Ricardo Henríquez Larrazábal

Digital Transformation and Business Models in Maritime Trade Supply Chains

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Digital Transformation and Business Models in Maritime Trade Supply Chains

Doctoral thesis by

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To my parents, Ricardo and Miriam.

To the memory of three international merchants:

> *Abraham Cohen Henriquez, aka Francisco Vaez de León (Spain, 1572 – Amsterdam, 1638). A Sephardic Jew, he emigrated to Amsterdam due to the religious persecution, and eventually became one of the early shareholders of the* Dutch West India Company.
>
> *His 5th great-grandson, Salomon Daniel Cohen Henriquez (Curaçao, 1830 – Hamburg, 1908). Who from his Hamburg-based company,* S.D.C. Henriquez & Co.*, imported and exported products from/to Venezuela, the West Indies and Central America.*
>
> *And his son (my 2nd great-grandfather), Pablo de Jongh Henriquez (Curaçao, 1854 – Maracaibo, 1909). Who ran* de Jongh Henriquez & Ca.*, a Maracaibo-based firm that exported and imported products to/from Europe.*

My journey continues yours.

Acknowledgements

The journey that led me towards this PhD research began in November 2009 at Sentosa, Singapore, the southernmost point of continental Asia. Sitting at the tip of the islet on an afternoon, I contemplated the myriad of ships anchored at the Singapore Strait (at that time there were more than usual, due to the deep trough in international trade caused by the 2008 global financial crisis). There and then, I realised that my friend and law firm partner Gustavo Omaña was right: I had to get involved in the maritime industry. A fascination for international trade and maritime shipping was awaking in me.

The next year, following Gustavo's advice, I enrolled on the Specialization in International Maritime Trade at the Caribbean Maritime University in Caracas. I was fortunate to have great professors, among them Gustavo himself, Simón Molina (RIP), Rosana Salama and, most specially, José Sabatino, who generated in me a keen interest in seaports and became my advisor for the Specialization's research thesis.

At the end of 2012, I decided to emigrate from Venezuela, move to Barcelona, and begin a Master in International Business at EAE Business School. By that time, Rosana (now Dr. Salama) was conducting her own PhD at the Nautical Faculty of Barcelona, Catalonia Polytechnic University, and she graciously introduced me to Dr. Jesús Martínez Marín, who in turn introduced me to Dr. Xavier Martínez de Osés. Both have been my friends and mentors in this journey and, eventually, became my PhD thesis directors. Thanks Jesús and Xavi for showing an exceptional patience, pushing me to persevere, while at the same time giving me the freedom (perhaps too much!) to shape my research in the direction that I wanted. Thanks also to Montse Margalef, from the Department of Nautical Sciences and Engineering, for her continuous support on administrative issues throughout these years.

In the summer of 2013, Cristina Tomás taught us a course in international finance at EAE Business School. It was clear from the outset how many shared intellectual interests we had, so we quickly became the good friends we have been since. Thank you Cristina for being such a significant support throughout these years, for opening me the doors to become a professor at EAE Business School, and for co-authoring one of the papers of this thesis.

Shortly after beginning my doctoral program, in the spring of 2017 I had the fortune of being accepted as a visiting PhD researcher at the Department of Technology and Operations Management of Rotterdam School of Management, Erasmus University. I am specially indebted to Prof. Ting Li for making possible that visit and for her intellectual guidance during my time there. Prof. Rob Zuidwijk gave me great insights as to where my research should be headed, most particularly his suggestion to focus on innovation in business models. Professors Eric van Heck and Anne-Francoise Rutkowski led a workshop on Information Management Research that turned out to be crucial in my research. I thank both for the significant guidance they provided me at such an early stage of my PhD journey. Finally, Ainara Novales (now Dr. Novales), herself a PhD researcher at the department, was a kind and friendly peer during my 3-months stay.

Walking down along some docks at Rotterdam on a calm sunset of May 2017, I had another realization and my journey took a turn. Those days I was reading Max Weber's classical work *The Protestant Ethic and the Spirit of Capitalism*, quite interested in the notion of the "calling" for entrepreneurial activity, presumably embedded in Lutheranism. What I realised was that, for all my academic interest in researching how new technologies could transform maritime industry, I was myself feeling this "calling" to become an entrepreneur and contribute to this transformation.

