). Nevertheless, our interviewees emphasized that an oversupply of data is currently a relatively rare phenomenon in IFT. This is why it is even more critical to provide data accurately (i.e., quality over quantity).

In addition, *platform governance* that lacks clear liability for platform downtime, wrong data, or cargo damage acts as an adoption barrier on the demander side. Platforms that are exclusively operated by IFT sellers are disfavored by demanders because they perceive that a lack of neutrality can result in missing competition from other IFT sellers. In such a case, prices become incomparable and, thus, demanders fear that they need to purchase IFT services at higher prices. Due to the price sensitivity of the IFT market, high *prices* for the services offered and additional *costs* for platform usage (consisting of upfront investment for IT implementation and recurring fees) are major adoption barriers for demanders.

**Prop. 4:** The more transparency demanders get on available prices and offerings, and the more accurate the data provided, the higher platform adoption of demanders will be. In this regard, providing data in the right amount and quality, while keeping costs low, is crucial to avoid exceeding the data saturation point of demanders.

**Organization** As the platform provider perspective has shown, demanders with little slack *firm resources* see the risk that adopting digital platforms hampers their day-to-day business and creates more effort than it reduces. This issue is not only manifested in the demanders’ lack of knowledge about the functionality and value proposition of existing IFT platforms but also in their lack of awareness that digital IFT platforms exist.



Firm resources are partially linked to the *firm background*, particularly the size of the adopting firm. As our interviewees argued, smaller freight forwarders neither have strong in-house IT capabilities nor financial resources to “simply purchase external [IT] know-how” (M2) for the implementation of digital platforms. Another aspect is the previous IFT experience of a firm. At first sight, it seems contradictory that our interviews revealed a setting-dependent impact of this factor: One might expect that demanders with more IFT experience are more aware of the platforms emerging in this context and, hence, more likely to adopt them. However, our interviews showed that past IFT encounters have left a negative aftertaste with some demanders (e.g., due to unpunctual shipments), so they try to avoid IFT for future transports.

This general skepticism about IFT is accompanied by pretexts against digital platforms among the *personnel*. However, a shift in the behavior of demanders is on the horizon as many managers of family-owned freight forwarders are about to arrange their succession to a new generation in this decade. By reflecting on themselves, demanders expect this generation change to drive platform adoption by reducing pretexts and increasing management support: “I notice that when the older generation – the generation before me – retires, there is an uplift in digitization” (D1).

**Prop. 5:** The lower the digitization awareness and IT capabilities of demanders, and the less attractive their previous IFT experiences, the lower platform adoption of demanders will be (especially among smaller freight forwarders). However, a new management generation is expected to lower platform adoption hurdles by increasing management support and addressing typical pretexts.

**Environment** In addition to mirroring the challenging *market conditions* emphasized by platform providers, demanders mentioned further IFT characteristics as barriers. Particularly, small freight forwarders often do not have the required technical equipment (in particular, craneable semi-trailers) to use IFT. We further noticed that they perceive missing flexibility as a disadvantage of IFT, while larger freight forwarders are skeptical that they “get the required [IFT] capacities” (D3) to handle their large freight volume. Hence, technical challenges and the lack of an attractive IFT service portfolio overshadow the positive use cases that IFT platforms can provide. As a result, some demanders do not see IFT as an option and are consequently not considering IFT platforms. However, at the same time, increasing sustainability requirements, cost pressure, and labor shortage urge freight forwarders to shift freight transport to IFT and require them to increase operational efficiency through digital platforms. From the perspective of demanders, using platforms not only reduces the number of freight dispatchers needed but also “makes it [the day-to-day business] very,

very easy for the employees” (D1), which is why they expect that fewer highly skilled freight dispatchers are needed.

As a final adoption driver, we noticed that the demanders’ view on *peers and stakeholders* matters: Since freight forwarders use platforms as an additional sourcing channel, they expect platforms operated by larger and more influential platform providers to offer a larger network of users than small platform providers. “The more terminals are connected, the more profitable it is” (D2) is how one demander described the resulting positive network effects. Consequently, larger platform provider firms with the ability to offer an attractive network drive adoption.

**Prop. 6:** The larger the platform (in terms of the size of the platform provider and user network) and the more intense cost pressure and labor shortage in the IFT industry, the higher platform adoption of demanders will be. However, it is a prerequisite that demanders overcome general challenges (in terms of equipment and knowledge) before entering the IFT market.

