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**Adoption, Value Co-Creation, and Governance of
Inter-Organizational Information Technology in Wood
Networks**



Göttinger Wirtschaftsinformatik

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A. Foundations

The first chapter of this cumulative dissertation is divided into three parts. It begins by introducing the effective usage of inter-organizational information technology (IT) in German wood networks and presenting a general outline. The subsequent section provides information regarding the context of this study, i.e., the German wood industry and inter-organizational IT support. Finally, the last section reviews literature from the field of information systems research in the three areas relevant for this thesis: the adoption and usage of inter-organizational IT, IT-based value co-creation, and the governance of inter-organizational IT.



1 Introduction

The following sections first describe the motivation for studying the topic of this thesis and then present the research questions. Afterward, the structure of the thesis is explained, followed by a description of the research design and the anticipated contributions.

1.1 Motivation

Wood, in terms of living and dead tree biomass, is one of the four major global carbon pools (Lippke et al., 2011) and has been garnering increasing attention from practitioners, researchers, and policy makers due to its high potential for carbon mitigation (Albrecht et al., 2008; Osterburg et al., 2013; Wördehoff et al., 2011; see Figure A-1). In Germany, a total of 105.5 million tons of CO₂ emissions are avoided each year due to the material and energetic usage of wood (Rüter et al., 2011); this is equal to about 13 percent of Germany's annual carbon emission (UN Statistics Division, 2011). The effective use of wood for improving the carbon balance is now an integral part of many public initiatives (Osterburg et al., 2013). For example, the Ministry of Energy, Agriculture, the Environment and Rural Areas of Schleswig-Holstein aims to increase the material and energetic usage of wood by 30 percent by 2019 (base year 2009) (MELUR, 2009). Similar goals and measures can be found in 11 of the 16 energy- and climate-protection strategies of Germany's federal states (Osterburg et al., 2013).

Wood contributes to the carbon balance in three ways: long-term use directly increases the total carbon storage, it can displace other fossil-intensive materials, and its energetic utilization directly substitutes fossil fuels (Lippke et al., 2011; Wördehoff et al., 2011). Through the lens of cascade utilization, the ultimate goal is to maximize the material usage and reuse of wood before the final energetic utilization (Arnold et al., 2009). For instance, for building materials such as wall studs, floor joists, or cladded walls, a reduction of 2 to 10 kg of CO₂ is estimated per 1 kg use of wood fiber (Lippke and Edmonds, 2009). The increased material usage has a yearly carbon mitigation of around 17 million tons for Germany (Osterburg et al., 2013). Moreover, the energetic usage of wood directly substitutes for fossil fuels, particularly if the wood would have otherwise been burned or deposited in a landfill without capturing any energy (Lippke and Edmonds, 2009). For Germany, a yearly CO₂ mitigation of around 30 million tons is estimated if wood residuals were used instead of fossil fuels (Rüter, 2010). Altogether, enabling the wood industry to effectively use wood in cross-organizational utilization cascades, and promoting wood as a substitute for other climate-damaging materials are promising ways of improving the carbon balance.

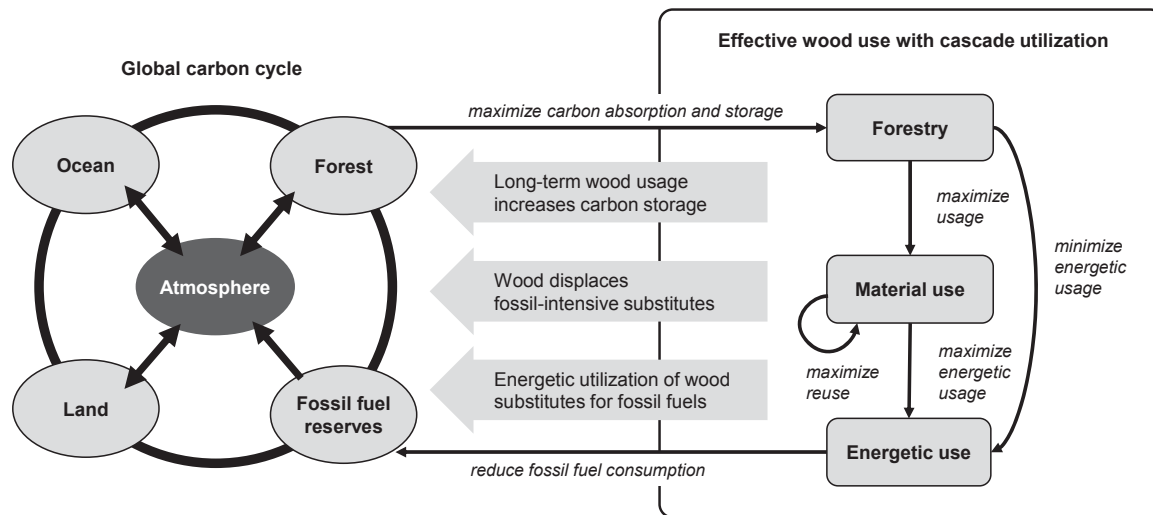


Figure A-1 Potentials of effective wood utilization in the context of the global carbon cycle (Lippke et al., 2011)