That summer I got an opportunity to work for a blockchain development company in Dubai, and later on for a fintech startup in Beer Sheva, Israel. I am deeply grateful to my friend Itai Cohen, the co-founder and CEO of the startup in question, for what was for almost a year a unique professional experience.

By the end of 2018, I was already engaged in setting up my own startup project, originally conceived as a trade finance solution and, since the beginning of 2020, as a more encompassing digital platform for SMEs involved in international trade. It was quite difficult to find a balance between my entrepreneurial activity and my dedication to the PhD, but eventually things started to flow in the right direction. During this time, one person in particular became a significant journey companion: my good friend Mayela González. Mayela, I will always be indebted to you for listening and supporting me through challenging days.

Throughout my live, I have been lucky when it comes to friendship. I am grateful for having such wonderful friends as Luis Ochoa, Daniel Oquendo, Francisco Delgado, Karin Steegmayer and, lately, my fellow entrepreneur Geilan Malet-Bates. Thanks for sharing and continuing to share with me *"las buenas, las malas y las feas"*. My siblings, Luisa, Samuel, Mariana and Tomás have always been there to show that, above almost anything else, family matters.

Last, but not least. For one year (and counting) I've had the privilege to work from the coolest coworking space on this planet: the Digital Hub Logistics Hamburg, located in the historical *Speicherstadt* (not far away from where my 3rd great-grandfather's company offices once stood). I am deeply grateful to all of the Hub's staff, most particularly to Annabelle Dirks and Aileen Schmuck for their kindness, and for caring about my entrepreneurial and academic journey.

Hamburg, 31 March 2022

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List of Abbreviations

3G	Third generation port
3PL	Third-party logistic provider
4G	Fourth generation port
4IL	Fourth industrial revolution
5G	Fifth generation port
ADB	Asian Development Bank
ADR	Action Design Research
AfDB	African Development Bank
AI	Artificial intelligence
AML	Anti-money laundering
API	Application programming interface
AR	Augmented reality
ATA	Actual time of arrival
BE	Bill of exchange
BEST	Barcelona Europe South Terminal
BL	Bill of lading
BMI	Business model innovation
BPA	Barcelona Port Authority
BTC	Bitcoin
CEO	Chief Executive Officer
CIO	Chief Innovation Officer
DC	Documentary collection
DeFi	Decentralised finance
DLT	Distributed ledger technology
DSR	Design science research
DvP	Delivery vs. payment
ECA	Export credit agency
EDI	Electronic data interface
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
ESG	Environmental, social and governance criteria
ESPO	European Sea Ports Organisation
ETA	Estimated time of arrival
EU	European Union
GeTS	Global eTrade Services
GPS	Global positioning system
GVC	Global value chains
ICC	International Chamber of Commerce

ICO	Initial coin offering
ICT	Information and communication technology
IEO	Initial exchange offering
IoT	Internet of things
IRM	Information Resource Management
IS	Information systems
ISR	Information Systems Research
IT	Information technology
JSON	JavaScript Object Notation
KBV	Knowledge-based view
KYC	"Know your customer"
LC	Letter of credit
MBS	Mortgage-backed security
OCR	Optical character recognition
OECD	Organisation for Economic Co-operation and Development
P2P	Peer-to-peer
PCS	Port community system
PwC	PricewaterhouseCoopers
R&D	Research and development
RBV	Resource-based view
RTG	Rubber Tyred Gantry crane
RV	Relational view
SBM	Sustainable business models
SBN	Smart business network
SC	Strategic connectivity
SCon	Smart contract
SLC	Standby letter of credit
SME	Small and medium enterprises
SSM	Sustainable shipping management
STO	Security token offering
SWIFT	Society for Worldwide Interbank Financial Telecommunication
TEU	Twenty foot equivalent unit
TL	TradeLens
UCP 600	Uniform Customs & Practice for Documentary Credits (version 600)
UNCTAD	United Nations Conference on Trade and Development
UK	United Kingdom
US	United States of America
VR	Virtual reality
WCED	World Commission on Environment and Development
WEF	World Economic Forum
WTO	World Trade Organization
XML	Extensible markup language

