IRINA ROMOCHKINA

When Interests Collide

Understanding and modeling interests alignment using fair pricing in the context of interorganizational information systems

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Waar belangen conflicteren:
Begrijpen en modelleren van het oplijnen van belangen door eerlijke prijsmechanismen bij interorganisationele informatiesystemen

Thesis

to obtain the degree of Doctor from the
Erasmus University Rotterdam
by command of the
rector magnificus

Prof. dr. R.C.M.E. Engels

and in accordance with the decision of the Doctorate Board.

The public defence shall be held on
Friday the 5th of June 2020 at 11.30 hrs

by

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Erasmus Research Institute of Management – ERIM
The joint research institute of the Rotterdam School of Management (RSM)
and the Erasmus School of Economics (ESE) at the Erasmus University Rotterdam
Internet: www.erim.eur.nl

ERIM Electronic Series Portal: repub.eur.nl/

ERIM PhD Series in Research in Management, 451
ERIM reference number: EPS-2020-451-LIS
ISBN 978-90-5892-583-1

Design: PanArt, www.panart.nl

This publication (cover and interior) is printed by Tuijtel on recycled paper, BalanceSilk®
The ink used is produced from renewable resources and alcohol free fountain solution.
Certifications for the paper and the printing production process: Recycle, EU Ecolabel, FSC®, ISO14001.
More info: www.tuijtel.com

Acknowledgments

I received support from many people during my Ph.D. trajectory but, first and foremost, I would like to extend my gratitude to my supervisors, Rob Zuidwijk and Peter van Baalen. They started this journey with me during my master studies when I first got interested in the topic of port community systems. Following my master thesis project, Peter and Rob found a way to create a Ph.D. position that would allow me to continue my research and, over the next years, provided support, feedback, and guidance whenever I needed them. I will be forever grateful for this opportunity they gave me.

Erasmus Research Institute of Management (ERIM) is a great institution that supported both my master and my Ph.D. studies at Erasmus University. I am obliged to all the people who envisioned it and kept the institute going ever since. MPhil program provided a great foundation for my Ph.D. track and gave me a chance to explore different research areas before committing to my Ph.D. topic. Numerous courses, workshops and conference visits organized and sponsored by ERIM gave me exposure to the global academic research community which is crucial for doing relevant research in our day and age. I am also thankful to two research projects — NLI (National Logistics Infrastructure), funded by the Dutch government, and CASSANDRA (Common Assessment and Analysis of Risk in Global Supply Chains), funded by the European Union — that provided financial support to my Ph.D. trajectory and put me in touch with important seaport experts.

I am very grateful to my doctoral committee members — Eric van Heck, Albert Veenstra, Rommert Dekker, Claudia Loebbecke, Joan Rodón Mòdol — who dedicated their valuable time to reviewing my dissertation, challenging me and pushing me to go even further. I am especially thankful to Eric for organizational support he provided me with throughout the years. I am grateful to Albert for introducing me to the topic of port community systems and putting me in touch with many business contacts in the Port of Rotterdam who were crucial to my research.

My Ph.D. experience was greatly enriched by my incredible peers. I am very grateful to Basak who we went on a great number of adventures with; to Colin, Misagh, Ning, Pourya, Mehdi for becoming my MPhil family during my first years in the Netherlands; to Sarita for the amazing department environment she created and multiple events she organized to bring department Ph.D. candidates together; to Wouter and Nick for their friendship, never ending enthusiasm and amazing creativity; to Panos and Konstantina for introducing me to Greek hospitality; to Xiao for being a great flatmate and true party spirit; to Evsen, Luuk, Paul and Clint for being great colleagues.

Finally, I would like to acknowledge the support that I received from my friends and family. My parents never hesitated to invest in my education. It is due to their unwavering support and faith in me that, first, I was able to move to Moscow to get my bachelor degree and then to the Netherlands to get my master degree. I was also lucky to find friends in the Netherlands who helped me to stay connected to my Russian roots. Daniela, Ilya, Roma, Alexei, Egor, Patricia, Dumitru, Yana – thank you a lot for keeping up my spirits. Finally, I would like to extend my gratitude to my partner, Luigi Cogliani, whose support helped me to push the project over the finish line.

Огромное спасибо моим родителям и всей моей семье за безграничную поддержку и веру в меня.

Irina Romochkina
London, March 2020

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Chapter 1

Introduction

Digital communication is at the heart of modern society. During the last two decades, companies such as Facebook and Instagram have revolutionized how people interact with each other. Although less visible to the public, how organizations interact with each other has been rapidly changing as well. Companies such as Salesforce and Descartes have introduced new ways for organizations to interact with their customers and supply chain partners by relying on software-as-a-service business models and cloud-based platforms.

However, the adoption of novel communication technologies at the organizational level faces many more challenges than does adoption by regular individuals. Organizations are much more cautious when it comes to data security and data sharing. Whereas individual users are happy to provide Facebook with their data in return for services, organizations need to carefully evaluate how the service provider will use their data and whether they will be properly reimbursed for sharing such a valuable resource. Furthermore, companies need to evaluate how the adoption of one or another technology will affect their competitive position, the quality of the services provided, their dependence on supply chain partners, and so on. All of these factors make a company's decision to adopt a new communication technology much more difficult.

Interorganizational information systems (IOSs) are information systems shared by two or more organizations. This general term is used in the academic literature to describe diverse systems, such as customer relationship management systems, airline reservation systems, transportation tracking systems, and many others. One of the most important characteristics of IOSs is that they bring value to their adopter only if other companies have also adopted the system. Adopting a transportation tracking tool is useless when your transportation provider is not using data from or providing data to the tool.

Modern IOSs are forming the backbone of business communities' information infrastructures. For instance, all major seaports use port community systems to coordinate the flow of goods and to make that flow as smooth and efficient as possible. Such systems are used by hundreds of companies of different sizes and playing different roles (e.g., shipping lines, freight forwarders, terminal operators, and customs authorities). Given the diverse interests and demands of different companies, developing an IOS that will be attractive to all prospective users is quite a challenge. However, the successful integration of the diverse interests of prospective IOS users is a necessity for the IOS's long-term survival. Hence, the overarching question addressed by this dissertation is: "How can and why should the diverse interests of different organizations be aligned when developing an interorganizational information system for the benefit of a business community?"

IOSs have been around for more than forty years. Previous researchers have addressed this question from multiple angles, but the ever-changing nature of business practices and technologies means that it remains. One of the instruments to which we pay specific attention in this dissertation has not, to the best of our knowledge, been previously considered — monetary reimbursement for data shared by IOS adopters. The investigation into this instrument is one of the main contributions of this dissertation, not only to IOS research but also to general information systems research because it addresses the more general question of "putting a price tag" on the data.

1.1 A brief history of IOS research

Interorganizational information systems first appeared in the form of online database vendors and time-sharing services in the 1960s (Kaufman 1966).

During the next two decades, IOSs grew in complexity and capability to include electronic fund transfer systems, a variety of supplier-buyer order processing systems, and online professional tool support systems (Barrett 1986). One of the best documented cases of IOSs established in the early 1960s is that of airline reservation systems developed in the United States (Copeland and McKenney 1988). Once airlines had established their electronic systems for maintaining seat inventory, they started actively marketing these systems to individual travel agents to establish direct links between consumers and their reservation systems. That dynamic resulted in fierce competition between the major airline carriers American and United for dominance of the airline reservation systems landscape, which lasted around a decade (Copeland and McKenney 1988).

Up to the 2000s, the vast majority of IOSs were based on electronic data interchange (EDI) as the data transfer technology. EDI encompasses a large number of different standards (UN/EDIFACT, ANSI ASC X12, GS1 EDI). These standards specify the exact structure of an electronic message, which ensures that the recipient can properly interpret the message sent by the sender. Various EDI standards were developed by different industries and in different geographical regions. Given the widespread reliance on EDI, IOS research up to the end of the 20th century was practically synonymous with EDI research. Previously published papers focused on the prospective benefits of IOSs and the consequences of their adoption for dyadic buyer-supplier relationships and industries as a whole (Bakos 1991, Premkumar et al. 1994).

Throughout the 1990s, IOSs became increasingly commonplace. All major industries, including automotive, air transportation, sea transportation, healthcare, and finance, developed their own EDI standards and electronic marketplaces. The initial hype regarding the revolutionary nature of the new technology is slowly receding and, even though the majority of practitioners and researchers acknowledge the increased efficiency and decreased costs of such communication, reports on the numerous challenges facing IOS adopters started piling up. Among the many barriers impeding the spread of IOS were the low flexibility of standards, expensive initial development and installation costs, and shifts in bargaining power among companies.

In the early 2000s, the introduction of the XML standard for messages, which is more flexible and not bound by the strict rules of data location, made IOSs more attractive for small and medium companies. The next important technological innovation in the IOS area was the introduction of cloud-based platforms and the accompanying software-as-a-service business model. The initial investment costs required for IOS adoption were significantly decreased and IOS flexibility improved. Companies such as Salesforce and Descartes offer their standardized customer relationship and supply chain management solutions worldwide.

To date, however, technological innovations have not addressed all of the barriers to IOS adoption, which are often social. Companies' IOS requirements differ depending on their size and role in the value chain (Iacovou et al. 1995, Markus et al. 2006). Finding an IOS that fits the requirements of all organizations is impossible. Modern companies operate in a world in which they can use one IOS to support their communication with suppliers, another IOS to support their communication with buyers in the United States, yet another for buyers in the European Union, and so on. Some of the existing IOSs rely on the EDI technologies from the 1990s, whereas others use the latest cloud-based solutions. Although technological progress continues to remove barriers to IOS adoption, some prevail to this day because of the social and collective nature of the phenomenon, which requires the cooperation of many different actors to ensure IOS' success.

1.2 Research motivation and main contributions

Real problems facing practitioners in the Port of Rotterdam inspired this research project. There is a long established tradition of collaboration between the Rotterdam School of Management and Rotterdam Port companies. IOSs were first introduced in the Port of Rotterdam in the late 1980s, and the field has been actively developing ever since. In 2011, under the umbrella of the National Logistics Infrastructure project, Rotterdam Port companies initiated an even closer cooperation with the university on the topic of IOSs. It emerged that certain problems faced by port companies were yet to be addressed in the academic research, and this dissertation was envisioned to fill this gap.

The first major issue that we investigated was the option of monetary reimbursement to IOS users for data provision to increase its attractiveness for the user community. This instrument has not been previously discussed in the IOS literature. Given the nature of port operations, a small number of large companies concentrate a vast amount of data on the goods that flow through the port grounds. Accordingly, they also contribute a lot of these data to the port community system. When many small freight forwarders and inland transporters use PCS services, they benefit from the data provided by these large companies. The latter often perceive that it is unfair that they provide so much data to the community and do not receive preferential treatment in return. Hence, in collaboration with the PCS provider, we investigated the possibility of establishing a fair sharing scheme for the use of PCS services, which would reward the provision of not only traditional IT services in the form of software and equipment but also of the data provided to the system by various IOS users. We demonstrate that the use of such a scheme could improve the incentives for port companies to adopt this type of system.

The second major issue that has not been discussed in the academic literature was the proliferation of different interorganizational information systems in real life. Port companies had access to a centralized port community system but also used EDI messages to support communication among shipping lines and terminal operators, Web portals for inland transporters to report their arrival and to check the status of containers, customs declaration portals to submit documentation to authorities, and so on. However, most IOS studies focused on a single IOS or a comparison of IOSs rather than the organization and the variety of IOSs that it uses. This focus precluded studies from investigating how the IOS already in use affects a company's decision to adopt a new IOS and the IOS characteristics that need to be considered when adopting a new IOS. We attempt to fill this research gap by introducing the notion of an IOS landscape. We show that the IOS landscape is dynamically shaped by the diverse and often contradictory interests that port companies are pursuing. We conclude that new, innovative IOS management models are required to align those interests to ensure that the community benefit is maximized.

The overarching question that we attempt to answer with this dissertation is **how can and why should the diverse interests of different organizations be aligned when developing an interorganizational information system for the benefit of a business community.** First, we describe a fair sharing mechanism that could serve as an instrument for aligning those diverse interests (Chapters 2 and 3). Then, we proceed to introduce the notion of the IOS landscape in which firms operate and stress the importance of aligning interests in IOS development for the business community (Chapter 4).

1.3 Dissertation outline

This dissertation consists of three studies that investigate the problem of cooperation and interest alignment in the context of interorganizational information systems. All three studies rely on concepts and methodologies developed within the field of game theory to describe the phenomenon under consideration. The studies differ in the level of analysis and specific methodologies applied.

In Chapter 2, we present a case study of a business community platform in a seaport setting. We focus on pricing challenges faced by this type of interorganizational information system. We find that traditional cost-based pricing methods in the form of transaction and subscription fees cope poorly with the following business community platform characteristics: 1) users of the system also can be contributors (i.e., they provide data for the system); and 2) the services within the platform can have a hierarchical structure in which old services provide input for new services. We propose a new pricing strategy that accounts for these specific challenges. This strategy relies on two building blocks: user value-based pricing and fair sharing. The approach aims to align the incentives for individual users to adopt a business community platform and the community-wide benefit from the platform's introduction. We believe that the use of a new pricing strategy, such as that developed in Chapter 2, could serve as an additional instrument for the alignment of members' interests in the adoption of the business community platform as the main communication channel.

In Chapter 3, we continue to investigate fair sharing and rewards for data provision in the IOS context. We demonstrate that for a vertical IOS such a fair sharing scheme can create additional incentives for co-opetition among competitors by estimating the value gain for a data provider that comes from the participation of another data provider. The degree of the positive externalities among providers depends on the network structure that, in turn, determines the importance of coordination among competitors for IOS adoption. Furthermore, we investigate the role that network density plays in the success of such a scheme. This chapter is valuable for understanding why IOS landscape development and adoption occur differently in different business communities (e.g., in different global seaports) and how the success of the new pricing strategy can depend on the business community structure.

Chapter 4 introduces the case study of an IOS landscape of the Port of Rotterdam. This paper addresses the research question of how the interests of different companies belonging to the same business community affect the shape of the IOS landscape. Thus, the level of analysis in this paper is the business community and all IOSs being used by companies in that community. In this chapter, we introduce the new concept of the IOS landscape. We define the IOS landscape of a firm as the collection of all interorganizational information systems that a firm can potentially use to connect to its existing and prospective partners (e.g., customers, suppliers, and government organizations). The information exchange among organizations, i.e., which information is available to which partner, and the quality of this information, is shaped by the IOS landscape. We characterize the IOS landscape along four dimensions: the number of IOSs, their architecture, their interoperability, and their substitutability. These dimensions reflect the degree of favorability of the IOS landscape for a firm. In this paper, we adopt a collective action lens to analyze the chances that the IOS landscape is formed in accordance with the common interests of the business community. That community has an IOS landscape consisting of a shared neutral business community platform accessible to everyone. This chapter facilitates answering our overarching research questions by delineating the variety of interests that firms can pursue when developing IOSs and how those interests interfere with the development of the IOS landscape in a form that would be beneficial for the business community as a whole. Hence, in Chapter 4, we answer the “why” part of our overall research question and demonstrate how companies create barriers to the data flow and data reuse within the business community.

In the last chapter, we discuss our main findings and contributions, acknowledge the limitations of our study, and provide recommendations for future research in the area.

1.4 Declaration of contributions

Rob Zuidwijk and Peter van Baalen served as first and second supervisors on my Ph.D. dissertation and provided guidance, support, and feedback throughout the project. Albert Veenstra and Rob Zuidwijk have been pivotal in setting up collaborations and providing access to many interviewees in the Port of Rotterdam.

This research was financially supported by a research grant from the Erasmus Research Institute of Management, the research project National Logistics Infrastructure sponsored by the government of the Netherlands, and the research project CASSANDRA sponsored by the European Union. When performing the computations for Chapter 2, I used the cloud facilities graciously provided by the SURF organization.

Chapter 2, which I wrote independently, is based on the research I conducted in collaboration with Rob Zuidwijk for the National Logistics Infrastructure project. Rob Zuidwijk provided substantial support in adjusting the Shapley value calculation algorithm to make the computational time reasonable. His ideas were the driving force behind the mathematical transformations discussed in the appendix to that chapter. Port community system representatives provided significant feedback from the practitioner’s point of view. Peter van Baalen and Rob Zuidwijk provided important review comments in multiple iterations.

I conducted most of the work for Chapter 3 independently, with valuable review comments and edits from my supervisory team.

The interviews described in Chapter 4 were conducted either by me or in collaboration with Albert Veenstra. I handled the interview transcriptions and analyses. Frequent discussions with Peter van Baalen helped me shape the theoretical framework guiding the paper. I wrote Chapter 4 independently. Peter van Baalen, Rob Zuidwijk, and Eric van Heck provided valuable review comments and edits.

Chapter 2

A Strategy to Address Business Community Platforms' Pricing Challenges

Abstract: In this paper, we present an exploratory case study of a business community platform in a seaport setting. We focus on pricing challenges faced by this type of interorganizational information system. We find that traditional cost-based pricing methods in the form of transaction and subscription fees poorly cope with the following business community platform characteristics: 1) users of the system also can be contributors (i.e., they provide data for the system); and 2) the services within the platform can have a hierarchical structure in which old services provide input for new services. We propose a new pricing strategy that accounts for these specific challenges. This strategy relies on two building blocks: user value-based pricing and fair sharing. The approach aims to align the incentives for individual users to adopt a business community platform and the community-wide benefits from the platform's introduction.

2.1 Introduction

The success of economic clusters such as Silicon Valley drew the attention of public agencies, industry associations, and individual firms to the importance of shared infrastructures that support business ecosystems (Porter 2000). Today, firms often attempt to collaborate at one level while competing at others (Levy et al. 2003). Business community platforms are "digital infrastructures designed to support interoperable business processes across ecosystems in a particular business community" (Markus and Loebbecke 2013). Such platforms can be found in a variety of industries: the Mortgage Electronic Registry System in the U.S. mortgage lending industry (Markus et al. 2006), Port Community System PortIC in the Port of Barcelona (Rodón and Sesé 2010), and e-prescribing network in the U.S. healthcare system (King 2013). The goal of business community platforms is to support communication, coordination, and collaboration among the members of a specified business ecosystem.

Previous research dedicated significant attention to the business platform development challenges associated with their collective good nature (Volkoff et al. 1999, Markus and Bui 2012, Rodón and Sesé 2010, Gengatharen and Standing 2005), which could be addressed using more effective governance mechanisms. The role of a pricing mechanism in platform development has been only briefly mentioned but not investigated in greater detail. In our paper, we intend to fill this gap.

We present an exploratory case study of a Port Community System (PCS) — an interorganizational information system that is targeted at supporting communication and operational coordination among the companies belonging to a specific port cluster (Rodon et al. 2008). We find that traditional cost-based pricing methods in the form of transaction and subscription fees poorly cope with the following business community platform characteristics: 1) users of the system also can be contributors (i.e., they provide data for the system); and 2) the services within the platform can have a hierarchical structure in which old services provide input for new services.

In this paper, we develop a new pricing mechanism to tackle these business community platform characteristics. The approach aims to align the incentives for individual users to adopt a business community platform and the community-wide benefit from the platform's introduction. The suggested pricing mechanism is based on user value and fair sharing. Using an example of a PCS service, we present in detail how the approach can be implemented. We discuss the potential consequences of applying such a pricing mechanism in practice that would significantly change the distribution of benefits from the platform adoption among community members.

The remainder of this paper is organized as follows. First, we review the existing body of literature on business community platforms, information systems pricing, and the application of fair sharing principles in information systems and supply chain management research. Second, we discuss the methodology applied in the research project. Then, we move on to introduce the case and the new pricing approach. Finally, we discuss the potential advantages and disadvantages of the new pricing mechanism suggested and conclude by summarizing our results and their implications for IOS research and practice.

2.2 Literature review

2.2.1 Business community platforms

Business community platforms play the role of information infrastructure for a particular business community and can greatly affect the competitive position of the business network vis-à-vis other networks. A business network's "smartness" reflects its ability to outperform other networks in efficiency, effectiveness, revenues, joint profitability, and competitive sustainability (Dunn and Golden 2008). The key capabilities of smart business networks are: (1) the ability for the quick connect and disconnect with an actor; (2) the selection and execution of business processes across networks; and (3) establishing the decision rules and the embedded logic within the business networks (Van Heck and Vervest 2008). Business community platforms play a key role in facilitating these capabilities (Basu and Muylle 2008, Hirnle and Hess 2008).

The development of business community platforms is associated with a number of specific challenges. First, they are meant to generate collective benefits rather than offer a strategic advantage to any individual firm, which brings about a free-rider problem at the investment stage (Volkoff et al. 1999, Markus and Bui 2012). At the individual firm level, it makes sense to wait for a platform to be built by others and join it once it is created because the other platform members will not benefit from excluding a new member at a later stage (Markus and Bui 2012). Even after the platform has been established, heterogeneous ecosystem members should be properly induced to join the system, use it, and contribute high-quality data to it. In many cases, given the collective nature of community platform benefits, individual contributions and rewards are not perfectly matched (Volkoff et al. 1999). If members believe that their interests are not properly integrated into the system, they will not use it and the platform will most probably collapse (Volkoff et al. 1999, Rodón and Sesé 2010, Markus and Bui 2012). Finally, business community platforms collect a vast amount of data necessary for their operations. These data resources could become a source of additional revenues for platform operators and pose a competitive threat to certain community members (Markus and Bui 2012).

The role of effective governance mechanisms in overcoming business community platform development challenges has been stressed by many researchers (Volkoff et al. 1999, Markus and Bui 2012, Rodón and Sesé 2010, Gengatharen and Standing 2005, Basu and Muylle 2008). The ownership structure and governance of the platform should reflect the diverse groups of stakeholders (Gengatharen and Standing 2005, Hirnle and Hess 2008). Gengatharen and Standing (2005) recommended identifying community members with high owner-innovativeness to ignite platform development and ensure its initial adoption. Volkoff et al. (1999) stressed that a specific leadership structure is required for the development of community platforms that should change with the development progress. An external intermediary or a sponsor should initiate the project, but only the formation of interorganizational teams at various levels and executive support within each partner will ensure a successful system design and implementation (Volkoff et al. 1999). The order and timing of the introduction of specific platform features should correspond to the motivation behind the platform creation and match the sophistication and technological capabilities of the community members (Gengatharen and Standing 2005). Rodón and Sesé (2010) drew attention to the role of the initial social structure of the community and the potential contradictions between that structure and the structure when using the platform. A business community platform may transform the social structure of the community by changing data and procedures or shifting the balance of power (Rodón and Sesé 2010). A platform implementation strategy should be devised based on the identification of such potential contradictions to ensure successful platform adoption. Markus and Bui (2012) demonstrated that the formalization of the governance structure is very important to overcoming the business community platform development challenges (Markus and Bui 2012). Furthermore, that the community platform is owned by only one of the community members is highly unlikely because it will introduce additional difficulties to ensuring that the heterogeneous interests of the community are taken into account and that community members believe in that. Even if the community platform is owned by outside investors, member participation in decision making is crucial for platform development.

Previous research has stressed the importance of aligning heterogeneous community member interests for the successful introduction of the business community platforms. In many cases, economic incentives have been mentioned as a way to align the incentive structure to make up for the shifts introduced in the community social structure. However, to the best of our knowledge, no research yet exists in the area of pricing in the case of business community platforms. In the next subchapter, we review the literature on pricing in the context of interorganizational information systems and information systems in general.

2.2.2 Pricing of information systems

In traditional IOS literature, the term “pricing” is not often used. IOS research has started with the investigation of EDI networks that supported buying-selling transactions and that were most often initiated by a powerful and resourceful company that usually did not explicitly charge its partners for using the system. Subsidies and penalties could be used as a form of economic incentives for suppliers to join the system because the network owner directly benefited from its partners adopting the system. Riggins et al. (1994) demonstrated that the buyer may experience initial supplier adoption of the network, followed by a “stalling” problem because of negative externalities. To overcome this problem, the buyer may find it optimal to subsidize some suppliers’ costs to join the network in the second stage (Riggins et al. 1994). Barua and Lee (1997) compared subsidizing and penalizing strategies in the form of buying more or fewer products for fostering IOS adoption in a vertical market involving one manufacturer and two suppliers (Barua and Lee 1997). They showed that, regardless of the cost structure, IOS adoption can become an unfortunate strategic necessity for a smaller supplier. Nault (1997) investigated the possibility of a subsidy provided by the IOS supplier to the IOS adopter in the contexts of a monopoly and a duopoly. He showed that the possibility of such a subsidy increases when the added value after the adoption is indispensable and when IOS adopters do not decrease their transaction volume relative to before the IOS state.

Once the IOS provided by independent intermediaries appeared, the owners of the system could not benefit from companies adopting the system without actually charging them for its use. To the best of our knowledge, only one paper was published on the pricing strategies for IOSs. Yoo et al. (2002) analyzed the optimal pricing strategies for independent intermediaries providing e-marketplaces. They showed that to maximize their profits, intermediaries need to recognize whether the strength of the positive network effects for buyers is greater than that for suppliers or vice versa. When the strength of the positive network effects for buyers is greater than that for suppliers, reducing the supplier charges and increasing the level of information services to buyers is optimal. In the reverse case, the intermediary should increase supplier charges. One of the simplifying assumptions used by the authors was that equal prices were charged to all suppliers and all buyers.

In the general information systems literature, three IS pricing strategies received the most attention from the researchers: flat-fee pricing (e.g., subscription fees), usage-based pricing (e.g., traffic fees), and the combination of the two, namely, a two-part tariff. Information goods are characterized by high fixed costs of production and relatively low variable costs. The marginal costs of providing information services with enough capacity are negligible, making flat-fee pricing attractive from the providers' point of view (Fishburn et al. 2000, Oi 1971). In contrast, the costs of monitoring users' behavior are also diminishing, making the usage-based tariffs more interesting for suppliers, especially in a monopolistic situation (Choi et al. 1997, Metcalfe 1997). Sundararajan (2004) demonstrated that, in the presence of any monitoring costs, sellers of information goods benefit from offering their customers a combination of usage-based pricing and unlimited usage fixed-fee pricing. Wu and Banker (2010) considered customer heterogeneity and suggested that the two-part tariff is the most profitable for the monopolist under the assumption of zero marginal costs of production and zero costs for monitoring consumption.

The development of the software-as-a-service (or leasing) model through which software provider charges customers based on use and continuously improve the product has put competitive pressure on traditional perpetual software vendors that charge a licensing fee and periodically upgrade the quality of their software (Guo and Ma 2018). Dou et al. (2017) demonstrated that the better model in terms of provider profit maximizing depends on how the information good depreciates, namely, whether the value depreciates only for consumers who have consumed or experienced the good or service (selling model dominates) or for all consumers irrespective of their experience with the product (leasing model dominates).

Information systems pricing strategies can be divided into two broad groups: cost-based tariffs and value-based tariffs (Harmon et al. 2009, Pasura and Ryals 2005). Cost-based tariffs are oriented toward covering the costs and earning a margin. They rarely take into account the actual value that the customers receive from using the information service. A number of researchers argued for the introduction of value-based pricing, which suggests using the customers' readiness to pay for the product as a reference point rather than production costs. Doing so is supposed to increase the profitability of the information services (Harmon et al. 2009, Pasura and Ryals 2005). However, the problem with the implementation of value-based pricing is that customers are rarely eager to reveal their actual willingness-to-pay because it is in their interests to obtain a lower price for the product (Pasura and Ryals 2005). The advantage of value-based pricing is its long-term nature given its focus on monetizing the value being created for the customer, whereas the cost recovering approach to pricing arguably has a short-term orientation (Harmon et al. 2009).

2.2.3 Fair sharing in information systems and supply chain management research

In our paper, we rely on a fair sharing concept of the Shapley value developed in the cooperative branch of game theory (Shapley 1953, Leng and Parlar 2005). Cooperative game theory is concerned primarily with coalitions — groups of players — who coordinate their actions and pool their winnings (Branzei et al. 2008). One of the most prominent problems being studied within the discipline is how to divide the extra earnings (or cost savings) among the members of the formed coalition. The Shapley value suggests a way to divide the total value of the product created by a coalition of players that takes into account the relative importance of the individual players. The Shapley value can be calculated in the following way:

$$\varphi_i(v) = \sum_{S \subseteq N \setminus \{i\}} \frac{|S|!(|N|-|S|-1)!}{|N|!} \cdot \Big(v(S \cup \{i\}) - v(S)\Big),$$

where $|N|$ is the number of players and $|S|$ is the number of players in coalition S.

The Shapley value uniquely satisfies the combination of the following important conditions: additivity, anonymity, efficiency, and dummy player property. An efficiency property means that the total gain is being distributed among the contributors. An anonymity property requires that the players with identical contributions receive identical rewards. The dummy player property means that the player with zero contribution to the coalition does receive a reward. Finally, the additivity property ensures that if the game can be represented as a sum of two games, then the Shapley value for a player in this game can be represented as the sum of two Shapley values in the smaller games.

Over the years, many allocation principles have been suggested that can be considered fair: Shapley value, Core, and Nucleous (Leng and Parlar 2005, Nagarajan and Sošić 2008). In addition to the Shapley value uniquely satisfying the aforementioned conditions, it has two other advantages over the other allocation principles. First, it always exists. Second, practitioners tend to have a good intuitive understanding of the principle that makes it easier for them to accept the fairness of the allocation.

It is important to acknowledge that the Shapley value has its drawbacks as well. The first drawback is its computational complexity, which grows exponentially with an increase in community size (Özener and Ergun 2008, Suri and Narahari 2008, Misra et al. 2010). For certain applications, it is possible to transform the Shapley value into a less computationally intensive form (Suri and Narahari 2008, Misra et al. 2010). However, it is not always the case and depends on the game assumptions and structure. Second, although the Shapley value is easier to explain to practitioners than other game-theoretical allocation principles, practitioners can find solutions that they consider fair and that are easier for them to grasp. For instance, two companies can agree that one is paying for storage, whereas another is paying for the transportation of common stock. This might not be the best solution from a theoretical point of view; however, as long as participants agree on its fairness, it would work. Finally, in general, the Shapley value does not possess a certain number of characteristics that might be desired of a fair allocation principle, such as cross-monotonicity (i.e., any member's benefit does not decrease with the addition of a newcomer) or the positive benefit property (i.e., joining the coalition brings benefits compared with being standalone) (Young 1994, Özener and Ergun 2008).

Nevertheless, the Shapley value has found application in a number of information systems management research projects. Misra et al. (2010) suggested applying the Shapley value in the context of delivery networks for live streaming, video on demand, and software updates that are based on a peer-to-peer architecture. They proposed an incentive mechanism that ensures that users dedicate part of their resources to support content delivery in exchange for a price reduction. The authors evaluate the cost reduction that the service provider achieves from peer assistance. Then they distribute system-generated revenues according to the value added by the service provider and users through their participation. Kleinberg et al. (2001) leveraged the Shapley value concept to estimate the fair reward to individuals for sharing their private information in contexts such as marketing surveys or recommendation systems. They showed that, in the case of marketing surveys, when a clear majority exists for individuals' preferences the Shapley value "confers a vanishingly small quantity on individuals outside this majority". In contrast, recommendation systems reward novel contributions. Van Alstyne et al. (1995) applied the Shapley value in their study of incentive principles that drive information sharing and affect database value. The Shapley value was used to evaluate the compensation granted to each member of the coalition formed to provide database services. Based on their theoretical framework, the authors formulated seven normative principles for improved database management.

The Shapley value concept found even more applications in supply chain management research (Nagarajan and Sošić 2008). Raghunathan (2003) analyzed the value of demand information sharing in a one manufacturer–N retailer model. With the help of the Shapley value, the authors evaluated the expected manufacturer and retailer shares generated from information sharing. They found that a higher demand correlation among retailers increases the manufacturer surplus and reduces the retailer surplus. Kemahlioglu Ziya (2004) investigated the formation of a coalition between a supplier and retailers to enable retailers to pool on joint inventory. The Shapley value was used to distribute the total profits among the members and coordinate the supply chain. Leng and Parlar (2009) modeled demand information sharing in a three-level supply chain (manufacturer–distributor–retailer) and used the Shapley value to allocate savings. Granot and Sošić (2003) studied a decentralized distribution system with inventory sharing among retailers. They showed that the Shapley value promotes decisions that maximize the profits from inventory sharing, providing the players remain in the grand coalition.

2.3 Port community system pricing challenges

2.3.1 Case study approach

This paper is based on an exploratory case study (Eisenhardt 1989, Yin 2004) of a single business community platform — a port community system. A port community system (PCS) is an interorganizational information system targeted at supporting communication and operational coordination among companies belonging to a specific port cluster (Rodon et al. 2008). The case study allowed us to identify the business community platform characteristics that are important for practitioners and have not been previously discussed in the literature (Yin 2004).

The PCS under consideration was established in one of the major European ports in the early 2000s. During the period of this study, the PCS was subsidized by the respective port authority. We interact with the provider when they are reconsidering their pricing strategy and analyzing various alternatives. The initiative was driven by the feedback that the PCS provider was receiving from the user community.

The data collection process was undertaken during a one-year period (September, 2013 — August, 2014) through interviews and the analysis of internal documents. We relied on interviews with business community platform representatives to understand the nature of the current difficulties that practitioners are facing. As we progressed, we collected internal documents of the business community platform on business model, design, and adoption forecast data for a new information service that was under development at that moment. The collected information was used to develop a new pricing mechanism that could incorporate characteristics specific to business community platforms. The developed pricing mechanism is based on game-theoretical modeling. We base our analysis in this paper on the hypothetical business activity in a port for one year. For confidentiality reasons, we do not use the actual data provided by the company. Finally, the suggested pricing mechanism was evaluated in a workshop with business community platform representatives. The outcome of the workshop is incorporated in the discussion part of our paper.

2.3.2 Pricing challenges of a port community system

From the time of PCS establishment, the provider used a combination of traditional information pricing service methods: transaction and subscription fees. Monthly subscription fees were supposed to cover development and service maintenance costs. Fees per message were meant to cover the costs of running the IT infrastructure. The PCS user base comprised various organizations that significantly differed in size and IT capabilities: shipping lines, terminal operators, freight forwarders, inland transporters, and others. Naturally, larger companies handled larger volumes of cargo, translating into larger amounts of messages exchanged via the PCS and more transaction fees. The fees also differed depending on the company's business role to reflect the heterogeneity of the platform benefits. For instance, terminal operators were estimated to receive greater benefits from the use of an "inland transport planning" service relative to their counterparts — barge operators. Hence, fees for using the service were higher for terminal operators than for barge operators.

As the system grew, two issues appeared that were not considered by the existing pricing model. First, some large port companies — which were at the heart of the port information exchange network — started perceiving that they were treated unfairly by the platform. They not only received information from the platform but also provided a lot of data to it that were used by the other parties. However, they received no compensation whatsoever for the data provided, which was also true for other users who most of the time not only used the PCS information services but also provided data to the platform. In the case of terminal operators, this issue was most prominent, given the large amount of data that went through them.

Furthermore, once initial information services were established, the PCS provider started developing new services on top of old ones that were reusing the output of the initial services. For instance, the system could create and submit customs manifests for freight forwarders based on the information provided by shipping lines and terminal operators for other information services, such as the "discharge list," which were not intended to be used by freight forwarders. This technical innovation raised a number of new commercial and legal issues that had to be addressed, such as fair retribution to the original data contributor for reusing the data and data ownership attribution. In this paper, we set aside the legal aspects of data reuse but focus on the problem of estimating the value of the data because it unites both of the issues sounded by the PCS users. The users would like to be compensated for the original data that they provide to the system and for the further reuse of these data in other information services.

In the next section, we introduce a new information service pricing strategy that addresses these two issues by estimating the value of the data provided by the port companies based on the fair sharing principles and by estimating the user value of an information service.

2.4 Pricing strategy modeling

2.4.1 Modeling service value

As previously mentioned, two main pricing approaches exist in the information systems (IS) literature: cost-based and user value-based. The cost-based approach is the one most widely used in practice because it is simpler to implement. However, that the data value in many cases is potentially much higher than the costs required to obtain or share the data is obvious. For our purposes, we rely on user value and the corresponding willingness-to-pay as the main driver for estimating retribution for data provision.

First, we assume that the willingness-to-pay of a service consumer C_j ($C_j \in \mathbf{C}$, $\mathbf{C}$ — set of all consumers) is proportional to the projected savings from using the information service and can be expressed as $w_j(s_j) = \alpha \cdot s_j$, where α ($\alpha \in (0, 1)$) is the parameter describing the share of projected savings that a consumer is willing to pay in the form of service fees. Parameter α is assumed to be the same for all consumers. Second, our analysis focuses on business community platforms that mostly support information exchange among companies with already established business relationships. Consumers' savings from using such a service are proportional to the number of messages that they receive through the system (Barua and Lee 1997) or to their transactional volume. The number of these messages are usually proportional to the company's transactional volume.

Each data element can be traced back to its origin (a company that provided the data or an information service that generated it). Such companies or information services providing input to an information service are data providers. Let us denote n_{ij} as the number of messages received by data consumer C_j from data provider P_i. The dependency of the savings of data consumer j on the data providers' participation (structure of the providers' coalition $\mathbf{K}$) can be expressed as $s_j(\mathbf{K}) = \bar{s} \cdot \sum_{i \in \mathbf{K}} n_{ij}$, where $\bar{s}$ represents the average savings per message, which can be an order, an invoice, a pre-arrival notification, or anything else.

Business community systems are network goods in which the network effect influences the amount of the per-message benefit, namely, the average savings per message grows with an increase in the number of data providers. Our previous assumption that the benefits are proportional to the number of messages exchanged through the system incorporates this fact. A higher number of the company's partners that use the system implies that more messages are going through it. However, the average benefit per message can also grow with the data providers' adoption rate. If all companies' partners adopt the community system then it no longer has to support alternative communication methods. As long as the adoption of the business community system is anything less than 100% from the side of the data consumer's business partners, the data consumer must support alternative communication channels, such as receiving e-mails with this information and manually inputting the received data into the system. Therefore, for each data consumer C_j, the amount of the savings per message depends on the share of providers that adopted the system out of all data providers with which the data consumer is dealing what we denote by $\bar{s}_j(\mathbf{K}) = f_j\big(\frac{\sum_{i \in \mathbf{K}} n_{ij}}{\sum_{i \in \mathbf{P}} n_{ij}}\big)$. Finally, we assume that function $f\big(\cdot\big)$ has the same shape for all data consumers: $f\big(\cdot\big)$ is monotonically non-decreasing and reaches its maximum with full adoption $\bar{s}_{max} = f(1)$.

To summarize, in our model a consumer's willingness-to-pay is proportional to the savings generated for the consumer from using the business community service. In return, these savings are driven by the number of messages that the consumer receives from the business community and how many of the consumer's business partners have adopted the service to share messages through it.

2.4.2 Modeling service provision structure

Now that we have estimated the value that users receive from the service, we need to estimate the relative contribution of each data provider. A business community system requires the participation of different types of organizations to function successfully. An IT provider develops software and supports the infrastructure on which the services function. Meanwhile, community organizations provide data to the services, which is what makes these services attractive for use by other organizations. Different types of organizations provide different types of data elements in different volumes. As a result of these joint activities, business community platform services can provide value to their users. However, the question exists, as to how to evaluate the relative contributions of all of the different actors that participate in the provision of PCS services by considering the differences in the types of resources that they provide and the amount of their contributions. In this model, we use the Shapley value approach previously introduced.

We propose to treat the provision of business community platform services as the formation of a coalition. Different services require the cooperation of different types of organizations. Thus, treating each service independently from another in cases in which the input or output of one service is not reused as input for another service is reasonable. In our model, we treat only business community members (i.e., data providers) as active players and consider software development and infrastructure support as costs that should be shared among the members. The reason we believe that these resources should be treated separately is that each business community member brings value to the community in the form of data that are unique and that, in most cases, cannot be substituted by the data provided by another organization. With respect to software development and infrastructure support services, a number of different external providers can fill this role during the initial platform establishment stage. Thus, treating the software and infrastructure provider as a community member with unique resources that cannot be replicated would be misleading. However, we should acknowledge that, at a certain maturity stage, an IT provider can become an indispensable player with unique technological resources that cannot be easily substituted by another firm. In such a case, an IT provider could become a member of the coalition as well.