Information and communication technologies can play a central role when it comes to the efficient utilization of wood in cross-organizational utilization cascades and the promotion of wood as a substitute for other fossil-intensive materials (Uusijärvi et al., 2010). Inter-organizational IT and supply chain integration is a prerequisite for effective information sharing and decision making among distributed organizations (Chen et al., 2013; Kumar and Dissel, 1996; Zhu and Kraemer, 2005); this also holds for the wood industry which optimizes the use of resources and avoid misallocation (Appelhanz, 2013; Uusijärvi et al., 2010). Optimizing algorithms for resource-efficient production planning, for example, need current demand data in order to maximize resource efficiency (Tiedemann and Ide, 2013). The same applies to the optimization of wood processing, where quality data from supplying companies is needed (Ide and Tiedemann, 2013). In general, with the help of inter-organizational IT, the improvements in rough planning, prediction processes, and the timely reaction to deviations can increase yields from wood by up to 20 percent (Uusijärvi et al., 2010). Moreover, tracking and tracing systems in the wood industry promise a wide range of benefits regarding resource efficiency (Dykstra et al., 2002; Taskhiri et al., 2013), including waste reduction (Kasturi, 2005) and environmental impact through route optimization (Hug, 2004). Finally, inter-organizational IT can also help improve the acceptance of new wood-based products and thus increase wood usage. With the development of new customer services such as product information systems, information regarding quality, quantity, or certifications of origin can be provided, helping to diminish purchase barriers (Appelhanz et al., 2015; Osburg et al., 2015).

Compared to other industries such as the automotive or optic industries, the wood industry has not yet adapted well to inter-organizational IT (Hewitt et al., 2011; Shook et al., 2002).



The industry is generally described as conservative in terms of adopting new technologies (Arano and Spong, 2012) and the use of inter-organizational IT remains at a basic level (Jabeur et al., 2013). However, an increased and effective usage of inter-organizational IT promises to create advantages in terms of higher resource efficiency, lower environmental impact, and cost reductions (Appelhanz et al., 2015; Häkli et al., 2013; Timpe, 2006; Uusijärvi, 2012).

The aim of this cumulative dissertation is therefore to provide insights into the effective usage of inter-organizational IT in the context of wood networks. It has a particular focus on discovering why organizations in the wood industry do not adapt well to this kind of technology, so that solutions for overcoming these adoption barriers can be found. This thesis goes one step further in seeking to provide insights for wood networks on how to effectively use and govern inter-organizational IT in cooperation with their partners. In doing so, practitioners, policy makers, and future researchers should be guided toward a more efficient utilization of wood through the support of inter-organizational IT.

1.2 Research Questions

The effective use of inter-organizational IT is a prerequisite for the efficient utilization of resources in networks of the wood industry and can support the promotion of wood as a substitute for other fossil-intensive materials. Therefore, the goal of this thesis is to contribute to the understanding of how to effectively promote, use, and govern information systems in cross-organizational collaborations in the wood industry. Following this aim, this thesis is structured along three fundamental research questions.

As the digitalization of inter-organizational collaboration promises to create significant advantages in terms of operational efficiency, cost reduction, and/or access (Kumar and Dissel, 1996; Zhu et al., 2004, 2013), IT use for an efficient information exchange is becoming increasingly widespread across most industries (Zhu et al., 2006c). Inter-organizational IT, such as workflow systems, electronic data interchange (EDI), and supply chain systems, improve coordination and communication between partners, facilitate knowledge sharing, and increase innovation (Chi and Holsapple, 2005). The low diffusion of both intra- and inter-organizational IT within the wood industry (Hewitt et al., 2011), despite the prospective benefits, is puzzling. This phenomenon of non-adoption can be found for both the initial adoption decision and post-adoption usage (Arano and Spong, 2012; Jabeur et al., 2013; Karuranga et al., 2005). Insight from other studies cannot directly be transferred to this context because most research concentrates on adoption rather than non-adoption (Chen and Holsapple, 2012;



Premkumar et al., 1995b; Zhu et al., 2003). Moreover, the wood industry is distinct from other industries in terms of industry structure and organizational culture (Kies et al., 2012; Mrosek et al., 2005; Shook et al., 2002). Hence, the first research question is derived as follows:

- 1) How can the adoption and use of inter-organizational IT in wood networks be effectively promoted?