Chapter 1. Introduction

1.1. Motivation

The last 15 years have witnessed an ongoing revolution in information technologies, big data analytics and interconnectivity. So-called "smart" devises, by means of embedded sensors, automatically generate and transmit real-time data, thus building an "internet of things" (IoT) (Ashton, 2009; Gubbi *et al.*, 2013; Kopetz, 2011). This has enabled a significant increase in the amount and quality of business-related information available for economic actors, giving birth to what has already being christened as the "fourth industrial revolution" (4IL) or "Industry 4.0", spanning broad areas like manufacturing and supply-chain (Schwab, 2016; Tjahjono *et al.*, 2017; Manavalan & Jayakrishna, 2019). Similarly, the financial industry has also been disrupted, giving rise to a new kind of economic player: the fintech company (Zavolokina *et al.*, 2016a, 2016b; Gomber *et al.* 2018). This disruption has both economic and technological grounds: it derived from the financial crisis of 2008-09 and ensuing Great Recession (Haddad and Hornuf, 2018; Lee and Chin, 2018); but it is also due to emerging technologies like distributed ledgers (blockchain) and digital currencies (Bitcoin) (Tapscott and Tapscott, 2016; Guo and Liang, 2016; Aste *et. al.*, 2018). An all-encompassing term used to refer to these phenomena has been "digital transformation" (Puthiyamadam, 2017).

In parallel with this technology-evolving background, a different sort of disruption has taken place: business model innovation. Successful companies like Uber or AirBnB have revolutionized value creation and profit making, not by creating new technologies or developing new industries, but by innovatively using current technologies in traditional industries like transportation and hospitality. As a consequence, the concept of business model innovation has received increasing attention in the academic world (Baden-Fuller and Morgan, 2010; Gassmann *et al.*, 2016; Zott and Amit, 2010).

In a globalized economy, maritime trade supply chains have not been oblivious to these developments (Sabatino, 2021; Salama, Martínez Marín, and Martínez de Osés, 2014). Comprising about 80% of world trade (UNCTAD, 2021b), maritime transportation remains the backbone of a global supply network that makes possible the increasing international interchange of goods and services (Lee and Song, 2017). As such, it has been the target of numerous innovating efforts, including digitization (Sánchez-González *et al.*, 2019), IoT and sensorization (Yang *et al.*, 2018), and new business models (Hollen *et al.*, 2013; Ferretti and Schiavone, 2016). Despite those initiatives, maritime trade remains a largely traditional industry: manufactured goods are transported through a decades-old container system (physical flows), key documents like bills of lading are issued and exchanged in paper-based form (information flows), and payments from importers to exporters are still channelled through centuries-old instruments like letters of credit (financial flows).

1.2. Research Questions

This doctoral dissertation focuses on the topic of business model innovation (BMI) in the context of maritime trade supply chains; in particular, BMI driven by digital transformation. The surge of new business models in tandem with the appearance of new technologies, especially during the last decade, points towards a likely influence of the latter on the former. Indeed, one theoretical approach to BMI is to consider it as essentially intermingled with technological innovation (Chesbrough and Rosenbloom, 2002; Teece, 2006).

It is, therefore, relevant to ask how this dynamic interrelation between digital transformation and business models plays in different contexts, among them in maritime trade supply chains. Accordingly, the main research question (RQ) of this dissertation is expressed in the following way:

> ***RQ**: What is the impact of digital transformation on business models, in the context of maritime trade supply chains?*

In order to provide a solid answer, the above question is decomposed into 4 sub-research questions, which are treated in each of the following chapters of this doctoral dissertation, and define the scope of the academic papers that constitute the basis of each chapter. Finally, in the last chapter, the chapter's findings are synthetized in order to answer the main research question.

The second chapter develops a theoretical synthesis, where physical, information and financial flows are understood under the technology/business model dynamic interrelation. The first sub-research question (RQ_1) is thus defined as follows:

> ***RQ_1**: How does digital transformation affect business models in terms of physical, information and financial flows?*

In elaborating an answer, Chapter 2 presents an explanation theory (Gregor, 2006) about the interrelation between digital transformation and business models, with special emphasis in how the former affect physical, information and financial flows. This theoretical exploration aims to develop a conceptual framework that serves as a basis for the three following chapters, which deal, in turn, with the interrelation between digital transformation and business model innovation regarding seaports (Chapter 3), shipping (Chapter 4), and trade finance (Chapter 5).