Information services can also play the role of data providers if they create information that was not previously available. For instance, when barge operators provide their data regarding planned terminal visits, an information service can aggregate and process those data to create an optimal schedule. If such a schedule is then reused as input for another information service, then the original information service should be treated as a data provider next to terminal and barge operators because it generated information that did not previously exist. When different information services are developed by the same organization, this dependency might not play a significant role. However, if the business community system relies on different providers for developing and supporting different information services, then it becomes important to reward the input provided by information services to other information services.

We assume that the costs of developing the software and information infrastructure are born by the coalition of data providers. The development costs of providers (DC^P) are independent of the number of providers participating in the coalition. In addition, providing access to the system for each data provider has fixed costs (FC^P) and running information infrastructure has variable costs (VC^P), which are proportional to the number of messages passing through the system. Fixed or setup costs are individually born by each company and include costs for companies' necessary new hardware and software acquisitions or development to access the IOS or integrate it with internal systems and changes in internal business processes to interface with the system and provide the required data elements among others (Barua and Lee 1997, Lee et al. 1999). Variable costs incorporate infrastructure operating costs that are proportional to the number of messages, and the costs of generating and inputting data per message among others. Forming the last group

— development costs — are the costs to develop the standard for messages and the exchange structure, and the costs to develop the software supporting the exchange. Development costs are independent of the number of companies providing data to the system. Business community platform consumers must also bear fixed (FC^C) and variable (VC^C) costs to use the system. In their structure, consumer fixed costs are very similar to data provider costs because a similar infrastructure is required to receive messages through the system. Consumer variable costs are fees that consumers are willing to pay to data providers to use the platform.

Under these assumptions, the characteristic function of our cooperative game for a given set of prospective consumers $\mathbf{C}$ can be formulated as the willingness-to-pay of all consumers adjusted for the costs that they and providers must bear:

$$\upsilon(\mathbf{K}) = \sum_{j\in\mathbf{C}} w_j - DC^P - FC^P \cdot |\mathbf{K}| - VC^P \cdot \sum_{j\in\mathbf{C}}\sum_{i\in\mathbf{K}} n_{ij} \tag{2.1}$$

where w_j represents consumer j's willingness-to-pay for the service.

$$w_j = \alpha \cdot f\left(\frac{\sum_{i\in\mathbf{K}} n_{ij}}{\sum_{i\in\mathbf{P}} n_{ij}}\right) \cdot \sum_{i\in\mathbf{K}} n_{ij} \tag{2.2}$$

A player's Shapley value is expressed in formula (2.3), which can be interpreted as the expected incremental contribution to the value of the coalition. A coalition of n players can be formed through $n!$ joining sequences. The incremental value of a player to a coalition may depend on when the player joins the coalition. Accordingly, the expected incremental contribution made by a player is determined by combining the incremental contribution made by a player for a given joining sequence and the probability $p(\mathbf{K}\cup\{P_i\})$ of that sequence occurring. Because the Shapley value reflects the player's added value to the grand coalition, we can ensure that the total profits for the community are maximized by including only the players with positive Shapley values into the coalition because the inclusion of any player with a negative Shapley value effectively reduces the coalition's expected profits. Consequently, by rewarding each data provider with the corresponding Shapley value, we align providers' interests in receiving a positive reward for participation with the community's interests in maximizing the total profits for the business network. The Shapley value can be written as:

$$\varphi_i(\upsilon) = \sum_{\mathbf{K} \subseteq \mathbf{P} \setminus \{P_i\}} p(\mathbf{K} \cup \{P_i\}) \cdot \Big(\upsilon(\mathbf{K} \cup \{P_i\}) - \upsilon(\mathbf{K})\Big) \tag{2.3}$$

We should note that the development costs of producing the business community platform service are independent of the number of data providers contributing to the system. Therefore, development costs are not distributed automatically by the Shapley value principle. To incorporate these costs as well, we must adjust the reward received by data provider P_i in the following manner:

$$r_i = \varphi_i(\upsilon) - \frac{\varphi_i(\upsilon)}{\upsilon(\mathbf{P}) + DC^P} \cdot DC^P = \varphi_i(\upsilon) \cdot \frac{\upsilon(\mathbf{P})}{\upsilon(\mathbf{P}) + DC^P} \tag{2.4}$$

We consider the situations in which the profits realized by the grand coalition of data providers are positive, i.e., $\upsilon(\mathbf{P}) > 0$, indicating that providers' reward is positive as long as the Shapley value is positive. By distributing the development costs in such a manner, we are ensuring that the necessary condition for individual participation (i.e., positive rewards) is aligned with the communal incentive of maximizing network-wide profits.

We assume that consumers and providers are rational, adopt the service, and participate in the service provision if they receive positive profits from this effort. Providers' profits equal the rewards allocated to them according to the Shapley value principle (vector r; see formula (2.4)). Provider P_i will join the coalition of service providers or "adopt" the service if $r_i > 0$, which is equivalent to $\varphi_i > 0$ (see formula (2.4)). The provider's Shapley value reflects the value of provider's participation for the user community. Thus, the increase in the revenues that the provider brings to the system might not be high enough to justify the costs of joining the system.

Consumers' revenues equal the savings that they obtain from using the service (vector s). By adjusting consumer savings for their fixed and variable costs, we can obtain the profits that consumers receive from adopting the service. For consumers to adopt the service makes sense only if that profit is positive.

One of the typical characteristics of business community systems is that data consumers are simultaneously data providers in those systems. However, for each service, distinguishing between these two roles that organization might have to play is possible. Theoretically, a company can plausibly only receive data provided by other companies, even though it rarely happens in practice. Thus, in our model, one organization can be represented by two players: one data consumer and one data provider. In the next section, we provide a detailed example of the application of a developed pricing model to an “inland manifest declaration” service developed by PCS provider which we interacted with.

2.5 Results

2.5.1 Inland manifest declaration: Service purpose and structure

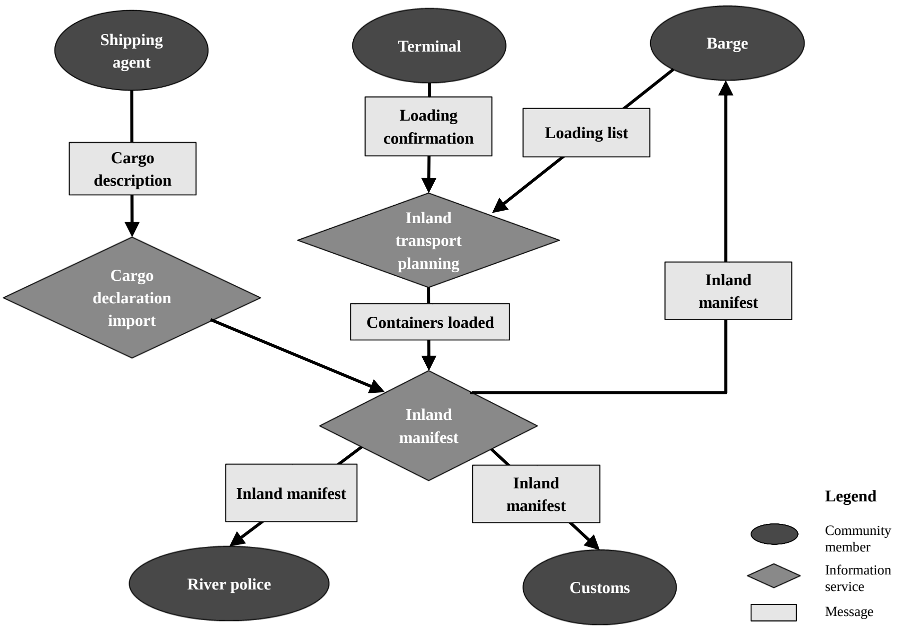
A PCS provider offers more than 30 services to the port community. The inland manifest declaration is a service to be rolled out that provides information on the cargo carried on board a barge to all relevant authorities. At present, barge skippers must have on their vessels a paper-printed declaration containing information on the cargo onboard. This declaration is compiled at the respective terminal from which goods are loaded onto the barge. Before providing this declaration to skippers, terminal workers must go to the customs office at the terminal premises to submit the declaration. Once done, the declaration is given to the barge skipper. During the barge trip, other relevant authorities such as the River police or the Ministry of Transport can order inspections of the vessel. They also require the inland manifest information to be able to carry out their inspections in a proper fashion. The inland manifest declaration service allows this information exchange to be conducted electronically, which provides significant savings for all parties involved — governments and businesses alike.

The inland manifest declaration service uses two other services as the data source for the declaration compilation. These services are “inland transport planning" and "cargo declaration import". The inland manifest service gets the loading list and the loading confirmation from the inland transport planning service. The loading list is provided by the barge operator. The loading confirmation is provided by the terminal operator. Based on the loading list and the loading confirmation, the list of containers actually on board the ship can be compiled with some key data elements, such as the movement reference number (MRN). However, for the declaration to be complete, more information on the cargo description is required. This information is from the cargo declaration import service that provides data elements, such as goods' weight, classification and others. Shipping lines and their agents are the companies providing these data elements to the cargo declaration import service when making use of it. The information on the cargo contents is crucial for authorities because they need to be able to evaluate the risks associated with the transportation and act accordingly in the event of an emergency. Figure 2.1 provides an illustration of the information exchange between services and actors required for the provision of the inland manifest service.

Importantly, note that the participation of all shipping agents and all terminal operators is of crucial importance to compiling an inland manifest for a barge vessel. The participation of all shipping agents is required because the containers being loaded onto the barge could have diverse origins. Thus, if the description of even one container brought by a non-participating shipping line is missing, then the complete manifest cannot be compiled automatically. A similar logic applies to the participation of terminal operators. During one visit to a harbor, a barge operator can visit multiple terminal operators. If one of the terminal operators does not participate, then the information on certain containers on board the barge will be missing, and the complete inland manifest cannot be compiled automatically.

A PCS provider incurs a number of costs for providing a service: service development costs, maintenance costs, and infrastructure support costs. In total, the PCS provider should receive €45,000 per year in the form of fees from service users to reach its zero-profit/zero-loss target. Please note that we use realistic costs estimations in the example but not the actual costs incurred by the PCS provider with which we interacted.

Figure 2.1: Information exchange supporting inland manifest service.



To estimate the value of the data contributions of port companies, namely, shipping agents, terminal operators, and barge operators, to the inland manifest service, we start with the estimation of the service value for users.

2.5.2 Service value for users

The inland manifest service has four direct user groups: terminal operators, barge operators, customs, and the river police. Governmental and business organizations cannot be treated equally. Although customs and the river police gain in administrative efficiency from using the service, the PCS provider does not expect them to pay for the service. Thus, regardless of how high their savings are, their willingness-to-pay for services equals zero. For that reason, we pay detailed attention only to the savings acquired by the business parties, namely, barge and terminal operators. We assume that the savings of these companies from using the inland manifest service can be used as an indication of their willingness-to-pay for using the service.

The savings that terminal operators receive from using the service come from two main directions. First, there are labor cost savings. At present, terminal personnel need to drive on a terminal train toward the customs office on the terminal's premises to hand over the documents, get them typed in, print them out again, and drive them back to a barge skipper. The digitization of declarations will eliminate this process and facilitate the information exchange with customs. Second, because of the long document exchange process, the time for one barge turn around is rather long. Now that the skippers will not have to wait for the physical document exchange, the terminals will be able to serve more barge operators within the same timeframe.

Based on this logic, we assume that the savings that terminal operators receive are proportional to the number of calls that barge operators make at the terminal and can be expressed as:

$$V_T^j = \bar{S_T}^j \left(\frac{N_{PCS}^j}{N_{Total}^j}, \frac{NC_{PCS}^j}{NC_{Total}^j} \right) \cdot N_{PCS}^j, \tag{2.5}$$

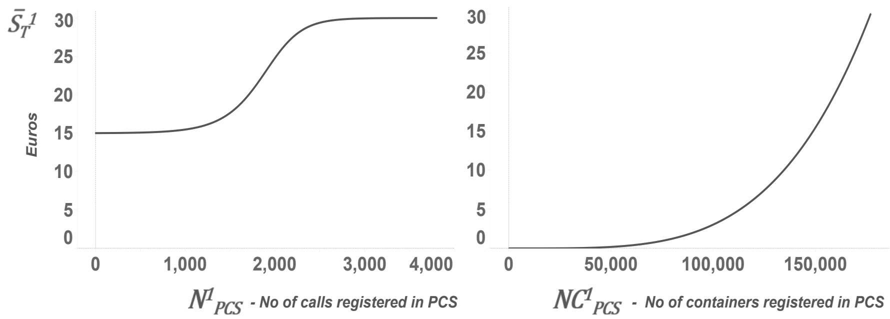
where V_T^j – represents the value of the inland manifest service for terminal operator j; $\bar{S_T}^j$ – represents the average savings per call for terminal operator

j; N^j_{PCS} – represents the number of calls in the system made at terminal operator j during a period; NC^j_{PCS} – represents the number of containers handled at terminal j for which data were provided to PCS.

The amount of savings per call that a terminal operator receives depends on the number of barge operators that provide data for it and the number of shipping agents that provide data for the service, which influences the quality of the service. To estimate the value of the data provided by those companies, we need to model how the lack of this information affects the value of the inland manifest service for terminal operators. The numeric parameters used in this model are based on expert opinions. However, they can also be estimated in a more precise manner by modeling the barge visit process and conducting an adoption sensitivity analysis. In the Appendix 2.A, we provide the exact parameters used in our simulation and detailed results. Figure 2.2 illustrates the dependency of the terminal savings per call on the barge operator and shipping agents' adoption assumed in our model. For terminals to achieve their savings shipping agents' adoption is more crucial. The service facilitates the digitization of the inland manifest declaration, which should cover all containers loaded on a barge at a terminal. These containers can have different origins and, in many cases, are brought to a terminal operator by different shipping agents. Therefore, typically, one declaration contains information provided by multiple shipping agents. What happens if one or more of these agents have not provided the information digitally? In such a case, we assume that this information has to be provided manually by terminal workers, which will significantly decrease the labor cost and time savings obtained by a terminal operator from using the service.

The savings for barge operators come from three directions. First, they obtain gains in administrative efficiency from the digitization of the information exchange. Second, barge operators gain in operational efficiency from faster turnaround times for barge vessels at the terminals. Finally, barge operators can also benefit from more efficient information exchanges among the authorities, which can result in a lower number of administrative checks or at least better coordination such that the same barge is not stopped multiple times by different agencies during one trip. In a similar fashion to the

Figure 2.2: Average savings per call for a terminal as a function of number of barge calls made at the terminal that went through the system (N^1_{PCS}) and total number of containers transported via the terminal which went through the system (NC^1_{PCS})



$$\bar{S_T}^j\left(\frac{N^j_{PCS}}{N^j_{Total}},\frac{NC^j_{PCS}}{NC^j_{Total}}\right)=15\cdot\left(\frac{NC^j_{PCS}}{NC^j_{Total}}\right)^4+\frac{(30-15)\cdot\left(\frac{NC^j_{PCS}}{NC^j_{Total}}\right)^4}{\left(1+1.5\cdot e^{-10\cdot\left(\frac{N^j_{PCS}}{N^j_{Total}}-0.5\right)}\right)^{\frac{1}{1.5}}}$$

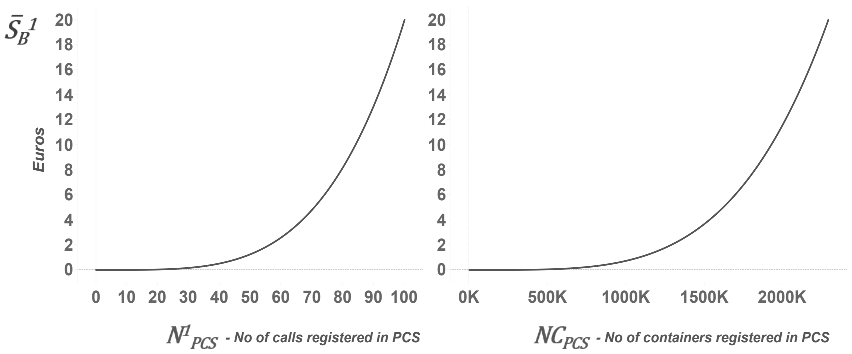
previous case, the value of the service for the barge can be expressed in the following manner:

$$V^i_B=\bar{S_B}^i\left(\frac{N^i_{PCS}}{N^i_{Total}},\frac{NC_{PCS}}{NC_{Total}}\right)\cdot N^i_{PCS}, \qquad (2.6)$$

V^i_B – represents the value of the inland manifest service for barge operator i; $\bar{S_B}^i$ – represents the average saving per call for a barge operator i; N^i_{PCS} – represents the number of calls in the system made by barge operator i during a period; and NC_{PCS} – represents the number of containers in the system for which shipping agents provided information during the year.

The amount of savings per call that a barge operator receives from using the service depends on the number of terminals and the number of shipping agents that have provided information for the service (see the illustration in Figure 2.3). In the case of the inland manifest service, the participation of terminal operators is more important relative to the participation of barge operators. Ideally, for the service to create the appropriate declaration, all the terminals should provide information to the PCS. Otherwise, the declaration created by the service is incomplete.

Figure 2.3: Average savings per call for a barge as a function of number of calls made barge that went through the system (N^1_{PCS}) and the number of containers transported through the port which went through the system (NC_{PCS})



$$\bar{S_B}^i\left(\frac{N^i_{PCS}}{N^i_{Total}}, \frac{NC_{PCS}}{NC_{Total}}\right) = 20 \cdot \left(\frac{N^i_{PCS}}{N^i_{Total}}\right)^4 \cdot \left(\frac{NC_{PCS}}{NC_{Total}}\right)^4.$$

Under the full adoption assumption, the value brought about by the information service is €1,040,000. However, we cannot expect terminal and barge operators to reimburse all of the savings that they created in the form of user fees. We must make assumptions regarding their willingness-to-pay for the service. Expert estimations from the representatives of the PCS estimate the willingness-to-pay at approximately 20% of the savings ($\alpha = 0.2$). We assume that this share is independent of company size and type. In this case, the total value to be divided among service producers equals €163,000 (€$1,040,000 \cdot 0.2 -$ €$45,000$). In such a case, we must adjust consumer willingness-to-pay for the costs incurred by the PCS provider. In the Appendix 2.A, we provide detailed results of all of the calculations at the individual company level.

2.5.3 Contributions' fair value

Now that we have estimated the value that users receive from the service, we need to estimate the relative contribution of each data provider. In the case of the inland manifest service, no companies are pure consumers of the system. Both terminal operators and barge operators receive value from using the service and provide data to the system. To avoid overestimating the value of their participation, we need to consider these roles separately: barge operators as data providers and barge operators as consumers, and terminal operators as data providers and terminal operators as consumers. Therefore, hypothetically, a company can use the system and pay its fees but does not have to make its data available for use for other companies. Only those in the data provider role will be reimbursed for participation in the system, which can be done by assuming 100% adoption from the consumer side in the characteristic function. Thus, we have the following players in the game: $TP = \{TP_j\}$ — represents the set of terminals-providers; $TC = \{TC_i\}$ — represents the set of terminals-consumers; $BP = \{BP_b\}$ — represents the set of barges-providers; $BC = \{BC_c\}$ — represents the set of barges-consumers; and $A = \{A_k\}$ — represents the set of shipping agents. $N = TP \cup BP \cup PCS \cup A$ — represents the superset of providers.
For a coalition S ($S \subseteq N$): $S \cap TP = S_T$; $S \cap BP = S_B$; $S \cap A = S_A$.
Characteristic function of the game:

$$v(S) = \begin{cases} 0 & \text{if } S_B = \emptyset \text{ or } S_T = \emptyset \text{ or } S_A = \emptyset \\ \sum_{j \in TC} \alpha \cdot V_T^j + \sum_{i \in BC} \alpha \cdot V_B^i - DC & \text{otherwise,} \end{cases} \tag{2.7}$$

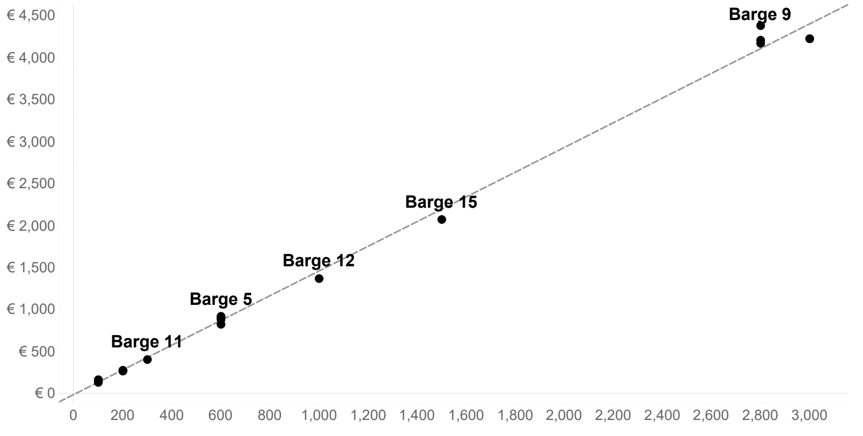
In Appendices 2.B and 2.C, we provide detailed expressions that can be used to calculate the Shapley values for this characteristic function and the R-script used for calculations. In the Appendix 2.B, we specify lemmas that were used to transform the regular Shapley value expression by benefiting from the specific form of our characteristic function. This transformation allowed for the calculation of the Shapley value within a reasonable time, whereas the original formula is too computationally expensive to be applied to real-life, large problems.

Based on the Shapley value principle, shipping agents combined receive the largest share of the total pie (approximately 66%) relative to the other two network roles. This statement is driven by the fact that the participation of shipping agents affects the service value creation for each user, barge and terminal operators alike. The participation of terminal operators is only important for barge operators who deal with them and vice versa. Hence, the Shapley values of barge operators and terminal operators are lower relative to the combined Shapley values of shipping agents.

The Shapley values of barge operators are highly correlated with their market shares expressed in the number of calls (see Figure 2.4). This correlation is mainly driven by the fact that the terminal service value to which they contribute is directly proportional to the number of calls in the system. Hence, the more calls the barge makes at the port, the more important is its participation for the terminals. However, there is no exact linear dependency. For instance, barge operators 1,2, and 3 make 100 calls per year each, but their Shapley values differ because they work with different terminal operators. This is caused by the differences in the network positions that those barge operators occupy. In the next chapter of this dissertation, we demonstrate that a linear dependency exists between Shapley values and the number of messages exchanged via the system (in our case, number of calls) if consumers' savings per message are constant and do not depend on data providers' adoption rate. However, this is not the case for the inland manifest service. The communication network structure, specifically its density, influences the Shapley value of individual barge operators. The Shapley value is also affected by the barge operator network position. For this reason, we refrain from finding the Shapley value approximations because they will be very tightly connected to this case and information exchange structure.

The influence of the network structure on Shapley values can be better illustrated with the case of shipping agents, for which it is more pronounced. Shipping agents influence the service value produced for terminal and barge operators in a more indirect manner by influencing the average savings per call. The average savings per call generated by the system depends on the relative share of containers that goes through the system for each terminal.

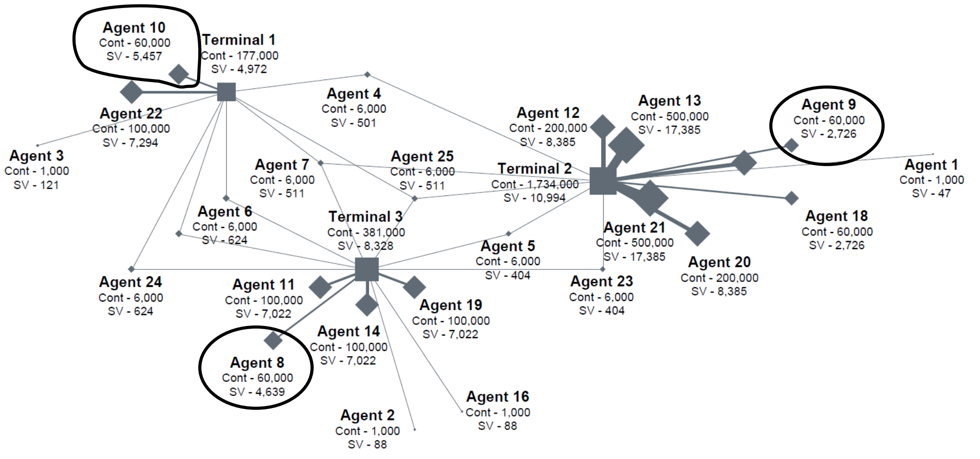
Figure 2.4: Shapley values of barge operators dependent on the number of calls made.



Therefore, the Shapley value of shipping agents depends on the number of containers transported. However, the correlation is far weaker than in the case of barge Shapley values and their market shares. Shipping agents 8, 9, and 10 transport the same number of containers, but their Shapley values differ (see Figure 2.5). Shipping agent 10, who works with terminal operator 1, has the highest Shapley value of approximately 9 cents per 100 containers. Shipping agent 9, who works with terminal operator 2, has the lowest Shapley value of approximately 4.5 cents per 100 containers. In this case, the agents' Shapley values have a reverse dependency on the size of the container terminal with which they are working, which is explained by the fact that the savings per container achieved by terminal operators depend on the share of containers in the system out of the total number of containers served by the terminal. Hence, for smaller terminal operators, the value of each container in the system has a stronger impact on the savings achieved relative to larger terminal operators.

The number of terminal operators in our network is relatively low. Hence, generalizing from such a low number of observations is difficult. However, the number of barge calls that terminals receive plays a more important role than the number of containers that go through the terminal to determine the

Figure 2.5: Shapley values of terminal operators and shipping agents dependent on the container network structure.



magnitude of the Shapley value. This is mainly driven by the shape of the service value function for barge operators.

2.5.4 Individual user fees and retributions to providers

Based on the calculated Shapley values, we can estimate the user fees and provider retributions. First, the community members should cover the costs incurred by the PCS provider. Once the development costs are covered, the remaining part of the value created is distributed among the data providers. To calculate the final amount that a community member should pay or receive from the system, we need to estimate the difference between users' willingness-to-pay estimations and the value of their contributions. If the latter is higher than the former, then the community member receives net retribution from the system; if the willingness-to-pay estimation is higher than the value of member's contribution, then this difference needs to be collected in the form of fees for using the system.

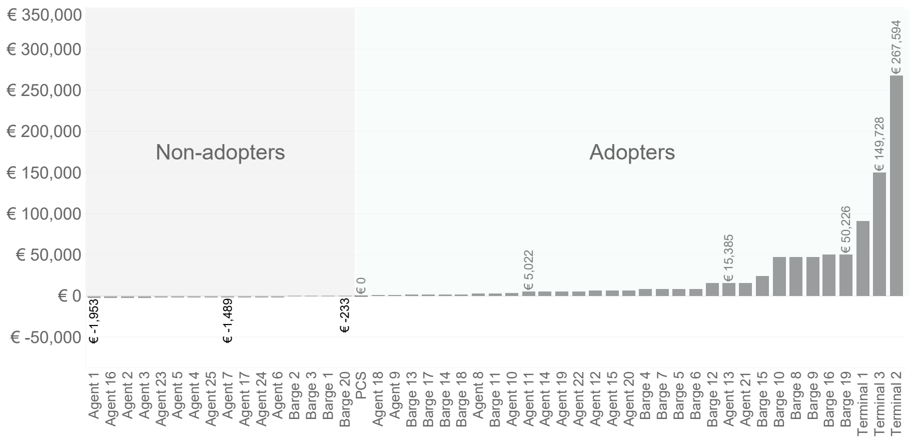
Under the suggested fair sharing scheme, terminal operators are asked to pay €100,506 in fees, and barge operators are asked to pay €52,878 in fees. The collected sum covers the services of the PCS provider, and shipping agents receive €108,381.

The resulting terminal and barge operator fees can be found in the Appendix 2.A. Because willingness-to-pay was directly proportional to the number of calls and the Shapley values of terminal operators were highly correlated with the number of calls, the resulting user fees exhibit almost a linear dependence on the number of barge calls made at the terminal. Running a linear regression analysis produced the following formula for barge fees: $BargeFees = 2.53 \cdot N_{PCS} + 13.37 (R^2 = 0.99)$, where N_{PCS} represents the number of barge calls registered in the system. The barge operators are expected to pay approximately €2.53 per call that goes through the system. In a similar manner, running a linear regression analysis produced the following formula for terminal fees: $TerminalFees = 5.20 \cdot N_{PCS} - 2527.28 (R^2 = 0.99)$, where N_{PCS} represents the number of barge calls registered in the system. Terminal operators are asked to pay €5.20 per call. In this case, the high level of correlation of users fees to the number of calls can make it easier for the provider to introduce the new system because it has a structure similar to traditional transactional pricing strategies that are proportional to the number of messages exchanged through the system. However, we must stress that this high correlation is mainly driven by the specifics of the information service that we study and the structure of the information exchange network. As we show in the next chapter, a higher communication network density of the community results in a stronger network effect that affects Shapley values, which reduces the correlation between user fees and the number of messages exchanged.

From the rational point of view, a community member will adopt the service only if gains from using it exceed the costs. For terminal and barge operators, the gains from using the service are represented by the savings that it generates. The costs of using the service for these community members are user fees and initial expenses from establishing the connection to the platform and adjusting business processes. For shipping agents, the gains from using the service are represented by the retribution that it receives from the community for the data provided. The costs are made up of one-off expenses required to establish the connection to the platform and to adjust business processes.

The one-off expenses required to establish a connection with the system and adjust internal business processes annualized over five years were estimated to be €5,000 for terminal operators, €2,000 for barge operators, and €2,000 for shipping agents. Based on the comparison between gains (user value and retributions) and costs (user fees and adoption costs), we find that adopting the service would be irrational for four barge operators and twelve shipping agents because the costs outweigh their gains. All other community members would benefit from the service adoption (see Figure 2.6).

Figure 2.6: Participation profits for selected community members.



In this case, acknowledging that 100% adoption is not in the interest of the port community is important. Community members who cannot adopt the service make very few calls or bring very few containers to the port during the year. The Shapley value reflects the potential savings that their service adoption generates for the community. If the retribution is not high enough to cover the required expenses, then the community is better off handling those rare ship and barge visits in a traditional manner with paper based declarations.

2.6 Discussion

We find that traditional cost-based pricing methods in the form of transaction and subscription fees are ill-equipped to cope with two business community platform characteristics: 1) users of the system also can be contributors; and 2) the services within the platform can have a hierarchical structure in which old services provide input for new services, as demonstrated in the port community system example. We develop a new pricing mechanism based on user value estimations and fair sharing, which attempts to take into account these characteristics to align the incentives of individual community members with common community goals.

The proposed scheme has a number of advantages. First, it maximizes the community benefit from the introduction of a PCS service by ensuring that it is beneficial for the relevant companies to adopt the system by estimating the value of the contribution of individual data providers and rewarding them accordingly.

Second, the proposed scheme is generalizable to a variety of information services. The majority of information service providers develop business cases in which they evaluate the savings that users can achieve after adopting the system. The extra step required is to evaluate how the adoption of the service by data providers influences the savings that can be achieved. Many operations research studies already made these types of estimations (Sahin and Robinson 2002, Huang et al. 2003, Ye and Wang 2013). These estimations do not need to be very precise as long as community members accept that they reflect reality.

Third, the scheme encourages data reuse in interconnected information services and, by this, improves the chances of multiple complementing services being developed. For instance, in our case the inland manifest service reuses the data provided by terminal and barge operators for the inland transport planning service. For certain small barge operators, adopting the inland transport planning service alone may not be beneficial because they do not receive enough savings from it, and their participation is not valuable enough for the community. However, once the inland manifest service is introduced, the value of those barge operators' participation for the community will grow because these data can be reused to produce the manifest and generate additional savings for terminal operators. The introduction of the additional service will create additional incentives for data providers to adopt the business community platform.

The rewards for data provision can improve the variety of information services offered to the business community. Currently, companies are willing to provide data for the services from which they receive direct benefits, predominantly in the form of operational savings. If the PCS provider intends to reuse the data for services from which data providers do not benefit directly, the provider usually has to overcome quite a lot of resistance and challenges. In our example, shipping agents receive no direct benefits from providing data to the inland manifest service. However, the monetary reward introduced in our pricing scheme provides an additional incentive for shipping agents to provide data to the platform. Monetary rewards can encourage companies to provide data, even if the data are being used only for services for other companies.

In this paper, we focused purely on the monetary aspect of data sharing. However, we acknowledge that aspects such as quality control, data provenance, and legal regime play a significant role in establishing a data marketplace (Koutroumpis et al. 2017). The pricing mechanism detailed in this paper has a number of shortcomings as well. First, the mechanism estimates the service value and corresponding provider rewards as if all users and providers existing in the community have adopted the service. In reality, information service adoption is stretched over a period and might not even attain the maximum level of adoption. The community provider has the choice of either estimating fees and rewards under the assumption of the optimum adoption level and subsidizing the system until that level is reached or gradually adjust information service pricing to reflect service adoption levels. The second approach might discourage early adopters if their savings from using the service are not substantial enough.

Second, already existing PCS services have been charged based on a traditional cost-based approach — the combination of transaction and subscription fees. Moving to another pricing approach that might result in the redistribution of benefits among community members will be a challenge. The new pricing mechanism may only applicable to newly introduced services for a certain transition period to allow the community to become acquainted with the new pricing principle. However, to gain the full benefits of the new pricing mechanism, it will need to be back rolled to the old services as well to ensure pricing fairness at all levels.

Finally, we applied the Shapley value concept to evaluate a fair reward for data provision. This is not the only existing fair sharing mechanism and not a concept that is widely accepted in practice. Significant effort will be required to ensure that the business community accepts the suggested principles as fair. The ways to achieve this could be joint workshops with industry representatives and the PCS provider that are targeted at achieving consensus regarding the user value and fair reward estimation for the service in question. In this case, that the PCS provider is viewed as a neutral and objective party that acts in the interests of the community as a whole is important.

2.7 Conclusion

In this paper, we focus on pricing challenges faced by business community platforms. We develop a new pricing mechanism that addresses two characteristics specific to business community platforms. These characteristics are 1) system users can be simultaneously system contributors; and 2) services within a platform can have a hierarchical structure in which old services provide input for new services. We identified these two characteristics with the help of an exploratory case study in a seaport setting. To the best of our knowledge these issues have not been discussed in the literature.

The pricing mechanism that we developed to address these challenges is based on two main principles: user value estimation and fair sharing. We rely on the Shapley value concept to evaluate the fair reward to the data providers that contribute to the system. The application of the pricing mechanism is demonstrated at the example of a single information service developed for a port community. The main advantage of the proposed pricing mechanism is that it aligns the incentives of individual community members with the business community-wide interests. However, we foresee that the introduction of the suggested pricing approach will face a number of challenges. One of the major ones is gaining acceptance and support from business community members who are accustomed to traditional information systems pricing mechanisms, especially in a situation in which the benefits of adopting the system will be redistributed relative to an earlier established “status quo.”

We believe that both IOS practitioners and IOS researchers will benefit from further investigations into business community platform pricing challenges. Clearly, these information systems have a number of unique characteristics related to their collective nature. We envision that the adoption of business community platforms can be significantly improved if more innovative pricing approaches specific to the system context are applied. Furthermore, the design of the systems themselves could be enhanced to properly incentivize community members to share more data with the wider business community.

2.A Model inputs and outputs

Value functions of terminal and barge operators

The value of the service for the terminal can be found as:

$$V_T^j = \bar{S_T}^j \left(\frac{N_{PCS}^j}{N_{Total}^j}, \frac{NC_{PCS}^j}{NC_{Total}^j} \right) \cdot N_{PCS}^j, \tag{8}$$

where V_T^j - value of the inland manifest service for a terminal operator j
$\bar{S_T}^j$ - average saving size per call for a terminal operator j and can be found as can be found as in Formula (9)
N_{PCS}^j - number of calls in the system made at a terminal operator j over a period of time
$\frac{N_{PCS}^j}{N_{Total}^j}$ - share of calls at the terminal j that went through the system out of total calls at the terminal j for that period of time
NC_{PCS}^j - number of containers handled at terminal j for which data were provided to PCS
$\frac{NC_{PCS}^j}{NC_{Total}^j}$ - proportion of containers handled at terminal j for which data to PCS were provided out of total number of containers handled at the terminal j

$$\bar{S_T}^j \left(\frac{N_{PCS}^j}{N_{Total}^j}, \frac{NC_{PCS}^j}{NC_{Total}^j} \right) = 15 \cdot \left(\frac{NC_{PCS}^j}{NC_{Total}^j} \right)^4 + \frac{(30-15) \cdot \left(\frac{NC_{PCS}^j}{NC_{Total}^j} \right)^4}{\left(1 + 1.5 \cdot e^{-10 \cdot \left(\frac{N_{PCS}^j}{N_{Total}^j} - 0.5 \right)} \right)^{\frac{1}{1.5}}} \tag{9}$$

The value of the service for the barge can be found as:

$$V_B^i = \bar{S_B}^i \left(\frac{N_{PCS}^i}{N_{Total}^i}, \frac{NC_{PCS}}{NC_{Total}} \right) \cdot N_{PCS}^i, \tag{10}$$

V_B^i - value of the Inland manifest service for a barge operator i
$\bar{S_B}^i$ - average saving size per call for a barge operator i and can be found as in Formula (11)

N^i_{PCS} - number of calls in the system made by a barge operator i over the period of time
N^i_{Total} — total number of calls made by a barge operator i over the period of time
NC_{PCS} — number of containers in the system for which shipping agents provided information over the year
NC_{Total} — total number of containers that were imported via the port over the year.

$$\bar{S_B}^i\left(\frac{N^i_{PCS}}{N^i_{Total}}, \frac{NC_{PCS}}{NC_{Total}}\right) = 20 \cdot \left(\frac{N^i_{PCS}}{N^i_{Total}}\right)^4 \cdot \left(\frac{NC_{PCS}}{NC_{Total}}\right)^4, \tag{11}$$

Table 1: Number of calls made by barges in the port over a year

	Terminal 1	Terminal 2	Terminal 3
Barge 1	100	0	0
Barge 2	0	100	0
Barge 3	0	0	100
Barge 4	0	300	300
Barge 5	300	300	0
Barge 6	300	0	300
Barge 7	200	200	200
Barge 8	800	800	1,200
Barge 9	1,200	800	800
Barge 10	800	1,200	800
Barge 11	0	300	0
Barge 12	0	1,000	0
Barge 13	0	200	0
Barge 14	0	0	200
Barge 15	0	1,500	0
Barge 16	0	2,000	1,000
Barge 17	0	200	0
Barge 18	0	0	200
Barge 19	0	2,000	1,000
Barge 20	100	0	0

Table 2: Number of containers brought by shipping agents to the port over a year

	Terminal 1	Terminal 2	Terminal 3
Agent 1	0	1,000	0
Agent 2	0	0	1,000
Agent 3	1,000	0	0
Agent 4	3,000	3,000	0
Agent 5	0	3,000	3,000
Agent 6	3,000	0	3,000
Agent 7	2,000	2,000	2,000
Agent 8	0	0	60,000
Agent 9	0	60,000	0
Agent 10	60,000	0	0
Agent 11	0	0	100,000
Agent 12	0	200,000	0
Agent 13	0	500,000	0
Agent 14	0	0	100,000
Agent 15	0	200,000	0
Agent 16	0	0	1,000
Agent 17	3,000	0	3,000
Agent 18	0	60,000	0
Agent 19	0	0	100,000
Agent 20	0	200,000	0
Agent 21	0	500,000	0
Agent 22	100,000	0	0
Agent 23	0	3,000	3,000
Agent 24	3,000	0	3,000
Agent 25	2,000	2,000	2,000

Table 3: Shapley values, user fees, retributions, and participation profits of individual companies

Participation profit calculated as *User value + Retribution - Fees - Adoption costs.* Adoption costs were estimated to be €5,000 for terminal operators and €2,000 for barge operators.

Company	User value	Shapley value	Fees	Retribution	Participation profit
Terminal 1	114000	4972	17828	0	91172
Terminal 2	327000	10994	54406	0	267594
Terminal 3	183000	8328	28272	0	149728
Barge 1	2000	167	233	0	-233
Barge 2	2000	135	265	0	-265
Barge 3	2000	139	261	0	-261
Barge 4	12000	827	1573	0	8427
Barge 5	12000	910	1490	0	8510
Barge 6	12000	922	1478	0	8522
Barge 7	12000	885	1515	0	8485
Barge 8	56000	4209	6991	0	47009
Barge 9	56000	4382	6818	0	47182
Barge 10	56000	4172	7028	0	46972
Barge 11	6000	407	793	0	3207
Barge 12	20000	1371	2629	0	15371
Barge 13	4000	271	529	0	1471
Barge 14	4000	279	521	0	1479
Barge 15	30000	2075	3925	0	24075
Barge 16	60000	4226	7774	0	50226
Barge 17	4000	271	529	0	1471
Barge 18	4000	279	521	0	1479
Barge 19	60000	4226	7774	0	50226
Barge 20	2000	167	233	0	-233

Table 4: Shapley values, user fees, retributions, and participation profits of individual companies (cont.)