Of course, IT adoption is not an end in itself. As Orlikowski (2000, p. 425) notes, “Technology per se can’t increase or decrease the productivity.” When aiming to increase IT adoption and use in wood networks, one must also ensure that network members can derive value from the IT investments. This idea of effective usage of information technology has a long tradition in information systems research (Burton-Jones and Grange, 2013). As several studies were unable to find a positive relationship between IT investments and organizational performance, this phenomenon has come to be known as the productivity paradox of IT (Brynjolfsson, 1993). While much effort has been invested into understanding how single organizations can profit from investing in IT, much less is known about how networks of organizations profit from common IT investments (Grant and Tan, 2013; Grover and Kohli, 2012). Insights into the interplay between inter-organizational IT and organizations in networks contribute to Provan and Kenis’s (2008) call for gaining a better understanding of how networks function and thus also network level outcomes. Indeed, the context of inter-organizational networks is different and more complex than the context of single organizations. If networks plan to invest in common IT-based information integration, heterogeneity in terms of their operating environment, culture, social capital, and goals must be considered. Further characteristics of inter-organizational collaboration, such as a lack of information integration among the partners, instability in the alliances, and a lack of hierarchical decision making (Winkler, 2006), make the effective alignment of business needs and IT investments even more challenging than in the intra-organizational context (King, 2013). Therefore, specific capabilities are needed to handle this complexity, which also applies to wood networks. With little prior experience in IT management and IT integration, guidance on how to effectively invest in common IT integration is particularly necessary. Accordingly, the second research question framing this thesis is as follows:

- 2) How does the use of IT in inter-organizational networks lead to co-created value?

The knowledge of how to profit from common IT integration allows wood networks to effectively target their investments in IT. However, with a higher degree of IT use and IT invest-



ments in such networks, the coordination of common IT resources becomes a crucial challenge (Chong and Tan, 2012). Thus far, most communication between organizations in the wood industry is analog, with a low level of IT integration (Hewitt et al., 2011). Moreover, IT implementation decisions are mainly driven by single organizations (Kasturi, 2005; Lycken, 2010). However, with greater IT integration in the context of long-term network collaboration, member organizations grow to be more dependent and vulnerable. Modes of network governance then become important in order to coordinate the individual needs, diverging goals, and integration and disintegration of partners (Provan and Kenis, 2008; Winkler, 2006). Thus far, little research has been conducted in the field of governance of inter-organizational IT (Grant and Tan, 2013; Trang et al., 2013a). However, the long-term effective usage of IT requires appropriate governance mechanisms (Weill and Ross, 2004). Hence, the last research question is formulated as follows:

3) How can IT in inter-organizational networks be effectively governed?

1.3 Structure of the Thesis

This thesis is cumulative in nature and comprises four parts that include eight interrelated studies (see Table A-1 and Figure A-2). While the first and last sections (Parts A and E) frame this thesis in the context of the effective usage of IT in the wood industry, the middle portion (Parts B, C, and D) covers the studies. Each part is related to one of the three research questions. Although all essays address the topic of effective inter-organizational collaboration, not all of them are conducted within the context of the wood industry. Nevertheless, each essay provides important answers to selected aspects of the research questions defined above and thus has important implications for wood networks. Four of these essays have been published in leading international IS conference proceedings, and one has been accepted for final publication in the *Pacific Asian Journal of the Association for Information Systems*. At the moment, three more studies are in review for renowned conferences or journals.

Part A, “Foundations,” starts with the motivational introduction and then presents the core research questions. Afterward, the dissertation project is outlined, including the research design and anticipated contributions. The next subsection sets this research in the application context of the German wood industry and the theoretical context of research on adoption of inter-organizational IT, IT-based value co-creation in networks, and governance of inter-organizational IT. Part A ends with an overview and classification of the research studies in the context of science philosophy.



Parts B, C, and D represent the core of the cumulative thesis, including eight essays in the fields of IT adoption, IT-based co-creation, and governance of inter-organizational IT. Part B is related to Research Question 1, which asked how to effectively promote the adoption and use of inter-organizational IT in wood networks. Four essays provide answers to this question. As a variety of different theories for explaining the phenomenon of IT usage exist, the first study (#1) elaborates on recommendations for the base model choice. The second study (#2) in this block builds upon these insights and uses a dedicated theoretical lens to analyze reasons for the non-adoption of IT in the wood industry. With knowledge on these causes, the third study (#3) investigates how measures should be designed in order to effectively promote IT. Finally, while the prior studies focus on the initial adoption and routinization at the firm level, the fourth study (#4) explicitly concentrates on factors affecting the individual post-adoption acceptance of inter-organizational IT.