Chapter 3 develops a case-study on the impact of Industry 4.0 technologies in the port of Barcelona; being more related with physical flows. We investigate the mechanisms and areas of influence of these technologies in a seaport context, aiming to answer the following sub-research question:

> ***RQ₂*:** *How Industry 4.0 technologies might drive business model innovation in a seaport context?*

Based on the well-known classification of Information Systems theory proposed by Gregor (2006), the goal of this chapter is to explain and predict (Type IV theory) the impact of Industry 4.0 in the business models adopted by seaports. The chapter delves into two constructs from Management Science: technology pull and market pull, in order to understand the mechanisms through which Industry 4.0 associated technologies exercise an influence on the operations, strategies and investments of a seaport. It builds a conceptual model, which is in turn evaluated against the results of the case-study conducted.

Chapter 4 is more focused with information flows. It presents also a theory for explaining and predicting, in this case, the potential of distributed ledger technology (DLT), most commonly known as blockchain, for disrupting the way information is generated, accessed and exchanged in maritime supply chains, and to act as a catalyst for more sustainable business models (SBM) in the shipping industry. The corresponding sub-research question is posed as follows:

> ***RQ₃*:** *What impact does DLT has on the adoption of SBM, as well as sustainable practices, in the shipping industry?*

The research presents a series of general propositions as to how DLT might facilitate information sharing and associative behaviours among actors in shipping networks, which in turn contribute to more sustainable business models and practices. These propositions are tested against a case study about a DLT-based information infrastructure platform for maritime trade supply chains: TradeLens.

Chapter 5 presents a research that develops theory for design and action (Gregor, 2006), and is concerned with financial flows in maritime trade. Under the design science research (DSR) methodology (March and Smith, 1995; Hevner *et al.*, 2004), it presents a design of a decentralised finance (DeFi) system that aims to provide a solution to the trade finance gap that persists in international trade. This design looks to answer the last sub-research question of the dissertation:

> ***RQ₄**: How to design a DeFi business model that would address some of the causes behind the trade finance gap?*

The chapter deals with a real-life problem that has caught attention in international policy discussions, and has become more acute as a consequence of the COVID-19 pandemic, negatively affecting import/export transactions, especially for SMEs in developing and emerging economies. As a potential answer to this practical problem, the chapter presents a design of a DeFi system that would lower transaction costs and information asymmetries, as well as increase sources of liquidity. This design looks also to serve as an example of technology-based business model innovation.

1.3. Theoretical Contribution and Practical Relevance

The overarching theoretical foundation of this doctoral dissertation is provided by three disciplines: Management Science, Maritime Studies, and Information Systems Research (ISR). In the case of ISR, as observed by several scholars in the field (Orlikowski 2009; Orlikowski and Barley, 2001; Orlikowski and Baroudi, 1991) the discipline is positioned at the confluence of technology, people and organizations. Accordingly, this dissertation looks to contribute to the body of knowledge in the relevant topic of the interaction between technology (digital transformation) and business models. The research purports, more specifically, to contribute to the understanding and assessment of technologies associated with the industry 4.0 paradigm, and their impact on a significant economic sector: maritime trade supply chains.

Using the aforementioned theoretical taxonomy by Gregor (2006), Table 1-1 presents the chapters included in this dissertation, identifying their respective sub-research question, type of theory and research method.

Table 1-1. *Chapters, sub-research questions, theory type and research methodology*

Chapter	Sub-research question	Type of theory	Research method
2	*RQ_1:* How does digital transformation affect business models in terms of physical, information and financial flows?	Theory for explaining	Theoretical Synthesis
3	*RQ_2:* How Industry 4.0 technologies might drive business model innovation in a seaport context?	Theory for explaining & predicting	Case Study
4	*RQ_3:* What impact does DLT has on the adoption of SBM, as well as sustainable practices, in the shipping industry?	Theory for explaining & predicting	Case Study
5	*RQ_4:* How to design a DeFi business model that would address some of the causes behind the trade finance gap?	Theory for design & action	Design Science Research

Regarding managerial practice, this dissertation looks to shed light on potential uses cases for the application of Industry 4.0 technologies in maritime trade. Above anything else, it is the purpose of this research to serve as an inspiration for entrepreneurs aiming to build start-ups with innovative business models and value propositions.