Participation profit calculated as *User value + Retribution - Fees - Adoption costs*. User value is equal to for agents and PCS. Adoption costs were estimated to be €5,000 for terminal operators and €2,000 for shipping agents.

Company	Shapley value	Fees	Retribution	Participation profit
Agent 1	47	0	47	-1953
Agent 2	88	0	88	-1912
Agent 3	121	0	121	-1879
Agent 4	501	0	501	-1499
Agent 5	404	0	404	-1596
Agent 6	624	0	624	-1376
Agent 7	511	0	511	-1489
Agent 8	4639	0	4639	2639
Agent 9	2726	0	2726	726
Agent 10	5457	0	5457	3457
Agent 11	7022	0	7022	5022
Agent 12	8385	0	8385	6385
Agent 13	17385	0	17385	15385
Agent 14	7022	0	7022	5022
Agent 15	8385	0	8385	6385
Agent 16	88	0	88	-1912
Agent 17	624	0	624	-1376
Agent 18	2726	0	2726	726
Agent 19	7022	0	7022	5022
Agent 20	8385	0	8385	6385
Agent 21	17385	0	17385	15385
Agent 22	7294	0	7294	5294
Agent 23	404	0	404	-1596
Agent 24	624	0	624	-1376
Agent 25	511	0	511	-1489
PCS	45000	0	45000	0

2.B Shapley value transformations

Before we derive the expression for Shapley values of different players, we need to formulate a number of lemmas which we will regularly rely on.

Lemmas

Lemma 1. Let N_1 and N_2 be two disjoint sets and $N = N_1 \cup N_2$. For $S \subseteq N$ we define $S_1 = S \cap N_1$ and $S_2 = S \cap N_2$. If g satisfies $g(S) = g(S_1, |S_2|)$, where $|S_2|$ is cardinality of S_2 then

$$\sum_{S \subseteq N} g(S) = \sum_{S_1} \sum_{l=0}^{|N_2|} \binom{|N_2|}{l} g(S_1, l)$$

Proof.

$$\sum_{S \subseteq N} g(S) = \sum_{S \subseteq N} g(S_1, |S_2|) = \sum_{S_1 \subseteq N_1} \sum_{S_2 \subseteq N_2} g(S_1, |S_2|) = \sum_{S_1} \sum_{l=0}^{|N_2|} \binom{|N_2|}{l} g(S_1, l)$$

□

Lemma 2. If N is a superset and every element $j \in N$ has a value m_j associated with it and f is a function that depends on the size of a set $|S|$ and on $m_S = \sum_{j \in S} m_j$ then

$$\sum_{S \subseteq N} f(m_S, |S|) = \sum_{k=0}^{m_N} \sum_{i=0}^{|N|} \lambda_{ki} f(k, i),$$

where λ_{ki} — the number of sets S with $m_S = k$ and $|S| = i$.

Proof. The statement follows from the fact that λ_{ki} exactly administers how many times $f(m_S, |S|)$ appears in the summation for $m_S = k$ and $|S| = i$. □

Lemma 3. Define λ_{ki}^{n-1} as the number of sets $S \subseteq \{1, \ldots, n-1\}$ with $m_S = k$ and $|S| = i$, where $m_S = \sum_{j \in S} m_j$.

Then λ_{ki}^n is defined recursively by:
$\lambda_{ki}^n = \lambda_{ki}^{n-1}$ when $0 \leq k \leq M$ ($M = \sum_{j=1}^{n-1} m_j$) and $0 \leq i \leq n-1$
$\lambda_{ki}^n = \lambda_{k-m_n,i-1}^{n-1}$ when $m_n \leq k \leq M + m_n$ and $1 \leq i \leq n$
if $m_n \leq M$ then $\lambda_{ki}^n = \lambda_{ki}^{n-1} + \lambda_{k-m_n,i-1}^{n-1}$ when $m_n \leq k \leq M$ and $1 \leq i \leq n-1$
if $m_n \geq M$ then $\lambda_{ki}^n = 0$ when $M \leq k \leq m_n$ and $0 \leq i \leq n$

Proof. Let us define $P^n(x,y) = \prod_{j=1}^{n-1}(y + x_j^m)$.
It can also be reformulated as:
$P^{n-1}(x,y) = \sum_{S \subseteq \{1,\ldots,n-1\}} x^{m_S} y^{n-1-|S|}$
Based on Lemma 2:
$P^{n-1}(x,y) = \sum_{k=0}^{M} \sum_{i=0}^{n-1} \lambda_{ki}^{n-1} x^k y^{n-1-i}$, where $M = \sum_{j=1}^{n-1} m_j$.
Let us add an element n with associated m_n:

$$P^n(x,y) = \sum_{S \subseteq \{1,\ldots,n\}} x^{m_S} y^{n-|S|} = \sum_{k=0}^{M+m_n} \sum_{i=0}^{n} \lambda_{ki}^n x^k y^{n-i} \tag{12}$$

Alternatively we may also write:

$$\begin{aligned} P^n(x,y) = P^{n-1}(x,y) \cdot (y + x^{m_n}) &= \left(\sum_{k=0}^{M} \sum_{i=0}^{n-1} \lambda_{ki}^{n-1} x^k y^{n-1-i} \right) \cdot (y + x^{m_n}) = \\ &= \sum_{k=0}^{M} \sum_{i=0}^{n-1} \lambda_{ki}^{n-1} x^k y^{n-i} + \sum_{k=0}^{M} \sum_{i=0}^{n-1} \lambda_{ki}^{n-1} x^{k+m_n} y^{n-1-i} = \\ &= \sum_{k=0}^{M} \sum_{i=0}^{n-1} \lambda_{ki}^{n-1} x^k y^{n-i} + \sum_{k=m_n}^{M+m_n} \sum_{i=1}^{n} \lambda_{k-m_n,i-1}^{n-1} x^k y^{n-i} \end{aligned} \tag{13}$$

Combining Formula (12) and Formula (13):

$$\sum_{k=0}^{M+m_n} \sum_{i=0}^{n} \lambda_{ki}^n x^k y^{n-i} = \sum_{k=0}^{M} \sum_{i=0}^{n-1} \lambda_{ki}^{n-1} x^k y^{n-i} + \sum_{k=m_n}^{M+m_n} \sum_{i=1}^{n} \lambda_{k-m_n,i-1}^{n-1} x^k y^{n-i} \tag{14}$$

From Formula (14) we can easilty derive the recursive defintion for λ_{ik}^n given in the lemma. □

Lemma 4. If N is a superset and g is a function that depends on element $i \in S$ and set $S \subseteq N$ then

$$\sum_{S \subseteq N} \sum_{i \in S} g(i, S) = \sum_{i \in N} \sum_{S \ni i} g(i, S).$$

Proof.

$$\sum_{S \subseteq N} \sum_{i \in S} g(i, S) = \sum_{S \subseteq N} \sum_{i \in N} g(i, S) \mathbb{1}_S(i),$$

$$\text{where } \mathbb{1}_S(i) = \begin{cases} 1 & \text{if } i \in S, \\ 0 & \text{if } i \notin S. \end{cases}$$

$$\sum_{S \subseteq N} \sum_{i \in N} g(i, S) \mathbb{1}_S(i) = \sum_{i \in N} \sum_{S \subseteq N} g(i, S) \mathbb{1}_S(i) = \sum_{i \in N} \sum_{S \ni i} g(i, S).$$

□

Shapley value of a terminal operator

$TP = \{TP_1, \ldots, TP_o\}$ — the set of terminals-providers
$TC = \{TC_1, \ldots, TC_o\}$ — the set of terminals-consumers
$BP = \{BP_1, \ldots, BP_q\}$ — the set of barges-providers
$BC = \{BC_1, \ldots, BC_q\}$ — the set of barges-consumers
$A = \{A_1, \ldots, A_r\}$ — the set of shipping agents $N = TP \cup BP \cup PCS \cup A$ — the superset of providers
For a coalition S ($S \subseteq N$):
$S \cap TP = S_T$, S_T — the set of terminals-providers in a coalition S
$S \cap BP = S_B$, S_B — the set of barges-providers in a coalition S
$S \cap A = S_A$, S_A — the set of shipping agents in a coalition S
Characteristic function of the game:

$$v(S) = \begin{cases} 0 & \text{if } S_B = \emptyset \text{ or } S_T = \emptyset \text{ or } S_A = \emptyset \\ \sum_{j \in TC} V_T^j + \sum_{i \in BC} V_B^i - DC & \text{otherwise,} \end{cases} \tag{15}$$

where V_T^j — value of the service for Terminal j
V_B^i — value of the service for Barge i

DC — size of the software development and infrastructure support costs

$$V_T^j = g^j\left(\frac{\sum_{i\in S_B} n_{ij}}{\sum_{i\in BP} n_{ij}}, \frac{\sum_{a\in S_A} nc_{aj}}{\sum_{a\in A} nc_{aj}}\right)\cdot \sum_{i\in S_B} n_{ij}, \tag{16}$$

where n_{ij} — number of calls made by Barge i at Terminal j; nc_{aj} — number of containers brought to Terminal j by Shipping Agent a.

$$V_B^i = f^i\left(\frac{\sum_{j\in S_T} n_{ij}}{\sum_{j\in TP} n_{ij}}, \frac{\sum_{a\in S_A} nc_{a}}{\sum_{a\in A} nc_{a}}\right)\cdot \sum_{j\in S_T} n_{ij} \tag{17}$$

where nc_a — number of containers brought to the port by Shipping Agent a.

Shapley value of a terminal-provider TP_t based on the general Formula 2.1:

$$\varphi_t(v) = \sum_{S\subseteq N\setminus\{TP_t\}} \frac{|S|!(|N|-|S|-1)!}{|N|!}\cdot\Big(v(S\cup\{TP_t\}) - v(S)\Big) \tag{18}$$

Added value from the participation of terminal-provider TP_t for a coalition S:

If $S_BP = \emptyset$ or $S_A = \emptyset$ then $v(S\cup\{TP_t\}) - v(S) = 0$ else

$$\begin{aligned} v(S\cup\{TP_t\}) - v(S) =& \sum_{j\in TC} V_T^j(S_B, S_A) + \sum_{i\in BC} V_B^i(S_T\cup\{TP_t\}, S_A) - DC - \\ & - \sum_{j\in TC} V_T^j(S_B, S_A) - \sum_{i\in BC} V_B^i(S_T, S_A) + DC = \\ =& \sum_{i\in BC}\Bigg[f^i\Big(\frac{\sum_{j\in S_T\cup\{TP_t\}} n_{ij}}{\sum_{j\in TP} n_{ij}}, \frac{\sum_{a\in S_A} nc_a}{\sum_{a\in A} nc_a}\Big)\cdot \sum_{j\in S_T\cup\{TP_t\}} n_{ij} - \\ & - f^i\Big(\frac{\sum_{j\in S_T} n_{ij}}{\sum_{j\in TP} n_{ij}}, \frac{\sum_{a\in S_A} nc_a}{\sum_{a\in A} nc_a}\Big)\cdot\sum_{j\in S_T} n_{ij}\Bigg] \end{aligned} \tag{19}$$

As we only have terminal-providers, barge-providers, and shipping agents in any given coalition of providers S, $|S| = |S_A| + |S_T| + |S_B|$. Taking into account Formula 19, Formula 18 can be rewritten:

$$\varphi_t(v)= \sum_{S \subseteq N \setminus \{TP_t\}} \frac{(|S_A|+|S_T|+|S_B|)!(|N|-|S_A|-|S_T|-|S_B|-1)!}{|N|!} \cdot \Big(v(S\cup\{TP_t\})-v(S)\Big) = \\ = \sum_{\substack{S \subseteq TP \cup BP \cup A \setminus \{TP_t\} \\ |S_B|>0 \\ |S_A|>0}} \frac{(|S_A|+|S_T|+|S_B|)!(|N|-|S_A|-|S_T|-|S_B|-1)!}{|N|!} \cdot \\ \cdot \sum_{i \in BC} \Bigg[f^i\Big(\frac{\sum_{j\in S_T\cup\{TP_t\}} n_{ij}}{\sum_{j\in TP} n_{ij}}, \frac{\sum_{a\in S_A} nc_a}{\sum_{a\in A} nc_a}\Big) \cdot \sum_{j\in S_T\cup\{TP_t\}} n_{ij} - \\ - f^i\Big(\frac{\sum_{j\in S_T} n_{ij}}{\sum_{j\in TP} n_{ij}}, \frac{\sum_{a\in S_A} nc_a}{\sum_{a\in A} nc_a}\Big) \cdot \sum_{j\in S_T} n_{ij} \Bigg] \tag{20}$$

Based on Lemma 1 we can transform the expression in the following way:

$$\varphi_t(v)= \sum_{i\in BC} \sum_{b=0}^{|BP|} \binom{|BP|}{b} \sum_{\substack{S \subseteq TP \cup A \setminus \{TP_t\} \\ |S_A|>0}} \frac{(|S_A|+|S_T|+b)!(|N|-|S_A|-|S_T|-b-1)!}{|N|!} \cdot \\ \cdot \Bigg[f^i\Big(\frac{\sum_{j\in S_T\cup\{TP_t\}} n_{ij}}{\sum_{j\in TP} n_{ij}}, \frac{\sum_{a\in S_A} nc_a}{\sum_{a\in A} nc_a}\Big) \cdot \sum_{j\in S_T\cup\{TP_t\}} n_{ij} - \\ - f^i\Big(\frac{\sum_{j\in S_T} n_{ij}}{\sum_{j\in TP} n_{ij}}, \frac{\sum_{a\in S_A} nc_a}{\sum_{a\in A} nc_a}\Big) \cdot \sum_{j\in S_T} n_{ij} \Bigg] \tag{21}$$

Based on Lemma 2 we can transform the expression in the following way:

$$\varphi_t(v)= \sum_{i\in BC} \sum_{b=0}^{|BP|} \binom{|BP|}{b} \sum_{\substack{S \subseteq A \\ |S_A|>0}} \sum_{m=0}^{|TP|-1} \sum_{k=0}^{\sum_{j\in TP} n_{ij}-n_{it}} \frac{(|S_A|+m+b)!(|N|-|S_A|-m-b-1)!}{|N|!} \cdot \\ \cdot LTB_{km}^{i\setminus t} \cdot \Bigg[f^i\Big(\frac{k+n_{it}}{\sum_{j\in TP} n_{ij}}, \frac{\sum_{a\in S_A} nc_a}{\sum_{a\in A} nc_a}\Big) \cdot (k+n_{it}) - f^i\Big(\frac{k}{\sum_{j\in TP} n_{ij}}, \frac{\sum_{a\in S_A} nc_a}{\sum_{a\in A} nc_a}\Big) \cdot k \Bigg] \tag{22}$$

where $LTB_{km}^{i\setminus t}$ — number of sets W such that $W \cap BC = \{BC_i\}$ and $TP_t \notin W$ and $W \cap A = \emptyset$ and $|W_T| = m$ (where m — number of terminals in the set W, we take into account in the summation the sets with zero terminals as well because we add Terminal operator TP_t which allows value creation) and $\sum_{j\in W_TP} n_{ij} = k$

Based on Lemma 2 we can transform the expression in the following way:

$$\varphi_t(v)=\sum_{i\in BC}\sum_{b=0}^{|BP|}\binom{|BP|}{b}\sum_{a=1}^{|A|}\sum_{p=0}^{\sum_{a\in A}nc_a}\sum_{m=0}^{|TP|-1}\sum_{k=0}^{\sum_{j\in TP}n_{ij}-n_{it}}\frac{(a+m+b)!(|N|-a-m-b-1)!}{|N|!}\cdot$$
$$\cdot LTB_{km}^{i\setminus t}\cdot LA_{pa}\cdot\Bigg[f^i\Big(\frac{k+n_{it}}{\sum_{j\in TP}n_{ij}},\frac{p}{\sum_{a\in A}nc_a}\Big)\cdot(k+n_{it})-$$
$$-f^i\Big(\frac{k}{\sum_{j\in TP}n_{ij}},\frac{p}{\sum_{a\in A}nc_a}\Big)\cdot k\Bigg], \tag{23}$$

LA_{pa} — number of sets R such that $R\cap BC=\emptyset$ and $R\cap BP=\emptyset$ and $R\cap TC=\emptyset$ and and $R\cap TP=\emptyset$ and $|R|=a$ (where a — number of shipping agents in the set R, we take into account in the summation the sets of size 1 and higher which allows value creation) and $\sum_{a\in R}nc_a=p$.

Taking into account PCS development costs:

$$\varphi_t(v)=\frac{\sum_{i\in BC}\sum_{j\in TC}n_{ij}\Big(f(1,1)+g(1,1)\Big)}{\sum_{i\in BC}\sum_{j\in TC}n_{ij}\Big(f(1,1)+g(1,1)\Big)+DC}\cdot$$
$$\sum_{i\in BC}\sum_{b=0}^{|BP|}\binom{|BP|}{b}\sum_{a=1}^{|A|}\sum_{p=0}^{\sum_{a\in A}nc_a}\sum_{m=0}^{|TP|-1}\sum_{k=0}^{\sum_{j\in TP}n_{ij}-n_{it}}\frac{(a+m+b)!(|N|-a-m-b-1)!}{|N|!}\cdot$$
$$\cdot LTB_{km}^{i\setminus t}\cdot LA_{pa}\cdot\Bigg[f^i\Big(\frac{k+n_{it}}{\sum_{j\in TP}n_{ij}},\frac{p}{\sum_{a\in A}nc_a}\Big)\cdot(k+n_{it})-$$
$$-f^i\Big(\frac{k}{\sum_{j\in TP}n_{ij}},\frac{p}{\sum_{a\in A}nc_a}\Big)\cdot k\Bigg] \tag{24}$$

Shapley value of a barge operator

Added value from the participation of barge-provider BP_b for a coalition S: If $S_TP=\emptyset$ or $S_A=\emptyset$ then $v(S\cup\{BP_b\})-v(S)=0$ else

$$v(S\cup\{BP_b\})-v(S)=\sum_{j\in TC}V_T^j(S_B\cup\{BP_b\},S_A)+\sum_{i\in BC}V_B^i(S_T,S_A)-DC-$$
$$-\sum_{j\in TC}V_T^j(S_B,S_A)-\sum_{i\in BC}V_B^i(S_T,S_A)+DC=$$
$$=\sum_{j\in TC}\Bigg[g^j\Big(\frac{\sum_{i\in S_B\cup\{BP_b\}}n_{ij}}{\sum_{i\in BP}n_{ij}},\frac{\sum_{a\in S_A}nc_{aj}}{\sum_{a\in A}nc_{aj}}\Big)\cdot\sum_{i\in S_B\cup\{BP_b\}}n_{ij}-$$
$$-g^j\Big(\frac{\sum_{i\in S_B}n_{ij}}{\sum_{i\in BP}n_{ij}},\frac{\sum_{a\in S_A}nc_{aj}}{\sum_{a\in A}nc_{aj}}\Big)\cdot\sum_{i\in S_B}n_{ij}\Bigg] \tag{25}$$

Shapley value of a barge-provider BP_b based on the general Formula 2.1:

$$\varphi_b(v) = \sum_{S \subseteq N \setminus \{BP_b\}} \frac{|S|!(|N|-|S|-1)!}{|N|!} \cdot \Big(v(S \cup \{BP_b\}) - v(S) \Big) \tag{26}$$

As we only have terminal-providers, barge-providers, and shipping agents in any given coalition of providers S, $|S| = |S_A| + |S_T| + |S_B|$. Taking into account Formula 25, Formula 26 can be rewritten:

$$\begin{aligned}
\varphi_b(v) = & \sum_{S \subseteq N \setminus \{BP_b\}} \frac{(|S_A|+|S_T|+|S_B|)!(|N|-|S_A|-|S_T|-|S_B|-1)!}{|N|!} \cdot \\
& \cdot \Big(v(S \cup \{BP_b\}) - v(S) \Big) = \\
= & \sum_{\substack{S \subseteq TP \cup BP \cup A \setminus \{BP_b\} \\ |S_T|>0 \\ |S_A|>0}} \frac{(|S_A|+|S_T|+|S_B|)!(|N|-|S_A|-|S_T|-|S_B|-1)!}{|N|!} \cdot \\
& \cdot \sum_{j \in TC} \Bigg[g^j \Big(\frac{\sum_{i \in S_B \cup \{BP_b\}} n_{ij}}{\sum_{i \in BP} n_{ij}}, \frac{\sum_{a \in S_A} nc_{aj}}{\sum_{a \in A} nc_{aj}} \Big) \cdot \sum_{i \in S_B \cup \{BP_b\}} n_{ij} - \\
& - g^j \Big(\frac{\sum_{i \in S_B} n_{ij}}{\sum_{i \in BP} n_{ij}}, \frac{\sum_{a \in S_A} nc_{aj}}{\sum_{a \in A} nc_{aj}} \Big) \cdot \sum_{i \in S_B} n_{ij} \Bigg]
\end{aligned} \tag{27}$$

Based on Lemma 1 we can transform the expression in the following way::

$$\begin{aligned}
\varphi_b(v) = & \sum_{j \in TC} \sum_{t=0}^{|TP|} \binom{|TP|}{t} \sum_{\substack{S \subseteq BP \cup A \setminus \{BP_b\} \\ |S_A|>0}} \frac{(|S_A|+t+|S_B|)!(|N|-|S_A|-t-|S_B|-1)!}{|N|!} \cdot \\
& \cdot \Bigg[g^j \Big(\frac{\sum_{i \in S_B \cup \{BP_b\}} n_{ij}}{\sum_{i \in BP} n_{ij}}, \frac{\sum_{a \in S_A} nc_{aj}}{\sum_{a \in A} nc_{aj}} \Big) \cdot \sum_{i \in S_B \cup \{BP_b\}} n_{ij} - \\
& - g^j \Big(\frac{\sum_{i \in S_B} n_{ij}}{\sum_{i \in BP} n_{ij}}, \frac{\sum_{a \in S_A} nc_{aj}}{\sum_{a \in A} nc_{aj}} \Big) \cdot \sum_{i \in S_B} n_{ij} \Bigg]
\end{aligned} \tag{28}$$

Based on Lemma 2 we can transform the expression in the following way:

$$\begin{aligned}
\varphi_b(v) = & \sum_{j \in TC} \sum_{t=0}^{|TP|} \binom{|TP|}{t} \sum_{\substack{S \subseteq A \\ |S_A|>0}} \sum_{l=0}^{|BP|-1} \sum_{k=0}^{\sum_{i \in BP} n_{ij} - n_{bj}} \frac{(|S_A|+t+l)!(|N|-|S_A|-t-l-1)!}{|N|!} \cdot \\
& \cdot LBT_{kl}^{j \setminus b} \cdot \Bigg[g^j \Big(\frac{k+n_{bj}}{\sum_{i \in BP} n_{ij}}, \frac{\sum_{a \in S_A} nc_{aj}}{\sum_{a \in A} nc_{aj}} \Big) \cdot (k+n_{bj}) - g^j \Big(\frac{k}{\sum_{i \in BP} n_{ij}}, \frac{\sum_{a \in S_A} nc_{aj}}{\sum_{a \in A} nc_{aj}} \Big) \cdot k \Bigg]
\end{aligned} \tag{29}$$

where $LBT_{kl}^{j \setminus b}$ — number of sets W such that $W \cap TC = \{TC_j\}$ and $BP_b \notin W$ and $W \cap A = \emptyset$ and $|W_B| = l$ (where l — number of barges in the set W, we take into account in the summation the sets with zero barges as well because we add Barge operator b which allows value creation) and $\sum_{i\in W_B} n_{ij} = k$

Based on Lemma 2 we can transform the expression in the following way:

$$\varphi_b(v)=\sum_{j\in TC}\sum_{t=0}^{|TP|}\binom{|TP|}{t}\sum_{a=1}^{|A|}\sum_{p=0}^{\sum_{a\in A} nc_{aj}}\sum_{l=0}^{|BP|-1}\sum_{k=0}^{\sum_{i\in BP} n_{ij}-n_{bj}}\frac{(|S_A|+t+l)!(|N|-|S_A|-t-l-1)!}{|N|!}\cdot$$
$$\cdot LBT_{kl}^{j\setminus b}\cdot LAT_{pa}^{j}\cdot\left[g^j\Big(\frac{k+n_{bj}}{\sum_{i\in BP} n_{ij}},\frac{p}{\sum_{a\in A} nc_{aj}}\Big)\cdot(k+n_{bj})-\right.$$
$$\left.-g^j\Big(\frac{k}{\sum_{i\in BP} n_{ij}},\frac{p}{\sum_{a\in A} nc_{aj}}\Big)\cdot k\right] \tag{30}$$

LAT_{pa}^{j} — number of sets R such that $R\cap TC=\{TC_j\}$ and $R\cap BP=\emptyset$ and $R\cap BC=\emptyset$ and $|R_A|=a$ (where a — number of shipping agents in the set R, we take into account in the summation the sets of size 1 and higher which allows value creation) and $\sum_{a\in R_A} nc_{aj}=p$.

Taking into account PCS development costs:

$$\varphi_b(v)=\frac{\sum_{i\in BC}\sum_{j\in TC} n_{ij}\Big(f(1,1)+g(1,1)\Big)}{\sum_{i\in BC}\sum_{j\in TC} n_{ij}\Big(f(1,1)+g(1,1)\Big)+DC}\cdot$$
$$\sum_{j\in TC}\sum_{t=0}^{|TP|}\binom{|TP|}{t}\sum_{a=1}^{|A|}\sum_{p=0}^{\sum_{a\in A} nc_{aj}}\sum_{l=0}^{|BP|-1}\sum_{k=0}^{\sum_{i\in BP} n_{ij}-n_{bj}}\frac{(|S_A|+t+l)!(|N|-|S_A|-t-l-1)!}{|N|!}\cdot$$
$$\cdot LBT_{kl}^{j\setminus b}\cdot LAT_{pa}^{j}\cdot\left[g^j\Big(\frac{k+n_{bj}}{\sum_{i\in BP} n_{ij}},\frac{p}{\sum_{a\in A} nc_{aj}}\Big)\cdot(k+n_{bj})-\right.$$
$$\left.-g^j\Big(\frac{k}{\sum_{i\in BP} n_{ij}},\frac{p}{\sum_{a\in A} nc_{aj}}\Big)\cdot k\right] \tag{31}$$

Shapley value of a shipping agent

Added value from the participation of shipping agent A_y for a coalition S:
If $S_TP = \emptyset$ or $S_BP = \emptyset$ then $\upsilon(S \cup \{A_y\}) - \upsilon(S) = 0$ else

$$\begin{aligned}
\upsilon(S \cup \{A_y\}) - \upsilon(S) = & \sum_{j \in TC} V_T^j(S_B, S_A \cup \{A_y\}) + \sum_{i \in BC} V_B^i(S_T, S_A \cup \{A_y\}) - DC - \\
& - \sum_{j \in TC} V_T^j(S_B, S_A) - \sum_{i \in BC} V_B^i(S_T, S_A) + DC = \\
= & \sum_{j \in TC} \Bigg[\Bigg(g^j \Big(\frac{\sum_{i \in S_B} n_{ij}}{\sum_{i \in BP} n_{ij}}, \frac{\sum_{a \in S_A \cup \{A_y\}} nc_{aj}}{\sum_{a \in A} nc_{aj}} \Big) - \\
& - g^j \Big(\frac{\sum_{i \in S_B} n_{ij}}{\sum_{i \in BP} n_{ij}}, \frac{\sum_{a \in S_A} nc_{aj}}{\sum_{a \in A} nc_{aj}} \Big) \Bigg) \cdot \sum_{i \in S_B} n_{ij} \Bigg] + \\
& + \sum_{i \in BC} \Bigg[\Bigg(f^i \Big(\frac{\sum_{j \in S_T} n_{ij}}{\sum_{j \in TP} n_{ij}}, \frac{\sum_{a \in S_A \cup \{A_y\}} nc_a}{\sum_{a \in A} nc_a} \Big) - \\
& - f^i \Big(\frac{\sum_{j \in S_T} n_{ij}}{\sum_{j \in TP} n_{ij}}, \frac{\sum_{a \in S_A} nc_a}{\sum_{a \in A} nc_a} \Big) \Bigg) \cdot \sum_{j \in S_T} n_{ij} \Bigg]
\end{aligned} \tag{32}$$

Shapley value of a shipping agent A_y based on the general Formula 2.1:

$$\varphi_y(\upsilon) = \sum_{S \subseteq N \setminus \{A_y\}} \frac{|S|!(|N| - |S| - 1)!}{|N|!} \cdot \Big(\upsilon(S \cup \{A_y\}) - \upsilon(S) \Big) \tag{33}$$

As we only have terminal-providers, barge-providers, and shipping agents in any given coalition of providers S, $|S| = |S_A| + |S_T| + |S_B|$. Taking into account Formula 32, Formula 33 can be rewritten:

$$\begin{aligned}
& \varphi_y(\upsilon) = \sum_{S \subseteq N \setminus \{A_y\}} \frac{(|S_A| + |S_T| + |S_B|)!(|N| - |S_A| - |S_T| - |S_B| - 1)!}{|N|!} \cdot \\
& \cdot \Big(\upsilon(S \cup \{A_y\}) - \upsilon(S) \Big) = \\
& = \sum_{\substack{S \subseteq TP \cup BP \cup A \setminus \{A_y\} \\ |S_T| > 0 \\ |S_B| > 0}} \frac{(|S_A| + |S_T| + |S_B|)!(|N| - |S_A| - |S_T| - |S_B| - 1)!}{|N|!} \cdot \\
& \cdot \Bigg(\sum_{j \in TC} \Bigg[\Bigg(g^j \Big(\frac{\sum_{i \in S_B} n_{ij}}{\sum_{i \in BP} n_{ij}}, \frac{\sum_{a \in S_A \cup \{A_y\}} nc_{aj}}{\sum_{a \in A} nc_{aj}} \Big) - g^j \Big(\frac{\sum_{i \in S_B} n_{ij}}{\sum_{i \in BP} n_{ij}}, \frac{\sum_{a \in S_A} nc_{aj}}{\sum_{a \in A} nc_{aj}} \Big) \Bigg) \cdot \sum_{i \in S_B} n_{ij} \Bigg] + \\
& + \sum_{i \in BC} \Bigg[\Bigg(f^i \Big(\frac{\sum_{j \in S_T} n_{ij}}{\sum_{j \in TP} n_{ij}}, \frac{\sum_{a \in S_A \cup \{A_y\}} nc_a}{\sum_{a \in A} nc_a} \Big) - f^i \Big(\frac{\sum_{j \in S_T} n_{ij}}{\sum_{j \in TP} n_{ij}}, \frac{\sum_{a \in S_A} nc_a}{\sum_{a \in A} nc_a} \Big) \Bigg) \cdot \sum_{j \in S_T} n_{ij} \Bigg] \Bigg)
\end{aligned} \tag{34}$$

$$\varphi_a(\upsilon) = \varphi_a^1(\upsilon) + \varphi_a^2(\upsilon), \tag{35}$$

where

$$\varphi_y^1(v) = \sum_{\substack{S \subseteq TP \cup BP \cup A \setminus \{A_y\} \\ |S_T|>0 \\ |S_B|>0}} \frac{(|S_A| + |S_T| + |S_B|)!(|N| - |S_A| - |S_T| - |S_B| - 1)!}{|N|!} \cdot \\ \cdot \sum_{j \in TC} \Bigg[\Bigg(g^j\Big(\frac{\sum_{i \in S_B} n_{ij}}{\sum_{i \in BP} n_{ij}}, \frac{\sum_{a \in S_A \cup \{A_y\}} nc_{aj}}{\sum_{a \in A} nc_{aj}}\Big) - \\ - g^j\Big(\frac{\sum_{i \in S_B} n_{ij}}{\sum_{i \in BP} n_{ij}}, \frac{\sum_{a \in S_A} nc_{aj}}{\sum_{a \in A} nc_{aj}}\Big)\Bigg) \cdot \sum_{i \in S_B} n_{ij} \Bigg] \tag{36}$$

and

$$\varphi_y^2(v) = \sum_{\substack{S \subseteq TP \cup BP \cup A \setminus \{A_y\} \\ |S_T|>0 \\ |S_B|>0}} \frac{(|S_A| + |S_T| + |S_B|)!(|N| - |S_A| - |S_T| - |S_B| - 1)!}{|N|!} \cdot \\ \cdot \sum_{i \in BC} \Bigg[\Bigg(f^i\Big(\frac{\sum_{j \in S_T} n_{ij}}{\sum_{j \in TP} n_{ij}}, \frac{\sum_{a \in S_A \cup \{A_y\}} nc_{a}}{\sum_{a \in A} nc_{a}}\Big) - \\ - f^i\Big(\frac{\sum_{j \in S_T} n_{ij}}{\sum_{j \in TP} n_{ij}}, \frac{\sum_{a \in S_A} nc_{a}}{\sum_{a \in A} nc_{a}}\Big)\Bigg) \cdot \sum_{j \in S_T} n_{ij} \Bigg] \tag{37}$$

Based on Lemma 1 we can transform the expression in the following way:

$$\varphi_y^1(v) = \sum_{j \in TC} \sum_{t=0}^{|TP|} \binom{|TP|}{t} \sum_{\substack{S \subseteq BP \cup A \setminus \{A_y\} \\ |S_B|>0}} \frac{(|S_A| + t + |S_B|)!(|N| - |S_A| - t - |S_B| - 1)!}{|N|!} \cdot \\ \cdot \Bigg(g^j\Big(\frac{\sum_{i \in S_B} n_{ij}}{\sum_{i \in BP} n_{ij}}, \frac{\sum_{a \in S_A \cup \{A_y\}} nc_{aj}}{\sum_{a \in A} nc_{aj}}\Big) - \\ - g^j\Big(\frac{\sum_{i \in S_B} n_{ij}}{\sum_{i \in BP} n_{ij}}, \frac{\sum_{a \in S_A} nc_{aj}}{\sum_{a \in A} nc_{aj}}\Big)\Bigg) \cdot \sum_{i \in S_B} n_{ij} \tag{38}$$

$$\varphi_y^2(v)=\sum_{i\in BC}\sum_{b=0}^{|BP|}\binom{|BP|}{b}\sum_{\substack{S\subseteq TP\cup A\setminus\{A_y\}\\|S_T|>0}}\frac{(|S_A|+|S_T|+b)!(|N|-|S_A|-|S_T|-b-1)!}{|N|!}\cdot$$
$$\cdot\Bigg(f^i\Big(\frac{\sum_{j\in S_T}n_{ij}}{\sum_{j\in TP}n_{ij}},\frac{\sum_{a\in S_A\cup\{A_y\}}nc_a}{\sum_{a\in A}nc_a}\Big)-$$
$$-f^i\Big(\frac{\sum_{j\in S_T}n_{ij}}{\sum_{j\in TP}n_{ij}},\frac{\sum_{a\in S_A}nc_a}{\sum_{a\in A}nc_a}\Big)\Bigg)\cdot\sum_{j\in S_T}n_{ij} \tag{39}$$

Based on Lemma 2 we can transform the expression in the following way:

$$\varphi_y^1(v)=\sum_{j\in TC}\sum_{t=0}^{|TP|}\binom{|TP|}{t}\sum_{S\subseteq A\setminus\{A_y\}}\sum_{l=1}^{|BP|}\sum_{k=0}^{\sum_{i\in BP}n_{ij}}\frac{(|S_A|+t+l)!(|N|-|S_A|-t-l-1)!}{|N|!}\cdot$$
$$\cdot LBT_{kl}^j\cdot\Bigg(g^j\Big(\frac{k}{\sum_{i\in BP}n_{ij}},\frac{\sum_{a\in S_A\cup\{A_y\}}nc_{aj}}{\sum_{a\in A}nc_{aj}}\Big)-$$
$$-g^j\Big(\frac{k}{\sum_{i\in BP}n_{ij}},\frac{\sum_{a\in S_A}nc_{aj}}{\sum_{a\in A}nc_{aj}}\Big)\Bigg)\cdot k, \tag{40}$$

where LBT_{kl}^j — number of sets W such that $W\cap TC=\{TC_j\}$ and $W\cap A=\emptyset$ and $|W_B|=l$ (where l — number of barges in the set W) and $\sum_{i\in W_B}n_{ij}=k$

$$\varphi_y^2(v)=\sum_{i\in BC}\sum_{b=0}^{|BP|}\binom{|BP|}{b}\sum_{S\subseteq A\setminus\{A_y\}}\sum_{m=1}^{|TP|}\sum_{k=0}^{\sum_{j\in TP}n_{ij}}\frac{(|S_A|+m+b)!(|N|-|S_A|-m-b-1)!}{|N|!}$$
$$\cdot LTB_{km}^i\cdot\Bigg(f^i\Big(\frac{k}{\sum_{j\in TP}n_{ij}},\frac{\sum_{a\in S_A\cup\{A_y\}}nc_a}{\sum_{a\in A}nc_a}\Big)-f^i\Big(\frac{k}{\sum_{j\in TP}n_{ij}},\frac{\sum_{a\in S_A}nc_a}{\sum_{a\in A}nc_a}\Big)\Bigg)k, \tag{41}$$

where LTB_{km}^i — number of sets W such that $W\cap BC=\{BC_i\}$ and $W\cap A=\emptyset$ and $|W_T|=m$ (where m — number of terminals in the set W) and $\sum_{j\in W_TP}n_{ij}=k$

Based on Lemma 2 we can transform the expression in the following way:

$$\varphi_y^1(v)=\sum_{j\in TC}\sum_{t=0}^{|TP|}\binom{|TP|}{t}\sum_{a=0}^{|A|-1}\sum_{p=0}^{\sum_{a\in A}nc_{aj}-nc_{yj}}\sum_{l=1}^{|BP|}\sum_{k=0}^{\sum_{i\in BP}n_{ij}}\frac{(a+t+l)!(|N|-a-t-l-1)!}{|N|!}\cdot$$
$$\cdot LBT_{kl}^j\cdot LAT_{pa}^j\cdot\Bigg(g^j\Big(\frac{k}{\sum_{i\in BP}n_{ij}},\frac{p+nc_{yj}}{\sum_{a\in A}nc_{aj}}\Big)-g^j\Big(\frac{k}{\sum_{i\in BP}n_{ij}},\frac{p}{\sum_{a\in A}nc_{aj}}\Big)\Bigg)k, \tag{42}$$

LAT_{pa}^j — number of sets R such that $R\cap TC=\{TC_j\}$ and $R\cap BP=\emptyset$ and $R\cap BC=\emptyset$ and $|R_A|=a$ (where a — number of shipping agents in the set

R) and $\sum_{a\in R_A} nc_{aj} = p$.

$$\varphi_y^2(\upsilon)=\sum_{i\in BC}\sum_{b=0}^{|BP|}\binom{|BP|}{b}\sum_{a=0}^{|A|-1}\sum_{p=0}^{\sum_{a\in A} nc_a - nc_y}\sum_{m=1}^{|TP|}\sum_{k=0}^{\sum_{j\in TP} n_{ij}}\frac{(a+m+b)!(|N|-a-m-b-1)!}{|N|!}\cdot$$
$$\cdot LTB_{km}^i\cdot LA_{pa}\cdot\left(f^i\Big(\frac{k}{\sum_{j\in TP} n_{ij}},\frac{p+nc_y}{\sum_{a\in A} nc_a}\Big)-f^i\Big(\frac{k}{\sum_{j\in TP} n_{ij}},\frac{p}{\sum_{a\in A} nc_a}\Big)\right)\cdot k, \quad (43)$$

LA_{pa} — number of sets R such that $R\cap BC=\emptyset$ and $R\cap BP=\emptyset$ and $R\cap TC=\emptyset$ and and $R\cap TP=\emptyset$ and $|R|=a$ (where a — number of shipping agents in the set R) and $\sum_{a\in R} nc_a = p$.