Part C concentrates on IT-based value co-creation and thus provides answers to Research Question 2 regarding how networks can gain value from inter-organizational IT. The first study (#5) elaborates on the core question of the functioning of IT value in networks. A framework is designed to guide how and where IT should be aligned with network processes in order to gain value from network IT. The second study in this block (#6) builds on these insights and determines which organizational capabilities are important for maximizing IT-based value co-creation.

Part D focuses on the governance of inter-organizational IT; insights from this section contribute to answering Research Question 3, i.e., how networks should govern their network IT. With the first study (#7), an overview of state-of-the-art literature on IT network governance is provided. The second study (#8) explicitly picks up a research gap from the previous study and aims to offer recommendations that consider situational factors of the network.

Finally, Part E closes this thesis by first explicitly reflecting the findings from all eight studies in the context of networks in the wood industry. Contributions to both current research and practitioners as well as implications for policy are then derived. The thesis closes with concluding remarks, which also include limitations of this work and further research needs.



Table A-1 Overview of studies included in this thesis

No	Outlet	Status	Ranking	Section	Core research question	Contribution
#1	International Conference on Information Systems 2014	Published	A	B.1	Which theoretical lens should be chosen when conducting IS adoption studies at the firm level?	Recommendations for the base model choice of empirical IS adoption studies
#2	Pacific Asian Conference on Information Systems 2015	Submitted	(C)	B.2	How do industry characteristics influence inter-organizational IS adoption decisions in the wood industry?	Insights into initial IS adoption inhibitors that are particular to the wood industry
#3	Journal of Cleaner Production	2 nd round of review	(B)	B.3	How can inter-organizational IS diffusion in the wood industry be effectively promoted?	Suggestions for how to promote initial IS adoption, specific to the German wood industry
#4	Hawaii International Conference on System Sciences 2014	Published	C	B.4	Can information security concerns explain post-adoption usage of collaboration information systems?	Insights into the influence of security concerns and network trust on post-adoption usage of collaboration systems
#5	Pacific Asian Conference on Information Systems 2014	Published	C	C.1	How do network co-create value through inter-organizational information systems?	Framework for how to effectively align inter-organizational IT with network processes
#6	The Journal of Strategic Information Systems	1 st round of review	(A)	C.2	What capabilities are important for aligning IS with network processes in network collaborations?	Recommendations regarding the building of IT capabilities, which facilitate IT alignment capabilities
#7	Americas Conference on Information Systems 2013	Published	D	D.1	To what extent has literature already explored concepts of IT governance in networks, and which areas provide direction for future research?	Overview of related literature, gaps in the current literature, and an agenda for research
#8	Pacific Asian Journal of the Association for Information	Forthcoming	n.a.	D.2	How can effective IT network governance structures be designed?	Insights into modes of governance and a theoretical framework on how to make an effective choice of an IT network governance mode

Note: The ranking is based on the VHB Jourqual 3 ranking. Parentheses indicate that the study is in review.