1.4. Research design

This research adopts the critical realist approach (Bhaskar, 1975; Mingers *et al.*, 2013), which sustains that there is an external, causally driven reality, which is independent of our empirical perceptions of it and cannot be reduced neither to what is observable or measurable (positivism), nor to the outcome of socially constructed meanings (interpretivism).

An important trait of critical realism is that it recognizes *'the existence of different types of objects of knowledge —physical, social and conceptual— which have different ontological and epistemological characteristics* [and] *therefore require a range of different research methods and methodologies to access them'* (Mingers *et al.*, 2013, p. 795). Critical realism, then, is a particularly suitable approach to complex objects of research, and for the application of multiple research methods.

In line with this, Table 1-1 shows how different methodologies are applied throughout the dissertation (Theoretical Synthesis, Case-Study and Design Science Research). This approach allows for a richer contextual treatment of the research topic, and aims to provide the findings with higher generalizability. The particular methodology used in each research paper will be described in more detail in the corresponding chapter.

1.5. Structure of the Dissertation

The structure of the dissertation is shown in Figure 1-1. This introduction (Chapter 1) has exposed the research motivation, main research questions and corresponding sub-research questions, theoretical contribution and practical relevance, research design, and the dissertation's structure. The main research question, regarding the impact of digital transformation and its associated technologies on business model innovation in maritime trade, is first addressed in a general, theoretical way (Chapter 2). Subsequently, this interrelation between digital transformation and business models is considered in separate chapters. Each of the chapters focus more closely on one of the three flows in a particular maritime trade context: Chapter 3 deals with seaports (physical flows), Chapter 4 studies information infrastructures in the shipping industry (information flows), and Chapter 5 develops a design research for trade finance (financial flows). Finally, Chapter 6 concludes, answering the main research question by summarizing and synthesizing the findings of each chapter. In it are also presented the theoretical and practical contributions, research limitations, as well as suggestions for future research.