Taking into account PCS development costs:

$$\varphi_y(\upsilon)=\frac{\sum_{i\in BC}\sum_{j\in TC} n_{ij}\Big(f(1,1)+g(1,1)\Big)}{\sum_{i\in BC}\sum_{j\in TC} n_{ij}\Big(f(1,1)+g(1,1)\Big)+DC}\cdot$$
$$\cdot\Bigg[\sum_{j\in TC}\sum_{t=1}^{|TP|}\binom{|TP|}{t}\sum_{a=0}^{|A|-1}\sum_{p=0}^{\sum_{a\in A} nc_{aj}-nc_{yj}}\sum_{l=1}^{|BP|}\sum_{k=0}^{\sum_{i\in BP} n_{ij}}\frac{(a+t+l)!(|N|-a-t-l-1)!}{|N|!}\cdot$$
$$\cdot LBT_{kl}^j\cdot LAT_{pa}^j\cdot\left(g^j\Big(\frac{k}{\sum_{i\in BP} n_{ij}},\frac{p+nc_{yj}}{\sum_{a\in A} nc_{aj}}\Big)-g^j\Big(\frac{k}{\sum_{i\in BP} n_{ij}},\frac{p}{\sum_{a\in A} nc_{aj}}\Big)\right)\cdot k+$$
$$+\sum_{i\in BC}\sum_{b=1}^{|BP|}\binom{|BP|}{b}\sum_{a=0}^{|A|-1}\sum_{p=0}^{\sum_{a\in A} nc_a-nc_y}\sum_{m=1}^{|TP|}\sum_{k=0}^{\sum_{j\in TP} n_{ij}}\frac{(a+m+b)!(|N|-a-m-b-1)!}{|N|!}\cdot$$
$$\cdot LTB_{km}^i\cdot LA_{pa}\cdot\left(f^i\Big(\frac{k}{\sum_{j\in TP} n_{ij}},\frac{p+nc_y}{\sum_{a\in A} nc_a}\Big)-f^i\Big(\frac{k}{\sum_{j\in TP} n_{ij}},\frac{p}{\sum_{a\in A} nc_a}\Big)\right)\cdot k\Bigg], \quad (44)$$

2.C R code for Shapley value calculation

Supporting function: user values

```
barge_value <- function(n,m){
value <−0.2 ∗ 2000 ∗ n ∧ 4 ∗ m ∧ 4
value
}
terminal_value <- function(n,m){
value <-0.2∗(1500∗m∧4+1500∗m∧4/(1+1.5∗exp((−20∗(n−0.5))))∧(1/1.5))
value
}
```

Supporting function: count sets

```
count_sets <- function(x){
N <- length(x) #number of terminals
S <- sum(x) #total number of all calls made by barge
library(Matrix)
y_temp <- Matrix(0, S+1,N+1,sparse=TRUE) #matrix for storing temporary results
y_temp[1,1]=1 #there is always one combination with 0 terminals and 0 calls made
#y_final <- array(0, dim=c(S+1,N+1))
y_final <- Matrix(0,S+1,N+1,sparse=TRUE)
for (c in 1:N){
m=x[c]
M_temp = 0
for (i in 1:c){
M = M_temp+x[i]
M_temp = M
}
for (i in 1:m) {
for (j in 1:c){
```

```
y_final[i,j]=y_temp[i,j]
}
}
if (M >= m+1) {
for (i in (m+1):M) {
for (j in 2:(N+1)){
y_final[i,j]=y_temp[i,j]+y_temp[i-m,j-1]
}
}
}
if (m==0) {
for (i in 1:(S+1)) {
for (j in 2:(N+1)){
y_final[i,j]=y_temp[i,j]+y_temp[i-m,j-1]
}
}
}
if (m>0){
for (i in (M+1):(S+1)) {
for (j in 2:(N+1)){
y_final[i,j]=y_temp[i-m,j-1]
}
}
}
y_temp <- y_final
print(paste("Finished Column_",c, "at", Sys.time()))
}
y_final
}
```

Terminal Shapley value

```
calls_matrix = read.csv("simulation_data_calls_calc.csv",
header=FALSE)
```

```
containers_matrix = read.csv(”simulation_data_containers_calc.csv”,
header=FALSE)
##############################
#Run scripts ”count_set” and ”value_functions” first#
##############################
sv_terminals <- vector(mode=”numeric”, length=0)
calc_time_terminals <- vector(mode=”numeric”, length=0)
containers_per_agent <- rowSums (containers_matrix, na.rm = FALSE)
total_containers <- sum(containers_per_agent)
total_calls_per_barge <- rowSums (calls_matrix, na.rm = FALSE)
N <- length(containers_per_agent)+nrow(calls_matrix)+ncol(calls_matrix)
#total number of players
N_Barges <- nrow(calls_matrix)
N_Terminals <- ncol(calls_matrix)
#################################
#Possible combinations of shipping agents and containers#
#################################
print(paste(”Started LA calculation”, Sys.time()))
LA <- count_sets(containers_per_agent)
indices<-which(LA>0, arr.ind=TRUE)#[-1,]
number_non_zeroes <- nrow(indices)
array_LA_3d <- vector(mode=”numeric”, length=0)
for (z in 1:number_non_zeroes){
number_occurences <- LA[indices[z,1],indices[z,2]]
size_containers <- indices[z,]
vector_temp <- c(size_containers,number_occurences)
array_LA_3d <-rbind(array_LA_3d,vector_temp)
}
array_LA_3d_nrows <- nrow(array_LA_3d)
for (t in 1:N_Terminals){
print(paste(”Started Shapley calculation for Terminal_”,t, Sys.time()))
start_time<- proc.time()
sv_terminal_temp=0
```

```
sv_terminals[t]=0
for (i in 1:N_Barges){
t
if (calls_matrix[i,t]>0){
########################################
#Possible combinations of barge operator and other terminal operators
and respective number of calls#######################
print(paste("Started LTB_calculation for Barge",i, Sys.time()))
barge_i_calls_per_terminal_no_terminal_j<- as.numeric(calls_matrix[i,-t])
LTB <- count_sets(c(barge_i_calls_per_terminal_no_terminal_j))
indices<-which(LTB>0, arr.ind=TRUE)
number_non_zeroes <- nrow(indices)
array_LTB_3d <- vector(mode="numeric", length=0)
for (z in 1:number_non_zeroes){
number_occurences <- LTB[indices[z,1],indices[z,2]]
size_calls <- indices[z,]
vector_temp <- c(size_calls,number_occurences)
array_LTB_3d <-rbind(array_LTB_3d,vector_temp)
}
array_LTB_3d_nrows <- nrow(array_LTB_3d)
############################
#Main Shapley Value formula###########
############################
for (b in 0:(N_Barges)){
print(paste("b=",b, "at", Sys.time()))
for (y in 1:array_LA_3d_nrows){
for (z in 1:array_LTB_3d_nrows){
sv_terminal_temp<-choose(N_Barges,b)*factorial(array_LA_3d[y,2]-1+
+array_LTB_3d[z,2]-1+b)*factorial(N-array_LA_3d[y,2]+1-
-array_LTB_3d[z,2]+1-b-1)/factorial(N)*array_LTB_3d[z,3]*
*array_LA_3d[y,3]*(barge_value((array_LTB_3d[z,1]-1+
+calls_matrix[i,t])/total_calls_per_barge[i],
```

```
(array_LA_3d[y,1]-1)/total_containers)*(array_LTB_3d[z,1]-1+calls_matrix[i,t])-

barge_value((array_LTB_3d[z,1]-1)/total_calls_per_barge[i],
(array_LA_3d[y,1]-1)/total_containers)*(array_LTB_3d[z,1]-1))
sv_terminals[t]<-sv_terminals[t]+sv_terminal_temp
}
}
}
}
}
calc_time_terminals[t]=proc.time()-start_time
print(proc.time()-start_time)
}
write.csv(sv_terminals, file = "sv_terminals.csv")
write.csv(calc_time_terminals, file = "calc_time_terminals.csv")
```

Barge Shapley value

```
calls_matrix = read.csv("simulation_data_calls_calc4.csv",
header=FALSE)
containers_matrix = read.csv("simulation_data_containers_calc4.csv",
header=FALSE)
sv_barges <- vector(mode="numeric", length=0)
calc_time_barges <- vector(mode="numeric", length=0)
containers_per_agent <- rowSums (containers_matrix, na.rm = FALSE)
total_containers <- sum(containers_per_agent)
total_calls_per_terminal <- colSums (calls_matrix, na.rm = FALSE)
total_containers_per_terminal <- colSums (containers_matrix, na.rm = FALSE)
N <- length(containers_per_agent)+nrow(calls_matrix)+ncol(calls_matrix)
#total number of players
N_Barges <- nrow(calls_matrix)
N_Terminals <- ncol(calls_matrix)
for (b in 1:N_Barges){
print(paste("Started Shapley calculation for Barge_",b, Sys.time()))
```

```
start_time<- proc.time()
sv_barge_temp=0
sv_barges[b]=0
check_temp <- vector(mode="numeric", length=0)
check<-vector(mode="numeric",length=0)
for (j in 1:N_Terminals){
print(paste("Started evaluating contribution for Terminal_",j, Sys.time()))
if (calls_matrix[b,j]>0){
########################################
#Possible combinations of shipping agents and containers per terminal#
########################################
containers_per_terminal_per_agent <- containers_matrix[,j]
print(paste("Started LA_calculation",j, Sys.time()))
LA <- count_sets(containers_per_terminal_per_agent)
indices<-which(LA>0, arr.ind=TRUE)#[-1,]
number_non_zeroes <- nrow(indices)
array_LA_3d <- vector(mode="numeric", length=0)
for (z in 1:number_non_zeroes){
number_occurences <- LA[indices[z,1],indices[z,2]]
size_containers <- indices[z,]
vector_temp <- c(size_containers,number_occurences)
array_LA_3d <-rbind(array_LA_3d,vector_temp)
}
array_LA_3d_nrows <- nrow(array_LA_3d)
########################################
#Possible combinations of terminal operator and other barge operators
and respective number of calls########################
print(paste("Started LBT_calculation",j, Sys.time()))
terminal_j_calls_per_terminal_no_barge_b<- calls_matrix[-b,j]
LBT <- count_sets(terminal_j_calls_per_terminal_no_barge_b)
indices<-which(LBT>0, arr.ind=TRUE)#[-1,]
number_non_zeroes <- nrow(indices)
array_LBT_3d <- vector(mode="numeric", length=0)
```

```
for (z in 1:number_non_zeroes){
number_occurences <- LBT[indices[z,1],indices[z,2]]
size_calls <- indices[z,]
vector_temp <- c(size_calls,number_occurences)
array_LBT_3d <-rbind(array_LBT_3d,vector_temp)
}
array_LBT_3d_nrows <- nrow(array_LBT_3d)
#############################
#Main Shapley Value formula###########
#############################
for (t in 0:(N_Terminals)){
print(paste("t=",t, "at", Sys.time()))
for (y in 1:array_LA_3d_nrows){
for (z in 1:array_LBT_3d_nrows){
sv_barge_temp<-choose(N_Terminals,t)*factorial(array_LA_3d[y,2]-1+
array_LBT_3d[z,2]-1+t)*factorial(N-array_LA_3d[y,2]+1-
array_LBT_3d[z,2]+1-t-1)/factorial(N)*array_LBT_3d[z,3]*
*array_LA_3d[y,3]*(terminal_value((array_LBT_3d[z,1]-
-1+calls_matrix[b,j])/total_calls_per_terminal[j],
(array_LA_3d[y,1]-1)/total_containers_per_terminal[j])*(array_LBT_3d[z,1]-

-1+calls_matrix[b,j])-terminal_value((array_LBT_3d[z,1]-
-1)/total_calls_per_terminal[j],(array_LA_3d[y,1]-1)/
/total_containers_per_terminal[j])*(array_LBT_3d[z,1]-1))
sv_barges[b]<-sv_barges[b]+sv_barge_temp
}
}
}
}
}
print(proc.time()-start_time)
calc_time_barges[b]=proc.time()-start_time }
write.csv(sv_barges, file = "sv_barges.csv")
```

```
write.csv(calc_time_barges, file = ”calc_time_barges.csv”)
```

Shipping agent Shapley value

```
calls_matrix = read.csv(”simulation_data_calls_calc4.csv”,
header=FALSE)
containers_matrix = read.csv(”simulation_data_containers_calc4.csv”,
header=FALSE)
containers_per_agent <- rowSums (containers_matrix, na.rm = FALSE)
sv_agents <- vector(mode=”numeric”, length=0)
calc_time_agents <- vector(mode=”numeric”, length=0)
total_containers <- sum(containers_per_agent)
total_calls_per_terminal <- colSums (calls_matrix, na.rm = FALSE)
total_calls_per_barge <- rowSums (calls_matrix, na.rm = FALSE)
total_containers_per_terminal <- colSums (containers_matrix,
na.rm = FALSE)
N <- length(containers_per_agent)+nrow(calls_matrix)+ncol(calls_matrix)
#total number of players
N_Barges <- nrow(calls_matrix)
N_Terminals <- ncol(calls_matrix)
N_Agents <- length(containers_per_agent)
for (x in 1:N_Agents){
sv_agent_temp=0
sv_agents[x]=0
start_time<- proc.time()
print(paste(”Started calculation for agent_”,x, ”at”, Sys.time()))
##################
#Terminals value contributions#
##################
for (j in 1:N_Terminals){
#######################################
#Possible combinations of shipping agents and containers per terminal
without shipping agent X#########################
containers_per_terminal_no_agent_x <- as.numeric(containers_matrix[-x,j])
```

```
LA <- count_sets(containers_per_terminal_no_agent_x)
indices<-which(LA>0, arr.ind=TRUE)#[-1,]
number_non_zeroes <- nrow(indices)
array_LA_3d <- vector(mode=”numeric”, length=0)
for (z in 1:number_non_zeroes){
number_occurences <- LA[indices[z,1],indices[z,2]]
size_containers <- indices[z,]
vector_temp <- c(size_containers,number_occurences)
array_LA_3d <-rbind(array_LA_3d,vector_temp)
}
array_LA_3d_nrows <- nrow(array_LA_3d)
#######################################
#Possible combinations of terminal operator j and all barge operators and
respective number of calls##########################
terminal_j_calls_per_terminal<- as.numeric(calls_matrix[,j])
LBT <- count_sets(terminal_j_calls_per_terminal)
indices<-which(LBT>0, arr.ind=TRUE)#[-1,]
number_non_zeroes <- nrow(indices)
array_LBT_3d <- vector(mode=”numeric”, length=0)
for (z in 1:number_non_zeroes){
number_occurences <- LBT[indices[z,1],indices[z,2]]
size_calls <- indices[z,]
vector_temp <- c(size_calls,number_occurences)
array_LBT_3d <-rbind(array_LBT_3d,vector_temp)
}
array_LBT_3d_nrows <- nrow(array_LBT_3d)
############################
#Part 1 Shapley Value formula############
############################
for (t in 0:N_Terminals){
for (y in 1:array_LA_3d_nrows){
for (z in 1:array_LBT_3d_nrows){
sv_agent_temp<-choose(N_Terminals,t)*factorial(array_LA_3d[y,2]-1+
```

```
+array_LBT_3d[z,2]-1+t)*factorial(N-array_LA_3d[y,2]+1-
-array_LBT_3d[z,2]+1-t-1)/factorial(N)*array_LBT_3d[z,3]*
*array_LA_3d[y,3]*(terminal_value((array_LBT_3d[z,1]-
-1)/total_calls_per_terminal[j],(array_LA_3d[y,1]-1+
+containers_matrix[x,j])/total_containers_per_terminal[j])-
-terminal_value((array_LBT_3d[z,1]-1)/total_calls_per_terminal[j],
(array_LA_3d[y,1]-1)/total_containers_per_terminal[j]))*
*(array_LBT_3d[z,1]-1)
sv_agents[x]<-sv_agents[x]+sv_agent_temp
}
}
}
}
#################
#Barges value contributions#
#################
##################################
#Possible combinations of shipping agents without agent x#
##################################
LA <- count_sets(containers_per_agent[-x])
indices<-which(LA>0, arr.ind=TRUE)#[-1,]
number_non_zeroes <- nrow(indices)
array_LA_3d <- vector(mode=”numeric”, length=0)
for (z in 1:number_non_zeroes){
number_occurences <- LA[indices[z,1],indices[z,2]]
size_containers <- indices[z,]
vector_temp <- c(size_containers,number_occurences)
array_LA_3d <-rbind(array_LA_3d,vector_temp)
}
array_LA_3d_nrows <- nrow(array_LA_3d)
for (i in 1:N_Barges){
########################################
#Possible combinations of barge operator and other termianl operators
```

```
and respective number of calls########################
barge_i_calls_per_terminal<- as.numeric(calls_matrix[i,])
LTB <- count_sets(barge_i_calls_per_terminal)
indices<-which(LTB>0, arr.ind=TRUE)#[-1,]
number_non_zeroes <- nrow(indices)
array_LTB_3d <- vector(mode="numeric", length=0)
for (z in 1:number_non_zeroes){
number_occurences <- LTB[indices[z,1],indices[z,2]]
size_calls <- indices[z,]
vector_temp <- c(size_calls,number_occurences)
array_LTB_3d <-rbind(array_LTB_3d,vector_temp)
}
array_LTB_3d_nrows <- nrow(array_LTB_3d)
##############################
#Part2 Shapley Value formula###########
##############################
for (b in 0:(N_Barges)){
for (y in 1:array_LA_3d_nrows){
for (z in 1:array_LTB_3d_nrows){
sv_agent_temp<-choose(N_Barges,b)*factorial(array_LA_3d[y,2]-1+
+array_LTB_3d[z,2]-1+b)*factorial(N-array_LA_3d[y,2]+1-
-array_LTB_3d[z,2]+1-b-1)/factorial(N)*array_LTB_3d[z,3]*
*array_LA_3d[y,3]*(barge_value((array_LTB_3d[z,1]-
-1)/total_calls_per_barge[i],(array_LA_3d[y,1]-1+
+containers_per_agent[x])/total_containers)-barge_value((array_LTB_3d[z,1]-

-1)/total_calls_per_barge[i],
(array_LA_3d[y,1]-1)/total_containers))*(array_LTB_3d[z,1]-1)
sv_agents[x]<-sv_agents[x]+sv_agent_temp
}
}
}
}
```

```
calc_time_agents[x]=proc.time()-start_time
}
write.csv(sv_agents, file = "sv_agents.csv")
write.csv(calc_time_agents, file = "calc_time_agents.csv")
```

Chapter 3

Enhancing Co-opetition with a Fair Sharing Approach for Interorganizational Information Systems

Abstract: In the modern environment characterized by competition among not only individual companies but also business networks, interorganizational information systems (IOSs) play an important role as building blocks of the network information infrastructure. Despite many technological advancements in the last decades, many enterprises still face difficulties with IOS adoption. The need for co-opetition — simultaneous competition and cooperation — among community members and the uneven distribution of benefits among them have been often identified as barriers for IOS adoption. To address these issues, we develop an analytical fair sharing model for IOS users based on the Shapley value principle. The use of the Shapley value ensures that individual members' rational interests are aligned with the interests of the community as a whole. We demonstrate that such a fair sharing scheme can create additional incentives for co-opetition among competitors by estimating the value gain for a data provider that comes from the participation of another data provider. The magnitude of the positive externalities among providers depends on the network structure that, in its turn, determines the importance of

coordination among competitors for IOS adoption. In high-density networks, the benefits from coordination are greater than in low-density networks.

3.1 Introduction

Interorganizational communication methods have gained in importance in the modern business environment, which is characterized by competition among not only individual companies but also large business networks (Riggins et al. 1994, Markus and Loebbecke 2013). Interorganizational information systems (IOS) provide a way for fast and high-quality information exchange that is superior in many aspects to other communication technologies, such as e-mail, telephone, or fax (Bakos 1991, Premkumar et al. 1994). Consequently, we observe a number of business network-wide initiatives to introduce IOS as the communication standard among organizations in the context of extended supply chains (Steinfield et al. 2011), industries (King and Konsynski 1995, Markus et al. 2006, Damsgaard and Lyytinen 2001), or clusters of economic activity (Rodon and Ramis-Pujol 2006, Van Baalen et al. 2009). Such initiatives are usually aimed at reducing communication costs and improving the quality of network-wide information exchange (Damsgaard and Lyytinen 2001, Markus et al. 2006, Markus and Loebbecke 2013) and, through this, enhancing the competitiveness of adopting community vis-à-vis other business networks (Riggins et al. 1994, Ba et al. 2001).

However, many reports exist on the difficulties that such projects face at different stages, from IOS development to its adoption and use (Damsgaard and Lyytinen 2001, Beck and Weitzel 2005, Markus et al. 2006). Interorganizational knowledge sharing in the business community context entails co-opetition when companies need to simultaneously compete and cooperate (Levy et al. 2003). The fine balance between the benefits that an information receiver can gain from the independent use of shared information and the synergetic value influences the firm's decision on whether or not to cooperate (Levy et al. 2003). Benefits heterogeneity and their uneven distribution within an adopting community have been often named among the culprits that stand in the way of a successful network-wide IOS introduction (Fulk et al. 1996, Steinfield et al. 2011, Van Baalen et al. 2009). IOS is not a neutral technological input into an interorganizational relationship but an artifact that has the potential to both increase and decrease information asymmetries among partners (Cho et al. 2017). Collective action is required to produce an IOS (Kumar and Van Dissel 1996, Monge et al. 1998, Markus et al. 2006). However, when not all actors receive enough benefits from using the system, additional instruments are called for to ensure their participation (Fulk et al. 1996, Monge et al. 1998). Large companies can use subsidizing or penalizing strategies to persuade their partners to adopt an IOS (Riggins et al. 1994, Barua and Lee 1997, Beck and Weitzel 2005). However, such incentivizing instruments are difficult to scale when the targeted adopting community is quite broad, such as in the case of extended supply chains, industries, or clusters, and different types of organizational incentives might be called for (Ba et al. 2001). Moreover, IOS benefits might be distributed unevenly among different business network roles given the nature of the technology. For instance, often argued is that buyers in many e-markets benefited from the use of the system to a larger extent than suppliers (Wise and Morrison 2000, Wang and Benaroch 2004). In view of these issues, many researchers have called for the design of an efficient mechanism to distribute the surplus generated by an IOS by using game-theoretical modeling (Clemons and Kleindorfer 1992, Riggins et al. 1994, Ba et al. 2001). Wang and Benaroch (2004) demonstrate that the e-market will not break down if the buyer could share a certain part of his or her profits with the supplier. Other researchers have suggested that the use of fair sharing models can improve IOS adoption rates (Steinfield et al. 2011) because it will ensure that the benefits from IOS use are distributed in a more even fashion. However, in practice, not many reported cases exist in which such advanced surplus sharing models have actually been implemented. Steinfield, Markus, and Wigand (2011) mentioned that fair sharing approach was successful in their study, but they do not provide any specifics on the scheme that was used. To the best of our knowledge, no analytical studies exist that investigated the application of fair sharing schemes to the case of IOSs. In this paper, we intend to fill this gap through the application of game-theoretical principles, specifically the Shapley value allocation mechanism.

Over the years, a lot of different factors have been found that affect the organization's decision to adopt an IOS: external environment, organizational readiness, perceived benefits, transaction characteristics and others (Robey et al. 2008). Initially, economic models mainly focused on EDI networks that supported buying-selling transactions. Such systems were typically initiated by a strong buyer who occasionally had to exert a certain influence on its suppliers to make them adopt the system. Riggins et al. (1994) demonstrated that the buyer may experience the initial supplier adoption of the network, followed by a "stalling" problem attributable to negative externalities. The researchers showed that the buyer may find it optimal to subsidize some suppliers' costs to join the network in the second stage. Barua and Lee (1997) compared subsidizing and penalizing strategies in the form of buying more or fewer products for fostering IOS adoption in a vertical market involving one manufacturer and two suppliers. They showed that, regardless of the cost structure, IOS adoption can become an unfortunate strategic necessity for a smaller supplier. Nault (1997) investigated the possibility of a subsidy provided by the IOS supplier to the IOS adopter in the contexts of a monopoly and a duopoly. He showed that the possibility of such a subsidy increases when the added value after adoption is indispensable and when IOS adopters do not decrease their transaction volume relative to before IOS state.

Empirical studies of IOS adoption added other dimensions that are difficult to investigate using economic modeling. Chwelos et al. (2001) showed that organizational readiness, perceived benefits, and external pressure were determinants of EDI adoption, with external pressure and readiness being more important factors than benefits. Teo et al. (2003) showed that the institutional environment in the form of normative, mimetic, and coercive pressures also influences the organization's intention to adopt EDI. The potential for the exploitation of strategic information by the IOS provider can serve as a barrier for IOS adoption. In such a case, multiparty ownership can be a way to mitigate this risk (Han et al. 2004). Nicolaou and McKnight (2006) demonstrated the role of perceived information quality in the decision to use an IOS. Zhu et al. (2006) investigated the influence of the network effect and adoption costs on the organization's decision to switch from a proprietary EDI-based IOS to an open standard Internet-based IOS. They found that EDI users are much more sensitive to the costs of switching to the new standard. Venkatesh and Bala (2012) demonstrated that expected benefits and relational trust had significant effects on the adoption of interorganizational business process standards, which is a precondition for a successfully functioning IOS. Furthermore, the authors showed that the factors pertaining to not only the focal firm but also its trading partners — a partner's process compatibility, standards uncertainty, and technology readiness — play a role.

A separate stream of research has been dedicated to the issue of IOS adoption by small and medium companies (Iacovou et al. 1995, Chen and Williams 1998, Chau and Hui 2001, Beck and Weitzel 2005). Large companies can more easily benefit from IOS implementation because of the large number of messages that can be exchanged electronically (Mukhopadhyay et al. 1995, Beck and Weitzel 2005). The low volume of potentially electronically exchangeable orders and invoices makes it much more difficult to cover the fixed costs of IOS implementation for small and medium companies (Iacovou et al. 1995, Beck and Weitzel 2005). To overcome these barriers, Iacovou et al. (1995) advised initiators "to pursue promotional efforts to improve partners' perceptions of EDI benefits, provide financial and technological assistance to partners with low organizational readiness" (Iacovou et al. 1995, p. 465). In contrast, Beck and Weitzel (2005) argued that EDI and WebEDI solutions are economically dominated by the use of faxes for interorganizational communication for small and medium firms because of the differences in their organizational processes relative to the processes of large firms that usually develop solutions and standards. Small companies rarely use advanced internal information systems, which is one of the preconditions for realizing full EDI benefits. The authors suggest an alternative to traditional EDI solutions, which is more attractive for small firms, given the smaller size of the required initial investment (Beck and Weitzel 2005). Using an example of Australian SMEs, Power and Gruner (2017) showed that SME managers often make decisions regarding technology standards by focusing on short-term performance benefits for their firm rather than the supply chain as a whole.

The majority of empirical IOS adoption studies had a firm or a dyad as the unit of analysis. The environment was analyzed as perceived by focal companies. Some of the economic studies considered two-tier networks with buyers as their central nodes and multiple suppliers in a second tier (Riggins et al. 1994, Barua and Lee 1997). However, today, many IOS initiatives have a much wider targeted adopting community. Steinfield et al. (2011) described the AIAG effort to develop data standards and a technical architecture, which would enable coordination in extended supply chains. This project targeted multiple automotive manufacturers and their multiple suppliers. Rodon and Ramis-Pujol (2006) reported on the development of a port community system in a Spanish port, which targeted the entire port cluster, encompassing diverse port business network roles such as freight forwarders, customs, inland terminals, haulage contractors, banks, and others. To be successful, such network-wide IOS initiatives must be able to accommodate the interests of companies that are performing different business roles and that have different sizes. The use of penalizing and subsidizing strategies suggested by previous researchers was a good fit for the earlier IOSs that focused on a single buyer. These instruments are difficult to scale to a broader network with a larger number of companies without a single powerful dominating firm. Following the suggestions of previous researchers (Clemons and Kleindorfer 1992, Riggins et al. 1994, Ba et al. 2001), we decided to investigate the field of cooperative game theory to seek instruments that would facilitate the development of easy to scale incentive mechanisms. We focus our analysis on the Shapley value principle because of a number of unique properties that it possesses, which are subsequently discussed in detail. The most important of these properties is that the Shapley value aligns the interests of individual companies in obtaining positive participation returns with the interests of the community as a whole to maximize the benefit to the network from an IOS introduction.

We construct a Shapley value-based fair sharing scheme for the distribution of IOS benefits for the case of information links. Bakos (1991) distinguished between two IOS types in the vertical markets: information links and electronic markets. The main difference between these IOS types is that information links support already existing business relationships, whereas electronic markets assist in establishing new ones. Hence, the benefits that users can realize from the implementation of these IOS types differ significantly. The goal of the fair sharing scheme is to ensure that not only IOS initiators benefit from IOS but that the gains of the adopting community as a whole are maximized. Information links are based on interorganizational business processes, which are usually developed within consortia such as RosettaNet standards in the semiconductor and electronic components industry, or MISMO standards in the U.S. mortgage industry (Markus et al. 2006, Bala and Venkatesh 2007). Such IOSs are implemented to automate, integrate, and facilitate value chain activities, such as supply chain management, scheduling, collaborative forecasting, and inventory management (Bala and Venkatesh 2007). We distinguish among two roles that users play in such systems: IT service data providers and consumers. Consumers receive benefits from using an IOS in terms of efficiency gains in their processes, whereas data providers must be reimbursed for their participation. We acknowledge that, in most cases, the information exchange goes both ways, and companies play both roles in one IOS. Our model can be extended to incorporate this property. Often noted that is that the benefits from IOS adoption depend on the position in the business network that the firm occupies (Van Baalen et al. 2009, Rodón and Sesé 2010, Steinfield et al. 2011). Rodón and Sesé (2010) noted that in the case of PortIC IOS in the Port of Barcelona, freight forwarders who only used the IOS to submit B2B messages gained less than shipping agents who used B2B to receive messages. Distinguishing between consumers and data providers allows us to account for the uneven distribution of costs and benefits among different business network roles participating in an IOS.

We show that if the IOS consumption has a strong network effect, which is true for the majority of the IOS, the Shapley value-based fair reward creates positive externalities not only between data consumer and data provider groups but also within the data provider group. The reward for one data provider grows if the other provider joins the system. Thus, the Shapley value-based reward can serve as an additional incentivizing instrument in the co-opetition environment. The size of these positive externalities depends on the network density. In low-density networks, the positive externalities among providers disappear, which reduces the importance of the coordination among data providers in such networks. Over the years, many initiatives have been adopted to make the use of specific IOS or data exchange schemes a standard for certain industries (King and Konsynski 1995, Damsgaard and Lyytinen 2001, Markus et al. 2006, Rodon and Ramis-Pujol 2006). However, the same technology spreads differently in different industries (Damsgaard and Lyytinen 2001). Our analysis of the connection between the network structure and IOS adoption sheds light on one of the possible reasons. For companies in business networks with low density to achieve the full benefits from IOS use is easier. They do not require coordination with competitors to do this. In contrast, the business networks with high density will benefit from the coordination, which usually requires additional efforts from the community members. Thus, in certain industries, the adoption process might go much smoother because the communication network structure makes it easier to reach the full benefits of the new technology without coordination with the competitors in the network. In addition, we demonstrate that, under Shapley value-based fair sharing conditions, the reward of a data provider depends on his or her transaction volume. Therefore, even under fair conditions, the participation of small actors might not be valuable enough to reimburse their participation costs. Thus, 100% adoption — often the goal of the network-wide initiatives — can be actually suboptimal not only from the viewpoint of individual companies but also from the community perspective.

The remainder of this paper is organized as follows. In the next section, we introduce our model and the main assumptions behind it. In section three, we analyze the factors that influence the size of the reward to a data provider under Shapley value-based fair sharing conditions. In section four, we consider the interdependence among the network structure, coordination, and adoption. We conclude our paper with a discussion of the main insights from our paper and their relevance for both theory and practice, and we suggest a number of future research avenues and possible model extensions.

3.2 Model

An interorganizational information system as a product of digital technology has a layered architecture that consists of four layers: contents (i.e., data), service (i.e., software), network, and device (Yoo et al. 2010). In the case of an IOS, different companies usually provide these four layers. Often, one company develops software and IOS-specific infrastructure, such as in the cases of ePortSys (Rodon and Ramis-Pujol 2006) or the MOSS project (Steinfield et al. 2011), whereas the business network members (i.e., IOS users) provide data to the system and pay for the devices required to connect to and use the system. IOS consumers are usually companies from the same business network. They use IOS services for multiple reasons: to reduce transaction costs, improve information quality and customer service, and others. (Iacovou et al. 1995). The success of an IOS depends strongly on the adoption of the system by both data providers and service consumers. In many cases, companies that provide data to an IOS are simultaneously consumers of the very same system. For instance, in the MOSS project that developed a shared standards-based collaboration hub to improve communication efficiency in automotive supply chains, the automotive manufacturer was supposed to share data with the system in the form of order requests and receive data from the system in the form of order acceptances from suppliers (Steinfield et al. 2011). This situation made automotive manufacturers simultaneously data providers and service consumers for the same IOS.

To construct the fair sharing model for an interorganizational information service, we utilize concepts from cooperative game theory that have been successfully applied for this purpose in logistics and supply chain management (Bartholdi III and Kemahlioğlu-Ziya 2005, Krajewska et al. 2008, Leng and Parlar 2009). The cooperative branch of game theory is concerned primarily with coalitions — groups of players — that coordinate their actions and pool their winnings (Branzei et al. 2008). One of the most prominent problems being studied in cooperative game theory is how to divide the extra earnings (or cost savings) among the members of the formed coalition. In the case of IOS, we suggest treating providers' decision to participate in the information service as a decision to join the coalition of providers. Using an information service creates savings for consumers. We assume that consumers are willing to sacrifice part of the obtained savings in the form of fees for using the system. The pool of these fees, which consumers are willing to pay, can be treated as the value that can be realized by a providers' coalition and should be shared fairly among them.

3.2.1 IOS value and costs

A cooperative game consists of a set of players (in our case, providers) $\mathbf{P}$ and a characteristic function $\nu(\mathbf{K})$ that specifies the maximum value that can be realized by a coalition $\mathbf{K} \subseteq \mathbf{P}$. For each set of players, it should be possible to estimate the best-case costs reduction scenario, that is, the maximum value of the coalition. The characteristic function in the case of IOS reflects how the total willingness-to-pay of IOS users changes depending on the participation of different data providers. We exclude from our coalition analysis the company that develops software for IOS and supports infrastructure, treating it as a development cost. The reason for this exclusion is that, in the reported cases, the difficulties with IOS adoption tend to be on the users' side (i.e., data providers). We are not aware of cases in which finding a company to write the software or operate the infrastructure was difficult once the financing was available. Meanwhile, securing the participation of business network members and their use of IOS can be a significant challenge.

The maximum potential coalition profit can be found as the difference between the willingness-to-pay of consumers for using the service and the costs to provide the service. In reality, extracting the actual willingness-to-pay of consumers in the form of fees can be difficult because it is in their interest not to reveal it (Lahiri et al. 2013). However, the focus of this paper is on the fair sharing mechanism and its influence on adoption decisions. Therefore, we believe that assuming that each IOS consumer will pay the maximum as specified by their willingness-to-pay for the service is acceptable, which provides an upper bound of the potential profits of the coalition. In the future, the model can be extended by relaxing this assumption.

To describe how consumers' willingness-to-pay depends on the participation of different providers, we make a number of additional assumptions. First, we assume that consumer C_j's willingness-to-pay ($C_j \in \mathbf{C}$, $\mathbf{C}$ — set of all consumers) is proportional to the projected savings from using the service and can be expressed as $w_j(s_j) = \alpha \cdot s_j$, where α ($\alpha \in (0, 1)$) is the parameter that describes the share of projected savings that a consumer is willing to pay in the form of fees. We assume that parameter α is the same for all consumers. Second, in our analysis, we focus on interorganizational information services that facilitate information exchange along the value chain among companies with already established business relationships. Consumers' savings from using such IOSs are proportional to the number of messages that they receive through the system or to their transactional volume. The messages being exchanged through the information link IOSs are orders, invoices, arrival notifications, and others (Bakos 1991). The number of these messages is usually proportional to the company's transactional volume. This assumption is consistent with the work of Barua and Lee (1997). We denote n_{ij} as the number of messages received by data consumer C_j from data provider P_i. Then, the dependency of the savings of data consumer j on data providers' participation (structure of the providers' coalition $\mathbf{K}$) can be expressed as $s_j(\mathbf{K}) = \bar{s} \cdot \sum_{i \in \mathbf{K}} n_{ij}$, where $\bar{s}$ represents the average savings per message, which can be an order, an invoice, a pre-arrival notification, or anything else.

Furthermore, we analyze cases in which the network effect influences the size of the per-message benefit as well, namely, the average savings per message is growing as the number of data providers increase. Traditionally, IOSs have been studied as network goods because the value of the system for data consumers grows with the number of data providers in the system (Bakos 1991, Clemons and Kleindorfer 1992). Our previous assumption that benefits are proportional to the number of messages exchanged via the system incorporates this fact. As more of the company's partners use the system, the number of messages that go through it increases. However, the average benefit per message can also grow with data providers' adoption rate. If all of a company's partners adopt the IOS, then the company does not have to support alternative means of communication. If the adoption of an IOS from the side of the data consumer's business partners is anything less than 100%, the data consumer will have to support alternative business practices, such as receiving e-mails with this information and manually inputting it into the system. Therefore, for each data consumer C_j the savings per message depends on the share of providers that adopted the system out of all data providers with which the data consumer is dealing, denoted by $\bar{s}_j(\mathbf{K}) = f_j\big(\frac{\sum_{i\in\mathbf{K}} n_{ij}}{\sum_{i\in\mathbf{P}} n_{ij}}\big)$. Finally, we assume that function $f\big(\cdot\big)$ has the same shape for all data consumers: $f\big(\cdot\big)$ is monotonically non-decreasing and reaches its maximum with full adoption, $\bar{s}_{max} = f(1)$.

We assume that the costs of developing the software and information infrastructure are born by the coalition of data providers. Providers' development costs (DC^P) are independent of the number of providers participating in the coalition. Additional costs include the fixed costs (FC^P) of providing access to the system for each data provider and the costs of operating the information infrastructure (VC^P), that are proportional to the number of messages going through the system. Fixed or setup costs are born individually by each company. They include new hardware and software acquisitions or development by companies that are needed to access the IOS or integrate it with the internal system, changes in internal business processes to interface with the system and provide the required data elements, and others (Barua and Lee 1997, Lee et al. 1999). Variable costs incorporate the infrastructure operating costs that are proportional to the number of messages, the costs of generating and inputting data per message, and others. Variable costs or costs per message for an IOS are usually very low relative to the fixed costs for all digital technology products (Bakos 1991). The costs of developing the standard for messages and the exchange structure and the costs to develop the software that supports the exchange are independent of the number of companies providing data to the system. They form the last group — development costs. IOS consumers also must bear fixed (FC^C) and variable (VC^C) costs to be able to use the system. In their structure, consumer fixed costs are very similar to the data provider costs because a similar infrastructure is required to receive messages through the IOS. Consumer variable costs are fees that consumers are willing to pay to data providers to use an IOS.

Under these assumptions, the characteristic function of our cooperative game for a given set of prospective consumers **C** can be formulated as follows:

$$v(\mathbf{K}) = \sum_{j\in\mathbf{C}} w_j - DC^P - FC^P \cdot |\mathbf{K}| - VC^P \cdot \sum_{j\in\mathbf{C}} \sum_{i\in\mathbf{K}} n_{ij} \tag{3.1}$$

where w_j represents willingness-to-pay for the service of consumer j.

$$w_j = \alpha \cdot f\left(\frac{\sum_{i\in\mathbf{K}} n_{ij}}{\sum_{i\in\mathbf{P}} n_{ij}}\right) \cdot \sum_{i\in\mathbf{K}} n_{ij} \tag{3.2}$$

IOS can also suffer from negative externalities. For example, the use of the system by competitors can negatively affect a consumer's benefits if the latter wanted to gain a competitive advantage via IOS adoption (Bakos 1991, Clemons and Kleindorfer 1992). However, we limit our current analysis only to positive externalities. In the future, the model can be extended to incorporate negative externalities by redefining the willingness-to-pay function and introducing a term to penalize the competitors' participation in the system.