### The seller perspective

**Technology** Similar to IFT demanders, sellers appreciate platform *benefits* that arise from the automation and digitization of their operations and the enlargement of their sales channel. Sellers can, for example, use IFT platforms to acquire new customers or sell residual capacities on the spot market. Moreover, platforms become tools for improving customer relationships through value-added services and ensuring higher service quality. Nevertheless, the potential creation of transparency on offered services and prices poses significant adoption barriers for IFT sellers: First, IFT contracts are commonly based on bilateral negotiations of long-term agreements with confidential conditions and prices. Offering IFT services through digital booking platforms requires the (partial) disclosure of this information and could tempt IFT demanders to renegotiate existing, long-standing agreements. Especially when offering discounts on residual capacities, “existing customers could cancel their existing freight slot and ask for the cheap slot” (M3). Second, sellers are worried that disclosing data could lead to a drain of confidential information (e.g., regarding the partners involved, the transport routes used, and their capacity utilization) and could let competitors and customers draw conclusions on the sellers’ operational business (e.g., the profitability of the firm). This culmination of barriers lets sellers frequently conclude that the risk of providing transparency is higher than the benefit.

Moreover, we found that the adoption decision of sellers is driven by high *data* quality and accuracy as well as data

security and privacy. However, data availability has a differing impact on the platform adoption of sellers, depending on whether sellers provide or receive data. Collecting data and feeding this data into a platform with a specific data format can be costly and is currently viewed critically by sellers: “Tracking and monitoring our freight is in a very early stage. Most of the freight is not tracked at all” (S4). Data availability is, hence, an adoption barrier when sellers need to provide data that is difficult to collect. On the receiving side, sellers appreciate high data availability, for example, when their customers place orders digitally through the sellers’ own systems.

Furthermore, as the platform provider perspective has shown, some large IFT sellers tend to launch their own platform-like systems and, consequently, do not foster data exchange through standardized interfaces. Having their own closed systems with proprietary data protocols gives them full ownership over their data and helps them exploit information asymmetries to avoid price comparisons against competitors. It enables sellers to charge higher *prices* for their IFT services and gives them control over the *costs* of the system. In this vein, our interviewees mentioned that sellers rigorously calculate a “business case for each interface” (S1), which is why high implementation and usage costs of platforms pose additional adoption barriers.

Finally, even though neutral *platform governance* can increase trust in the platform and, hence, increase platform adoption of sellers, some sellers have “a big issue with [a third-party platform that pretends to be neutral] [...] since one of the owners is a competitor of [the seller]” (S3). Hence, the impact of platform neutrality on platform adoption of sellers depends on whether sellers doubt promoted neutrality.

**Prop. 7:** The better IFT sellers can enlarge their sales channels through platforms without increasing competition and cost, the higher platform adoption of sellers will be. If sellers perceive that platforms create too much transparency, they tend to launch their own platform-like systems to avoid the drain of confidential data.

**Organization** From an organizational point of view, our interviews revealed that IFT sellers, on average, exhibit a slightly higher degree of digitization than demanders, which supports platform adoption. This digitization advantage could be due to their firm size since IFT sellers tend to be larger firms, equipping them with a larger body of available *firm resources* (Cichosz et al., 2020). However, the size of the adopting sellers has a setting-dependent impact and provides an interesting twist: Larger sellers usually have advanced IT capabilities. Hence, they are predestined to adopt platforms. But as previously mentioned, some larger sellers use these capabilities for in-house

development of IT systems and have historically reached a critical size, allowing them to force their customers to place orders within these systems. Hence, this market power causes larger sellers to refuse other platforms, as one market expert observed: “[A large IFT seller] said, ‘I have a very large network. I will not support a [third-party] platform by placing my offerings there’” (M1). In this sense, the seller in question is not willing to increase the attractiveness of third-party platforms and to risk losing existing customers to competitors.

In addition, IFT experience, as a characteristic of the *firm’s background*, is influencing the platform adoption of sellers, but, in contrast to demanders, this rationale is less about their previous IFT encounters. It is more about their IFT proficiency, which has an ambiguous impact on sellers’ platform adoption: While IFT proficiency can be a driver for sellers to professionalize their services through a platform, it can be a barrier for sellers who do not want confidential information to drain through a platform.

**Prop. 8:** The stronger the digitization and IT capabilities of sellers are, the higher platform adoption of sellers will be. However, sellers can reach a critical size that enables them to launch their own platform-like systems to avoid boosting third-party platforms and losing customers.

**Environment** The overall challenging *market conditions* that apply to IFT platform providers and demanders also apply to sellers. For sellers, a particularly pronounced challenge is cost pressure. Sellers compete with road-based transport, which is often considered more cost-competitive than rail-based IFT. This competitive disadvantage of IFT requires sellers to increase the cost efficiency of IFT services through automation and drives platform adoption.