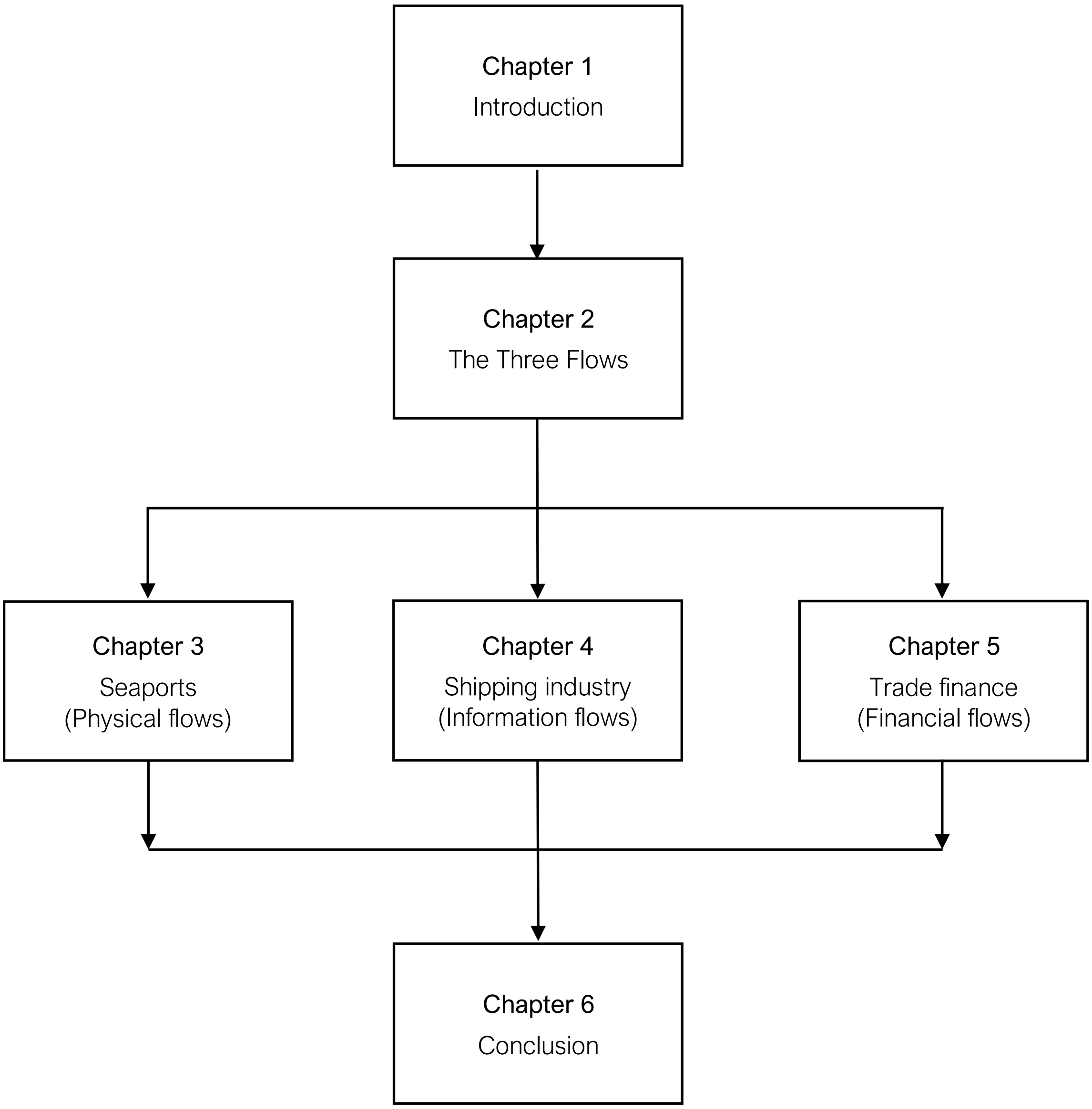

Figure 1-1. *Structure of the Dissertation*

Chapter 2.
The three flows in maritime supply chains

2.1. Introduction

Global value chains (GVC) surged at the end of the twentieth century as a result of significant advances in three interrelated areas: the movement of goods, the movement of finance, and the movement of information. Containerization fundamentally changed the way physical goods were transported, allowing never seen levels of efficiency and standardization, and bringing about globalization of supply chains (Hoffmann and Kumar, 2010; Stopford, 2009). Financial markets were also globalized, in part as a result of liberalization policies adopted during the nineties —with their due share of negative consequences (Stiglitz, 2002)—, and in part because large financial institutions became themselves more global. The internet, digital telecommunication, and web standards increased exponentially the speed and volume of data and information transfers across the globe, as well as making them far easier (Lituchy and Rail, 2000; Graham and Hardaker, 2000).

As value chains and trade routes have extended worldwide, firms and other trade-related organizations (like seaports) have become increasingly aware that operational excellence in handling physical, financial and informational flows is a significant driver of increased performance and competitive advantage (Lee and Whang, 1998; Sahin and Powell Robinson, 2002). Multinational companies have developed far reaching, fragmented and sophisticated networks of partners in order to take advantage of labor price differences, with labor-supply abundant countries in Asia establishing themselves as global manufacturing centres (Appelbaum, 2008; Timmer *et al.*, 2014). Maritime transportation companies, on the other hand, have built complex hub-and-spoke logistics networks, particularly for container transportation, around key seaports across different geographic regions (again, Asia being the region with the largest hubs) (Fugazza and Hoffmann, 2017; Notteboom and Rodrigue, 2008). Seaports themselves have entered into competition and collaboration dynamics, evolving from simple sea/land interfaces for cargo movements into value aggregating centres for logistics processes (Munim and Haralambides, 2018; Yap and Lam, 2006; Yap *et al.*, 2006). During this process, the importance of technology —and most especially, information and communication technology (ICT) infrastructures— for achieving operational excellence in handling the three flows in global supply chains, has been continuously observed (Gunasekaran and Ngai, 2004; Rai *et al.*, 2006; Wang, Y. *et al.*, 2020).