3.2.2 Individual provider and consumer participation profits

Using game-theoretical principles, we can estimate the fair reward to each data provider based on the defined characteristic function. In game theory, an allocation φ is a vector in which φ_i is the payoff to player P_i. Over time, a number of fair allocation principles have been developed such as core (Gillies 1959), nucleolus (Schmeidler 1969), and Shapley value (Shapley 1953), which possess different desirable properties. In our case, we decided to use the Shapley value allocation principle because it uniquely satisfies the combination of the following important conditions: additivity, anonymity, efficiency, and dummy player property (Shapley 1953). Efficiency property means that the total gain is being distributed among the contributors. Anonymity property requires that players with identical contributions receive identical rewards. The dummy player property means that the player with a zero contribution to the coalition does not receive any reward. Finally, the additivity property ensures that if the game can be represented as a sum of two games, then the Shapley value for a player in this game can be represented as a sum of two Shapley values in smaller games. These properties are meaningful and practical in terms of our problem. Efficiency ensures that all of the revenue collected by providers is being redistributed among them. Anonymity and dummy player properties correspond to generally accepted notions of "fairness." The additivity property ensures that the Shapley value allocations do not depend on bargaining time among the players. We assume that all parties know how the Shapley value allocation principle works and find this division of revenue as mutually acceptable and reached without additional bargaining costs. Moreover, the use of the Shapley value as an allocation principle allows the overall profits to the community to be maximized, as will become clear from our further discussion.

A player's Shapley value can be found as expressed in formula (3.3) and can be interpreted as the expected incremental contribution to the value of the coalition. There are $n!$ joining sequences through which a coalition of n players can be formed. The incremental value of a player to a coalition may depend on when the player joins the coalition. Accordingly, the expected incremental contribution made by a player is determined by combining the incremental contribution made by a player for a given joining sequence and the probability $p(\mathbf{K} \cup \{P_i\})$ of that sequence occurring. Because the Shapley value reflects the added value of the player to the grand coalition, by including only the players with positive Shapley values into the coalition, we can ensure that the total profits for the community are maximized because the inclusion of any player with a negative Shapley value effectively reduces the coalition's expected profits. Consequently, by rewarding each data provider with the corresponding Shapley value, we align the individual interests of providers of receiving a positive reward for participation with the interests of the community in maximizing the total profits for the business network. However, important to acknowledge is that the Shapley value distribution principle is not aligned with the individual interests of maximizing the participation reward because certain providers could be better off under other distribution schemes that account for their power position in the network, such as described by Clemons and Kleindorfer (1992). The Shapley value can be written as:

$$\varphi_i(v) = \sum_{\mathbf{K}\subseteq\mathbf{P}\setminus\{P_i\}} p(\mathbf{K}\cup\{P_i\})\cdot\Big(v(\mathbf{K}\cup\{P_i\}) - v(\mathbf{K})\Big) \tag{3.3}$$

We note that the development costs of producing the IOS are independent of the number of data providers contributing to the system. Therefore, the development costs are not distributed automatically by the Shapley value principle. To incorporate these costs, we must adjust the reward received by data provider P_i in the following way:

$$r_i = \varphi_i(v) - \frac{\varphi_i(v)}{v(\mathbf{P}) + DC^P}\cdot DC^P = \varphi_i(v)\cdot\frac{v(\mathbf{P})}{v(\mathbf{P}) + DC^P} \tag{3.4}$$

We consider situations in which the profit realized by the grand coalition of data providers is positive, that is, $v(\mathbf{P}) > 0$, indicating that providers' rewards are positive as long as the Shapley value is positive. By distributing development costs in such a way, we are ensuring that the necessary condition for individual participation (i.e., positive rewards) is aligned with the communal incentive of maximizing the network-wide profits.

We assume that consumers and providers are rational — adopt the service, and participate in the service provision if they receive positive profits from doing so. Providers' profits equal the rewards allocated to them according to the Shapley value principle (vector r, see formula (3.4)). Provider P_i will join the coalition of service providers or "adopt" the service if $r_i > 0$, which is equivalent to $\varphi_i > 0$ (see formula (3.4)). The provider's Shapley value reflects the value of the provider's participation for the user community. Thus, an increase in the revenues that the provider brings to the system may not be high enough to justify the costs of joining the system. In the third section, we analyze in detail on what the Shapley value that the provider is entitled to depends.

Consumers' revenues are equal to the savings that they obtain from using the service (vector s). We assume that consumers also must incur fixed (FC^C) and variable (VC^C) costs if they want to use the information service. Similar to data providers, they must buy new hardware and software to access the

IOS or integrate it with the internal system, and must change their internal business processes to interface with the system and make use of the provided data elements (Barua and Lee 1997, Lee et al. 1999). Consumers' variable costs are their fees for the system or their willingness-to-pay level, as specified in formula (3.2).

The total costs of using the service for consumer C_j can be expressed as the sum of fixed and variable costs. Consumer C_j will adopt the service if the savings from using the service are greater than adoption costs: $s_j > FC^C + \alpha \cdot f\big(\frac{\sum_{i\in\mathbf{K}} n_{ij}}{\sum_{i\in\mathbf{P}} n_{ij}}\big) \cdot \sum_{i\in\mathbf{K}} n_{ij}$ or, taking into account the previous formulation of the dependence of savings on the number of messages, $(1-\alpha) \cdot f\big(\frac{\sum_{i\in\mathbf{K}} n_{ij}}{\sum_{i\in\mathbf{P}} n_{ij}}\big) \cdot \sum_{i\in\mathbf{K}} n_{ij} > FC^C$. The left side of the inequality grows with the number of messages that a consumer receives through the system. Thus, the higher the consumer's the business volume, the higher the probability that the consumer will adopt the service. This relationship is consistent with the common observation in the IOS literature that smaller companies often struggle with IOS adoption because of the high initial investment costs required, which are not always offset by the savings realized from using the service (Beck and Weitzel 2005). We assume that parameter α is independent of the savings received, that is, the consumer is willing to sacrifice a fixed share of the savings. In reality, it is fair to expect that α is actually changing depending on the savings realized by the user. We believe that this expectation can be a fruitful future of the model; however, in the current analysis, we stick to the assumption of a fixed α to avoid "overloading" the initial model.

3.2.3 Adoption dynamics

We assume that the system adoption dynamics occur in the following manner. Each provider estimates the participation profits for different combinations of adopting consumers. Each consumer is doing the same for different combinations of providers. Each side has complete information regarding the preferences of the other side, and providers decide whether or not to provide the service before consumers decide whether or not to adopt the service. If we assume that, initially, each data provider decides on whether or not to join the service independently of other data providers, then the service will be created only if at least for one provider P_i there is at least one combination of consumers $\mathbf{L}_i$ ($\mathbf{L}_i \subseteq \mathbf{C}$) that makes it profitable for the provider to participate ($\varphi_i > 0$) and such that, for each consumer in this combination, it is profitable to adopt the service even if consumers obtain data only from this single provider P_i (for $\forall C_j \in \mathbf{L}_i : \ (1-\alpha) \cdot f\big(\frac{n_{ij}}{\sum_{i \in P} n_{ij}}\big) \cdot n_{ij} > FC^C$). This provider-consumers combination ($\mathbf{A} = \{P_i\} \times \mathbf{L}_i$) will form the adopting community. If more than one provider satisfy this condition, then the adopting community will be the union of such provider-consumer combinations.

If we assume that data providers can coordinate their decisions on whether or not to provide the service (i.e., provider can have 100% confidence that another provider will provide the service if they agree on it), then the service will be created if at least for one combination of providers $\mathbf{K}$ ($\mathbf{K} \subseteq \mathbf{P}$) there is at least one combination of consumers $\mathbf{L}_K$ ($\mathbf{L}_K \subseteq \mathbf{C}$) that makes it profitable for all providers in $\mathbf{K}$ to participate (for $\forall P_i \in \mathbf{K} : \ \varphi_i > 0$) and such that, for each consumer in this combination, it is profitable to adopt the service even if receive gets data only from this combination of providers (for $\forall C_j \in \mathbf{L}_K : \ (1-\alpha) \cdot f\big(\frac{\sum_{i \in \mathbf{K}} n_{ij}}{\sum_{i \in \mathbf{P}} n_{ij}}\big) \cdot \sum_{i \in \mathbf{K}} n_{ij} > FC^C$). This provider-consumer combination ($\mathbf{A} = \mathbf{K} \times \mathbf{L}_K$) will form the adopting community. If more than one combination of providers satisfies this condition, then the adopting community will be the union of such provider-consumer combinations.

We consider cases only for which the value of the service provided by the total community is greater than the development costs. We assume that the variable costs of the service provision are negligible (Bakos 1991). Thus, in our model, the adoption of the service mainly depends on the relationship between the savings obtained by individual consumers and the fixed acquisition costs. Consumer C_j will never adopt the service if $\sum_{i \in \mathbf{P}} n_{ij} < \frac{FC^C}{(1-\alpha) \cdot f(1)}$. The savings are proportional to the company's business volume, thus, a higher number of large companies among the consumers results in a higher adoption rate among consumers. Regarding data providers, their adoption depends on the relationship between their contribution to the system and their costs. In the next section, we analyze the provider characteristics that influence the size of the reward and, subsequently, providers' adoption decisions.

The suggested fair sharing model can be easily extended to the case in which data providers to an IOS are also the consumers of its services. In our earlier example of the MOSS project, an automobile manufacturer provided order requests via the system and received order confirmations from suppliers in return. This IOS service can be viewed as a combination of two one-way data flows: from manufacturer to supplier and in reverse. For each subservice, estimating consumer savings, corresponding fees, and provider rewards is possible. Then, for each player who was a consumer in one subservice and a provider in another, the consumer savings should be combined with provider rewards, and the corresponding fees, fixed costs, and provider variable costs should be deducted. If the resulting participation profits are positive, then for the player to adopt an IOS is rational. In the remainder of the paper, we consider the case in which each company performs only one role: data provider or service consumer. However, as we have just demonstrated, this model can be used as a building block for a more complicated scenario in which a company performs both roles.

3.3 Network effect, network structure, and fair reward size

We start our model analysis by considering a basic scenario in which consumers' savings depend on the number of messages exchanged via an IOS in a linear manner. Consumers' savings per message are fixed and equal to b ($f(x) = b$). We assume that all coalition formation sequences have the same probability. Then, the Shapley value of data provider P_i can be found as follows (see Appendix 3.B for details):

$$\varphi_i(v) = \sum_{k=0}^{|\mathbf{P}|-1} \binom{|\mathbf{P}|-1}{k} \frac{(k)!(|\mathbf{P}|-k-1)!}{|\mathbf{P}|!} \cdot \left((\alpha \cdot b - VC^P) \cdot \sum_{j \in \mathbf{C}} n_{ij} - FC^P \right) \tag{3.5}$$

Taking into account that α, b, and VC^P are all fixed parameters, the inspection of formula (3.5) allows us to formulate our first proposition.

Proposition 1. When consumers' savings per message are constant ($f(x) = b$), the Shapley value of data provider P_i depends on the transaction volume of *this provider ($\sum_{j \in \boldsymbol{C}} n_{ij}$) in a linear manner.*

Throughout this paper, we assume that the variable costs of producing the service are negligible; that is, consumers' willingness-to-pay per message is higher than the variable costs of producing that message ($\alpha \cdot b - VC^P > 0$). Therefore, when consumers' savings are linear in the number of messages exchanged through IOS, the higher the total transactional volume of a provider, the higher the fair reward to a provider for participation in the IOS. The participation of larger companies is more valuable from the business network point of view because it results in larger total consumer savings. Furthermore, in this scenario, two suppliers with similar total transactional volumes receive the same reward irrespective of how their transactions are distributed among consumers within the network.

However, we previously discussed that a more realistic assumption regarding consumers' per message savings would be that they are also growing with the adoption rate. Thus, the second scenario to consider is the one with the network effect in the consumers' savings function ($\bar{s}_j(\mathbf{K}) = f\big(\frac{\sum_{i \in \mathbf{K}} n_{ij}}{\sum_{i \in \mathbf{P}} n_{ij}}\big)$). Once we have adjusted the characteristic function of the game, the Shapley value for data provider P_i can be found as follows (see Appendix 3.B for details):

$$\varphi_i(v) = \sum_{\mathbf{K} \subseteq \mathbf{P} \setminus \{P_i\}} \frac{(|\mathbf{K}|)!(|\mathbf{P}| - |\mathbf{K}| - 1)!}{|\mathbf{P}|!} \cdot \Bigg[\sum_{j \in \mathbf{C}} \Bigg(\Bigg[\alpha \cdot f\Bigg(\frac{\sum_{p \in \mathbf{K}} n_{pj} + n_{ij}}{\sum_{p \in \mathbf{P}} n_{pj}} \Bigg) - \\ - VC^P \Bigg] \cdot n_{ij} + \Bigg[\alpha \cdot f\Bigg(\frac{\sum_{p \in \mathbf{K}} n_{pj} + n_{ij}}{\sum_{p \in \mathbf{P}} n_{pj}} \Bigg) - \\ - \alpha \cdot f\Bigg(\frac{\sum_{p \in \mathbf{K}} n_{pj}}{\sum_{p \in \mathbf{P}} n_{pj}} \Bigg) \Bigg] \cdot \sum_{p \in \mathbf{K}} n_{pj} \Bigg) - FC^P \Bigg] \tag{3.6}$$

We observe that the relationship between a provider's business volume and the Shapley value becomes more complex. The Shapley value is not simply proportional to a provider's total transactional volume but depends on the distribution of this volume among different consumers and the transactional volumes of these consumers with other providers. In this scenario, a provider is being rewarded for increasing the savings per message for the messages received by its customers from other providers. Thus, in the presence of the network effect in the average savings per message, the provider's reward depends not only on its transactional volume but also on the transactional volumes of its customers with other providers. This situation implies that we can have two providers in the same network with identical total transactional volumes but different Shapley values because of the differences in their customer bases, which is not the case when the savings per message are constant. We refer you to Appendix 3.B for detailed explanations of how we arrived at these conclusions.

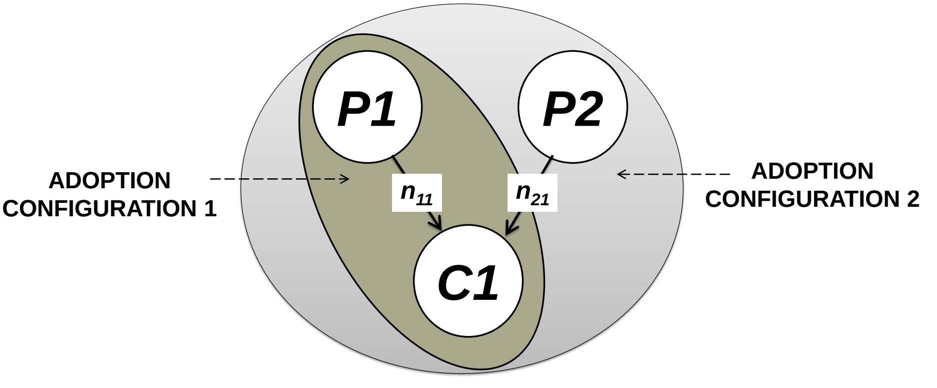
Proposition 2. When consumer savings per message are growing with providers' adoption rate ($f'(x) > 0$), each consumer's total business volume is fixed (for $\forall j : \sum_{p \in \boldsymbol{P}} n_{pj}$ — constant), and the variable costs are negligible ($\alpha \cdot f(x) > VC^P$ for $x > 0$), then the Shapley value of data provider P_i is positively related to its business volume with each customer (n_{ij}) and depends on the network structure (i.e., the transaction volumes of provider's consumers with other data providers).

To understand the influence of the network structure on the reward size, we consider the example of a small business network that consists of one consumer and two data providers. The business volume between provider P_1 and consumer C_1 requires an exchange of n_{11} number of messages, and the business volume between provider P_2 and consumer C_1 requires an exchange of n_{21} number of messages. From the perspective of data provider P_1, we can consider two options: the provider provides the service alone or together with provider P_2 (see Figure 3.1). In the first case, the Shapley value of provider P_1 can be found as follows: $\varphi_1^1 = \alpha \cdot f(\frac{n_{11}}{n_{11}+n_{21}}) \cdot n_{11} - VC^P \cdot n_{11} - FC^P$. In the second case: $\varphi_1^2 = \frac{1}{2} \cdot \alpha \cdot n_{11} \cdot \Big(f(\frac{n_{11}}{n_{11}+n_{21}}) + f(1)\Big) + \frac{1}{2} \cdot \alpha \cdot n_{21} \cdot \Big(f(1) - f(\frac{n_{21}}{n_{11}+n_{21}})\Big) - VC^P \cdot n_{11} - FC^P$. The difference in the Shapley values for data provider P_1 between the two adoption configurations is:

$$\varphi_1^2 - \varphi_1^1 = \frac{1}{2} \cdot \alpha \Big(\big(f(1) - f(\frac{n_{11}}{n_{11}+n_{21}})\big) \cdot n_{11} + \big(f(1) - f(\frac{n_{21}}{n_{11}+n_{21}})\big) \cdot n_{21} \Big) \quad (3.7)$$

As we consider the positive network effect between consumers and the number of providers ($f'(x) > 0$), the Shapley value for the second adoption configuration is higher: $\varphi_1^2 - \varphi_1^1 > 0$. Therefore, the participation of data provider P_2 in the information system increases the Shapley value of data provider P_1 even though the number of messages provided by this data provider P_1, and the fixed and variable costs remain the same. This situation occurs because the consumer does not realize the full potential savings per message exchanged with provider P_1 without the participation of provider P_2. The consumer receives only $f(\frac{n_{11}}{n_{11}+n_{21}})$ in savings per message exchanged with provider P_1 if this is the only provider adopting the service. When both providers adopt the service, the consumer can obtain $f(1)$ of savings per message exchanged with both providers. The growth in consumer savings results in a higher Shapley value realized by provider P_1 when the other provider is involved in the service provision. Thus, in our example, the presence of the positive network effect between consumer gains and provider participation results in a positive network effect between provider gains and other providers' participation.

Figure 3.1: Two adoption configurations



We can generalize our observation to the networks of larger size by examining formula (3.6). We refer you to Appendix 3.B for a detailed discussion on this matter. Two main mechanisms exist through which the participation of other providers influences the Shapley value of provider P_i. First, the savings per messages realized by consumers on messages exchanged between them and provider P_i are affected because the average savings depend on the adoption rate of other providers. Second, the adoption of the service by other providers increases the Shapley value of provider P_i, given the influence of this provider's participation on the consumer savings realized for the messages exchanged between consumers and those other providers. Importantly, we note that this provider–provider positive network effect appears only when providers share a common consumer. A higher number of consumers that providers have in common with each other results in a stronger influence of providers' adoption on the gains realized by other providers.

Proposition 3. When consumers' savings per message are growing with providers' adoption rate ($f'(x) > 0$), the Shapley value of a data provider is positively related to the participation of another data provider if those providers have consumers in common.

This proposition can be easily related to the business network level characteristic of network density, which can be used to describe the existence of common customers among providers. Network density is defined as the ratio of the number of links in the network to the number of possible edges (Seidman 1983). We define that a link exists between data provider P_i and consumer C_j if $n_{ij} > 0$. The maximum number of links that are possible in a network with n providers and c consumers is $n \times c$, taking into account that no links can exist between consumers, and no links can exist between providers, and the edges are one-way directed (from provider to consumer). The minimum number of links that are possible is equal to c. In this case, each customer is connected to at least one provider. Thus, the network density lies in the interval $[\frac{1}{n}, 1]$. We refer to a network with the minimum number of links as a low density network (density ratio is $\frac{1}{n}$) and a network with the maximum number of links as a high density network (density ratio is 1).

The positive network effect among providers appears only if they serve the same customer. Providers in a low density network do not have common consumers. Consequently, the Shapley value received by a provider in such a network is not affected by the adoption of the service by other providers. In a high density network, each provider's Shapley value is affected by the service adoption by every other provider because they all have common consumers. In a network with density in between two extreme points, both types of providers can exist — those whose gains are affected by the adoption of the service by other providers and those whose gains are indifferent to it. A higher network density results in a higher number of providers affected by the provider–provider network effect. Accordingly, even if two business networks have the same number of providers, the same number of consumers, and the same transaction volume per consumer and per provider, it does not necessarily mean that the Shapley values of providers in these networks will be the same across all adoption configurations. Network density can play a role in how the total value created by an IOS is distributed among the providers depending on their network position as measured by the number of ties that they have with consumers and the number of ties that their consumers have with other providers. Hence, Proposition 3 can be reformulated into Proposition 4 for the business network level in the following manner.

Proposition 4. When consumers' savings per message grow with providers' adoption rate ($f'(x) > 0$) and the network has high density (density ratio is 1), the Shapley value of each provider depends on the service adoption by every other provider. When consumers' savings per message grow with providers' adoption rate ($f'(x) > 0$) and the network has low density (density ratio is $\frac{1}{n}$), providers' Shapley values are indifferent to the service adoption by other providers. When the network has a medium density ratio (density ratio lies in the interval $[\frac{1}{n}, 1]$), then there can be two types of providers: those whose Shapley values are affected and unaffected by the participation of other providers. Providers with Shapley values that are unaffected by others can exist only if providers exist that do not have customers in common with other providers.

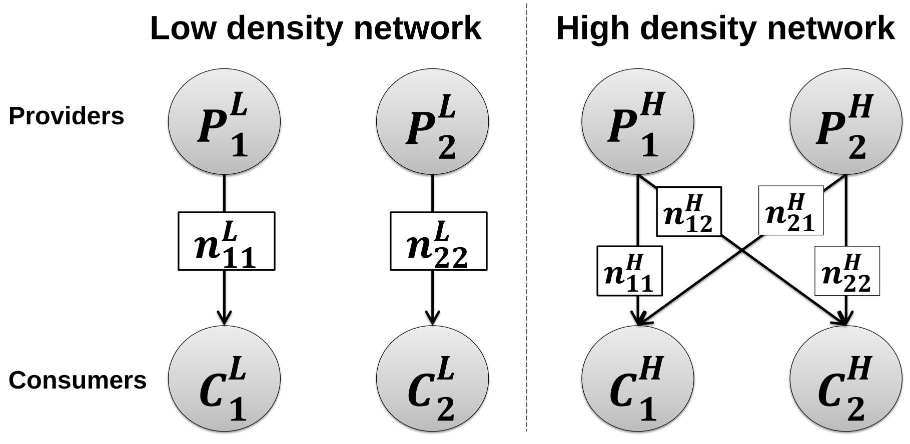
3.4 Network structure, coordination, and adoption

The presence of the network effect between consumers and providers brings about a positive network effect among providers in terms of higher Shapley values but only for certain network structures. In turn, this difference can influence how the same information service is adopted in business networks that are the same size and have the same business volume but differ in density. In this section, we analyze the implications of different network structures and coordination scenarios for an interorganizational service adoption under fair sharing. We distinguish between low and high-density networks that differ in the number of connections among providers and consumers (see the illustration for 2×2 networks depicted in Figure 3.2). To facilitate the comparison between two network structures, we assume that consumers and providers in the high density network have the same business volume as consumers and providers in the low density network ($\sum_{j \in \mathbf{C}} n_{ij}^H = \sum_{j \in \mathbf{C}} n_{ij}^L$, $\sum_{i \in \mathbf{P}} n_{ij}^H = \sum_{i \in \mathbf{P}} n_{ij}^L$). Furthermore, we consider two coordination scenarios: (1) when data providers do not coordinate their decision to adopt the service and assume that they cannot count on the participation of others and (2) when data providers jointly decide to adopt the service. In practice, a scenario with coordination could be represented by the formation of a consortium among providers with the goal to promote the use of a certain IOS, such as the Mortgage Electronic Registry System (MERS), for which community members were co-owners of the system (Markus and Bui 2012). In contrast, when an IOS is offered by an independent system provider, each data provider can separately decide whether or not to adopt the system, which is an example of uncoordinated adoption, such as e-Modal, the terminal gate appointment system being used in the ports of Los Angeles and Long Beach. The system is offered by an independent software provider, and each terminal operator decided independently from another whether or not to adopt the system (Van Baalen et al. 2009).

3.4.1 Uncoordinated adoption

Providers and consumers make their adoption decisions by comparing their rewards and savings with their costs. The provider's reward can be calculated using formula (3.4). We previously mentioned that the variable costs of the IOS provision are typically negligible. Therefore, we assume that they are always low enough to be covered by customers' per message willingness-to-pay. However, the fixed costs are often an issue in IOS adoption. Therefore, we define the barrier costs as the fixed costs higher than which the provider or the customer will not adopt the service. The barrier fixed costs for data provider P_i under the condition that only customer C_j adopts the service are

Figure 3.2: Messages flows in low and high density 2×2 networks



denoted as $B(P_i|C_j)$. The barrier fixed costs can be found by estimating the value that the provider or consumer receives from using the system depending on the different adopter configurations.

For uncoordinated adoption, we assume that providers do not know anything about the actions of other providers. Hence, provider P_i estimates the value of the system for all possible adopter combinations, which can include any number of consumers but only one provider P_i. Both providers' fair sharing reward and consumers' willingness-to-pay depend on the volume of transactions that go through the system. To understand whether full adoption is possible, investigating only the smallest provider and the smallest consumer in the network (smallest in terms of the number of transactions going through the IOS) is sufficient. If the barrier fixed costs are high enough for the smallest provider to adopt the system, then other providers will adopt as well. The same is true for consumers.

To investigate how network structure affects the chances of an IOS being adopted by an entire community, we need to investigate how it affects the barrier fixed costs of the smallest members. For a low density network in which each provider is connected to only one consumer, we have a provider–consumer pair that is the smallest in terms of the number of messages exchanged. Their barrier costs are as follows: $B(P_s^L|\mathbf{C}^L) = n_{ss}^L \cdot (\alpha \cdot f(1) - VC^P)$

and $B(C_s^L|P_s^L) = (1-\alpha) \cdot f(1) \cdot n_{ss}^L$, where n_{ss}^L is the number of messages exchanged among them. For of a high density network, the barrier costs of the smallest provider are $B(P_s^H|\mathbf{C}^H) = \sum_{i \in \mathbf{C}} (\alpha \cdot f(\frac{n_{si}^H}{\sum_{j \in \mathbf{P}}^H n_{ji}}) - VC^P) \cdot n_{si}^H$, and the barrier costs of the smallest consumer assuming the service adoption of its main corresponding provider are $B(C_s^H|P_d^H) = (1-\alpha) \cdot f(\frac{n_{ds}^H}{\sum_{j \in \mathbf{P}} n_{js}^H}) \cdot n_{js}^H$. Easy to demonstrate is that if the smallest consumers and the smallest providers have the same transaction volumes in high and low-density networks (i.e., $n_{ss}^L = \sum_{j \in \mathbf{C}} n_{sj}^H = \sum_{i \in \mathbf{P}} n_{is}^H$) and $f'(x) > 0$) then $B(P_s^L|\mathbf{C}^L) > B(P_s^H|\mathbf{C}^H)$ and $B(C_s^L|P_s^L) > B(C_s^H|P_d^H)$ (see Appendix 3.B for details).

The barrier fixed costs for the smallest provider and consumer are higher for the low density network. Therefore, the low density network is more likely than the high density network to adopt the expensive technology if the actions of providers are uncoordinated because it has a higher tolerance for fixed costs. The main reason for this tolerance is that the low density network can more easily reap the full benefits of the technology implementation because it is independent of the actions of other providers in the network. For the same reason, each actor in the low density network can tolerate much higher adoption costs than its counterpart in the high density network.

Proposition 5. When consumers' savings per message from using an IOS service grows with the providers' adoption rate ($f'(x) > 0$), and data providers decide to participate independently of each other under the fair sharing scheme, the acceptable fixed costs adoption region is larger for the low density network than for the high density network.

3.4.2 Coordinated adoption

If providers can coordinate their decisions on the adoption of an IOS, the number of prospective IOS adoption configurations that they can consider increases. Now they include the possibility of different providers participating as well. To understand how the coordination among providers influences the chances of an IOS being adopted, we need to consider the differences in the fixed barrier costs for the smallest provider and the smallest consumer. For the general case of the $n \times c$ high density network, the full adoption region has at least two limits when there is coordination among providers: barrier costs of the smallest data provider under the assumption that all provider's consumers use the service and at least one of the other providers coordinates $B(P_s^H|P_d^H, \mathbf{C}^H)$ and barrier costs of the smallest consumer under the assumption that its largest provider adopts the service together with one other provider $B(C_s^H|P_d^H, P_z^H)$. $B(C_s^H|P_d^H, P_z^H) = (1-\alpha) \cdot f\left(\frac{n_{ds}+n_{zs}}{\sum_{i \in \mathbf{P}} n_{is}}\right) \cdot (n_{ds}+n_{zs})$; $B(C_s^H|P_d^H) = (1-\alpha) \cdot f\left(\frac{n_{ds}}{\sum_{i \in \mathbf{P}} n_{is}}\right) \cdot n_{ds}$. It is easy to demonstrate that, in the high density network in the case of coordination among providers, the fixed barrier costs of the smallest provider and consumer are higher (see Appendix 3.B). In the high density network, if providers coordinate their adoption decision, they expect to create more value for consumers together and, accordingly, to receive higher rewards from the service provision. Such joint actions increase the network tolerance for the fixed costs of service adoption.

Proposition 6. When consumer's savings per message increases with the providers' adoption rate ($f'(x) > 0$) and the network structure has high density, the acceptable fixed costs adoption region for 100% adoption is larger when providers coordinate their participation decisions rather than make them independently.

However, for the low density network, customers' barrier costs remain the same as in the uncoordinated adoption case because they are only sensitive to the participation of their counteragent in the service ($B(C_s^L|P_s^L) = (1-\alpha) \cdot f(1) \cdot n_{ss}^L$). The Shapley values of the data providers will also be identical to the ones that they would receive in the uncoordinated scenario in which they do not consider the participation of other providers because their customers only interact with them, and other providers' participation does not influence their savings ($B(P_s^L|\mathbf{C}^L) = n_{ss}^L \cdot (\alpha \cdot f(1) - VC^P)$). This consequence is directly the result of Proposition 3, which states that providers' Shapley values are positively related if those providers have consumers in common, which is not the case for low-density networks. Thus, in low-density networks, the acceptable adoption regions are indifferent to whether providers coordinate their participation decisions or decide independently from one another.

Proposition 7. When consumers' savings per message increases with providers' adoption rate ($f'(x) > 0$) and the network structure has low density, the acceptable fixed costs adoption regions are indifferent to whether providers co-

ordinate their participation decisions or make them independently from one another (i.e. $B(P_s^L|P_d^L, \boldsymbol{C}^L) = B(P_s^L|\boldsymbol{C}^L)$ *and* $B(C_s^L|P_d^L, P_z^L) = B(C_s^L|P_d^L)$*).*

When we compare uncoordinated and coordinated adoption, remembering our assumption regarding development costs is important. We assumed that $\upsilon(P_1^H) > 0$, $\upsilon(P_2^H) > 0$, $\upsilon(P_1^L) > 0$, and $\upsilon(P_2^L) > 0$. If we relax this assumption and imagine that the value produced by smaller providers is not high enough to justify the development costs ($\upsilon(P_2^H) < 0$ and $\upsilon(P_2^L) < 0$), the value created jointly might be high enough to cross this barrier $\upsilon(P_1^H \cup P_2^H) > 0$ and $\upsilon(P_1^L \cup P_2^L) > 0$. Then, the coordination of the decision among providers can make it possible for the smaller provider to adopt the service as well because the development costs can be shared with the larger provider proportionally to the Shapley values. Thus, although the acceptable fixed costs are indifferent to whether providers coordinate their participation decisions or make them independently from each other for the case of low network density, the acceptable development costs are not indifferent. The acceptable development costs for coordinated adoption will be higher because they can be shared with other providers.

3.5 Discussion

3.5.1 Study contributions and limitations

In this paper, we develop a Shapley value-based fair sharing mechanism for the case of the information links IOS, which aligns the interests of individual organizations with those of the business network as a whole. The use of the Shapley value for the calculation of fair reward ensures that the network-wide profits from IOS adoption can be maximized. The system development costs are shared among providers proportionally to their Shapley values, which ensures that if the company is valuable to the community, then it will adopt the IOS. The main benefit of the designed approach is that it creates positive externalities for IOS data providers from the participation of other data providers (Proposition 3). Community-wide IOS initiatives have been reported to struggle with bringing together competitors to cooperate on the system development (Levy et al. 2003). In this case, Shapley value-based rewards provide additional incentives for co-opetition .

The size of the positive externalities among providers depends on the network density (Proposition 4). In the low density network, the provider's reward depends only on its transaction volume. In this case, each consumer is only served by one provider. Thus, consumers can realize full potential savings from IOSs once the corresponding provider has adopted the system. However, in the high density network, some or all consumers are served by multiple providers. For such a consumer to realize the full potential savings from IOS adoption, the participation of all providers with which the consumer is dealing is required. Accordingly, the fair reward to providers connected by a common consumer depends on the participation of the other providers serving the same consumer. In the presence of the network effect, the higher the number of other providers in the IOS serving the same consumer(s), the higher the realized savings and the larger the fair reward to the provider (Propositions 3 and 4).

The network effect and network density affect the community's tolerance toward the high fixed costs of adoption per company. When data providers decide independently on whether or not to join the IOS (i.e., uncoordinated adoption), then the acceptable amount of fixed costs is higher for the network with low density than the network with high density (Proposition 5). In the low density network, providers know that once they adopt the system, their consumers can fully realize their savings. Meanwhile, in the high density network, if providers assume that other providers do not participate, then their consumers cannot realize the full potential savings because of the network effect. Thus, the provider's reward will be higher in the low density network (assuming both providers have the same business volume). Because the reward is higher, the provider's tolerance to the increasing fixed costs of IOS adoption per company is stronger. Although the fair sharing mechanisms are rarely implemented in practice, we believe that this observation might add to our understanding of the differences in the spread of the same IOS technologies in different business networks, as evidenced by Damsgaard and Lyytinen (2001). Certain industry structures make realizing the benefits from IOS introduction easier. Consequently, technology in those industries spreads much faster.

Under fair sharing conditions, networks with high density can benefit from coordination among providers: the region of acceptable fixed costs for providers and consumers becomes larger if providers coordinate their adoption decisions rather than make them independently (Proposition 6). This happens because providers that coordinate expect that consumers will receive higher savings from an IOS and, accordingly, providers will receive higher rewards. However, in the low density network, the acceptable region of providers' fixed costs is indifferent to the coordination (Proposition 7). Their consumers will not benefit from providers' cooperation because the savings that they receive from an IOS do not depend on the participation of other providers. In contrast, the development costs are independent of the number of IOS providers. Thus, in the low density network, providers can still benefit from coordination by sharing the development costs among them. These insights suggest that the success of the implementation of the fair sharing model depends on not only the business network structure but also the ability of competitors within the network to cooperate and coordinate their actions. Previous research has underlined the importance of collective action for IOS development (Monge et al. 1998, Markus et al. 2006). Our analysis demonstrates additionally that the propensity for cooperation is much more important when the business network has high density because the realization of adopters' full benefits requires the adoption of the IOS by a much larger number of players.

The Shapley value-based approach allows for the differentiation between the contributions of different companies and promoting the participation of crucial actors (Propositions 1 and 2). Previous research has often reported two types of conflicts with respect to the uneven distribution of benefits in the IOS adopting community: among companies performing different business roles (Rodón and Sesé 2010) and among companies of different sizes (Fulk et al. 1996, Van Baalen et al. 2009, Steinfield et al. 2011). The separation of IOS users into data providers and data consumers makes it possible to analyze the influence of the participation of individual organizations on the savings realized by other community members. This explicit contribution evaluation can solve the conflict of the uneven distribution of IOS benefits among different business roles.

We assume that the consumer savings from using the information links IOS is proportional to the company's transactional volume, which is consistent with previous research (Barua and Lee 1997). From this assumption, it follows that a fair reward to providers is proportional to their transactional volumes (Propositions 1 and 2). Therefore, the community more highly values the participation of larger companies relative to small ones. The fair reward is negatively related to the fixed costs required of a provider to adopt the system (Formula 3.6). Thus, if the per-company fixed costs of adopting the system are high, the fair reward to a small company may be negative because its participation actually diminishes the community's profit. The savings realized from messages sent to consumers might not be high enough to counteract the costs to connect the company to the IOS. In such a case, from the community perspective, using other means of communication can be preferred to exchange information with these small companies. Thus, 100 % adoption by community members does not necessarily ensure maximum community profits from using the technology. In this respect, lower adoption levels can be more beneficial.

Beck and Weitzel (2005) encouraged the use of modified EDI solutions by small companies because those solutions have smaller required initial investment. However, those solutions tend to have higher variable costs from the provider's side because they allow for reduced process automation (e.g., human operators are required to input the data into solutions using a Web interface (McLaren et al. 2002)). An increase in variable costs results in a decrease in the fair reward to the provider that, in return, manifests in lower barrier fixed costs. Thus, even if the modified solution has lower fixed costs, it still might not be adopted by small companies under the fair sharing scheme if the variable costs associated with the new solution increase to an unacceptable level. This outcome — with less than 100% adoption of even a modified solution — will still be optimal from the community perspective because the additional benefits from the IOS adoption by those companies will not outweigh the associated costs for bringing them in.

Our model is the first attempt to evaluate the potential of applying a fair sharing approach to the redistribution of IOS benefits to improve IOS adoption. We made a number of limiting assumptions that can be relaxed and explored in future research. We assumed that each IOS consumer would pay according to their maximum willingness-to-pay, which can be a challenge to realize in the real-world setting. We estimated consumers' willingness-to-pay as a fixed share of the realized savings when, in reality, expecting that this share changes depending on the savings realized by the user is fair. In our model, the Shapley value estimation is based on the assumption of equal probability of different coalitions and the sequencing of providers' joining. Discriminating based on the probabilities of that different provider coalitions form can be a fruitful direction for further research.

3.5.2 Practical implications

We believe that our analysis provides useful insights for practitioners. First, we suggest a fair sharing approach to the redistribution of IOS benefits that, with certain adjustments, could be used in the charging model for IOS services. Admittedly, estimations of Shapley values can be a computational challenge for large networks. However, for certain game types, the Shapley value formula can be successfully adjusted to be computed in pseudo-polynomial time (Reinhardt and Dada 2005). For high density communication networks, such a reward scheme will provide additional incentives for data providers to cooperate and coordinate their actions. This approach can successfully eliminate the problem of the uneven distribution of IOS benefits among users with different roles in the business network. As for solving the problem of IOS adoption by small companies, this fair sharing model has significant potential if the targeted business network has high connection density; that is, many larger companies have a lot of connections to many smaller companies, and IOS use is characterized by a strong network effect — the costs of maintaining communication channels parallel to the IOS are very high. Moreover, our analysis highlights the importance of understanding the communication structure within the business network for IOS providers to realize the value of fostering cooperation. Networks with low connection density require much fewer cooperation-fostering efforts for a successful IOS implementation and adoption than networks with high connection density.

3.6 Conclusion

IOSs provide great opportunities for improving information exchanges among firms and reaping to the full extent the benefits from information digitization and the ease of information transfer through the use of modern technologies. Because competition today happens not only at the individual company level but at the business network level as well, the successful adoption of IOSs by business network members has become important. The necessity of cooperation among competitors, uneven distribution of benefits among IOS users, and high fixed costs of adoption have been often named among the barriers for community-wide IOS adoption. A number of researchers have suggested that the use of fair sharing schemes can be beneficial in the IOS context. To the best of our knowledge, in this paper, we develop the first analytical model of the fair sharing of IOS benefits. We demonstrate that the Shapley valued-based fair sharing approach can provide additional incentives for cooperation among competitors. This approach also has good potential to solve problems related to IOS benefit redistribution among different network roles and limited application in solving the problem of small firm adoption. Furthermore, we analyze the influence of IOS characteristics, network structure, and coordination potential on the effectiveness of the fair sharing mechanism. Our findings have implications for initiatives that aim to improve IOS adoption within large business network contexts, such as industries or clusters of economic activity.