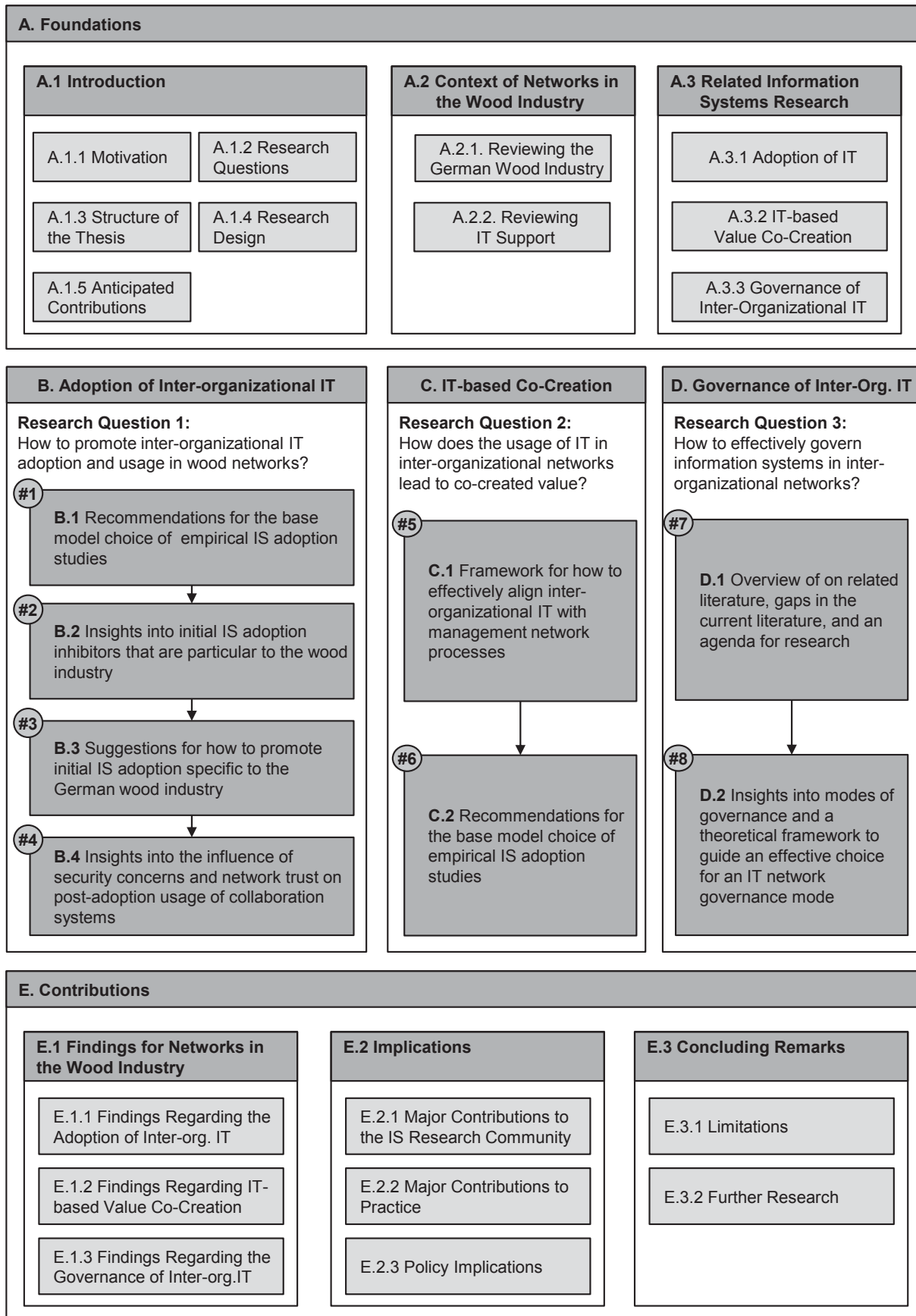


Figure A-2 Overview of the thesis structure



1.4 Research Design

The interdisciplinary research field of information systems encompasses a variety of research designs and methods (Wilde and Hess, 2007). At the interface between business administration and computer science, information systems researchers typically strive to answer questions related to the productive application of IT to organizations and society (Gregor and Hevner, 2013; Hevner et al., 2004; Kuechler and Vaishnavi, 2012). One can differentiate between two intertwined research paradigms: design science research and behavioral science research. Design science-oriented research aims to build IS artifacts to provide utility (Hevner et al., 2004), with the primary interest thus lying in the question of effectiveness. As this type of research offers solutions to practical problems, it allows knowledge to be transferred from science to practice (Wieringa, 2009). In contrast, behavioral science-oriented research aims to develop and justify theories to explain the interplay of humans, tasks, and technologies. The objective is to deeply understand the phenomenon and find the “truth” in the principles and laws that form the world. As a solid knowledge base is the foundation for effective solution design (Hevner et al., 2004), this thesis primarily follows the behavioral science-oriented approach. Rather than providing ready-made IS and management solutions for the wood industry, it focuses on gaining a deep understanding of the problem domains of non-adoption, IT-based co-creation, and governance. This thesis seeks to present foundational insights into the relationships between causes and effects and, in doing so, provides a basis for precisely defining future solutions.

Next to the decision for a research paradigm, a research approach typically encompasses two further elements: the epistemological positioning and the choice of research methods (Becker et al., 2003). The epistemological positioning defines how the reality is captured by the researcher and distinguishes the positivistic and the interpretive stances. While the positivist believes that the world under study has a single, objective truth (Hudson and Ozanne, 1988) and is independent from the researcher (Carson et al., 2001), the interpretivist argues that the reality is socially constructed and depends on the experiences of the researcher. Accordingly, interpretivist research aims to see the meaning behind behavior rather than to generalize and predict causes and effects (Hudson and Ozanne, 1988). Because this thesis aims to uncover explanations in order to provide guidance for future decision makers – and therefore per se assumes external reality – all studies take a positivistic stance. Nevertheless, in light of interpretative research tradition, it must be acknowledged that both science and personal experience might have influenced the research process.