The last 15 years, however, have shown how fragile these sophisticated GVC networks are, and how a disruption in one of the flows critically affects the other two (Chor and Manova, 2012; Levchenko *et al.*, 2010). For instance, the disruption of financial markets as a result of the 2008 crisis had an immediate impact in the levels of international trade; and the ensuing recessions and regulatory reforms in banking have been key factors in maintaining a large trade finance gap that affects trade opportunities, particularly for small and medium enterprises (SME) in emerging economies. More recently, the COVID-19 pandemic has generated severe disruptions in physical supply chains, equally affecting trade-related financial flows (El Baz and Ruel, 2021).

These phenomena, their related problematics, and the answers to them, have been researched by several academic disciplines; among them, Management Science, Maritime Studies, and Information Systems Research. Cross-disciplinary studies on global supply chains and the integration of physical, financial and informational flows are however, with a few exceptions (Kano *et al.*, 2020; Sanders and Wagner, 2011), not easy to find. This chapter, therefore, develops a theoretical synthesis based in perspectives provided by the aforementioned disciplines, in order to provide a general theoretical background for the research conducted in the subsequent chapters. The sub-research question associated with this chapter is the following:

> ***RQ$_1$:*** *How does digital transformation affect business models in terms of physical, information and financial flows?*

2.2. Literature Review

These constructs have been developed in academic studies from Management Science, Maritime Studies, and Information Systems Research. The main concepts utilized to build an explanation theory (Gregor, 2006) are business model innovation, maritime trade supply networks, and digital transformation.

2.2.1. Business model innovation

The business model construct has been described and defined through a variety of theoretical perspectives. A generally accepted —and somewhat vague— definition is that business models are the particular ways in which a firm creates, distributes and captures value (Osterwalder and Pigneur, 2010). Beyond this common understanding, several schools have surged inside the Management Science discipline, offering competing paradigms about what specifically a business model is (Gassmann *et al.*, 2016). For the *Activity Systems school*, a business model consists of the set of interdependent activities undertaken by a firm to realise its value proposition, and the specific structure, content, and governance of its transactions (Amit and Zott, 2015; Zott and Amit, 2007, 2010). The content consists of the activities performed by the firm, the structure refers to how they are linked with each other, and the governance defines who executes them. The *Cognitive school* understands business models as "models" in the way that biology and economics utilise them, that is, as cognitive representations that help to classify real things (Baden-Fuller and Morgan, 2010). These models become blueprints for managers who wish to adopt specific strategies. The *Recombination school* defines a business model as a recombination of patters that answer four key questions of a business: who? (customer), what? (product), how? (processes), and why? (revenues) (Gassmann *et al.*, 2014, 2016). This school has clear ties with the concept of architectural innovation, understood as the reconfiguration of core elements of products and processes by a firm, as a way of redefining its value creation, delivery and capture activities (Henderson and Clark, 1990).

More recently, Cachon (2020) decomposes a business model into two core elements: the supply model (how the firm uses and manages resources to generate customer value) and the revenue model (how the firm extracts part of the value that customers give to its products).

2.2.2. Maritime trade supply networks

Maritime studies have analysed how transportation networks work, and how they should be designed to optimize operational efficiency. Multimodal networks, built over the standardization allowed by containerization, have been a prolific field of study (Song and Lee, 2009). The network construct itself has been used to visualise the dynamics that govern the flow of physical goods around the globe, including raw materials, semi-manufactured parts, and finalized products (Andersen and Christensen, 2005; Zhang *et al.*, 2013).

Among the many actors that play roles in maritime networks, shipping liners and seaports have received particular attention in academic papers (Notteboom and Winkelmans, 2001; Lam and Yap, 2011; Sanchez and Wilmsmeier, 2011; Wilmsmeier and Hoffmann, 2008). The concentration trend in both sectors, attributable to economies of scale, is considered a suboptimal network configuration (Lam *et al.*, 2007), and studies have pointed out the desirability of collaboration frameworks and the exploitation of complementary relationships among ports, as a way of increasing the network's efficiency (Lam and Yap, 2011; Panayides and Song, 2009; Seo *et al.*, 2016).

Apart from suggesting optimal maritime network configurations, studies have analysed efficiencies and challenges in various stages and processes of the maritime supply chain, including port infrastructure (Haralambides, 2002), container transshipment (Lirn *et al.*, 2004; Munim and Haralambides, 2018; Vis and Koster, 2003), container stacking (Dekker *et al.*, 2007), warehouses (Koster *et al.*, 2017), and inland transportation (Zuidwijk and Veenstra, 2015).