Surprisingly, in the *peers and stakeholders* context, the firm size of the platform provider has a different impact on seller adoption than on demander adoption. Large seller firms see it critical to rely on small platform providers and are, therefore, more likely to adopt platforms provided by larger firms. However, large sellers are also worried about platforms “becoming too big to avoid” (S4) and, thereby, exerting too much market pressure on them.

Like platform providers, sellers assess *environmental regulations* as an adoption driver: “There are political goals concerning a modal shift, which implies a significant increase of rail-based transport. This alone is already a driver for digitization” (S2). On the other hand, sellers see risks for platform adoption in operational regulations: “There are regulatory requirements that necessitate paper-based processes, especially when it comes to dangerous goods” (S4). Hence, some existing regulations are incompatible with the digital workflow of platforms.

**Prop. 9:** The more platforms grow beyond a size that enables them to exert pressure on sellers, the lower platform adoption of sellers will be. Sellers also raise concerns about operational regulations that enforce paper-based processes and, consequently, hamper platform adoption.

### Cross-case analysis: Levers to increase platform adoption

The three cases have provided an in-depth understanding of IFT platform adoption from the perspectives of IFT platform providers, sellers, and demanders. Comparing the adoption decisions of demanders and sellers, as well as the interests of platform providers, reveals that tensions emerge. This is why the subsequent cross-case analysis distills nine levers along the contextualized TOE framework suitable to mitigate these tensions, nurture adoption drivers, and lower adoption barriers. These levers are allocated to the identified factors in Fig. 4.

#### Technology

*Increased transparency* is a topic that was highly debated among our interviewees. As the within-case analyses have shown, demanders benefit from increased transparency, for example, through easy price comparison, while sellers fear price competition. Several interviewees even concluded that the business model of sellers is often based on a lack of transparency and resulting information asymmetry: “There is a high price volatility for the same service. This is an indicator that a lack of transparency is used to do business” (M1). So far, previous research has acknowledged that increased transparency can be a driver for technology adoption (e.g., Al-Jabri & Roztock, 2015; Tan & Sundarakani, 2021), but it has neglected the negative impact of transparency, or more generally speaking, the impact of digital confidentiality. Massimino et al. (2018) emphasize that the overall operations and supply chain management literature has failed to address the digital confidentiality of digital assets due to its historical focus on the physical distribution of products. For the IFT context, our findings suggest that allowing sellers to customize and restrict information sharing for specific demander groups can help mitigate these tensions. Platform providers are already in the process of designing such features, as voiced by our interviewees: “There is a standard rate and a customer-specific rate. [...] You can store all these different rates in our platform” (P6). Hence, we identify:

**Lever 1:** To balance the need for business confidentiality on the oligopolistic seller side and the transparency affinity on the fragmented demander side, platform

providers should enable sellers to distinguish between a standard rate visible to any platform user and individual rates only visible to previously selected users.

Closely related to transparency is the *availability and accuracy of data*. Both user groups appreciate the availability of high-quality data on platforms. However, the user groups do not agree on the type of data they require from each other: Sellers request demanders to increase data availability by placing orders digitally, while demanders request sellers to share prices and real-time tracking data. The data saturation point on the demander side could help tackle this tension. Platforms could focus on data quality (instead of quantity) and selectively increase data availability for crucial data types. Especially the provision of real-time tracking data is currently lacking in IFT. Some demanders even “equip [their] containers with sensors” (D2) to ensure data availability. Merging data from multiple sources (e.g., sellers and demanders) could, therefore, be a measure to increase data availability and quality to boost platform adoption. However, merging data requires standardized data interfaces and the implementation of such interfaces is expected to be a lengthy process. As we found *interface standardization* to be an adoption barrier for large IFT sellers but a driver for IFT demanders, one platform provider in our sample aims to address this tension by jointly developing an open and neutral data exchange standard for IFT together with sellers and demanders. This data exchange standard accounts for the requirements of both user groups. In addition, such standards can potentially reduce the overall number of interfaces demanders must adapt to while meeting the requirements of large sellers. This is why we recommend:

**Lever 2:** Platform providers as intermediaries should aim to bring sellers and demanders to the table to jointly define and establish data exchange standards. As this is likely to be a lengthy process, in the meantime, platform providers should focus on implementing customized data interfaces with existing platforms and IT systems to merge and mutually exchange data.