Both the research paradigm and the epistemological positioning influence the choice of research methodology (Becker et al., 2003). Assuming a positivistic, behavioral science-oriented stance, this thesis combines qualitative and quantitative research methodologies from social sciences. In the classical sense of mixed-method research, exploratory and explanatory research methods are combined to gain rich insights into the research inquiry (Venkatesh et al., 2013). An overview of the research design for each study can be found in Table A-2.

Table A-2 Overview of research design and theoretical foundations of studies included in this thesis

No	Core research question	Epistemology	Paradigm	Data coll.	Data analysis	Theoretical foundation
#1	Which theoretical lens should be chosen when conducting IS adoption studies at the firm level?	Positivistic	Behaviorally oriented	Cross-sectional survey (N = 204)	Structural equation modeling and predictive power analysis	Technology-Organization-Environment Model, Task-Technology Fit Model, Unified Theory of Acceptance and Use of Technology
#2	How do industry characteristics influence inter-organizational IS adoption decisions in the wood industry?	Positivistic	Behaviorally oriented	Mixed methods: 11 expert interviews, N = 204 survey data	Mixed methods: exploratory interview and confirmatory path analysis	Technology-Organization-Environment Model
#3	How can inter-organizational IS diffusion be effectively promoted in the wood industry?	Positivistic	Behaviorally oriented	Cross-sectional survey (N = 204)	Structural equation modeling and importance-performance analysis	Technology-Organization-Environment Model
#4	Can information security concerns explain post-adoption usage of collaboration information systems?	Positivistic	Behaviorally oriented	Cross-sectional survey (N = 121)	Structural equation modeling	Technology Acceptance Model
#5	How do networks co-create value through inter-organizational information systems?	Positivistic	Behaviorally oriented	Cross-sectional survey (N = 198)	Scale development and mean comparison	Strategic Alignment Model
#6	What capabilities are important for aligning IS with network processes in network collaborations?	Positivistic	Behaviorally oriented	Cross-sectional survey (N = 310)	Path analysis, higher-order modelling, and mediation analysis	Dynamic Capability Framework, Relational View, Strategic Alignment Model
#7	To what extent has literature already explored concepts of IT governance in networks, and which areas could provide potential directions for future research?	Positivistic	Design and behaviorally oriented	Structured literature review, (N = 28)	Data analysis with concept matrices	IT Governance Perspectives by De Haes and Van Grembergen (2005)
#8	How can effective IT network governance structures be designed?	Positivistic	Design and behaviorally oriented	Multiple case study research (5 cases, 8 interviews)	Confirmatory multiple case study methodology	Contingency Theory



In all cases, a theoretical lens from management or information systems research has informed the theory-building process. While all studies are behaviorally oriented in nature, none of them is an end in itself and each provides practical implications for solution designs. Furthermore, three studies explicitly provide frameworks to guide decision making for practitioners in the wood industry. A rich data set, including a total of 19 interviews and 833 questionnaires, was evaluated in detail within six different data-collection processes. A structured literature review methodology and expert interviews were used to gain exploratory insights. Moreover, a variety of quantitative methods, such as structural equation modeling, mediation analysis, importance-performance analysis technique, and power analysis, were used for confirmatory research designs. Altogether, this thesis follows the call for pluralistic research design (Venkatesh et al., 2013).

1.5 Anticipated Contributions

This thesis is directed to several groups involved in both research and practice. First of all, it aims to offer recommendations to decision makers in the wood industry. Practical but scientifically validated suggestions should be developed in the field of IT adoption in order to guide managers and policy makers in overcoming adoption barriers. The results should explain not only what leads to non-adoption and non-acceptance but also how measures ought to be derived from these insights. Moreover, the knowledge on IT value co-creation and governance mechanisms should be generated in such a way that it is adaptable to the context of the wood industry. This requires the consideration of theories such as contingency theory that generate multiple recommendations for different contexts. As behavioral research on information systems is sometimes criticized for its lack of practical relevance (Gregor and Hevner, 2013; Österle et al., 2011), the thesis also seeks to provide tools and decision frameworks to network managers. With the help of such tools, which can be applied directly in practice, wood networks should generally be able to improve the value they can create from IT resources.

For policy makers, this thesis provides a solid knowledge base that they can consult regarding legislative processes. Due to its economic and ecological importance, the wood industry already has a strong presence in public attention. There is a variety of public and governmental actions that aim to strengthen resource efficiency in the wood industry (Osterburg et al., 2013). Knowledge regarding the effective usage of IT should guide policy makers in their design of incentives and measures in order to promote the competitiveness of wood as an ecological alternative for other fossil-intensive products. Therefore, concrete policy implications are provided within this thesis.