3.A Inventory of mathematical notations

Notation	Explanation
$\mathbf{P}$	set of all data providers
$\mathbf{K}$	coalition of data providers
$\nu(\cdot)$	characteristic function of the game
$\mathbf{C}$	set of all data consumers
w_j	willingness to pay of consumer C_j
s_j	savings realized by consumer C_j from using the information service
α	parameter describing which share of projected savings a consumer is willing to pay in form of the fees
n_{ij}	number of messages received by consumer C_j from data provider P_i
$\bar{s}$	average savings per message
$f(\cdot)$	function describing dependency of the average savings per message on the number of messages in the system (i.e. data providers participation)
DC^P	information service development costs
FC^P	provider fixed costs of information service provision
VC^P	provider variable costs of information service provision
FC^C	consumer fixed costs of information service adoption
VC^C	consumer variable costs of information service adoption
φ_i	Shapley value of data provider P_i
r_i	reward received by data provider for information service provision
$B(P_i\|C_j)$	barrier fixed costs for the data provider P_i under the condition that only customer C_j adopts the service

3.B Proofs sections 3.3 and 3.4

Proposition 1

We consider the scenario when the average savings per message of the consumer are fixed and equal to b $(f(x) = b)$. In this case, the characteristic function of the game has the following shape:

$$v(\mathbf{K}) = \alpha \cdot b \cdot \sum_{j\in\mathbf{C}} \sum_{i\in\mathbf{K}} n_{ij} - DC^P - FC^P \cdot |\mathbf{K}| - VC^P \cdot \sum_{j\in\mathbf{C}} \sum_{i\in\mathbf{K}} n_{ij} \tag{8}$$

We assume that all sequences of coalition formations have the same probability. Then the general formula for Shapley value calculation (formula (3.3)) should be adjusted:

$$\varphi_i(v) = \sum_{\mathbf{K}\subseteq\mathbf{P}\setminus\{P_i\}} \frac{|\mathbf{K}|!(|\mathbf{P}| - |\mathbf{K}| - 1)!}{|\mathbf{P}|!} \cdot \Big(v(\mathbf{K} \cup \{i\}) - v(\mathbf{K})\Big) \tag{9}$$

Added value of P_i for a coalition $\mathbf{K}(P_i \notin \mathbf{K})$ in the scenario with linear function:

$$\begin{aligned}
v(\mathbf{K}\cup\{P_i\}) - v(\mathbf{K}) = {} & \alpha \cdot b \cdot \sum_{j\in\mathbf{C}} \sum_{p\in\mathbf{K}\cup\{P_i\}} n_{pj} - DC^P - FC^P \cdot |\mathbf{K}\cup\{P_i\}| - \\
& - VC^P \cdot \sum_{j\in\mathbf{C}} \sum_{p\in\mathbf{K}\cup\{P_i\}} n_{pj} - \alpha \cdot b \cdot \sum_{j\in\mathbf{C}} \sum_{p\in\mathbf{K}} n_{pj} + DC^P + \\
& + FC^P \cdot |\mathbf{K}| + VC^P \cdot \sum_{j\in\mathbf{C}} \sum_{i\in\mathbf{K}} n_{pj} = \\
& = (\alpha \cdot b - VC^P) \sum_{j\in\mathbf{C}} n_{ij} - FC^P
\end{aligned} \tag{10}$$

Now we can substitute the general formula for value added in formula (9) with the case specific one derived in formula (10):

$$\varphi_i(v) = \sum_{\mathbf{K}\subseteq\mathbf{P}\setminus\{P_i\}} \frac{(|\mathbf{K}|)!(|\mathbf{P}| - |\mathbf{K}| - 1)!}{|\mathbf{P}|!} \cdot \Big((\alpha \cdot b - VC^P) \sum_{j\in\mathbf{C}} n_{ij} - FC^P\Big) \tag{11}$$

The probability coefficient can be reformulated and the final formula for Shapley value of provider P_i has the following shape:

$$\varphi_i(v) = \sum_{k=0}^{|\mathbf{P}|-1} \binom{|\mathbf{P}| - 1}{k} \frac{k!(|\mathbf{P}| - k - 1)!}{|\mathbf{P}|!} \cdot \Big((\alpha \cdot b - VC^P) \sum_{j\in\mathbf{C}} n_{ij} - FC^P\Big) \tag{12}$$

Proposition 2

Once we introduce the network effect in the savings function of the consumers, the characteristic function of the game should be adjusted:

$$v(\mathbf{K}) = \sum_{j\in\mathbf{C}} \alpha \cdot f\left(\frac{\sum_{i\in\mathbf{K}} n_{ij}}{\sum_{i\in\mathbf{P}} n_{ij}}\right) \cdot \sum_{i\in K} n_{ij} - DC^P - FC^P \cdot |\mathbf{K}| - VC^P \cdot \sum_{j\in\mathbf{C}} \sum_{i\in\mathbf{K}} n_{ij} \tag{13}$$

Added value of P_i for a coalition $\mathbf{K}(P_i \notin \mathbf{K})$ given the new characteristic function:

$$\begin{aligned}
v(\mathbf{K}\cup\{P_i\}) - v(\mathbf{K}) = \sum_{j\in\mathbf{C}} \alpha \cdot f\big(\frac{\sum_{p\in\mathbf{K}\cup\{P_i\}} n_{pj}}{\sum_{p\in\mathbf{P}} n_{pj}}\big) \cdot \sum_{p\in\mathbf{K}\cup\{P_i\}} n_{pj} - DC^P - \\
- FC^P \cdot |\mathbf{K}\cup\{P_i\}| - VC^P \cdot \sum_{j\in\mathbf{C}} \sum_{p\in\mathbf{K}\cup\{P_i\}} n_{pj} - \sum_{j\in\mathbf{C}} \alpha \cdot f\big(\frac{\sum_{p\in\mathbf{K}} n_{pj}}{\sum_{p\in\mathbf{P}} n_{pj}}\big) \cdot \sum_{p\in\mathbf{K}} n_{pj} + \\
+ DC^P + FC^P \cdot |\mathbf{K}| + VC^P \cdot \sum_{j\in\mathbf{C}} \sum_{p\in\mathbf{K}} n_{pj} = \\
= \sum_{j\in\mathbf{C}} \Bigg((\alpha \cdot f\big(\frac{\sum_{p\in\mathbf{K}\cup\{P_i\}} n_{pj}}{\sum_{p\in\mathbf{P}} n_{pj}}\big) - VC^P) \cdot \sum_{p\in\mathbf{K}\cup\{P_i\}} n_{pj} - \\
- (\alpha \cdot f\big(\frac{\sum_{p\in\mathbf{K}} n_{pj}}{\sum_{p\in\mathbf{P}} n_{pj}}\big) - VC^P) \cdot \sum_{p\in\mathbf{K}} n_{pj} \Bigg) - FC^P
\end{aligned} \tag{14}$$

Accordingly, the Shapley value formula can be adjusted:

$$\varphi_i(v) = \sum_{\mathbf{K}\subseteq\mathbf{P}\setminus\{P_i\}} \frac{(|\mathbf{K}|)!(|\mathbf{P}|-|\mathbf{K}|-1)!}{|\mathbf{P}|!} \cdot \Big(\sum_{j\in\mathbf{C}} \Big((\alpha \cdot f(\frac{\sum_{p\in\mathbf{K}\cup\{P_i\}} n_{pj}}{\sum_{p\in\mathbf{P}} n_{pj}}) - VC^P)\cdot$$

$$\cdot \sum_{p\in\mathbf{K}\cup\{P_i\}} n_{pj} - (\alpha \cdot f(\frac{\sum_{p\in\mathbf{K}} n_{pj}}{\sum_{p\in\mathbf{P}} n_{pj}}) - VC^P) \cdot \sum_{p\in\mathbf{K}} n_{pj}\Big) - FC^P\Big) =$$

$$= \sum_{\mathbf{K}\subseteq\mathbf{P}\setminus\{P_i\}} \frac{(|\mathbf{K}|)!(|\mathbf{P}|-|\mathbf{K}|-1)!}{|\mathbf{P}|!} \cdot \Big(\sum_{j\in\mathbf{C}} \Big((\alpha \cdot f(\frac{\sum_{p\in\mathbf{K}} n_{pj} + n_{ij}}{\sum_{p\in\mathbf{P}} n_{pj}}) - VC^P)\cdot$$

$$\cdot(\sum_{p\in\mathbf{K}} n_{pj} + n_{ij}) - (\alpha \cdot f(\frac{\sum_{p\in\mathbf{K}} n_{pj}}{\sum_{p\in\mathbf{P}} n_{pj}}) - VC^P) \cdot \sum_{p\in\mathbf{K}} n_{pj}\Big) - FC^P\Big) =$$

$$= \sum_{\mathbf{K}\subseteq\mathbf{P}\setminus\{P_i\}} \frac{(|\mathbf{K}|)!(|\mathbf{P}|-|\mathbf{K}|-1)!}{|\mathbf{P}|!} \cdot \Big(\sum_{j\in\mathbf{C}} \Big((\alpha \cdot f(\frac{\sum_{p\in\mathbf{K}} n_{pj} + n_{ij}}{\sum_{p\in\mathbf{P}} n_{pj}}) - VC^P) \cdot n_{ij} +$$

$$+\Big(\alpha \cdot f(\frac{\sum_{p\in\mathbf{K}} n_{pj} + n_{ij}}{\sum_{p\in\mathbf{P}} n_{pj}}) - \alpha \cdot f(\frac{\sum_{p\in\mathbf{K}} n_{pj}}{\sum_{p\in\mathbf{P}} n_{pj}})\Big) \cdot \sum_{p\in\mathbf{K}} n_{pj}\Big) - FC^P\Big) \qquad (15)$$

Now we see that the relationship between the business volume of the provider and the Shapley value becomes more complex. Taking into account that $f'(x) > 0$, it is obvious from formula (15) that keeping the total business volume of each consumer constant ($\sum_{p\in\mathbf{P}} n_{pj}$) the higher is the business volume of the provider P_i with each individual customer (n_{ij}) the higher is the reward that the provider is being assigned assuming that the variable costs per transaction are negligible ($\alpha \cdot f(x) > VC^P$ for $x > 0$). We cannot predict the influence of the change in the total business volume of the provider ($\sum_{j\in\mathbf{C}} n_{ij}$), however, because the change can be associated with the rise of the business volume with one customer (for instance $n_{i1} \uparrow$) and the fall of the business volume with another customer (for instance $n_{i2} \downarrow$). The total change might be positive but the downward effect of n_{i2} reduction might have a more pronounced effect because of the network structure parameters (e.g. transactional volumes of customers 1 and 2 with other providers — $\sum_{p\in\mathbf{K}} n_{p1}$ and $\sum_{p\in\mathbf{K}} n_{p2}$) that are present in formula (15).

In addition we can see from formula (15) that the provider is being rewarded for increasing the average savings per message for the messages received by its customers from the other providers: the term $\sum_{j \in \mathbf{C}} \Big[\alpha \cdot f\Big(\frac{\sum_{p \in \mathbf{K}} n_{pj} + n_{ij}}{\sum_{p \in \mathbf{P}} n_{pj}}\Big) - \alpha \cdot f\Big(\frac{\sum_{p \in \mathbf{K}} n_{pj}}{\sum_{p \in \mathbf{P}} n_{pj}}\Big)\Big] \cdot \sum_{p \in \mathbf{K}} n_{pj}$ in formula (15). Thus, in the presence of the network effect in the average savings per message the provider's reward depends not only on the provider's transactional volume but also on the transactional volumes of their customers with other providers ($\sum_{p \in \mathbf{K}} n_{pj}$). This means that in the same network we can have two providers with identical total transactional volumes but with different Shapley values because of the differences in their customer bases which is not the case when the savings per message are constant.

Proposition 3

In the context when savings per message are increasing in the number of messages exchanged the Shapley value of provider P_i can be found as:

$$\begin{aligned}\varphi_i(v) = \sum_{\mathbf{K} \subseteq \mathbf{P} \setminus \{P_i\}} \frac{(|\mathbf{K}|)!(|\mathbf{P}| - |\mathbf{K}| - 1)!}{|\mathbf{P}|!} \cdot \Bigg[\sum_{j \in \mathbf{C}} \Bigg(\Bigg[\alpha \cdot f\Bigg(\frac{\sum_{p \in \mathbf{K}} n_{pj} + n_{ij}}{\sum_{p \in \mathbf{P}} n_{pj}}\Bigg) - \\ - VC^P\Bigg] \cdot n_{ij} + \Bigg[\alpha \cdot f\Bigg(\frac{\sum_{p \in \mathbf{K}} n_{pj} + n_{ij}}{\sum_{p \in \mathbf{P}} n_{pj}}\Bigg) - \\ - \alpha \cdot f\Bigg(\frac{\sum_{p \in \mathbf{K}} n_{pj}}{\sum_{p \in \mathbf{P}} n_{pj}}\Bigg)\Bigg] \cdot \sum_{p \in \mathbf{K}} n_{pj}\Bigg) - FC^P\Bigg] \qquad (16)\end{aligned}$$

The role of participation of other providers is captured by the term $\sum_{p \in \mathbf{K}} n_{pj}$ which refers to all messages exchanged between consumer C_j and providers in coalition $\mathbf{K}$ which does not contain provider P_i. This term plays two roles in the formula. First, it affects the savings per messages realized by consumer C_j: $f\big(\frac{\sum_{p \in \mathbf{K}} n_{pj} + n_{ij}}{\sum_{p \in \mathbf{P}} n_{pj}}\big)$. As total potential number of messages exchanged between consumer C_j and providers ($\sum_{p \in \mathbf{P}} n_{pj}$) is fixed irrespective of providers' participation, the higher is the number of other providers adopting the service ($\sum_{p \in \mathbf{K}} n_{pj} \uparrow$), the higher is the Shapley value received by provider P_i ($\phi_i \uparrow$). Second, the adoption of the service by other providers increases the Shapley value of provider P_i due to the influence that the participation of this provider has on the consumer savings realized for the messages exchanged between the consumer C_j and those other providers: $\alpha\left(f\left(\frac{\sum_{p\in\mathbf{K}} n_{pj}+n_{ij}}{\sum_{p\in\mathbf{P}} n_{pj}}\right) - f\left(\frac{\sum_{p\in\mathbf{K}} n_{pj}}{\sum_{p\in\mathbf{P}} n_{pj}}\right)\right) \cdot \sum_{p\in\mathbf{K}} n_{pj}$. It is important to note that this provider–provider positive network effect appears only when providers share a common consumer. If providers P_e and P_i do not serve the same consumer, then the set of all consumers $\mathbf{C}$ can be divided into two distinct subsets, subset $\mathbf{C}_e$ which contains all consumers communicating with provider P_e and subset $\mathbf{C}_i$ which contains all consumers communicating with provider P_i, such as $\mathbf{C}_e \cap \mathbf{C}_i = \emptyset$. In formula (16) for $j \in \mathbf{C}_e$ $n_{ij} = 0$ which means that consumers from those subset will not contribute to Shapley value of provider P_i. For $j \in \mathbf{C}_i$ $n_{ej} = 0$ which means that the participation of provider P_e will not contribute to the savings realized by consumers from subset $\mathbf{C}_i$ and in its turn will not influence the Shapley value of provider P_i. Thus, in a business network there exists a positive effect of provider–provider adoption among providers that have at least one consumer in common. The higher the number of consumers that providers have in common with each other, the stronger will be the influence of providers' adoption on the gains realized by other providers.

Proposition 5

In the general case of nxc network when data providers make the participation decision independently of each other, the size of the full adoption region has at least two upper limits: the barrier costs of the smallest provider assuming the full adoption from the consumers' side ($B(P_s|\mathbf{C})$) and the barrier costs of the smallest consumer assuming the service adoption of its main corresponding provider ($B(C_s|P_d)$). In case of a low density network where each provider is connected to only one consumer we have a pair provider–consumer which is the smallest in terms of the number of messages exchanged. Their barrier costs are the following: $B(P_s^L|\mathbf{C}^L) = n_{ss}^L \cdot (\alpha \cdot f(1) - VC^P)$ and $B(C_s^L|P_s^L) = (1-\alpha) \cdot f(1) \cdot n_{ss}^L$ where n_{ss}^L is the number of messages exchanged between them. In case of a high density network the barrier costs of the smallest provider can be found as $B(P_s^H|\mathbf{C}^H) = \sum_{i\in\mathbf{C}}(\alpha \cdot f(\frac{n_{si}^H}{\sum_{j\in\mathbf{P}}^H n_{ji}}) - VC^P) \cdot n_{si}^H$ and the barrier costs of the smallest consumer as $B(C_s^H|P_d^H) = (1-\alpha)\cdot$

$f(\frac{n_{ds}^H}{\sum_{j\in\mathbf{P}} n_{js}^H}) \cdot n_{js}^H$. It is easy to demonstrate that if the smallest consumers and the smallest providers have the same transactions volumes in high and low density networks (i.e. $n_{ss}^L = \sum_{j\in\mathbf{C}} n_{sj}^H = \sum_{i\in\mathbf{P}} n_{is}^H$) and $f'(x) > 0$ then $B(P_s^L|\mathbf{C}^L) > B(P_s^H|\mathbf{C}^H)$ and $B(C_s^L|P_s^L) > B(C_s^H|P_d^H)$:

$$B(P_s^L|\mathbf{C}^L) - B(P_s^H|\mathbf{C}) = n_{ss}^L \cdot (\alpha \cdot f(1) - VC^P) - \sum_{j\in\mathbf{C}} (\alpha \cdot f(\frac{n_{sj}^H}{\sum_{i\in\mathbf{P}} n_{ij}^H}) -$$
$$-VC^P) \cdot n_{sj}^H = \sum_{j\in\mathbf{C}} n_{sj}^H \cdot (\alpha \cdot f(1) - VC^P) -$$
$$-\sum_{j\in\mathbf{C}} (\alpha \cdot f(\frac{n_{sj}^H}{\sum_{i\in\mathbf{P}} n_{ij}^H}) - VC^P) \cdot n_{sj}^H = \alpha \sum_{j\in\mathbf{C}} \left(f(1) - f(\frac{n_{sj}^H}{\sum_{i\in\mathbf{P}}^H n_{ij}}) \right) \cdot n_{sj}^H$$

$$f'(x) > 0 \Longrightarrow f(1) > f(\frac{n_{sj}^H}{\sum_{i\in\mathbf{P}}^H n_{ij}}) \Longrightarrow B(P_s^L|\mathbf{C}^L) > B(P_s^H|\mathbf{C}^H)$$

$$B(C_s^L|P_s^L) - B(C_s^H|P_d^H) = (1-\alpha) \cdot f(1) \cdot n_{ss}^L - (1-\alpha) \cdot f(\frac{n_{ds}^H}{\sum_{i\in\mathbf{P}} n_{is}^H}) \cdot n_{is}^H$$

$$f'(x) > 0 \Longrightarrow f(1) > f(\frac{n_{ds}^H}{\sum_{i\in\mathbf{P}} n_{is}^H})$$

$$n_{ss}^L = \sum_{i\in P} n_{is}^H \Longrightarrow n_{ss}^L \geq n_{is}^H$$

Hence, $B(C_s^L|P_s^L) > B(C_s^H|P_d^H)$.

Proposition 6

For the general case of $n \times c$ high density network the full adoption region has at least two upper limits when there are no coordination between providers: barrier costs of the smallest data provider under the assumption that all provider's consumers use the service and at least one of other providers coordinate ($B(P_s^H|P_d^H, \mathbf{C}^H)$ — analogous to $B(P_2^H|P_1^H, C_1^H, C_2^H)$ for 2×2 network) and barrier costs of the smallest consumer under the assumption that the largest provider of this consumer adopts the service together with one other provider ($B(C_s^H|P_d^H, P_z^H)$ — analogous to $B(C_2^H|P_1^H, P_2^H)$ for 2×2 network). The upper limits of the high density network with no coordination scenario have been formulated earlier ($B(P_s^H|\mathbf{C}^H)$ and $B(C_s^H|P_d^H)$). It is easy to demonstrate that if the networks are identical in terms of transactional volumes and network structure then $B(P_s^H|P_d^H, \mathbf{C}^H) > B(P_s^H|\mathbf{C}^H)$ and $B(C_s^H|P_d^H\ P_z^H) > B(C_s^H|P_d^H)$:

$$B(C_s^H|P_d^H, P_z^H) = (1-\alpha)\cdot f\Big(\frac{n_{ds}+n_{zs}}{\sum_{i\in\mathbf{P}} n_{is}}\Big)\cdot(n_{ds}+n_{zs})$$

$$B(C_s^H|P_d^H) = (1-\alpha)\cdot f\Big(\frac{n_{ds}}{\sum_{i\in\mathbf{P}} n_{is}}\Big)\cdot n_{ds}$$

$f'(x) > 0 \Longrightarrow f\Big(\frac{n_{ds}+n_{zs}}{\sum_{i\in\mathbf{P}} n_{is}}\Big) > f\Big(\frac{n_{ds}}{\sum_{i\in\mathbf{P}} n_{is}}\Big) > 0$
$n_{ds}+n_{zs} > n_{ds} \Longrightarrow (1-\alpha)\cdot f\Big(\frac{n_{ds}+n_{zs}}{\sum_{i\in\mathbf{P}} n_{is}}\Big)\cdot(n_{ds}+n_{zs}) > (1-\alpha)\cdot f\Big(\frac{n_{ds}}{\sum_{i\in\mathbf{P}} n_{is}}\Big)\cdot n_{ds}$
$B(C_s^H|P_d^H, P_z^H) > B(C_s^H|P_d^H)$

$$B(P_s^H|P_d^H, \mathbf{C}^H) = \frac{1}{2}\sum_{j\in\mathbf{C}}\Big[\Big(\alpha\cdot f(\frac{n_{dj}+n_{sj}}{\sum_{i\in\mathbf{P}} n_{ij}}) - VC^P\Big)\cdot n_{sj} + \Big(\alpha\cdot f(\frac{n_{dj}+n_{sj}}{\sum_{i\in\mathbf{P}} n_{ij}}) -$$
$$-\alpha\cdot f(\frac{n_{dj}}{\sum_{i\in\mathbf{P}} n_{ij}})\Big)\cdot n_{dj}\Big] + \frac{1}{2}\sum_{j\in\mathbf{C}}\Big((\alpha\cdot f(\frac{n_{sj}}{\sum_{i\in\mathbf{P}} n_{ij}}) - VC^P)\cdot n_{sj}\Big) =$$
$$= \alpha\sum_{j\in\mathbf{C}}\Big[\Big(\frac{1}{2}\cdot f(\frac{n_{dj}+n_{sj}}{\sum_{i\in\mathbf{P}} n_{ij}}) + \frac{1}{2}\cdot f(\frac{n_{sj}}{\sum_{i\in\mathbf{P}} n_{ij}})\Big)\cdot n_{sj} + \frac{1}{2}\cdot\Big(\alpha\cdot f(\frac{n_{dj}+n_{sj}}{\sum_{i\in\mathbf{P}} n_{ij}}) -$$
$$-\alpha\cdot f(\frac{n_{dj}}{\sum_{i\in\mathbf{P}} n_{ij}})\Big)\cdot n_{dj}\Big] - VC^P\sum_{j\in\mathbf{C}} n_{sj}^H$$

$$B(P_s^H|\mathbf{C}^H) = \alpha\sum_{j\in\mathbf{C}} f\Big(\frac{n_{sj}^H}{\sum_{i\in\mathbf{P}} n_{ij}^H}\Big)\cdot n_{sj}^H - VC^P\sum_{j\in\mathbf{C}} n_{sj}^H$$

$f'(x) > 0 \Longrightarrow f\Big(\frac{n_{dj}+n_{sj}}{\sum_{i\in\mathbf{P}} n_{ij}}\Big) > f\Big(\frac{n_{sj}^H}{\sum_{i\in\mathbf{P}} n_{ij}^H}\Big) \Longrightarrow \frac{1}{2}\cdot f(\frac{n_{dj}+n_{sj}}{\sum_{i\in\mathbf{P}} n_{ij}}) + \frac{1}{2}\cdot f(\frac{n_{sj}}{\sum_{i\in\mathbf{P}} n_{ij}}) > f\Big(\frac{n_{sj}^H}{\sum_{i\in\mathbf{P}} n_{ij}^H}\Big)$

$B(P_s^H|P_d^H, \mathbf{C}^H) > B(P_s^H|\mathbf{C}^H)$

Chapter 4

A Tug-of-War: Shaping the Landscape of Interorganizational Information Systems

Abstract: Many firms must use more than one interorganizational information system (IOS) to support their communications with partners. The use of multiple systems can reduce the full benefits of IOS adoption. To account for this issue, we introduce a new concept: the landscape of interorganizational information systems. We rely on collective action theory to describe how actors' opposing strategies shape the IOS landscape and preclude the business community from attaining the landscape that represents collective level optimum because of the exclusive nature of this public good. Individual firms, alliances, and community representatives push the IOS landscape toward more standardization, more hub-type connections, and less substitutable IOSs, or toward less standardization, more point-to-point connections, and more substitutable IOSs. We support our theoretical propositions with evidence from a case study in a seaport setting. The developed theoretical framework can facilitate the understanding of why IOS landscapes differ from one seaport to another.

4.1 Introduction

Interorganizational information systems (IOSs) are used by many firms today to exchange information. A company must interact with a variety of organizations to support its operations. For example, it interacts with suppliers to obtain goods and services, with customers to sell produced goods and services, with banks to arrange financial affairs, and with governmental organizations to comply with regulations (Lee et al. 2005, Tuunainen 1998). Accordingly, IOSs support a variety of business processes, including buying and selling transactions between manufacturers and their suppliers (Baldi and Borgman 2001, Webster 1995, Ratnasingam 2000); electronic transmissions of payment information among payers, payees, and their banks (Teo et al. 2003); and tracking and tracing goods movements along transportation chains (Rodon and Ramis-Pujol 2006). To date, no reports have been made that a single IOS can support the complete variety of a company's interorganizational processes. Thus, many companies must use more than one IOS (Tuunainen 1998, Yoo et al. 2011, Lyytinen and Damsgaard 2011).

However, the vast majority of IOS studies focused on a single IOS or a comparison of IOSs rather than on the organization and the variety of IOSs that it uses. This focus precludes an investigation into how the IOS already in use affects the company's decision to adopt a new IOS (Lyytinen and Damsgaard 2011, Rolland et al. 2018), and the IOS characteristics that need to be considered when adopting a new IOS. To addresses this gap, we introduce a new concept — the IOS landscape — that can be categorized along the following dimensions: the number of IOSs, their architectures, their interoperability, and their substitutability. We support the relevance of the new concept by theorizing how the landscape dimensions can influence the benefits that a firm can achieve from IOS adoption.

We demonstrate the practical relevance of the concept in the setting of the Rotterdam Port business community. Today IOSs can have a significant impact on the international competitive position of port business networks. First, the efficient information exchange inside and among companies allows document processing delays that restrain the flow of goods to be minimized

(Bagchi and Paik 2001), which decreases the time during which goods are constrained from moving and increases the port's productivity. Second, better coordination within and among the companies results in a decrease in resource consumption and higher reliability (Douma et al. 2009, Imai et al. 2001). Third, information systems can make supply chains more transparent for customers (Van Baalen et al. 2009). Thus, IOSs can increase the quality of the services provided by a port cluster and improve a port's competitive position. However, the interplay among existing IOSs should be considered if the port is to leverage these opportunities.

To understand the forces that influence the formation of the IOS landscape, we use the collective action theory lens. This perspective allows us to analyze the variety, and often contradictory, of interests of actors in the development of the IOS landscape. Furthermore, the dynamics of the collective action of the interactions among the collectives allow us to describe the role that alliances and business community representatives play in forming the IOS landscape.

Through this paper, we make three main contributions. First, we demonstrate the importance of recognizing that modern firms use more than one IOS in their practices through our example of the port business network. Second, we introduce the concept of the IOS landscape and its dimensions. The use of this construct can enrich future studies of IOS development and adoption because it takes into account the interplay among different IOSs. Third, we describe the dynamics of the formation of the IOS landscape. We show how different organizational interests at various levels affect IOS landscape dimensions using the example of the Port of Rotterdam. The developed framework can be applied to IOSs studies in other contexts and can contribute to the understanding of why IOS landscapes differ from one seaport to another. Previous research stressed the advantages of common standards and the use of IOSs with shared neutral hub architectures (Markus et al. 2006, Steinfield et al. 2011). We demonstrate that the convergence of many different players and their interests is required to achieve such a state because of the exclusive public good nature of this type of IOS landscape. The competitive nature of individual companies ensures that such an equilibrium is not stable.

Once the shared IOS is in use by the majority, companies must think of new ways to distinguish themselves from the competition. As a result, new IOSs are developed and the proliferation of different systems and standards starts again.

The remainder of this paper is organized as follows. Based on the previous literature, we introduce the concept of the IOS landscape, the role of collective action in its formation, and its main characteristics. Then, we present the propositions derived from the literature that links the interests of business community members and the dimensions of the IOS landscape. In the fourth section, we discuss the method used to validate the propositions and demonstrate their relevance. Subsequently, we describe the findings of our case study of the IOS landscape of the Port of Rotterdam and reflect on our propositions in the discussion section. In the final section, we present our results, consider their implications for IOS research and practice, and discuss their limitations.

4.2 The landscape of interorganizational information systems

4.2.1 IOS landscape definition and characteristics

In this paper, we shift the focus of our research from an individual IOS being used by a firm to the variety of IOSs by which it is surrounded. We define a firm's IOS landscape as the collection of all interorganizational information systems that a firm can potentially use to connect to its existing and prospective partners (e.g., customers, suppliers, and government organizations). The information exchange among organizations — which information is available to which partner — and the quality of this information is shaped by the IOS landscape.

We propose to characterize an IOS landscape according to the number of IOSs, their architecture, their interoperability, and their substitutability. These dimensions were derived based on previous research and the inherent demands of the construct. Many authors pointed out the role that IOS architecture and interoperability levels play regarding the benefits that a firm can obtain from IOS adoption (Van Baalen et al. 2009, Steinfield et al. 2011, Zhao and Xia 2014). Steinfield et al. (2011) demonstrated that these dimensions play a role not only at the individual firm level but also at the business community level. The number of IOSs as a landscape dimension is a natural extension of the IOS landscape definition. Finally, IOS substitutability did not receive much attention in previous research, mostly because of the focus on the IOS rather than on the firm and the variety of IOSs that it can use. However, once the focus is shifted, we believe that the question arises immediately as to whether or not available IOSs perform the same functions. Next, we dive deeper into each of these landscape dimensions and discuss the firm's preferences for each.

We distinguish three types of IOS architectures depending on the number of actors that have access to one of its channels: point-to-point, private hub, and neutral or shared hub (Steinfield et al. 2011, Van Baalen et al. 2009). When we consider a firm's IOS landscape, we can distinguish only two types of connections: point-to-point and one-to-many. Depending on the side of the private hub that the firm is on, the private hub IOS can provide one-to-many connections (for the owner) or point-to-point connections (for non-owners). Neutral or shared hubs provide one-to-many connections for all of their users. The number of connections that a firm requires to connect to its partners influences the costs that it incurs to facilitate interorganizational communication. Each channel requires investments in specific hardware and software for support (Clemons and Kleindorfer 1992, Gosain et al. 2004). Furthermore, a higher number of channels results in higher risk that additional costs are incurred to ensure the integration between internal and external systems, which affects performance gains from IOS use (Truman 2000). A higher number of communication channels also increases the risk of having to support multiple standards in communications with firms' partners because each channel can be potentially based on a different standard. We can distinguish two extreme situations for the IOS landscape architecture dimension. On the one extreme, all of its channels can be point-to-point connections. On the other extreme, the firm can use one channel to connect to all of its partners.

An IOS is based on a set of standards called a B2B framework. This generic template provides functions that enable businesses to communicate efficiently over computer networks (Shim et al. 2000). The standardization of process and content interfaces requires agreement on the syntax, semantic, and pragmatic aspects of documents to be exchanged (Gosain et al. 2004). If a company uses IOSs that are based on different syntax or semantic standards, an additional application may be needed to translate messages from one IOS to the other. Even if those IOSs only communicate with internal systems, the costs of ensuring interoperability will still be higher if the IOSs are based on different standards. Efforts are required to make each of the systems interoperable with the internal system. A higher number of different standards that must be incorporated results in higher expenses to ensure interoperability. The interoperability dimension of a firm's IOS landscape has two extreme points. On the one extreme, all of the IOSs that a firm uses are based on different B2B frameworks. On the other extreme, all of the IOSs that a firm uses are based on a single B2B framework. In practice, the IOS architecture and standards are correlated. Systems with private hub architectures tend to rely on proprietary standards customized to the needs of the system owner (Kauffman and Mohtadi 2004, Gosain et al. 2004). Neutral or shared hubs tend to rely more on industry standards and non-proprietary e-business software capabilities (Kauffman and Mohtadi 2004, Steinfield et al. 2011) and, thus, can be integrated more easily and more cheaply with internal systems (Chau and Tam 1997, Xue et al. 2013).

A firm is usually involved in a variety of interorganizational processes and needs a variety of interorganizational information services to support them (Tuunainen 1998). These services can be characterized along two dimensions: roles that they connect and processes that they facilitate (Hong 2002). Roles are distinct, technologically separable, value-added activities undertaken by firms or individuals in a given business network (Kambil and Short 1994). Two or more IOSs can offer similar types of interorganizational information services. We define two of these services as substitutes if they connect the same business network roles and support the same business processes. Because an IOS can contain more than one interorganizational information service (Johnston and Vitale 1988), the two IOSs are substitutes only if all of the services provided by one have a substitute among the services provided by another. The IOSs can be partial substitutes if some of the services that one provides have substitutes among the services that the other provides but not all of them. Finally, IOSs are considered perfect substitutes if they connect the same business network roles, support the same business processes, and provide equal access to any trading partner (i.e., not limited to a specific set of companies).

The presence of IOS substitutes within a company's IOS landscape can have multiple consequences. If the company has a choice among IOSs that are perfect substitutes, then the situation is favorable for the firm because it can choose the IOS that better matches its requirements (e.g., price, quality). However, if the company operates in an environment in which the substitutes are not perfect, it will have to either invest in multiple systems to connect to multiple trading partners, or commit to only one IOS and give away part of its trading power because of the limited number of trading partners that support that IOS (Chismar and Meier 1992, Howard et al. 2003).

To summarize, a single firm can have the opportunity to adopt multiple IOSs that form its IOS landscape. This IOS landscape affects the benefits that the firm can reap from IOS adoption. In other words, IOS landscape dimensions, such as the number of IOSs, their architecture, their interoperability, and their substitutability, play an important role in determining the extent to which the full benefits of IOS adoption can be achieved. An individual firm would ideally operate in an IOS landscape that consists of a single IOS that provides access to all of its partners, which is possible only if the IOS landscape of the entire business community consists of a single IOS. Thus, the common interests of the business community are best served by a single IOS with a neutral hub architecture based on international standards (in case firms need to communicate with companies outside the business community). The formation of the IOS landscape with such desired characteristics is a collective action problem because it requires the coordination of different firms and alliances when they develop individual IOSs. Important to consider is the multi-level nature of the IOS landscape formation because, in most cases, IOSs are developed through firm alliances, and the main decisions regarding the IOS architecture, standards framework, and functionality are made within those alliances. Hence, considering the actions and interests of individual firms is not enough.

4.2.2 IOS landscape formation as a collection of collective actions

The development of an IOS requires the participation of multiple organizations. Previous research successfully used the lens of public goods and collective action theory to describe the process (Monge et al. 1998, Markus et al. 2006, Kumar and Van Dissel 1996). Collective action theory studies groups that are defined as collections of individuals with a common interest (Olson 1971). A common, collective, or public good is any good such that, if any individual consumes it, it cannot feasibly be withheld from others in that group (Olson 1971). A collective good possesses two defining characteristics: the impossibility of exclusion and the jointness of supply (Monge et al. 1998). Members of the collective cannot be excluded from using the good even if they have not contributed to its production; the use of the good by one member does not diminish the amount of good available for other users (Monge et al. 1998). An IOS is not a collective good, but the functionality that it provides to its participants is. This functionality can be the ability to reach other members of the collective via electronic channels or the access to the information shared by other users (Monge et al. 1998).

The problem with the production of a collective good is that each member of the collective decides to participate or not based on individual gains and costs. Members do not take into account the benefits that their participation will bring to the others. For this reason, a collective good is often underproduced. The characteristics of participants, their interests in consuming the public good, the available resources, and their costs and benefits are important predictors for the production of a collective good (Marwell and Oliver 1993, Monge et al. 1998). Olson (1971) demonstrated that larger groups face greater difficulties with collective goods production because, with the growth of group's size, the individual reward relative to the total gain is declining, which reduces the chances of individuals participating in the common cause. Moreover, a larger group faces higher organization costs of collective good production. An IOS is usually developed within an alliance of organizations

(Monge et al. 1998, Markus et al. 2006, Kumar and Van Dissel 1996, Lyytinen and Damsgaard 2011). Hence, the more organizations are required to participate in an IOS development, the lower the chances that the system will be actually created.

Previous research has identified a wide variety of interests that participants can pursue with respect to IOS development (Boonstra and de Vries 2008, Choudhury 1997, Robey et al. 2008). A single firm can participate in the development of multiple IOSs and, accordingly, belong to multiple alliances (Lyytinen and Damsgaard 2011). Interorganizational information systems have been previously studied through the lens of the collective action theory (Monge et al. 1998, Markus et al. 2006, Kumar and Van Dissel 1996, Constantinides and Barrett 2014). However, the focus of all of these studies has always been on one IOS, one set of standards, or one alliance. Khanna (1998) noted that a firm's decision to participate in an alliance can be affected by its activities outside the alliance because those activities can affect the stream of participation benefits. Accordingly, a firm's decision to adopt an IOS can be affected by the other IOSs that it is already using (Lyytinen and Damsgaard 2011).

The firm can either use an existing IOS developed by others or join an IOS alliance and participate in IOS development. Thus, the IOS landscape of a firm is being shaped by both types of IOS alliances — those in which the firm participates and those to which the firm does not belong but that develop IOSs that could be useful for the firm. The second type of alliances can be formed by the firm's information exchange partners (i.e., business and government organizations alike) or its competitors. An IOS landscape is a collective level construct with a structure shaped not only by the actions of individual organizations but also at a higher level by the actions of organizational alliances.

The unit of analysis for studying the IOS landscape should be shifted from the traditional ecosystems to business communities (Markus and Loebbecke 2013). Following Markus and Loebbecke (2013), an ecosystem is "an orchestrator's extended network of partners" whereas a business community is a "set of possibly overlapping ecosystems in a defined area of business activity." This wider unit of analysis allows taking into account that the actions of a firm belonging to a specific ecosystem may have effects that extend beyond its ecosystem. Accordingly, a firm's IOS landscape can be influenced by firms outside its ecosystem.

Analogous to the IOS case (Monge et al. 1998), the IOS landscape itself is not a collective good but the functionality that it provides is. The main IOS landscape functionality is to provide the ability to reach any prospective partner for a firm and to access the information shared by others. This functionality is an impure collective good because it requires the participation of many different firms to create it (i.e., jointness of supply) but does not possess the impossibility of the exclusion characteristic because limiting access to the IOS landscape (at least certain parts of it) to the individual firms is rather easy. Certain IOS landscapes are superior to others with respect to the costs of getting the required information through or from them or with respect to the information quality that they provide (Steinfield et al. 2011).

In this paper, we analyze the chances that the IOS landscape is being formed in accordance with the common interests of the business community. Olson (1971) demonstrated that for the case of large groups that do not invoke special coercion or incentive mechanisms to act in the common interests the following characteristics are important to predict whether the common good will be provided: 1) individual rewards for group-oriented actions; 2) the presence of an individual actor or small group of actors that could provide the collective good by himself or themselves; 3) the organization costs. In this paper, we focus on the first point by considering the individual interests of different actors who influence the formation of the IOS landscape. Constantinides and Barrett (2014) demonstrated that varying individual strategies can either hinder or sustain the production of the collective good in the IOS context. Wigand and Steinfield (2005) showed how industry-level change is moderated by the technological choices made by organizations. We investigate individual interests as a precursor for an actor forming a respective strategy.

Because IOS landscape formation is a collective good problem at the collective level, the actors that we should study are not only individual organizations but also their alliances. Moreover, although business communities do not have strategies, certain actors exist that are supposed to represent the common interests of a wider variety of community members (e.g., industry associations, government or semi-government organizations). Accordingly, our analysis of individual interests that influence the IOS landscape formation of a business community was organized at three levels: individual organizations, organizational alliances, and community interest representatives. Next, we discuss the interests of various individual actors that operate on different aggregation levels and that affect the formation of the IOS landscape and, accordingly, the chances of the IOS landscape satisfying joint community interests being developed without special incentive mechanisms in place.