Large sellers tend to favor their own platform-like systems, while demanders favor neutral platforms. This leads to tensions around platform governance. As the within-case analysis has shown, *platform neutrality* is generally appreciated by both user groups, but neutrality is disputed, especially by sellers that identify competitors among the investors of one platform from our sample. The obligation to neutrality per corporate charter, as outlined in the platform provider case, could solve this tension. One platform provider from our sample goes even further and operates on a nonprofit basis: “The platform is not operated out of commercial interest, in the sense that money is made from the

data” (S6). Such governance ensures that neither sellers nor demanders gain competitive advantages over other platform users. The importance of platform neutrality is underlined by previous research (Plasch et al., 2021; Rohn et al., 2021). Another way to ensure that neutrality and the interests of both user groups are safeguarded is the involvement of platform users in the platform development process. Platform users, for example, could become part of a joint venture to create a neutrally governed platform in the interest of all platform users. Therefore, we suggest:

**Lever 3:** Platform providers should foster trust in their—sometimes disputed—neutrality by officially self-committing to neutrality and by ensuring that the influence of platform investors with potentially conflicting interests is restricted.

In a competitive B2B market like the IFT market, sellers and demanders lament small profit margins that do not allow for *high costs of platform implementation and use*. This aspect is underpinned by one platform provider who recalled a conversation with its users: “My users tell me: ‘I already need to pay for the transport. Why should I pay for the data exchange?’” (P3). Obviously, platform users not only aim to minimize costs, but they also aim to maximize profits. This is why platform adoption of IFT sellers is driven by *high prices of IFT services offered on platforms* while demanders try to find the lowest possible price. Platform providers frequently address these conflicting interests through a monetization model that waives platform fees for demanders and requests a transaction-based fee from sellers. In doing so, sellers can keep upfront investments low and leverage efficiency benefits while still being able to price their services competitively. So, we advise:

**Lever 4:** To avoid putting further pressure on the tight margins in the IFT sector, platform providers should follow a transaction-based monetization model, allowing their users to test and use platforms without significant investments.

## Organization

As the within-case analysis has shown, larger demander firms are more likely to adopt IFT platforms than smaller firms. On the seller side, this relation is not as straightforward because large sellers have sufficient *IT capabilities* and *slack resources* to implement and adopt platforms, but they tend to use these capabilities and resources to establish their own systems and protocols. Therefore, platforms could tailor their digital product to different user *firm sizes*. As a larger demander voiced, data exchange platforms are more attractive for them than matchmaking platforms since large demanders have long-standing contracts and are less in need

of ad hoc bookings through matchmaking platforms: “We have frequently checked if [marketplaces] are relevant for us. [...] But our main concept is full load, not partial load” (D2). Hence, platforms could position themselves with a focus on matchmaking when targeting smaller firms while promoting a focus on data exchange for larger firms. This focus on data exchange includes the implementation of interfaces toward proprietary IT systems and protocols of seller firms. In doing so, platforms can serve as an adapter between incompatible IT systems and assist all IFT actors in connecting their IT systems. Hence, we summarize:

**Lever 5:** Platform providers should position themselves as matchmakers for smaller demanders and as data exchange platforms with the ability to connect incompatible IT systems.

Given the multitude of *pretexts* about platforms and digitization, support from platform providers, especially on an operational level, is essential: “Training, onboarding, calling again, reminding again, helping again” (M1) is how a market expert described this support in our interviews. Moreover, some platform providers identify proficient users within the seller and demander firms and provide “dedicated trainings” (P1) for these employees. To further support the implementation and use of platforms, our interviewees listed several additional measures: step-by-step platform implementation, coexistence of new platforms parallel to incumbent systems to ensure a gradual, seamless transition, and enablement of potential users to test the platform free of charge. These measures can help lower adoption barriers, and they let potential users, including the *management*, convince themselves of the benefits of using digital platforms. As a result, we present:

**Lever 6:** Platform providers should give potential users the opportunity to test their platforms free of charge and should intensively accompany the implementation and ramp-up phase through dedicated training as well as technical and operational support.

## Environment

The analysis of the environmental dimension reveals that the fear of being dependent on a single platform provider grows with increasing *platform provider size*, particularly among sellers. At the same time, IFT demanders favor larger platforms but also ask for low prices. Therefore, it is in the interest of sellers and demanders to avoid platforms becoming so big that they can significantly influence prices or operational processes. One of our demander interviewees goes even further and calls on the responsibility of shippers, in their role as potential IFT demanders, to use their “significant market power to steer” (D3) if and how IFT services shall be

used. In addition to Lever 2, the actors of the IFT ecosystem could, therefore, not only create joint data standards but also launch a joint platform. Such joint initiatives could lead to a win–win situation in the long run, as the risks and costs of launching a platform can be shared among several actors, each of which can represent its interests and needs. Accordingly, we suggest:

**Lever 7:** The whole IFT ecosystem, including sellers, demanders, platform providers, and shippers, should leverage alliances to establish a joint platform that mitigates the risk of being dependent on one large platform that is potentially able to influence operational processes as well as prices.