As this research is behaviorally oriented in nature, it particularly addresses researchers in both information systems science and those with a focus on the wood industry. Knowledge generated in this thesis advances the fundamental research streams on IS organization and strategy as well as the economics of IS – more specifically, the sub-streams of IT diffusion, business value of IT, and IS organization (Banker and Kauffman, 2004). This research translates concepts from network management literature (Alter and Hage, 1993; Dyer and Singh, 1998; Huxham and Vangen, 2005; Provan et al., 2007), thus contributing an inter-organizational perspective on all three phenomena. The integration of this perspective accounts for the increased relevance of networked businesses today, as competition increasingly shifts from the firm level to the network level (Li et al., 2005). For the context of inter-organizational IT adoption, this research mainly seeks to contribute with its particular focus on the wood industry, as general research in this field is regarded as rather mature. The field of IT-based co-creation has found more attention in recent years (Grover and Kohli, 2012); this research aims to contribute by integrating inter-organizational IT alignment research and thus increasing the understanding of the process of IT value derivation. Finally, the field of governance of inter-organizational IT is rather new and underrepresented in current IS literature (Grant and Tan, 2013; Trang et al., 2013a). Therefore, this research aims to provide an overview of the current state of knowledge and develop insights into how effective governance is shaped.

2 Context of Inter-Organizational Networks in the Wood Industry

Composed of various subsectors with more than 1.2 million employees and an annual turnover of about €170 billion, the wood industry is one of the largest sectors of the German economy (Mrosek et al., 2005). Moreover, the use of wooden raw materials for industry has doubled within the last two decades (Peters et al., 2010). This chapter first provides an overview of the German wood industry and the resource's flow in inter-organizational networks. Thereafter, the way in which IT supports inter-organizational wood networks is described with a particular focus on how information integration helps achieve economic and ecological goals.

2.1 Reviewing the German Wood Industry

The notion of clusters serves as a concept for describing the unit of analysis. Porter (1998) defines clusters as geographic concentrations of interconnected companies, such as specialized suppliers, service providers, firms in related industries, and associated institutions in a particular field. Within clusters, organizations cooperate in value chains, which entail all activities from the design of a product, through the production, and up to distribution to the end



customer (Arnold et al., 2009). These organizations are typically connected by cooperation within value chains as well as by competition between value chains. Following this conceptualization, the Commission of the European Communities defines the cluster “*Forst und Holz*” as raw timber-producing forestry enterprises; industries in the processing and manufacturing of semi-finished wood, pulp, and paper products; and downstream, wood-based manufacturing industries (Eurostat, 2002).

Contrary to general awareness, the wood industry is highly important for the German economy. The cluster comprises more than 150,000 companies, which together account for more than €170 billion in revenue (Mrosek et al., 2005). These companies employ 1.3 million people (Mrosek et al., 2005) – more than other important industries, such as the automotive industry with fewer than 800,000 employees (statista, 2013). While some branches are dominated by only a few big companies, such as in the pulp and paper industry, the German wood cluster is mainly composed of small- and medium-sized companies (Kies et al., 2012). An overview of the number of companies, employees, and sales for the cluster *Forst und Holz* is given in Table A-3.

Table A-3 Number of companies, employees, and sales of the German cluster “Forst und Holz” (Mrosek et al., 2005)¹

Industry	Companies	Employees	Revenue (in billion Euro)
Forestry	36,111	98,009	2.27
Wood working	2,128	40,978	9.22
Wood processing industry	2,824	182,538	27.34
Wood crafts	115,742	452,658	34.20
Paper industry	999	139,563	31.65
Publishing and printing trade	23,756	329,592	58.52
Timber trade and transport	2,850	35,500	9.94
Further suppliers	627	45,485	7.71
Forestry and timber total	185,037	1,324,323	180.85

When analyzing the flow of resources and products among the network of wood organizations, the aspect of output versus input orientation becomes important. While most clusters, such as the automotive or the optical industries, are defined according to their end products, the common ground of the wood cluster is the input (Kies et al., 2012). Accordingly, the starting point for analyzing manufacturing activities is not the end product but rather the production of wood as a raw material for further processing.

¹ While the study from Mrosek et al. (2005) bases on data from 2004 and 2005, it is the latest study which aggregates size, employment, and sales data for the whole German cluster “*Forst und Holz*.” However, excerpts from branch data available from Eurostat for the years 2008 and 2012 reveals similar results (Eurostat, 2015).