4.2.3 Individual interests shaping the IOS landscape

Firm interests

Traditionally, the benefits that IOS adopters can expect have been divided into two groups — direct and indirect benefits (Iacovou et al. 1995, Robey et al. 2008, Kuan and Chau 2001). Direct benefits include reduced transaction costs, improved cash flow, lower inventory, and higher information quality (Iacovou et al. 1995). Indirect benefits include better customer service, increased ability to compete, and improved trading partner relationships (Iacovou et al. 1995). The indirect benefits do not stem from IOS implementation alone, but also from the opportunities arising from related business process reengineering and strategy alterations.

The direct benefits from IOS adoption accrue at the operational level and increase as more of the firm's trading partners use the same IOS. Assuming that the system works perfectly, the more partners using the IOS, the lower the firm's transaction costs, the larger the amount of high-quality information in the system, the better the financial and operational planning of the firm. Theoretically, the greatest operational savings can be obtained if all companies in the firm's business network use the one and only IOS that has a shared hub architecture. In such a case, all trading partners rely on the same B2B framework, and perfect interoperability exists among them.

Proposition 1.1. The interests of companies to increase operational efficiency and reduce costs through an IOS lead to a decrease in the number of IOSs in the landscape, an increase in the number of IOSs with a shared hub architecture, improved interoperability, and lower substitutability in the IOS landscape of a business community.

However, companies could also focus on the indirect benefit of strengthening their competitive position, which could push IOS development in another direction. When all organizations use the same IOS, a level playing field results (Ciborra 2000). To stand out in the competitive field, companies must offer something their competitors cannot or do not offer. Resourceful companies can afford to develop their own IOS and supporting standards and enforce adoption to gain a competitive edge. Examples include DaimlerChrysler's and General Motors' procurement systems and American Airlines' booking system (Yoo et al. 2011, Chismar and Meier 1992). These systems can limit the number of trading partners that are allowed to use them and can positively influence partner relationships. Such closer relationships have the potential to foster innovation, establish trust, and improve flexibility and responsiveness among adopting organizations (Bakos and Brynjolfsson 1993). The higher the number of companies that want to gain a competitive advantage via an IOS, the more systems there will be and the higher the chances that these systems are at least partial substitutes. Furthermore, a firm using a B2B framework that differs from its competitors cannot only improve its performance vis-à-vis them but can also lock-in its business partners and improve the company's bargaining power by creating switching costs (Johnston and Vitale 1988).

Proposition 1.2. Companies' interests in gaining a competitive advantage through an IOS lead to an increase in the numbers of IOSs and point-to-point connections in the landscape, lower interoperability, and greater substitutability in the IOS landscape of a business community.

Thus, at the level of individual organizations, two contradicting forces influence IOS landscape development depending on the benefits that companies seek from IOS adoption. If the strategy is to increase operational efficiency through an IOS, a shared hub standardized IOS that can be used by all business partners would be the best choice. However, if the strategy is to gain a competitive advantage through an IOS, multiple IOSs, each with distinguishing standards and functionality, are a better choice. This approach will differentiate the companies from each other and improve their competitive positions vis-à-vis each other.

Alliance interests

The majority of companies are not resourceful enough to individually develop an IOS and ensure its adoption. They need to form alliances. We distinguish three types of IOS alliances depending on the roles of the participating actors: a competitive alliance, a value chain alliance, and a mixed alliance (Monge et al. 1998, Hong 2002). Participants in a competitive alliance perform common value activities and compete for customers in the product or service market. An example of a competitive alliance is a common claims database maintained by firms in the insurance market (Kumar and Van Dissel 1996, Monge et al. 1998). Members of a value chain alliance belong to the same value chain but perform different roles in it. The most straightforward example is a point-to-point EDI integration between a buyer and a supplier, such as in the case of Vendor Managed Inventory (Xue et al. 2013). Finally, a mixed alliance contains both competitors and companies along the value chain. Most e-markets have this type of structure because they have either many suppliers and at least one customer, such as the proprietary e-procurement systems of DaimlerChrysler and General Motors, or multiple customers and multiple suppliers, such as Covisint's platform (Yoo et al. 2011).

Competitive alliances are created to improve the operations of all participating members. Their aim is not to gain an advantage vis-à-vis another competitor but to develop community-wide innovation. Therefore, IOSs are designed to be highly interoperable with other systems to ensure that all alliance members can use them and benefit equally. The shared hub architecture is the most convenient choice for a competitive alliance because it ensures equal access for all members at a low cost. Finally, cooperation among competitors reduces the chances that another IOS with the same functionality is developed. Thus, we can formulate the following proposition.

Proposition 2.1. The formation of a competitive alliance within a business community leads to improved interoperability, lower substitutability of the business community IOS landscape, and the creation of a shared hub IOS.

Value chain alliances are formed to improve the competitive positions of their members. Such an advantage can be created by offering new services or products through an IOS or by improving service levels (Xue et al. 2013). Alliance participants are likely to develop their own standards rather than use the ones available for everyone in the industry. Proprietary standards help participants "stand out from the crowd" and ensure commitment by creating a lock-in situation (Son et al. 2005). The IOS is likely to have a point-to-point architecture. Some of its functionality can duplicate the functionalities of the other systems used by the companies outside of the alliance. The same holds true when one dominant party forms an alliance with multiple partners that perform the same role, such as in the case of the proprietary e-procurement system (Kauffman and Mohtadi 2004, Yoo et al. 2011). The only difference is that these systems have a private hub architecture that is still a point-to-point type of connection for everyone except the owner of the system.

Proposition 2.2. The formation of a value chain alliance or a mixed alliance with one dominant party within a business community leads to lower interoperability, higher substitutability of the business community IOS landscape, and a higher number of point-to-point connections.

A mixed alliance without a dominant party can be formed to increase the efficiency of the operations throughout the community (Markus et al. 2006, Yoo et al. 2011) or to increase the competitive position of the business community vis-à-vis other communities (Van Baalen et al. 2009). For such consortia, ease of access for all participants is important; therefore, they are more likely to choose a shared hub architecture rather than point-to-point connections. Ease of adoption by all members can only be ensured by using standards that are available to everyone inside the business community. This situation leads to improved IOS interoperability (Zhao et al. 2007). In mixed alliances, participants can also compete with one another which is likely to reduce the number of IOSs that perform the same functions.

Proposition 2.3. The formation of a mixed alliance without a dominant *party within a business community leads to higher interoperability, lower substitutability of the business community IOS landscape, and the creation of a shared hub IOS.*

Community representative interests

Commercial companies are not the only members of a business community. Institutional agencies, such as government organizations and industry associations, also play a significant role in IOS development (Damsgaard and Lyytinen 1998a,b, 2001, Andersen and Henriksen 2004). These institutional actors usually have more organizational resources and, thus, can exert a stronger influence on other organizations. They do not pursue the interests of individual companies or alliances but represent the interests of the community in general. Government agencies are interested in supporting the competitive positions of business communities because they provide jobs for their constituents. Industry associations aim to promote common goals for companies belonging to a certain industry.

In the IOS research field, the role of the government has been mostly studied in relation to electronic data interchange (EDI) diffusion. Damsgaard and Lyytinen (1998a) described the limited direct involvement of the Finnish government in EDI diffusion in the country during the 1990s. Andersen and Henriksen (2004) reported on the EDI action plan developed by the Danish government in 1996 and its limited impact on EDI diffusion within the country. Based on these studies on the role of the government in the EDI diffusion process, we suggest that any governmental involvement (direct or indirect) in IOS development in a certain business community fosters cooperation among companies rather than favors one company because the boundaries of a business community are usually limited to a single state.

Proposition 3.1. Efforts by government agencies (if any) tend to aim at ensuring IOS interoperability and reducing the number of IOSs in the business community. They tend to support the development of shared hub IOSs and aim at eliminating multiple systems that perform the same functionality.

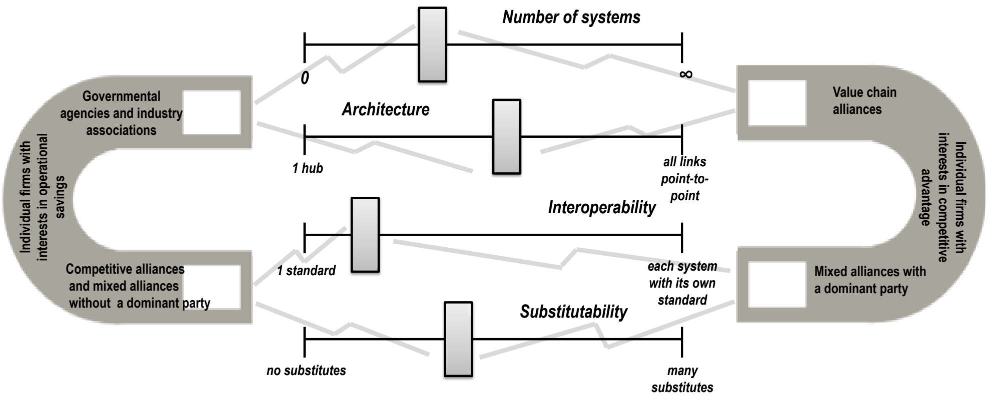
Industry associations are generally formed to promote the common interests of the organizations belonging to a specific industry or performing a specific role within it. Damsgaard and Lyytinen (2001) investigated the role of industry associations in the EDI diffusion process in the grocery sectors of Hong Kong, Denmark, and Finland. They find that these institutional agents were critical in knowledge building, knowledge deployment, and standard setting. Taking into account that the goal of industry associations is to promote cooperation, we believe that the following proposition should hold regarding the influence that these associations can have on the landscape of a business community.

Proposition 3.2. The efforts of industry associations (if any) tend to aim at ensuring IOS interoperability and reducing the number of IOSs in the business community. They tend to support the development of shared hub IOSs and aim at eliminating multiple systems performing the same functionality.

Figure 1 summarizes our theoretical framework. The IOS landscape can be categorized along four dimensions: the number of IOSs, their architecture, their interoperability, and their substitutability. Each of the last three dimensions has two extreme points that are rarely observed in practice. The number of systems can be anywhere between zero and infinity. Typically, the IOS landscape characteristics are somewhere between the extremes. Multiple players, such as individual firms, alliances, and institutional agents, can influence these four levers of the IOS landscape. Individual firms with interests in operational savings, competitive alliances, mixed alliances without dominant parties, governmental agencies, and industry associations affect the landscape such that the levers move in the direction of a lower number of systems with hub type architectures, higher interoperability, and lower substitutability. In contrast, individual firms with interests in competitive advantage, value chain alliances, and mixed alliances with a dominant party attract the levers in the opposite direction of multiple interorganizational systems — many of which are substitutes for each other and are based on point-to-point connections and different B2B frameworks.

Given the diverse and often opposite interests of individual actors within a business community, that an IOS landscape with characteristics representing business community joint interests can be achieved in practice is highly unlikely. Olson (1971) distinguished between exclusive and inclusive collective

Figure 4.1: Conceptual model. The tug-of-war for the IOS landscape.



goods. For an inclusive collective good, the supply of the collective good automatically expands with the growth of the group. For an exclusive collective good, the benefit that can be derived from the collective good has a limit that motivates the group members to reduce their group size. For exclusive groups, achieving 100% participation of those who remain in the group is almost always essential. Even one non-participant can take for himself all the benefits brought about by the action of the cooperating firms. We believe that an IOS landscape with characteristics that represent the joint interests of the business community is closer to being the exclusive collective good, which requires the cooperation of everyone in the business community to use a single, centralized IOS for all information exchange. Furthermore, if even one company decides to develop its own IOS with extra functionality to stand out against the competition (i.e., does not cooperate), then the IOS landscape becomes skewed in favor of the non-participant, which can benefit both from shared hub and private hub systems. Such a situation cannot be tolerated by competitors. Hence, we believe it is highly unlikely that the common interests will be fully realized in the case of the IOS landscape.

4.3 Methods

4.3.1 Research design

In this paper, we introduce a new IOS landscape concept and develop a number of propositions on how the influence of different actors shape its characteristics. The new concept and propositions were defined based on the literature review. To support our arguments and to demonstrate that this new concept is relevant for practice, we conducted an exploratory case study. An exploratory case study is aimed at defining questions, constructs, propositions, or hypotheses to be the object of a subsequent empirical study (Paré 2004). An exploratory case study is a good method for theory building because it ensures that the resultant theory is testable, relevant, and valid (Eisenhardt 1989, Yin 2004). We demonstrate in our case study how the constructs can be operationalized to test our propositions in future research. Furthermore, our case study provides initial empirical support for five out of seven of our theoretically derived propositions.

The container transportation network of the Rotterdam seaport was chosen as the setting for our analysis. The case study satisfied both theoretical sampling (Eisenhardt 1989) and convenience criteria. The active development of the IOS landscape of this organizational field started in the late 1980s, providing us with ample evidence for our analysis. Moreover, the companies in our analysis are still active in IOS development because they recognize the benefits of further improving existing communication channels. The Dutch government and affiliated organizations play an active role in the development of the information infrastructure, which allowed us to study their interests as well. Therefore, the setting allowed us to examine both current strategies of various players with respect to IOS development and the results of their previous efforts.

Our case study analysis follows an embedded design logic (Meyer 2001, Yin 2017). An embedded design facilitates our understanding of contrasts within the case and supports the generalizability of our research. We focused on the subunits of Rotterdam IOS landscape development, which could be separated along two dimensions: 1) time and 2) actors involved in the landscape development. For instance, the development of hinterland EDI involving terminal operators and a trucking community during 2013–2014 is one subunit within our case. Time does not play a role in our theoretically derived propositions. However, we used the different periods of our case study to split it into multiple subunits. This split allowed us to test our propositions in application to a variety of actors in different environments.

We enhanced research validity by using multiple data sources and perspectives from multiple actors on the unfolding of events (Meyer 2001). Furthermore, we asked interviewees for feedback once the paper was written to confirm that the events were properly interpreted.

4.3.2 Data collection and constructs

We identified the key group of actors in the port network based on the analysis of the port information exchange carried out by Van Oosterhout (2009). We limited our analysis to the companies that play a central role in the port network to ensure a deep understanding of these organizations. We focused on companies that play a crucial role in the exchange of information in the Port of Rotterdam and on those that unambiguously belong to the port business community. Organizations such as river police, banks, insurance agencies, shippers, and consignees belong to the network periphery and were excluded from our analysis.

We conducted in-depth, semi-structured interviews to collect data on the key milestones in the development of the IOS landscape of the Port of Rotterdam. We asked respondents to reflect on the decisions made by their organizations and to state the type of strategy that the company pursued with respect to the development of each IOS. We also reviewed the websites of port companies and agencies because, on many occasions, they describe the information communication technologies that organizations use and support. In some cases, we gained access to companies' internal documents that describe their information infrastructure. The use of multiple data sources allowed us to triangulate the data and strengthen the accuracy of our case study. In total, we conducted thirteen interviews: four with representatives of the port community system, three with representatives of various industry associations, one with a representative of a shipping line, three with representatives of terminal operators, one with a representative of a freight forwarder, and one with two customs representatives. Table 4.1 provides an overview of our respondents, their company affiliation, and their position within the company.

Table 4.1: Company representatives and their positions

Company	Role	Representative position
ECT	Terminal operator	Business Development Manager
APMT	Terminal operator	Commercial Manager
Terminal A	Terminal operator	Manager Applications & Customs
Yang Ming	Shipping agent	Deputy General Manager
Freight Forwarder B	Freight forwarder	Head Customs Controlling & Projects
Customs	Customs	Senior Policy Advisor IT
VRC	Industry association	Secretary & General Manager
VRTO	Industry association	Secretary General
KNV	Industry association	Secretary General
Portbase	Port community system	Former CEO, Strategy & Business Development Manager, Strategy & Business Development Consultant Director Marketing & Sales

All interviews were recorded and transcribed. The analysis of the data was performed in a structured manner using a case study protocol (Yin 2004, Paré 2004) that can be found in Appendix 4.A. The transcripts were coded in accordance with the constructs and propositions presented in the previous section. The development of industry-wide EDI standards and port community systems and the accompanying initiatives were coded as improvements in the landscape interoperability, lower substitutability and the creation of a shared hub IOS (in case of a port community system). Initiatives targeted at developing proprietary customized connections for use by a very limited set of actors were coded as decreasing IOS landscape interoperability and increasing substitutability and the number of point-to-point connections. The interviews gave us information on key events, past and present initiatives in

IOS development in the port area, and the companies' strategies behind these initiatives. In the case of individual companies (Propositions 1.1 — 1.2), we focused on the motivation that they provided for participating in different IOS initiatives. The main distinguishing factors to look out for were operational efficiency, cost savings, and competitive advantage. When company alliances were identified (Propositions 2.1 — 2.3), we inquired as to whether any dedicated IOS connections were initiated to support the alliance. Finally, with respect to government agencies and industry associations (Propositions 3.1 — 3.2), we registered the type of IOS development initiatives they supported, if any. We illustrate our findings with quotations from interviewees who reviewed this paper for factual accuracy.

4.4 Findings from a case study: IOS landscape of Rotterdam Port

The case study describes the information exchange in the Port of Rotterdam and the interorganizational information systems that were used to support this exchange, as of May 2014 (the month during which the data collection was finished). In 2004, the Rotterdam Port Authority established a neutral standard-based hub-type information system — a port community system — to support the competitive position of the port. This standardization of information exchange and the more efficient routing of information flows among the various actors would enable faster flow of containers through the port (Van Baalen et al. 2009). However, the convergence of the IOS landscape to use the port community system has yet to be successful. Multiple IOSs with similar functionalities were still in use in the port network. This case study investigates the interests of actors in the port network in the development of the IOS landscape and how these interests influenced the shape of the landscape.

4.4.1 Information exchange in the port network

Port business networks include various organizations. We focus on the container transportation network within port clusters. Shippers (companies sending the goods) or consignees (companies receiving the goods) are the final customers of the container transportation industry. The main actors involved in the physical handling of containers are shipping lines, terminal operators, inland carriers, and government inspection agencies. Shipping lines transport cargo over the sea. Terminal operators are involved with the first point of cargo discharge at the land side for imports or the last point of cargo discharge for exports. They are responsible for loading and unloading containers. Inland carriers such as truck carriers and barge and rail operators deliver cargo from the port to its final destination for imports or from the point of origin to the port for exports. Many more organizations are involved in transactions related to the movement of goods through the port. Freight forwarders are experts in logistics networks and organize shipments for shipping companies and consignees. They contract with carriers to move cargo and monitor cargo movements along the chain. Shipping agents represent the general interests of shipping lines at ports and can also perform activities similar to those of freight forwarders. Various government agencies are also members of the port community. Customs plays a major role in supervising cargo flows among nations. Other agencies, such as Veterinary Inspection, also have authority over certain types of cargo and can introduce additional checks and barriers to cargo movement. Port authorities monitor the movement of dangerous goods and provide additional services. Figure 4.2 illustrates the interactions among the organizations that facilitate container movements.

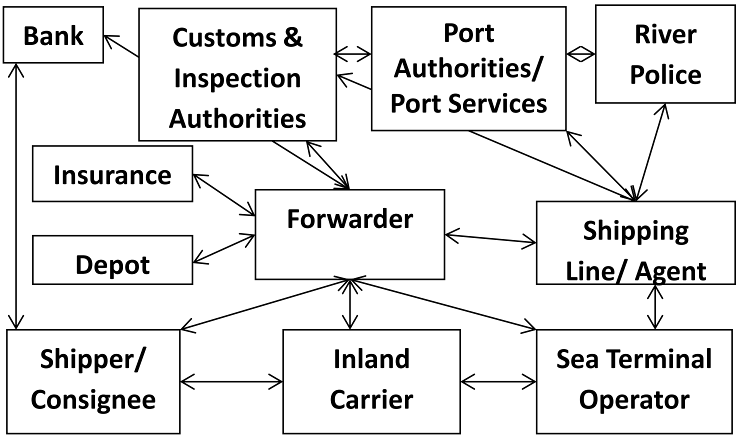
Our case study is organized in four subtopics: IOS for communication between shipping agents and terminal operators, IOS for communication between terminal operators and hinterland companies, IOS for communication with customs, and IOS for communication with port authorities. All of these IOSs form the IOS landscape of Rotterdam Port. As discussed previously, this split allows us to consider our propositions in multiple contexts within our single case and improve their generalizability.

4.4.2 Rotterdam Port IOS landscape development

Shipping agents and terminal operators

Shipping lines, terminal operators, and inland transporters must coordi-

Figure 4.2: Information exchange ties among different roles in the Port of Rotterdam (adapted from Van Oosterhout (2009) with modifications)



nate their actions to facilitate a smooth flow of containers from ships to their final destination points. The majority of shipping lines are global companies that offer regular services on specific routes. A shipping company is represented by an agent at each of the ports that it visits regularly.

As of 2014, Rotterdam Port had three major terminal operators: ECT (market share of approximately 65%), APM Terminals (market share of approximately 23%), and Terminal A (market share of approximately 7%). These terminal operators belonged to large global companies.

The digitization of information exchange among port companies started with the introduction of EDI messages that facilitated communication between terminal operators and shipping lines. In 1987, the User Group of Shipping Lines and Container Terminals (SMDG) was formed to develop and promote UN/EDIFACT EDI messages for the Maritime Industry (Van Baalen et al. 2000). The initial development process was slow, however, by the late 1990s, almost all of Rotterdam-based terminal operators and respective shipping lines used the following EDI messages: BAPLIE (Arrival, Forecast, and Actual Departure), MOVINS (Discharge/Loading Instructions), TANSTA (Tank Status), COPRAR (Container Discharge/Loading Order), COARRI

(Container Discharge/Loading Confirmation), COPARN (Container Announcement), COREOR (Container Release Order), and CODECO (Container Gate In/Gate Out Report). These point-to-point links were based on globally defined standards. The global nature of shipping line operations facilitated the development of global information exchange standards.

In 2004, the Port of Rotterdam Authority (PRA) established a neutral coordination hub, which also offered services to support the information exchange between shipping agents and terminal operators. Part of the functionality supported by these EDI messages was now also provided by Portbase, the port community system (PCS). In particular, the discharge list could have been sent through the community system. Shipping lines had to adopt the port community system to communicate with the Port Authority. Given that they had to establish the connection anyway, they were expected to start using PCS for communication with terminals as well. However, as of 2014, some shipping lines still preferred using their established point-to-point EDI connections rather than port community services because their old systems could be used "for free", whereas they had to pay subscription and traffic fees for the use of PCS services. This observation seems to contradict our Proposition 1.1, which states that companies' interests in cost reduction would encourage them to adopt a shared hub IOS in favor of point-to-point connection. However, this proposition is only supposed to be valid when all other factors are equal. In this situation, shipping lines had already invested in the development of point-to-point connections prior to shared hub systems becoming technologically available. Therefore, we are not considering the choice between two technologies but rather the decision to switch from one to another, which is different. Path dependency turns out to play a significant role in IOS landscape development, as will be repeatedly demonstrated in our case study, and certain company decisions depend on the decisions made earlier, when the technology choices were more limited. We will address this observation in greater detail in our discussion section.

The exact scope of the information exchanged via EDI connections between shipping lines and terminal operators could have been smaller or wider depending on the level of integration between the terminal and the shipping line. The exact level of integration was a commercial secret of terminal operators. We managed to find one example of a tighter integration in the Port of Rotterdam. The Maersk shipping line and APM Terminals operator shared a parent company and engaged in more advanced information exchange between them. For instance, the shipping line could also provide information regarding the predicted second modality that was to be used to pick up the container at the hinterland. This information helped the terminal with optimizing its stowage plan. This type of integration would have been difficult to arrange using the port community system at the time. This example serves as an illustration of Proposition 2.2 on value chain alliances. To engage in more advanced information exchange, the companies had to still rely on point-to-point connections and the development of their standards.

To summarize, in 2014, communication between terminal operators and shipping lines was predominantly based on point-to-point EDI connections, even though the port community system provided some functionality to support this as well. The main reason for this was the path dependency because, prior to PCS development, companies invested in point-to-point infrastructure, and for them to switch was expensive. Furthermore, by relying on point-to-point connections, value chain alliances could offer superior service to their clients with the assistance of more advanced information exchange.

Terminal operators and inland carriers

In early 1995, inspired by EDI success at seaside, the ECT terminal operator started a pilot project to exchange EDI messages with the inland side as well (Van Baalen et al. 2000). In the Port of Rotterdam, three inland transportation modalities exist. Cargo can be transported inland by road, barge, or rail. In 2012, 54% of the containers were transported by truck, 35.3% by barge, and 10.7% by train. The number of companies per modality differed significantly. Twenty eight rail operators, approximately 60 barge operators, and approximately 500 trucking companies were active in the port. This large diversity made it much more difficult to organize the community and ensure the successful adoption of EDI messages, especially by smaller trucking companies and barge operators. Furthermore, unlike shipping lines that typically only visit one terminal operator at the port, inland transporters pick up cargo from all operators. Because the pioneering EDI efforts were limited to ECT and did not include the other terminal operators, persuading inland transporters to use EDI messages was rather difficult. The rail operators were the most successful in adopting EDI because relatively few rail operators were in the port, and they only picked up cargo at the ECT terminal. Thus, ensuring their cooperation during the first wave of EDI introduction for inland carriers turned out to be much easier.

In the early 2000s, the spread of the Internet offered a new way to connect digitally for terminal operators with their inland partners: web portals. All terminal operators invested in the technology and offered the opportunity for inland transporters to report their arrival and check the status of containers via their portals. The introduction of the port community system in 2004 offered yet another route for inland carriers to be connected to terminal operators. PCS provided barge planning services for communication between terminal operators and barge operators, rail planning for communication between terminal operators and rail operators, and road planning for communication between terminal operators and trucking companies.

In 2014, all barge, rail, and terminal operators successfully adopted respective PCS services, that meant that a single information service now handled all barge- and rail-related operations in the port. Although the companies acknowledged the benefits of the common system, they had concerns, and the port community system did not become the default method for the trucking community to connect. Terminal A decided that using Portbase pre-announcement services for truckers was too expensive. Instead, truckers still had to use Terminal A's web portal when they reported their arrival. APM Terminals and ECT chose to support two options for road pre-arrival notifications: truckers could use either the port community system or the terminals' web portals. APM Terminals would have preferred everyone to use the port community system but was reluctant to enforce its use:

> We stimulate the use of Portbase for our existing terminal. We are not going to enforce it because quite a lot of companies are not members of the Portbase community. Membership is quite expensive. Because it's a competitive

> environment, management doesn't want to make it obligatory. We don't want to lose our partners. (APM Terminals representative)

The system enjoyed the support of industry associations as well, but that support was not enough to establish dominance:

> In general, the PCS is much better for the port community. It's more efficient to have a single interface for declarations instead of each company — ECT, APMT, Rotterdam World Gateway — having its own website. It works but it's not efficient because each party is trying to optimize its own business. Information about the whole supply chain of the port is incomplete. (VRTO Terminal Association Representative)

Although the PCS had been in use for 10 years and most companies acknowledged its benefits, by 2014, it had not become a common standard for communication between terminal operators and the trucking community. The coming changes in the competitive landscape for terminal operators posed additional challenges and offered new opportunities for the PCS to become the standard for information exchange. During the previous 10 years, the PRA worked on a land reclamation project, Maasvlakte II. Two new container terminals were to begin operations in 2014. One was to be operated by APM Terminals. The other, Rotterdam World Gateway, was to be jointly owned by a global terminal operator, DP World, and four shipping lines. These two new terminals were expected to significantly affect the market and damage the competitive position of ECT. These changes considerably influenced the terminals' strategy in IOS development.

Representatives of all terminal operators believed that, in the future, Portbase would be at the core of the communication with hinterland companies. However, when APM Terminals was actively working on promoting the use of PCS among smaller members of the port network, ECT felt it was being pressured to use the system:

> I think the market, our customers, our partners, and the community will probably pressurize us to use Portbase ... And especially when the new terminals use Portbase ... I think we'll feel that pressure indirectly. (ECT Representative)

> Our new terminal will exclusively use Portbase. We will use all its functionalities. We are in close contact with Portbase about developing new functionalities and improving the existing ones. We are now implementing new procedures at our new terminal. This means reaching out to about 5000 hinterland organizations: barge, rail operators, inland terminals, but especially logistics service providers. I think about 30% of these companies are not connected to Portbase. That is something which needs to be done. (APM Terminals Representative)

These differences in the perception of the port community system can be attributed to the differences in the competitive positions of the terminal operators. ECT enjoyed its dominant position in the Port of Rotterdam for decades. APM Terminals was the newcomer who, at the time, was actively expanding its operations. From the point of view of ECT, the port community system leveled out the playing field:

> You now see that the new terminals fully go for Portbase... And I can understand this because we have existed for like 45 years. We developed these services in the last 10–15 years. That took a bit of time. So if you're the new kid on the block here in Rotterdam, I can fully understand that you ask Portbase to develop these services for you because that's an easy way and it might be cheaper as well. (ECT Representative)

The representative of Terminal A also believed that Portbase was the best way to communicate in the future and that their customers and partners would probably make more use of Portbase services.

Both ECT and APM Terminals found it difficult to decide whether to develop a new e-service that would be available via the port community system. ECT had already transferred one of its customs services to Portbase. However, they did not consider this to be a default option:

> [I]nformation services can also be strategic. You can distinguish yourself from other companies in the port. So this is always the trade-off we have to make: can we cooperate with Portbase and offer exactly the same services as our competitors or do we still want to distinguish ourselves? (ECT Representative)

The APM Terminals representative favored broader cooperation in information exchange:

> It's very difficult first to assess in which areas you want to cooperate and in which areas you should compete . . . To a certain extent I really have to think what I would do within and without the port community context. The thing is you are connecting to the entire industry. If you create a specific solution for very specific kind of things you won't reach the entire sector. There are always limitations to a specific solution. So the best thing is to implement a community change, community innovation. (APM Terminals Representative)

In 2014, both terminal operators actively developed new hinterland integration strategies to stand out from the competition. They planned to use their e-services to support these new strategies. APM Terminals promoted its barge and rail shuttle connections and used its own web portal to concentrate shuttle information from other web sites. ECT created an intermodal organization, European Gateway Services, which acted as an organizer of hinterland transportation further inland. To provide this service, ECT formed an alliance with a number of inland transport operators and terminals. The terminal operator was developing a dedicated track and trace service for customers of the European Gateway Services as a value-added service that was likely to be offered outside the Portbase platform. ECT was offering some additional information to the community through its EGS app. Although the majority of users liked this app, some voiced concerns about the spread of different interfaces in the trucking community:

> We made an app for European Gateway services. And we supply container arrival information and also object arrival information. The app offers nice features also for truckers. Most truckers are very happy with it but some truckers tell us: "Everybody is building their own apps, everybody is building

> their own services. And our planners have to look for information on several platforms, from several different companies. Actually the only thing we want is a single access point, or even better, direct data feeds into our own system." (ECT Representative)

Therefore, the trucking companies would have preferred one point of access to manage their port visits. Their position is a good illustration of Proposition 1.1. However, a single interface to manage all interorganizational operations was unlikely to be built given terminal operators' new hinterland strategies.

Terminal operators' strategies serve as a good illustration of Propositions 1.1 and 1.2. On the one hand, an understanding existed that the community-wide solution was preferable because it provided access to a wider number of actors. An arrival pre-notification service became an industry standard by that time, and maintaining multiple platforms offering the same service made little sense. Historically, because terminal operators previously developed their own portals, the needed some time to switch from using their own portals to using Portbase for this. However, everyone agreed that using Portbase was the final destination for pre-arrival notifications. In contrast, terminal operators realized that the port community system leveled out their competitive field. The companies needed to have their own e-services to stand out, which we observed happening in the example of the APM Terminals and ECT hinterland integration strategies.

Port Authority

Many supervisory agencies, including the PRA, customs, the Food and Consumer Product Safety Authority, and Rotterdam-Rijmond Seaport Police, are active in the port. Here, we focus on only two agencies — the PRA and customs — because they deal with all goods flows, whereas the other agencies only have access to parts of these flows. The PRA is a non-listed public limited company. Its shares are owned by the Municipality of Rotterdam (approximately 70%) and the Dutch State (approximately 30%). The Port Authority is the manager, operator, and developer of Rotterdam's port and industrial area. The goal of this organization is "to strengthen the Port of Rotterdam's competitive position as a logistics hub and industrial complex of world standing."

In the early 2000s, the PRA initiated the development of the port community system with the aim to strengthen the port's competitive position. Their nearby competitors, the ports in Antwerp and Hamburg, already had similar successfully functioning projects. In 2014, the system was positioned as a neutral hub for all logistics information going through Dutch ports. The system supported both business-to-government and business-to-business communications. Initially, the port community system was solely owned by the PRA and was called Port Infolink. In 2009, Port Infolink merged with the port community system PortNET of the Port of Amsterdam. The new company, Portbase, was owned by the PRA (75%) and the Port of Amsterdam Authority (25%) and received substantial financial support from these organizations. The Harbour Master Division of the PRA ensures the smooth, safe, clean, and secure handling of shipping traffic. In 2014, shipping lines had to use Portbase to communicate with the PRA. They notified the authority about arrival times, the presence of dangerous cargo on board their ships, and waste disposal activities. The PRA received messages from the shipping lines via Portbase. An example was the "notification waste disposal" service. A shipping line could fulfill all of the obligations associated with a ship calling at the port by using the port community system.

The port community system was not initially meant to become the default method of communication with the PRA. The PRA already had its own system when Portbase was established, and it was quite reluctant to abandon it.

> They [Port of Rotterdam Authority] had their own system. They were not eager to develop a new system. They said, "We are doing it ourselves. Whenever we want to change certain things, we would go to our IT department and they would change it, but if we move to Portbase we would have to go to you." (Former Port Infolink CEO)

However, with time, the PRA embraced the port community system and completely outsourced the task of port information infrastructure development to this organization. Thus, in 2014, the IOS landscape of the PRA consisted of one system — the port community system. The development of Portbase is a good illustration of Proposition 3.1, which stated that government agencies aim to ensure interoperability and reduce the number of IOSs in the business community.

Customs

Customs traditionally play an important role in cross-border goods traffic and require significant information to be able to evaluate risks and to determine the legal status of cargo traffic. These authorities have the power to stop cargo movement in the event that certain documents are missing or are not filled in appropriately. Historically, in many ports, the automation of document exchange started with customs (Long 2009, King and Konsynski 1995).

In the late 1990s, Dutch customs developed two portals — SAGITTA and NCTS (for European Community transit declarations) — through which they accepted declarations from the trading community. Private software providers and firms from the port network could develop applications based on the standards used within these portals to enable companies to submit declarations using their software. Freight forwarders, shipping agents, and terminal operators were the three main actors responsible for communication with customs within the network that we consider. Portbase also provided services that facilitated declaration submissions to customs.

Dutch customs appreciated the work that Portbase did in terms of "orchestrating" the port community. Customs saw Portbase as a single-window system for communication with seaport traders:

> There are about 3000 companies using Portbase. We are only connected to Portbase. It's just easier to talk to them and let them do all the talking with the traders. For example, if you have a new release, you give it to Portbase and they test it. If you have 3000 companies with their own channels, you have to test all of them. (Customs Representative)

However, customs could not force companies to use Portbase but had to maintain a neutral position. Otherwise they could have been accused of monopolizing the market:

> You can use other declaration systems. It is not mandatory to use Portbase and you can always have your own direct channel. And I guess some of the big ones have. Because they, for instance, don't want to pay for their services because they are big enough to do it themselves. (Customs Representative)

Still, Customs took an active role in establishing Portbase:

> Maybe in the earlier days to start it up. One of our directors was on the Supervisory Board of Portbase so there was an obvious connection. But we couldn't make it mandatory, we only stimulate it a bit. Now things are settled and we're happy some activities are now clustered. (Customs Representative)
> Customs were important. Although we had two or three projects, but we would never have achieved the position Portbase has now without Customs. (Former Port Infolink CEO)

The role of customs in the development of Portbase provides support for Proposition 3.1. Although customs could not enforce the use of Portbase, they stimulated its use to encourage its adoption by the port community. Shipping agents could always opt for direct connections with the customs interface, and some of the large ones did so. However, the community realized that customs would prefer them to use the port community system for declaration purposes:

> You can also send your message directly to Customs without using the port community system but they won't be very happy because they will have to deal with lots of clients with different modes of communication. (Yang Ming Representative)

One of the global freight forwarders (the company was in the top 5 globally in 2014) operating in the port chose to support both communication channels. It appreciated Portbase because it allowed them to send one message to the hub, which could have been then divided over multiple destinations:

> We can send it through our system but it's much easier to send it through Portbase. The message is then split, one goes to the terminal operator, the other to Customs. We have access to more information in Portbase. (Freight Forwarder B Representative)

However, the global freight forwarder did not use Portbase for all communications with customs because its own system was more advanced in terms of functionality:

> [T]hey (Portbase) do not have all the modules to communicate with Customs (such as a module for transit documents, and import and export declarations). We offer a lot of tailor-made solutions in our system and that's why Portbase is not always optimal for all our clients. (Freight Forwarder B Representative)

Although the PRA could force shipping agents to use Portbase as the only way to communicate, customs could not do so. Customs still had to support multiple ways to communicate with its systems, even though it promoted

Portbase adoption by the community in less formal ways, which supports Proposition 3.1. The reason some companies still preferred to have dedicated point-to-point connections with customs was that, this way, they developed more advanced functionality. Customized point-to-point connections allowed these companies to offer superior services to their customers and stand out in the competitive field, which serves as a good illustration for Proposition 1.2.

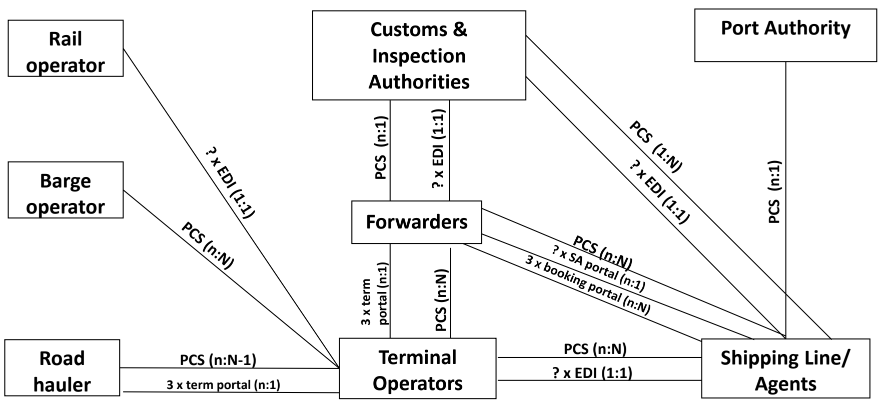
Rotterdam Port 2014 IOS landscape snapshot

To finalize our case study, we present an overview of the Rotterdam Port IOS landscape as we documented it in 2014. Not all of the landscape systems could have been discussed in detail, but we believe that providing an overview of all IOS systems functioning at the time strengthen our argument to study the IOS landscape.

Figure 4.3 provides a graphical illustration of the landscape. We see that only one neutral system with hub architecture exists, the port community system. For any two roles that it connected, the system provided the opportunity to connect all players performing the first role to all players performing the second role (n:N notation in the illustration). The booking portals between forwarders and shipping agents also had a many-to-many hub architecture. However, different booking portals were supported by different shipping lines. To obtain access to all shipping lines, the user still had to adopt all three portals. Systems with private hub architectures also existed: web portals of terminal operators and shipping agents (1:n or n:1 notation in the illustration). Because we do not know the exact number of shipping agents in the port, evaluating the exact number of web portals that they had was difficult.

The owners of those systems were the only ones who benefited from their hub type architecture. Freight forwarders and road haulers had to connect to each of those private hubs because they communicated with a variety of members. From their perspective, those systems had a point-to-point architecture. Finally, a significant variety of true point-to-point links existed (1:1 notation in the illustration), but their exact number was difficult to estimate. Terminal operators and shipping lines seem to be the actors that had to support the highest number of these direct connections.

Figure 4.3: IOS landscape of Rotterdam Port



The port community system could serve as a perfect substitute only for direct connections from shipping agents to customs. Not all terminal operators adopted all of the services provided by the port community system. Therefore, the system served only as a partial substitute for web portals of the terminal operators at the moment. The port community system did not provide the functionality of booking slots at the shipping lines. Therefore, it was only a partial substitute for the web portals of the shipping agents. The system also lacked certain functionalities with respect to customs compliance required by the freight forwarders. The system was a partial substitute for those point-to-point links. The port community system served as a partial substitute for the dedicated connections between terminal operators and shipping lines and did not seem to be developing in this area at the moment.