Emerging as an overarching observation, our interviewees see a significant need for action in the scope of *operational regulations* since data exchange standardization is not expected to happen without regulatory pressure. As voiced by one platform provider: “Motivation [for standardization] is needed. Motivation in the form of coercive measures.” (P7). In the short term, regulatorily enforced data exchange standards might pose an adoption barrier since they require the adaptation of existing data interfaces to new standards. However, in the long term, such standards are likely to pay off by reducing additional barriers, such as missing partner integration or high implementation costs. Moreover, they enable platforms to increase data availability and quality by mutually connecting all IFT actors. This leads to:

**Lever 8:** Policymakers should enforce data exchange standardization in the IFT sector, for example, by requiring all actors involved in IFT to adhere to a base standard that enables them to automate fundamental processes.

Even though national and international climate goals foster the adoption of IFT, our interviewees frequently called for stronger incentivization to use IFT through *environmental regulation*, as this would lead to higher IFT platform adoption. Platform providers called for higher prices for CO<sub>2</sub> emissions and increased cost competitiveness of non-road-based transport modes through truck tolls: “I hope that prices for CO<sub>2</sub> emissions and truck tolls have a positive impact on the whole [IFT] sector” (P2). This hope is echoed by the demander from our interviews that is currently refraining from IFT (as outlined in the “[Methodology](#)” section): “The CO<sub>2</sub> price is way too low. [...] Truck tolls can be an additional lever.” (D3). We therefore suggest:

**Lever 9:** Policymakers should incentivize IFT as a more sustainable transport mode and incidentally foster platform adoption, for example, by carefully adjusting CO<sub>2</sub> prices and truck tolls.

In sum, the levers derived highlight the need for action by platform providers, the overall IFT ecosystem, and policy-makers. Figure 5 summarizes our findings in response to our research questions: By synthesizing the factors that influence the adoption decision, the summary of our propositions addresses RQ1 (“*why*”), while the summary of the levers responds to RQ2 (“*how*”).

## Discussion

### Theoretical contribution

#### Enriching existing literature on B2B platform adoption

This is the first study to explore platform adoption in the IFT context, responding to the call of Shree et al. (2021) for industry-specific and case-based analyses of platform adoption. The applied MRT approach reveals that the TOE framework is a suitable structure for systematizing our answer to RQ1, which aimed to identify the factors (drivers and barriers) influencing IFT platform adoption.

When comparing the adoption factors identified in the literature (see Table 1) with the factors identified from our case-based data (see Fig. 4), our findings confirm that the benefits of a platform (see Prop. 4 and 7) and top management support in the adopting firm (see Prop. 2 and 5) are key factors supporting platform adoption. However, the impact identified in the literature varies (see the “[Theoretical background](#)” section). We found the impact of top management support on platform adoption, for example, to be positive in the IFT context. This is in line with Zeng et al. (2021), Zeng et al. (2020), and Najmul Islam et al. (2020), while Hamad et al. (2018) find the impact to be dependent on the adoption level.

Moreover, previous studies have acknowledged that data security and interface standardization can be drivers of B2B platform adoption (e.g., Garcia et al., 2019; Hamad et al., 2018; Plasch et al., 2021; Zeng et al., 2020, 2021, see Prop. 1). Our findings are in line with these studies. However, it is interesting that previous studies have paid little attention to the availability and quality of data as adoption drivers. The saturation point (see Prop. 4) concerning the amount of data available on the demander side is not reflected in the extant literature. One reason for its occurrence in the IFT context may be that other contexts (e.g., manufacturing or e-commerce) exhibit a higher degree of digitization. Hence, data availability and accuracy may be considered hygiene factors without a notable impact on platform adoption in highly digitized industries.

Our findings show that pretexts against digitization are pronounced in the IFT industry, particularly on the demander side (see Prop. 2 and Prop. 5). Pretexts have not