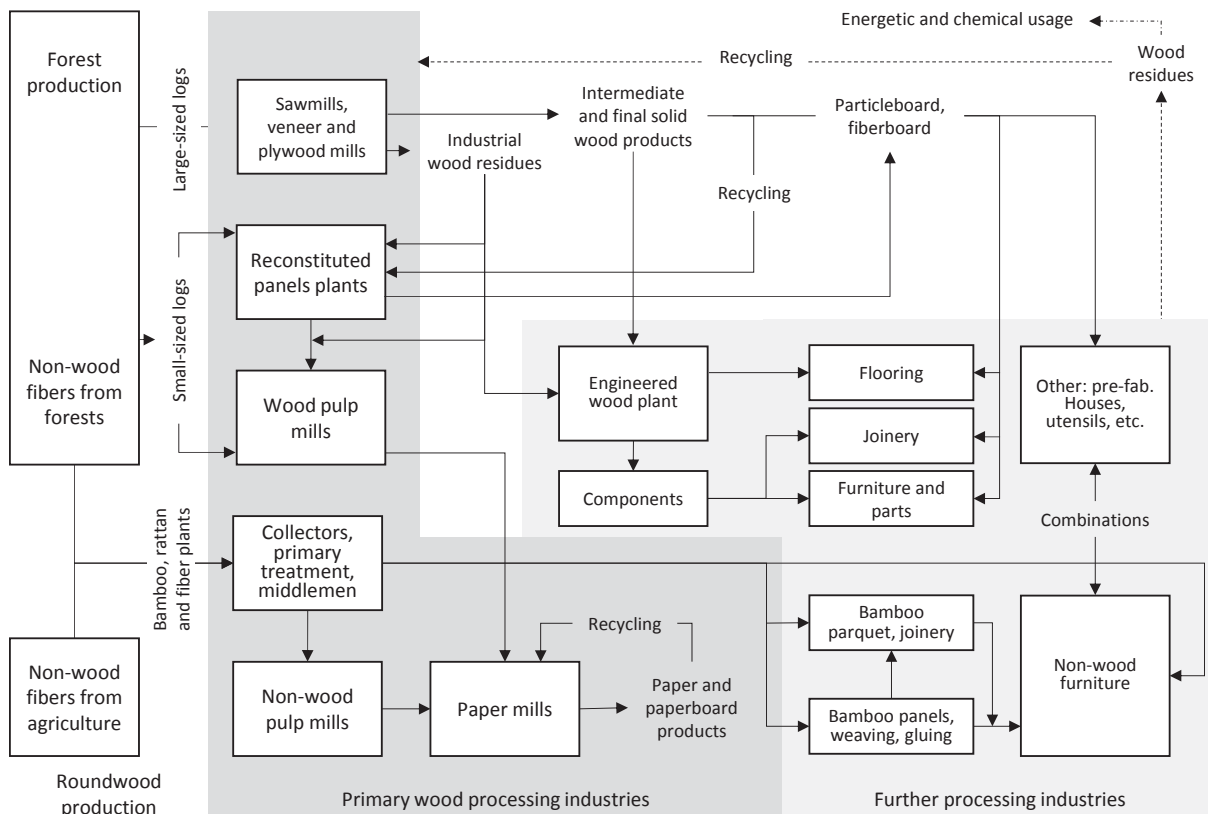


Figure A-3 Raw material and product flows (based on ITTO-ITC 2002)

In Germany, the total supply of wood into the system of primary processing and energetic usage is 135 million cubic meters per year.² This amount consists of 91 million m³ of wood from the forest – mainly wood logs, but also forest residuals or bark – and 44 million m³ from other sources, composted mainly of recycled and reused by-products (Mantau, 2012). While 67 million m³ of the wood is used for energetic purposes, 68 million m³ are processed in primary wood processing industries. Furthermore, the sawmills and veneer and plywood mills account for the highest share (around 37 million m³), followed by the wood-based panel industry with 17 million m³, the wood pulp industry with 11 million m³, and other material usage with 2 million m³ (Mantau, 2012). Semi-finished products from primary processing are then further processed into high value-added products. Due to the bulky nature and the comparably low value of wood raw material, the primary wood processing industries and the forest management have a close physical and economic linkage. Collaboration between the primary and further wood processing industries can be generally characterized as more loose and not necessarily, regional because the higher value of semi-finished goods, such as veneer or standard plywood, decrease transportation costs and thus allow efficient transportation over

² The estimations can be found in Mantau (2012) and mirror calculations of the wood supply and demand of the German wood cluster in 2010.