To summarize, we observe a lot of different IOSs functioning to support information exchange in the Port of Rotterdam in 2014. A neutral port community system existed that attempted to centralize this information exchange and to make it more efficient through the implementation of a single channel and data reuse. However, for various reasons, port community members were reluctant to fully embrace the port community system and continued supporting alternative communication means. In the next section, we discuss our propositions derived from the literature and the evidence that we identified within the case study that supports or contests them.

4.5 Discussion

4.5.1 Revisiting our propositions

Reflection on Proposition 1.1 — company interests in operational efficiency and cost reduction

Proposition 1.1 stated that the interests of companies in increasing operational efficiency and reducing costs through IOS decrease the number of IOSs in the landscape and increase number of IOSs with a shared hub architecture, improved interoperability, and lower substitutability in the business community IOS landscape. In the Port of Rotterdam context, evidence of such behavior is the support by private companies of the port community system and its active promotion to obtain cost savings and operational efficiency. We have identified mixed observations regarding this evidence.

On the one hand, in the Port of Rotterdam, the behavior of many companies supports this proposition. APM Terminals promoted Portbase among its hinterland partners to ensure that they could all be contacted through one channel. The trucking companies also wanted one interface for communicating with terminal operators. Otherwise, their planners had to look up information "on several platforms, from several different companies". The port community made a strong push to use Portbase as a standard for truckers' pre-arrival notifications. Rail and barge operators also adopted the port community system as a default way to communicate with terminal operators.

In contrast, many big companies still relied on their own IOS rather than use shared hub systems provided by other companies for cost-saving reasons. Shipping lines preferred using direct EDI messages to terminals rather than Portbase services, and Terminal A preferred its system to Portbase in its communication with trucking companies. In both cases, for the companies to use the shared system was more expensive rather than support their own. We believe that previous technology investment was the main factor that caused the contradiction between observations and our theoretically derived proposition. Our proposition is formulated as "all else being equal," meaning that previous investments into information infrastructure are disregarded. However, historically, point-to-point and private hub connections became available earlier than shared hub systems as a means of communication, and many companies had already invested in them. They were not choosing between investment in one or the other but between switching from one technology to another or using the established infrastructure.

Within a case study setting, finding observations which would control for all potential confounding factors is challenging. Our case did not offer us an observation in which a company had a clear choice between adopting a port community system or developing its own communication channel and was mainly driven by the operational efficiency considerations. Still, we believe that the efforts identified within the community to switch from multiple existing systems to using a shared hub for pre-arrival notifications for efficiency reasons are a strong indicator that our proposition is valid even when previous information infrastructure investments complicate the picture.

Reflection on Proposition 1.2 — company interests in gaining a competitive advantage

Proposition 1.2 posits that companies' interests in gaining a competitive advantage through IOS lead to an increase in the number of IOSs and point-to-point connections in the landscape, lower interoperability, and greater substitutability in the business community IOS landscape. In the Port of Rotterdam context, evidence of such behavior would be, after the port community system was introduced, private companies' support and development of their own point-to-point or private hub IOS with customized functionality. Certain strategies of terminal operators and freight forwarders observed in Rotterdam Port support this statement.

Freight forwarders did not use the port community service for all of their communication with customs because they could provide better customized services to their customers through their own solutions. Portbase did not allow them to stand out from the competition, which resulted in additional point-to-point connections in the business community that partially substituted for a shared hub system. Terminal operators APM Terminals and ECT were developing innovative solutions for hinterland operations to outperform their competitors, resulting in additional systems based on proprietary standards to which certain truckers had to connect to do business in the port.

In all of these examples, companies clearly intended to offer a superior service to their clients with the help of an IOS. Their drive to gain a competitive advantage brought about the further proliferation of IOSs in the port and the divergence in the landscape from a single-window port community system. We believe that these observations provide strong validation and support for Proposition 1.2.

Reflection on Proposition 2.2 — value chain alliance

We only focus on Proposition 2.2. because we could neither support nor disregard Propositions 2.1 and 2.3 because we found no competitive or mixed alliances in the port network at that time. Proposition 2.2 stated that the formation of a value chain alliance or a mixed alliance with one dominant party in a business community leads to lower interoperability, higher substitutability of the community IOS landscape, and a higher number of point-to-point connections. In the Port of Rotterdam context, observations that would support this statement would be alliances developing their own point-to-point or private hub IOS with customized functionality after the port community system was introduced.

We identified two value chain alliances in the port network: APM Terminals and Maersk Line, and the European Gateway Services alliance between ECT and hinterland transporters. Both identified cases support this proposition. Closer cooperation between APM Terminals and Maersk was based on the point-to-point connection. They exchange information on the second modality that was not being exchanged with other parties. The companies worked closely on this solution and had to develop their own standard to support it. ECT's European Gateway Services was also developing e-services that would sustain tighter integration between partnering terminal and transportation providers. Those services were likely to be available only to participating companies and were to be based on the private framework. The information was likely to be transferred through additional point-to-point connections between the terminal and other parties (i.e., private hub architecture).

However, we must admit that there could have been value chain alliances in the Port of Rotterdam that we did not identify and that did not rely on the use of dedicated IOSs because we could not interview all of the port community members.

Reflection on Proposition 3.1 and 3.2 — government agencies and industry associations

Propositions 3.1 and 3.2 posit that efforts by government agencies and industry associations (if any) tend to aim at ensuring IOS interoperability and reducing the number of IOSs in the business community. They tend to support the development of shared hub IOSs and aim at eliminating multiple systems that perform the same functionality. For the Port of Rotterdam, the actions of the PRA, customs, and various industry associations support these propositions.

All governmental agents and industry associations we analyzed promoted the adoption of Portbase, the system with a shared hub architecture and open standards. In the first place, PRA was the main instigator in establishing the port community system. Customs also promoted the use of Portbase even though they could not make it obligatory for use for declaration submissions. Industry associations such as VRTO, VRC, KNV were working at shaping a new business culture within a community by advancing the sense of a "moral obligation" to use the centralized system.

IOS landscape convergence

Although many organizations in the port were pushing toward the convergence of the IOS landscape and the use of the single system (Portbase), this convergence appeared unlikely. The main hurdle was that other port actors were interested in the competitive advantages that the use of other IOSs could bring. Hence, we conclude that, in the Port of Rotterdam business community, achieving the collective level optimum of an IOS landscape based on a single neutral hub architecture with common standards and without introducing additional incentivizing mechanisms or port community system redesign to allow service customization by individual companies was close to impossible.

In this case, individual interests precluded the achievement of collective goals. Many companies (mainly terminal operators) are resourceful enough to develop an IOS on their own, and they did so to stand out from the competition. The exclusive nature of the desired IOS landscape as a collective good requires 100% participation from business community members, meaning that in our case, only Portbase was to be used for interorganizational communication. Clearly, too many companies existed with interests that diverted the community from achieving this goal. Different organizations had different preferences regarding the configuration of the port IOS landscape. For instance, presently, all terminal operators were convinced that they would have to use Portbase in the near future for standard communication procedures with truckers. Truckers would receive the common interface for which they had been asking. Portbase needed almost ten years to get there. However, the terminals were already developing new private IOS solutions for hinterland communications to stand out in the competitive scene, indicating that the tug-of-war for the IOS landscape of the Port of Rotterdam would continue.

Limitations

We believe that the Port of Rotterdam case provided a good illustration of some of the factors that influence the development of a business community's IOS landscape. No single commercial organization had complete control over its IOS landscape. Trucking companies had to use multiple appointment systems because it was more convenient for terminal operators. The terminal operators felt that they were being pushed by industry associations representing the interests of truckers toward the use of Portbase. Even customs could not enforce the use of Portbase for declarations submissions and had to support multiple ways to communicate with trading partners.

However, we must admit that our case study provided limited opportunities to test the theoretically derived propositions. We showed how our propositions can be operationalized and validated using the example of the Rotterdam Port community. Still further tests are required to properly address the generalizability of the theory. We had two propositions for which we could not find any observations to support or refute them at all. A subsequent study could use a survey as a data collection instrument that would ensure a higher number of observations for the analysis and greater opportunities to control for the impact of other potentially confounding factors (such as the impact of previous investments in information infrastructure).

4.5.2 Implications for future research

Our case study and literature review prompted us to formulate two research avenues that we believe merit further investigation. The answers to these research questions would provide valuable contributions to the IOS literature and to the strategies of practitioners.

1. How does the network structure of the business community influence the shape of its IOS landscape?

For the Port of Rotterdam, the number of companies with similar roles in the network, and the structure of connections between them clearly influence the IOS landscape of the business community. Only three terminal operators exist, but there are many shipping lines. As a result, the number of IOSs developed by the terminals (i.e., terminal web portals) is low relative to the number of IOSs developed by shipping lines (i.e., shipping line web portals). The linkages between terminal operators and hinterland transporters are much denser than between terminal operators and shipping lines.

Therefore, terminals have more incentives for using shared hub solutions for hinterland communication, whereas they use dedicated point-to-point connections for communication with the shipping lines. The presence of vertically integrated alliances in the business community increases the chances that IOS alliances are formed. Previous IOS research has linked the choice of IOS type to the company's network position (Hu et al. 2011). A logical extension would be to further investigate how the network structure of the business community influences the dimensions of its IOS landscape.

Van Baalen et al. (2009) provided descriptions of IOSs functioning in the ports of Singapore, Los Angeles/Long Beach, Rotterdam, and Hamburg. The systems in different ports have diverse origins, functionalities, and coverage. Accordingly, the resulting IOS landscapes are quite different. Whereas the IOS landscape in Singapore port is dominated by Portnet, an IOS developed by the Port of Singapore Authority (PSA), the IOS landscape of the Port of Los Angeles/Long Beach is more fragmented because of the development of different IOSs by different terminal operators. The business community of the Singaporean port is organized around one major terminal operator owned by PSA, whereas more competition exists at the terminal operator level in other ports. This difference suggests to us that a strong connection exists between the underlying transactional network structure of the business community and its IOS landscape.

2. What are the successful strategies for practitioners to influence their IOS landscapes depending on their position in the business community?

Actors interested in sustaining the competitive position of a business community, such as the PRA, need to know how they can influence the IOS landscape. Steinfield et al. (2011) argued that it is in the interests of supply chain transparency to have a shared hub information system based on open standards as the core of the information infrastructure of the business community. However, as we have already shown, reaching such a state is difficult because of the varying interests of business community members. Portbase attempted to accomplish this goal since 2004. Yet, many other IOSs still sometimes perform the same functionality. The PRA made it obligatory to use Portbase for communication with them but lack the power to enforce Portbase adoption by every party in the community. Softer measures are required. For instance, industry associations currently promote a sense of "moral obligation" among companies to use Portbase by stressing its importance for port competitiveness. Naturally, the variety of available instruments depends on the member's position in the business network. Further investigation of this issue could help reveal other strategies that could be used by not only institutional agents but also commercial companies. We believe that both theory and practice would benefit from the answers to these research questions.

4.6 Conclusions

In this paper, we introduce a new concept of the IOS landscape. The spread of IOS in the business world has resulted in a variety of information exchange solutions that a firm can use to communicate with its partners. To date, the majority of IOS studies analyzed the benefits of IOS adoption independently from the other IOSs that a firm uses. We believe that this approach has a drawback because the characteristics of the IOS landscape in which a firm has to function influence the benefits that it can achieve by adopting a specific IOS.

We characterize the IOS landscape along four dimensions: the number of IOSs, their architecture, their interoperability, and their substitutability. These dimensions reflect how favorable the IOS landscape is for a firm. The higher the interoperability among the IOSs, the easier it is for a firm to reap the benefits from a single IOS adoption. The use of point-to-point architectures versus hub architectures increases the cost to support IOS communication. The necessity of adopting multiple systems with the same functionality to reach different trading partners also reduces the potential benefits of IOS adoption.

To understand how a firm's IOS landscape is shaped, we use the collective action framework and shift our analysis to the business community. We investigate the opportunities for achieving the shape of an IOS landscape that would reflect the collective level optimum without introducing special incentives. Based on previous research, we formulate seven propositions that link the interests of different actors to the characteristics of the business community's IOS landscape. At the individual firm level, a firm's strategy to increase operational efficiency and reduce costs via the IOS affects the IOS landscape differently than a firm's strategy to gain a competitive advantage through an IOS. At the firm alliance level, the type of alliance (competitive, value chain, mixed) influences the strategies that it pursues to develop the landscape. Finally, at the business community level, community representatives such as government organizations and industry associations can influence the IOS landscape to benefit the community at large. We conclude that the IOS landscape, which represents community-level goals, is an exclusive public good, which means that it requires 100% participation from community members to be produced — which is very difficult to achieve in practice, especially for larger business communities. We believe that our propositions enrich the theory of IOS development by considering the influence of IOSs on each other (with the assistance of the landscape concept) and by considering the contradicting interests of business community members.

We investigate our propositions in the context of the Port of Rotterdam business network. In recent years, information technologies have played an ever more important role in determining the competitive position of port networks in the global scene (Bagchi and Paik 2001, Van Baalen et al. 2009). The port community as a whole could benefit significantly from the establishment of an IOS landscape consisting of a single neutral hub system based on common standards. However, the various interests of port community members preclude that from happening, which means that, according to collective action theory, special instruments should be developed to foster the achievement of collective level goals. The case study provides an illustration and support for five out of our seven propositions. In addition, the case raises new research questions regarding the role of the network structure in shaping the IOS landscape and the ability of different actors to successfully influence the IOS landscape. Future research is required to answer these new research questions and to test our propositions in other conditions and contexts.

4.A Case study protocol

To ensure that the research can be replicated by other researchers we utilized a case study protocol for our study (Pare, 2004). Table 2 provides protocol overview.

Table 2: Case study protocol

Component	**Application**
Overview of the case study project (objectives, issues, topics being investigated)	The case study project overview has evolved overtime. Initial version was submitted as a research proposal for a PhD project. The final version served as a basis for introduction and conceptual model parts of Chapter 4.
Field procedures (credentials and access to site, sources of information)	Interviews with the informed stakeholders served as the main source of data for this research. Stakeholder contact details were gathered through two main sources: Erasmus University SmartPort center of excellence and Portbase. All interviews were conducted by the leading author. Previous interview results were discussed by the lead author with her supervisors prior to the next interview to ensure that all relevant data is collected. Each interview was organized in the following way: • Interview was conducted as per interviewees convenience • Interview lasted for approximately one hour • All interviews were recorded upon pre-agreement of interviewees • All interviewees were followed upon to confirm the quotes to be used and relevant case study excerpts
Interview guide (see below)	General interview guide was developed which was adjusted for each interview depending on the company's position in the port network and interviewee's position in the company.
Case study report guide	Detailed case study report was organised such as to document the full IOS landscape of each port company presented in the study. The abridged version of the report is presented in the part "Findings from a case study..." of Chapter 4. The report has gone through two feedback rounds with respondents for validation.

General interview guide

Introduction

The following elements were explained during the introduction:

- Purpose of the interview and of the research project
- Terms of confidentiality
- Format of the interview

General questions

- Detailed project presentation
- Interviewee role in the project
- Current interviewee position in the organization
- Past interviewee positions
- Other relevant background information

IOS landscape characteristics (number of systems, architecture, standards, functionality)

- Which information systems do you use for communication with your partners (partner definition adjusted depending on the interviewee company)?
- What kind of processes do these systems support? What types of messages are being exchanged via them?

- What standards do these systems rely on?
- If standard B2B frameworks were used, have there been any modifications introduced?
- How is the system architecture organized (point-to-point, private hub, shared hub)?

IOS landscape development

- Who do these systems belong to? Who developed them?
- Why did you choose these systems if alternatives exist?
- Are you currently developing any new information systems for the communication with your partners?
- If yes, why was the decision made to develop your own information system rather than use PCS?
- Do you have any special partnership arrangement with some port companies?
- What is your position towards PCS?
- Do you promote the use of PCS services?

Conclusion

Respondents were asked to share any documentation or supporting materials that they could provide. As a follow-up a case report was shared with the respondents with the opportunity for them to revise it. Initially each respondent received an abridged report with statements only related to his or her company and their direct quotes. Upon the completion of the initial feedback round all respondents received the full case report version and they again were provided with the opportunity to provide feedback. All of the feedback was subsequently integrated into the final report version.

Chapter 5

General Discussion

This dissertation explores the variety of interests that different companies pursue when developing interorganizational information systems. This dissertation also investigates a pricing strategy that could be used to align those interests for the benefit of the business community.

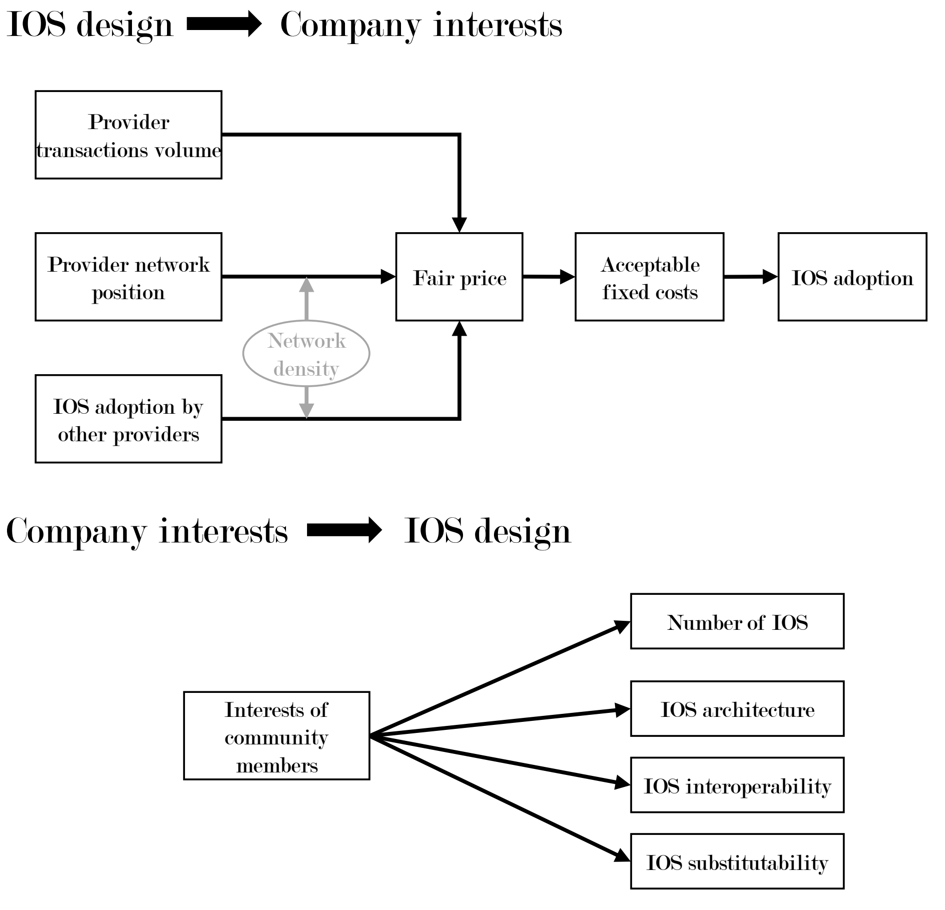
We demonstrate the recursive nature of the relationship between IOS design and its target user community's interests. On the one hand, with the help of pricing as an element of IOS design, an IOS provider can affect companies' interests in adopting the system. The fair pricing model (Chapters 2 and 3) increases adoption benefits for some community members and decreases them for the others relative to traditional pricing methods. Hence, IOS providers have a clear way to shape community adoption interests with the help of organizational instruments. Such an intervention would not even require changes to the IOS technology itself.

On the other hand, the interests of the IOS community serve as a precursor to IOS design and significantly influence the shape of the IOS being developed (Chapter 4). The IOS target community usually consists of a large variety of players, each pursuing their strategies. The interactions of these players result in multiple IOSs being developed and offered to the community at the same time. The functionality that these systems offer and the architecture and standards on which they are based, all depend on the interests that different actors are pursuing.

Thus, companies like PCS providers that are working on community information infrastructure development must understand both the variety of interests that affect the IOS landscape of the community and the instruments that could be used to affect community interests with respect to IOS development in return.

Figure 5.1 summarizes our findings on the interrelationships between IOS design and company interests. The remainder of this chapter expands on these findings and their implications for theory and practice.

Figure 5.1: Summary of research findings (as conceptual models)



5.1 Summary of main findings and contributions

Traditional pricing structures based on subscription and transaction fees do not sufficiently address two characteristics of modern business community platforms: users of the system can also be data contributors, and services within the platform can have a hierarchical structure in which old services provide input for new services. In Chapter 2, using the example of a port community system, we demonstrated a potential new pricing strategy that reimbursed data providers based on the value of their contribution to the community. We used the Shapley value concept to estimate the data contribution value because it facilitates the alignment between individual and communal interests. Furthermore, the user value focus of the solution — as opposed to traditional cost-based IOS pricing — enhances the opportunities for IOS development because 1) it only focuses on the services that provide value to the community and 2) the excess revenue generated when the cost of the solution is far lower than the value can be used to finance the development of new features.

We demonstrated that such a pricing mechanism aims to align the interests of individual companies when adopting a service with communal interests. Among other aspects, certain small companies might actually be excluded from the adoption community because their participation would not yield a high enough value for the business community. In our example, this is the case with a number of small barge operators who rarely visit the port and for whom connecting to the port community platform makes no economic sense (at least in the full form whereby corresponding fixed connection costs would be incurred).

In Chapter 3, we showed that such a Shapley value-based pricing scheme can be used in the general case of any vertical IOS, and its main advantage is promoting co-opetition. The competitors participating in such an IOS benefit from other competitors joining the system because higher values created for data consumers are translated into higher reimbursements received by data providers. Such a pricing mechanism can tip the scale in the tug-of-war battle between individual and communal interests, as demonstrated in Chapter 4 in favor of communal interests because this pricing scheme provides additional incentives for data sharing at the individual level.

Furthermore, we also started investigating the role that network density could play in the adoption of a Shapley value-based pricing scheme. We showed that it can be more effective for business communities with high network densities. Our analysis demonstrated that realizing benefits from IOS adoption can be much easier in low-density networks without much coordination among data providers, which could be a factor that explains why adoption of similar business community platforms proceeds differently in different business networks.

In Chapter 4, we demonstrated that modern companies operate in an environment in which they have access to multiple interorganizational information systems that can differ in the functionality they provide, standards on which they rely, and architecture on which they are based. The existence of such vibrant IOS landscapes is a direct consequence of the divergent interests that companies belonging to the same business community pursue when it comes to IOS development. Even though a business community as a whole would benefit operationally from having a single IOS hub that can be used to handle all cross-company transactions, such a state is close to impossible to achieve because of the interests of individual companies in obtaining a competitive advantage over their peers. Importantly, IOS developers must acknowledge that their IOSs will most likely not be the only one their clients use when developing their product and market strategy — unless they figure out how to address the opposition between individual and communal goals. The main challenges in achieving a single business community IOS hub are not technical but organizational. Hence, we believe that solutions to those challenges should be sought not only on the technical side but on the organizational side as well.

The overarching question of this dissertation is, "How can and why should the diverse interests of different organizations be aligned when developing an interorganizational information system for the benefit of a business community?" In the thesis, we demonstrated that, given the natural course of events, the interests of individual organizations and alliances push the IOS landscape of the business community in opposite directions. Therefore, the state that is beneficial for the community as a whole is unlikely to be achieved. We proposed a new pricing mechanism for the business community platforms that can serve as an instrument for aligning those interests and partially remedying the problem. We acknowledge that this pricing mechanism cannot eliminate all of the IOS-related business community conflicts but can serve as a step in the right direction.

5.2 Limitations

Our research has a number of limitations, and each chapter lists the limitations of the analysis presented in greater detail. Therefore, we only mention here the overarching topics that are relevant for this dissertation as a whole. First, all of our papers are grounded in the investigation of a single seaport community, which may have introduced a specific bias to our analysis. The analysis of other contexts in which IOS and business community platforms function is required to ensure that our findings are applicable to other settings as well.

In all of our studies, we used a game-theoretical lens to investigate the subject. This perspective is very useful for analyzing the interactions of different agents who have different interests and for predicting the outcome of those interactions. However, other theoretical perspectives could add additional dimensions to the answer to our research question. For instance, the use of institutional theory could demonstrate how the business environment, existing social norms, and business rules play a role in determining companies' objectives and the strategies they use to pursue them.

We focused our attention only on one mechanism targeting the alignment of IOS users' interests: pricing. However, other mechanisms such as IOS governance and technical design can play a role in interest alignment and can influence the effectiveness of pricing. Price is traditionally perceived as an indicator of a good's quality, consumer value, and resources required for that good's production. These traditional roles could conflict with the new role of the interest alignment mechanism that can impede user adoption. We did not have the opportunity to test the designed pricing scheme in a real-life setting. The application of the pricing mechanism in practice can uncover additional challenges or benefits for community members. Furthermore, we used a number of simplifying assumptions in our analysis, which we discussed in the respective chapters and could prove too unrealistic for practical applications of the pricing scheme. However, we believe that reasonable modifications should be possible to adjust for those aspects if they arise.

5.3 Recommendations for future research

Platform research and a two-sided market perspective on interorganizational information systems have not been discussed at length in our dissertation. However, investigating interorganizational information systems from this angle brings about additional merits. Platforms are architectures that incorporate three core elements: core components with low variability, complementary components with high variability, and interfaces for modularity between core and complementary components (Baldwin et al. 2009). The modular architecture of platforms gives rise to two-sided markets in which an intermediary can charge two sides — buyers and sellers — for their access to and use of the platform. The peculiar characteristic of this type of market is that the intermediary determines not only the price level for its service but also the price structure, for example, one side can partially or completely subsidize the other side. In the case of non-profit platforms, access charges exactly offset each other because one side receives the charge paid by the other side (Rochet and Tirole 2003).

In the IS research, software-based platforms such as Apple's iOS and Google's Android received significant attention (Tiwana et al. 2010, Tilson et al. 2012, Gronli et al. 2014, Eaton et al. 2015, Karhu et al. 2018). A software-based platform is an extensible codebase of a software-based system that provides core functionality shared by the modules that interoperate with it and the interfaces through which they interoperate (Tiwana et al. 2010). However, the software or service level is only one of four layers of modularity identified as forming parts of a digital product. The other three layers are devices, networks, and contents (Yoo et al. 2010). The content or data layer also can generate a two-sided market among data users, data providers, and an intermediary, as we demonstrated in Chapters 2 and 3.

Digital products as two-sided markets at the content level have received attention in examples of B2C products, such as Facebook, Google, or other online communities (Park et al. 2009, Christofides et al. 2009, Cheung et al. 2011, Kwon et al. 2017). Digital B2C products that have been extensively studied operate based on advertising revenues. In exchange for access to the digital product, consumers reveal information about themselves and their preferences, which is later used for targeted advertising on the same platforms. The incentives for consumers to contribute to such platforms have been extensively studied and include "qualitative" returns as service quality and reputation, in addition to access to basic services (Brousseau and Pénard 2007). The data-sharing mechanism in the B2B context is very different and has received little attention on the platform or in the two-sided market research stream.

We believe that this dissertation also contributes to the literature on platforms or two-sided markets with respect to platforms connecting content providers with content users in a B2B setting. We have investigated a fair sharing approach to specifying the pricing structure for such platform types. Further research into the mechanisms that can be used to promote the provision of data in the context of B2B platforms in vertical value chains could be beneficial. Furthermore, business community platforms that we have been investigating are moving toward transforming themselves into the platforms at the software layer. In the business community platform serving the Port of Antwerp, different IT providers and community members can develop information services that can be installed on the joint community platform, similar to the principles applied in the App store and Google market. Such an approach has the potential to allow companies to participate in the communal initiative and share data with the common database while simultaneously gaining a competitive advantage through the development of company-specific apps. Developing in practice the interplay between two-sided markets at the software and contents layers in interorganizational information systems definitely provides a lot of research opportunities to understand how these markets affect each other and whether they contribute to increased benefits for the business community.

Another interesting future research opportunity that we see is connected to blockchain, the technology underpinning the cryptocurrency Bitcoin that recently received significant attention as a new way of organizing interorganizational communication. First, pilots have been developed to demonstrate blockchain applications to ease paperwork processing in ocean freight, identify counterfeit products, facilitate origin tracking, and operate the Internet of things (Hackius and Petersen 2017). The volume of the research modeling potential for blockchain applications in supply chain is steadily growing (Tian 2016, Casado-Vara et al. 2018, Abeyratne and Monfared 2016, Apte and Petrovsky 2016).

A “blockchain” is a distributed digital ledger that maintains an immutable record of transactions on the web, and is incapable of being falsified after the event (Pilkington 2016, Apte and Petrovsky 2016). The major difference relative to the IOS that we described in our thesis is the decentralized nature of blockchain platforms. Eliminating the need for third-party intermediation or control removes the friction in all types of value exchanges that can arise in the form of costs, risk, information, and control (Bogart and Rice 2015). However, the heterogeneity of benefits that was present in earlier IOSs is present in blockchain applications for supply chains as well and is mainly driven by the different positions that actors occupy along the value chain (Hackius and Petersen 2017, Abeyratne and Monfared 2016). Hence, we believe that a need exists to design participation incentive mechanisms for users of blockchain platforms as well, which will account for this inherent heterogeneity of benefits.

Blockchain implementations support smart contracts — computerized transaction protocols that execute the terms of a contract (Casado-Vara et al. 2018). These protocols allow for a transaction to be automated, yet documented and controlled. Casado-Vara et al. (2018) proposed that smart contracts can also specify an award system for blockchain participants. We believe that an investigation into the incentive mechanisms that can be inscribed into blockchain smart contracts and the role of fair sharing in them is a promising research direction that is currently of great relevance for practitioners. Since 2015, IBM and Maersk have been jointly working on a global trade blockchain platform, TradeLens, which has just recently finished the pilot stage. Currently, the platform faces the challenge of convincing the industry to use it as a standard for communication, similar to many previous solutions. Some industry participants already wonder whether this new platform is truly different from other ecosystems that came before it, such as Universal Trade Network, which have yet to get off the ground (Allison 2018).

5.4 Concluding remarks

Information technology is developing at a rapid pace. Every decade or so, innovations arise that promise to revolutionize the manner in which information is exchanged among companies: EDI, XML, e-commerce platforms, blockchain. To date, no single technology has addressed all of the conflicts that arise within the IOS context because of its collective good nature. It might be the case that none ever will. We believe that organizational innovations accompanying the development of information technology have a lot of promise in solving the conflicts arising with IOS development. Further research in this area could contribute not only to theory but also to the IOS practitioners.

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Summary

Over the decades, companies have been working on making communications with their partners faster, cheaper, and more reliable. Today, every organization uses at least some type of an interorganizational information system in its routine operations, whether for communication with their business partners or with authorities. Interorganizational information systems (IOSs) are information systems shared by two or more organizations. IOSs can support a variety of interactions: customer relationship management, airline reservations, transportation tracking, and so on. One of the unifying characteristics of all IOSs is that they bring value to their adopter only if other companies have also adopted the system; this adoption depends on how well the interests of different companies have been integrated into the IOS design.

In Chapter 2, we narrow our focus to a single IOS — the business community platform. Based on an exploratory case study, we discover that traditional cost-based pricing methods result in tension among IOS users because some of them feel as if they are contributing a lot of data to the platform without receiving appropriate acknowledgment or reward in return. Furthermore, the business community platform structure more easily enables services within the platform to have a hierarchical structure in which old services provide data input for new services. To properly reimburse the companies providing data to the business community platform, we propose a new pricing strategy that relies on two building blocks: user value-based pricing and fair sharing. We show that such a pricing approach aligns the incentives for individual users to adopt a business community platform and reap community-wide benefits from the platform's introduction.

In Chapter 3, we consider the application of the new pricing strategy to a more general case of any vertical IOS, that targets competitors as their user community. We demonstrate that a fair sharing scheme can create additional incentives for co-opetition, simultaneous competition, and cooperation, among IOS adopting competitors by estimating the value gain for a data provider that comes from the participation of another data provider. The size of the positive externalities among IOS data providers depends on the business community network structure. In turn, this structure determines the importance of coordination among competitors for IOS adoption. In high-density networks, the benefits from coordination are higher than in low-density networks.

In Chapter 4, we demonstrate how different companies' interests affect the development of IOSs at the business community level. To describe the process, we introduce a new concept: the landscape of interorganizational information systems. We rely on collective action theory, and consider how opposing strategies of actors shape the IOS landscape and preclude the business community from attaining the landscape that represents the collective level optimum because of the exclusive nature of this public good. Individual firms, alliances, and community representatives push the IOS landscape toward more standardization, more hub-type connections, and less substitutable IOSs, or toward less standardization, more point-to-point connections, and more substitutable IOSs. We support our theoretical propositions with evidence from a Rotterdam seaport case study.

Overall, this research contributes to the IOS literature by stressing the importance of interests' alignment when developing IOSs for maximizing business community gains from IOS adoption. We provide a detailed investigation into how the pricing mechanism based on fair sharing can serve as an instrument for achieving such an alignment. We believe that research and practice would benefit from research into other managerial instruments to align the interests of IOS users.

Dutch Summary / Nederlandse Samenvatting

In de afgelopen decennia hebben bedrijven veel geïnvesteerd in informatie- en communicatietechnologie (ICT) om de communicatie met hun partners sneller, goedkoper en betrouwbaarder te maken. Vrijwel elke organisatie maakt tenminste gebruik van één soort inter-organisationeel informatiesysteem in haar dagelijkse operaties om te communiceren met haar bedrijfspartners of met overheden. Inter-organisationele informatiesystemen (IOS's) zijn informatiesystemen die gebruikt worden door meerder organisaties. Een IOS kan verschillende soorten interacties ondersteunen: customer relationship management, vluchtreserveringen, traceren van transport, etc. Kenmerkend voor al deze IOS's is dat ze alleen waarde kunnen creëren wanneer ook andere organisaties van de IOS gebruikmaken. Dit hangt weer af van de mate waarin de belangen van de deelnemende bedrijven zijn geïntegreerd in het IOS-ontwerp.

In hoofdstuk 2 richten we ons onderzoek op een individuele IOS als een platform voor een bedrijfsnetwerk. Op basis van een verkennende case study, vinden we dat traditionele kost-gebaseerde prijsbepalingsmethoden tot spanningen leiden tussen IOS-gebruikers, omdat enkele bedrijven menen dat ze veel data bijdragen aan het platform zonder hiervoor de juiste erkenning of beloning te krijgen. Bovendien maakt de algemene structuur van een bedrijfsnetwerk platform het mogelijk de diensten hiërarchisch te op te bouwen, waarbij bestaande diensten gegevens leveren voor nieuwe diensten. Om de bedrijven die data leveren aan een bedrijfsnetwerk platform op gepaste te compenseren, stellen we een nieuwe prijsbepalingsstrategie voor die bestaat uit twee onderdelen: prijsbepaling gebaseerd op gebruikerswaarde en prijsbepaling op basis van eerlijk delen. We laten zien dat dergelijke prijsmethoden gebruikers er toe kunnen bewegen een bedrijfsnetwerkplatform in gebruik te nemen en zo het netwerkwijde voordeel van het platform te bewerkstelligen.

In hoofdstuk 3 overwegen we de toepassing van een nieuwe prijsstrategie op een meer algemene situatie van IOS die zich richt op concurrenten en hun gebruikersnetwerk. We laten zien dat een eerlijk delen-strategie drijfveren kan creëren voor co-opetition¬, d.w.z. samenwerking tussen concurrenten die de IOS adopteren. Dit gebeurt door het schatten van de waardetoevoeging voor een gegevensprovider veroorzaakt door de deelname van een andere gegevensprovider. De grootte van positieve externaliteiten tussen IOS gegevensproviders hangt af van de netwerkstructuur van het bedrijfsnetwerk, die op zijn beurt het belang van coördinatie tussen concurrenten voor IOS-acceptatie bepaalt. De voordelen van coördinate zijn groter in netwerken met hoge dichtheid dan in netwerken met lage dichtheid.

In hoofdstuk 4 laten we zien we hoe de belangen van verschillende bedrijven van invloed zijn op de ontwikkeling van een IOS op het bedrijfsnetwerk niveau. Om dit proces te kunnen beschrijven, introduceren we eerst een nieuw concept: het domein van inter-organisationele informatiesystemen. Gebaseerd op de collectieve actietheorie, onderzoeken we hoe tegenstrijdige strategieën van spelers het IOS domein vormgeven en voorkomen dat het bedrijfsnetwerk het stadium van het collectieve optimum bereikt, vanwege het exclusieve karakter van dit publieke goed. Individuele bedrijven, allianties en netwerkvertegenwoordigers duwen het IOS domein hetzij naar meer standaardisatie, meer hub-achtige verbindingen en minder substitueerbare IOS's, of naar minder standaardisatie, meer point-to-point verbindingen en meer substitueerbare IOS's. Wij onderbouwen onze theoretische veronderstellingen an de hand van een empirische case study van de Rotterdamse zeehaven.

Samenvattend, dit onderzoek draagt bij aan het IOS-onderzoek door de nadruk te leggen op het belang van het op één lijn brengen van belangen bij de ontwikkeling van IOS en om op deze wijze de winsten voor het bedrijfsnetwerk uit de IOS-acceptatie te maximaliseren. We onderzoeken in detail hoe het prijsbepalingsmechanisme op basis van een eerlijk delen-strategie helpt om een dergelijke afstemming te bereiken. Wij zijn van mening dat zowel onderzoek als praktijk baat hebben bij verder onderzoek naar andere managementinstrumenten ten behoeve van de afstemming van de belangen van IOS gebruikers.

About the Author

Irina Romochkina was born on October 13, 1987, in Yangiyul, the USSR. She completed her high school education in 2004 and graduated with excellence from Vladimir Commercial Lyceum. Irina continued her education at Lomonosov Moscow State University and received her Bachelor of Science in Economics degree with distinction in 2008. After the completion of her undergraduate studies, Irina worked as an intern for Volkswagen Group Rus. In 2009, Irina started the MPhil in Business Research program with a concentration in Logistics and Information Systems, offered by ERIM at Erasmus University Rotterdam. In 2011, she successfully received her Master of Science degree with appellation Cum Laude. The work on her master thesis inspired Irina to continue the academic track. During the same autumn, she joined the department of Decision and Information Sciences of Rotterdam School of Management as a Ph.D. Candidate.

Irina's research focuses on logistics interorganizational information systems, specifically the interests that companies pursue when developing such systems and the different incentive alignment mechanisms being applied in this context. During her Ph.D. trajectory, Irina closely cooperated with practitioners by being a member of two research projects: NLI (National Logistics Infrastructure), funded by the Dutch government, and CASSANDRA (Common Assessment and Analysis of Risk in Global Supply Chains), funded by the European Union. The resulting work has been presented at various workshops and conferences, including the European Academy of Management Conference, the Institute for Operations Research and the Management Sciences Conference. Irina also has been involved as a teaching assistant for the following master's level courses: Global Logistics and Information Technology and Ports in Global Networks.

Since 2014, Irina has been working as a management consultant for Kearney. In this role, Irina has been focusing on projects in the logistics field in which advanced analytics methods are applied. This position allows Irina to apply her academic background to solving specific problems faced by practitioners.

Portfolio

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Over the decades, companies have been working on making communications with their partners faster, cheaper, and more reliable. Today, every organization uses at least some type of an interorganizational information system (IOS) in its routine operations, whether for communication with their business partners or with authorities. One of the unifying characteristics of all IOSs is that they bring value to their adopter only if other companies have also adopted the system; this adoption depends on how well the interests of different companies have been integrated into the IOS design.

This dissertation investigates the variety of interests that companies pursue when developing an IOS and how fair sharing can facilitate the alignment of those interests. We propose a new pricing strategy that relies on two building blocks: user value-based pricing and fair sharing. We demonstrate that a fair sharing scheme can create additional incentives for co-opetition, simultaneous competition, and cooperation, among IOS adopting competitors and that network structure plays an important role in IOS adoption in this case. We also demonstrate how different companies' interests affect the development of IOSs at the business community level. To describe the process, we introduce a new concept: the landscape of interorganizational information systems.

Overall, this research contributes to the IOS literature by stressing the importance of interests' alignment when developing IOSs for maximizing business community gains from IOS adoption. We provide a detailed investigation into how the pricing mechanism based on fair sharing can serve as an instrument for achieving such an alignment.

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