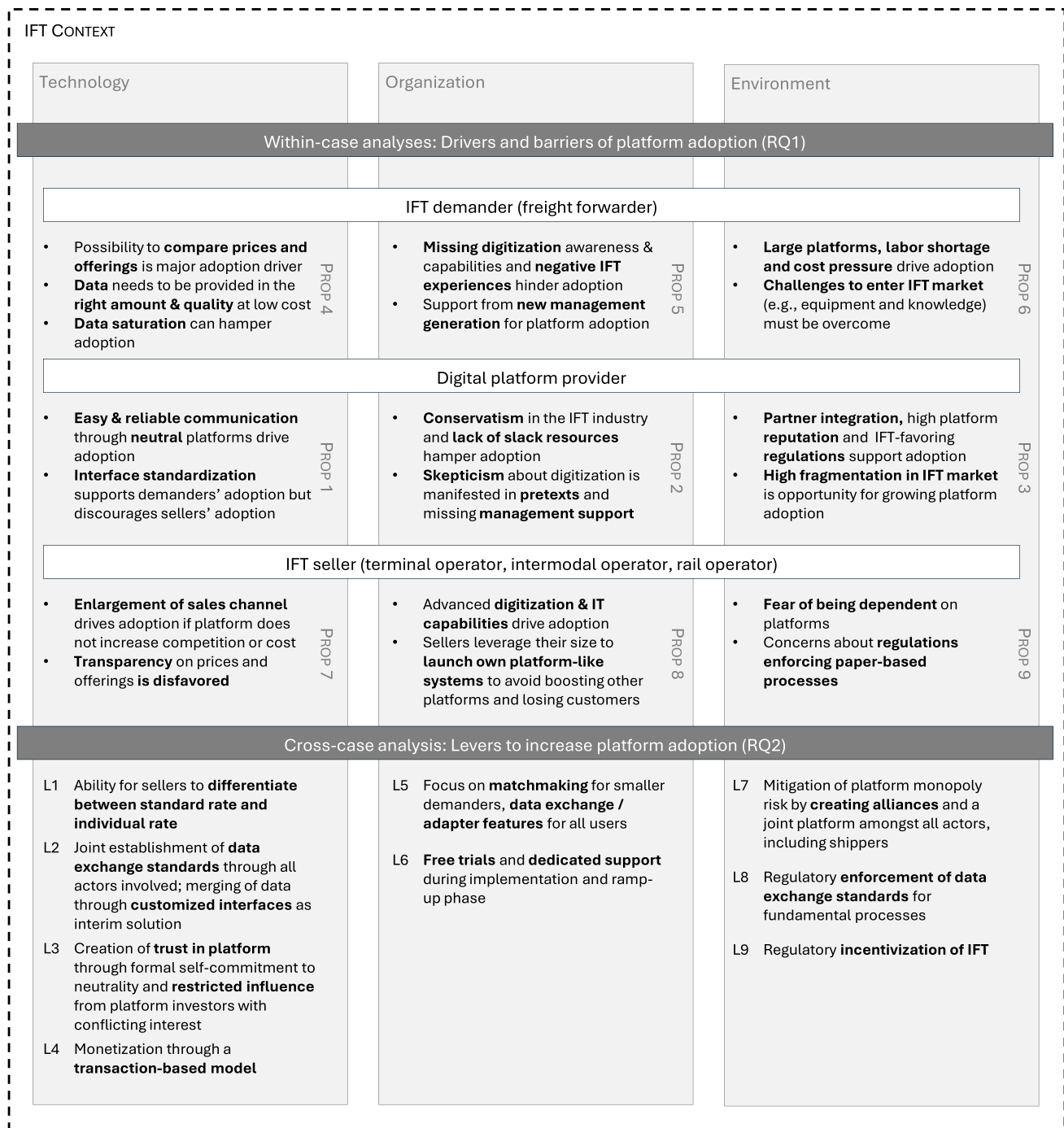


Fig. 5 Summary of findings along the TOE framework and the three cases

been explicitly identified as platform adoption barriers by other studies (see Table 1). However, resistance to change has raised attention in the literature as a crucial factor that can determine the success or failure of general corporate change processes (e.g., Pardo del Val & Martínez Fuentes, 2003). This emphasis in the literature underlines that change management is a critical success factor for digital

transformation (Kohnke, 2017), particularly in a conservative industry like IFT.

In contrast to other studies, our study has not been able to identify strategic benefits resulting from platform adoption (Marzi et al., 2023) as adoption drivers. This difference might be connected to our observation that many IFT actors, especially small freight forwarders, lack a dedicated



digitization strategy. Consequently, they consider operational benefits rather than strategic benefits when opting for or against IFT platforms. Moreover, we have not been able to identify demand uncertainty as an adoption barrier (Najmul Islam et al., 2020), which might be due to the dominance of long-term contracts in the IFT industry, ensuring steady and plannable service utilization. However, using matchmaking platforms to sell remaining capacities on the spot market could lead to a flexibilization of contracts. In this case, we expect demand uncertainty to become an adoption driver since platforms can be leveraged to fill these capacities.

### Analysis from the perspectives of different actors involved

Our research design enabled us to analyze platform adoption from the perspectives of different IFT actors. Our findings suggest conflicting interests between the two platform user groups, especially regarding the creation of transparency and interface standardization: IFT demanders favor market transparency and interface standardization (see Prop. 1 and 4), while IFT sellers have no interest in satisfying these desires (see Prop. 1 and 7). Although platforms in a non-IFT context might exhibit other types of user groups, considering demanders and sellers as typical platform user groups can provide valuable insights into why platform adoption is impeded. From a broader perspective, this situation can be regarded as a principal-agent dilemma with demanders as principals and sellers as agents. Among both parties, there are goal conflicts and information asymmetries, which are typical for principal-agent relationships (Eisenhardt, 1989a): Demanders are looking for reliable and reasonably priced freight transport services but lack an overview of prices and offerings on the IFT market. Sellers can exploit this lack of transparency and comparability by asking for higher prices. Applying this perspective to cloud computing marketplaces, Hauff et al. (2014) show that platforms can help reduce these asymmetries. However, at the same time, platforms create new uncertainties for cloud service providers (e.g., about the neutrality of the platform provider). Likewise, digital IFT platforms in their position as intermediaries enhance market transparency and supply chain visibility, but doubts raised about their neutrality show that new uncertainties emerge in the IFT sector as well. Our derived levers respond to RQ2 and can serve as “puzzle pieces” to mitigate this dilemma. These levers can further be interpreted in the broader context of measures that are suitable to overcome the principal-agent problem (see Hauff et al., 2014): signaling (Lever 6), incentivization (Levers 1, 4, 5, 9), and monitoring (Levers 2, 3, 7, 8). In doing so, our answer to RQ2 enriches the abstract concept of principal-agent theory with practical and concrete measures in the IFT context.

### Embedding in the context of supply chain automation

Our findings on automating manual interaction and data exchange in IFT through the adoption of digital platforms serve as a basis to discuss implications for the automation of supply chains. In line with the definition of supply chain automation presented in the introduction of this study, digital platforms are suitable to replace human activities (Nitsche et al., 2021). Therefore, the pretexts we found in our interviews (see Prop. 2 and Prop. 5) are likely to arise from the fear of losing jobs and intensify a general resistance to digitization and change. From an empirical perspective, Balsmeier and Woerter (2019) show that automation through digitization increases the need for highly skilled employees and requires less lowly skilled employees. They show that this effect is mainly driven by machine-based digital technologies (such as robots) and not by non-machine-based digital technologies like digital platforms. Hence, it is important for supply chain automation projects to outline the implications for employees transparently. In the IFT context, for example, employees might not have been adequately informed that digital platforms are not designed to substitute physical handling processes. Instead, they are designed to support transport volume growth despite labor shortage by automating standard processes and enabling employees to focus on complex and hard-to-automate tasks (e.g., reacting to disruptions).

As we have outlined, the emerging IFT platforms differ in their core functions by matching demanders and sellers or by automating data exchange (see Bosson et al., 2025). Users of data exchange platforms benefit from increased operational efficiency and quality as these platforms reduce manual interaction and communication errors through automated data exchange. However, the benefits of matchmaking platforms (i.e., enlarged sales and sourcing channels and increased transparency on prices and offerings) do not result from automation (so far) since freight dispatchers are still manually looking for the right offer to book. To further increase the degree of automation, matchmaking platforms would need to take over a decision-making role. These insights from the IFT context can be compared with the wave model introduced by Klumpp (2018) for the acceptance of automation in business logistics systems: IFT demanders and sellers seem to accept specific competencies of platform-based automation (wave 1), but automated decisions in the daily business (wave 2) or even autonomous systems (wave 3) do not seem to be accepted yet. In the future, moving the IFT industry “beyond automation towards autonomy” (Xu et al., 2021, p. 1) is likely to reduce transaction costs and could be an important lever to increase the resilience of freight transport and, hence, future supply chains (Xu et al., 2021).

Lastly, freight logistics represents one subsystem of supply chains. Beyond the interfaces among IFT actors, there are interfaces to other parts of the supply chain, such as the purchasing and production functions (see Chen & Paulraj, 2004). These parts of the supply chain involve additional actors, which may have similar drivers and barriers when adopting automation technologies such as digital platforms. Our levers can serve as a starting point to foster digital platform adoption when establishing platforms to automate supply chains beyond freight transport (e.g., digital sourcing channels for manufacturing firms).

## Managerial insights

From a practical perspective, our findings raise awareness of the existence of IFT platforms and put potential platform users in the position to make informed adoption decisions by considering the risks and benefits associated with IFT platforms. Important adoption barriers, such as the prevalence of pretexts, should be taken seriously by managers of platform user firms since they can encompass more than a “generic” resistance to change. The potential impact of automation on job profiles and job availabilities should be discussed openly with affected employees, such as freight dispatchers.

For IFT platform providers, our overview of adoption barriers and drivers helps them better understand the mechanisms and rationales behind their users’ platform adoption. Such an overview assists them in comparing their current business strategy with the strategy of other platform providers and with the requirements of their (potential) users. By answering RQ2, the cross-case analysis and resulting levers provide direct guidance for platform providers on how platform adoption can be fostered.

In the bigger picture, our findings suggest that policymakers have an indirect but valuable impact on platform adoption. Barriers to entering the IFT market hamper platform adoption of demanders. This is why policymakers can indirectly support platform adoption by establishing regulations that favor IFT. Our findings outline the establishment of standards to facilitate data exchange (see Lever 8) and the incentivization to use IFT (see Lever 9) as suitable starting points. Moreover, policymakers should carefully observe and steer the socio-economic impact that supply chain automation can have on employees, for example, through a change in qualification requirements (see Balsmeier & Woerter, 2019).

Even though our case-based data identified several IFT characteristics (such as its complexity and the need for specific IFT equipment) as reasons for low platform adoption, we would like to emphasize that platforms themselves are also suitable to decrease general IFT barriers, for example, by facilitating booking processes or automating repetitive

tasks. IFT adoption and platform adoption are, therefore, interdependent and should always be considered mutually.

## Conclusion

Using a multiple-case study research approach, our study explored the adoption of digital IFT platforms, leading to a comprehensive overview of 30 factors that influence the adoption decision. Through a systematic coding procedure, we clustered the identified factors into categories that helped us contextualize the TOE framework within the IFT context. This contextualization served as a basis to analyze within and across three cases how the platform adoption decision is influenced from the perspective of IFT sellers, demanders, and platform providers.

Our findings suggest that, in line with previous research, the benefits and usability of a platform as well as top management support are important drivers of platform adoption. However, we discovered that increased transparency on prices and offerings drives platform adoption on the IFT demander side while it hinders adoption on the seller side. The same applies to the standardization of data exchange interfaces. We attribute these tensions between IFT demanders and sellers to the existence of information asymmetries resulting from a principal-agent relationship between IFT demanders (principals) and IFT sellers (agents).

Major hurdles for platform adoption on both user sides are (sometimes irrational) pretexts. These pretexts concern digital platforms and digitization. We interpret the pretexts as barriers that go beyond a general resistance to change, as supply chain automation through digital platforms can lead to a change in job profiles, causing fears of losing jobs. Even though IFT can help decarbonize a firm’s supply chain, its complexity is frequently given as a reason for not using IFT. Our findings suggest that supply chain automation through platforms can significantly contribute to overcoming these barriers, mainly through automated data exchange and easy booking of IFT services. Therefore, we derive nine practical levers that promise to foster platform adoption.

Nevertheless, our study is not without limitations. Even though our sample contains selected interviewees who are not actively using digital IFT platforms, it only contains firms that are familiar with the IFT industry. Moreover, we focus on the German IFT market, in which transactions frequently involve actors from multiple countries. Even though these connections to other countries facilitate the transferability of our findings to countries in Western Europe, other markets might exhibit specific adoption patterns and could necessitate follow-up research. Furthermore, our qualitative research approach is suitable for identifying factors influencing platform adoption (RQ1)

but not for quantifying the strength of the identified drivers and barriers. This strength could be tackled suitably in a large-scale empirical study (e.g., a survey). Lastly, our study focuses on IFT as an exemplary, highly competitive B2B market due to hard-to-differentiate transport services and the plurality of actors involved (Wallbach et al., 2019). These market characteristics led us to derive levers suitable for increasing platform adoption specifically in the IFT context (RQ2). However, generalizability should be further investigated by using the levers as a starting point to compare platform adoption in other highly competitive B2B or even B2C networks.

Given the complexity, the high division of labor, and an increasing shortage of skilled labor in the IFT industry, automation should be an obvious choice for a wide variety of activities. Our study shows that non-physical and easy-to-automate activities, such as data exchange and booking processes, are predestined for automation by digital platform providers. In line with recent literature (e.g., Jackson et al., 2024; Xu et al., 2021), we anticipate further automation potential, which can lower entry barriers to IFT and, hence, support supply chain decarbonization: Sourcing and sales activities for IFT services could be automated through GenAI-based chatbots. Trust between IFT actors could be increased through blockchain-based tracking of containers, and physical transshipment processes in terminals could be facilitated through automated data capture based on IoT sensors, to name a few potential use cases. We encourage scholars to focus their future research on how the integration of these technologies impacts the trajectory toward highly digitized and automated supply chains.

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