Beyond the specifics of network configuration and efficiency in its nodes, stages and processes, it has been suggested that supply chain networks, among them maritime transportation ones, might become "smart" if their business logic can be embedded into algorithm-controlled, self-executing processes (Vervest *et al.*, 2005, Vervest and Zheng, 2009).

2.2.3. Digital transformation

Digitization is usually understood as the migration from physical or mechanically-based products or objects to computer-based ones. A clear and well-known example is the disruption of photography, from a physical base (film) to an electronic base (jpg or png files are 0s and 1s in a memory drive). In the context of maritime trade supply chains, there has been a continuous advocacy for digitising trade documents like bills of lading or letters of credit, a process still under way (ICC, 2020; Voorspuij and Becha, 2021; WEF, 2020).

Digital transformation is, however, a concept that goes beyond digitization, being closer to how some use the term "digitalization" (Jensen *et al.*, 2019). Matt *et al.* (2015) define it as strategies coming from a business-centric perspective that *'focus on the transformation of products, processes and organizational* *aspects owing to new technologies'* (p. 339). The authors distinguish this way digital transformation strategies from IT strategies, which limit their focus to the management of IT infrastructures. Digital transformation is also distinguished from process automation and optimization, which focus on operational efficiency and effectiveness (Porter, 1996). It goes farther than IT infrastructure to also include changes in products, structures, agency and business models (Baiyere *et al.*, 2020; Matt *et al.*, 2015; Vial, 2019).

Digital transformation does not limit itself either to the firm's boundaries, and instead comprehends both internal and inter-organizational interactions (Bensaou and Venkatraman, 1996). For information intensives industries, like logistics, digital transformation increases relational value, defined as mutual benefits jointly cocreated by two or more firms (Dyer and Singh, 1998) or entire networks (Kauffman *et al.*, 2010). This relational value can be cocreated in the context of both physical, information and financial flows across the supply chains (Rai *et al.*, 2012).

Recent IS research provides a new perspective, taken from information ecology and social anthropology to study digital transformation. According to Wang (2021) digital transformation should be understood in the context of ecosystems and how IT tools provide to different actors the information needed to integrate them themselves into a functioning whole (i.e., an ecosystem). On the other hand, Baygi *et al.* (2021) call for a shift from actor-centric orientations toward a flow-oriented approach and vocabulary, in order to grasp the driving forces of digitally enabled transformation.

2.2.4. Research Method

This chapter applies a theoretical synthesis method to develop a theoretical background for the research conducted in this doctoral dissertation, mainly exposed in the subsequent chapters. Theoretical synthesis has been used in classical studies (Bensaou and Venkatraman, 1996; Grimes, 1978), as a method to extend well-established theories as anchoring constructs, and provide novel explanations about phenomena. Its utilization spans studies from Management Science (Maertz and Griffeth, 2004), Information Systems Research (Bhattacherjee *et al.*, 2012), International Business (Paul, 2020), as well as in the context of doctoral dissertations (Wasesa, 2017).

In conducting the synthesis, we are influenced by the previously mentioned literatures on Management Science, Maritime Studies and Information Systems Research. As anchoring constructs, we use physical flows, information flows, and financial flows, being particularly indebted to the work of Rai *et al.* (2006, 2012) on the subject of supply chains and logistics.

In order to build an explanation theory, we analyse each of the mentioned constructs, asking three basic questions about them: 1) *What?* The description of respective units of flow; 2) *How?* The mechanisms that underpin them; and 3) *Why?* The driving forces behind physical, information and financial flows. We then consider the three flows as a whole, analysing their integration dynamics. Finally, we propose a novel approach to understanding the nature of business models in terms of the three flows.

2.3. Theoretical synthesis

Before treating each type of flow, it is convenient to make some general remarks about the concept itself. That something *flows* means that it *moves*. It is not enough to say that it *changes*; flowing is a term related with spatial change, either in a strict physical sense of movement, or a more generic one that associates what flows to different entities, spatially distinct (as it will be explained in more detail regarding financial flows).

As a result, the physical flow construct is easier to grasp than the information and financial flow ones, and these follow the first by analogy.

2.3.1. Physical flows

2.3.1.1. What flows?

In the context of maritime trade supply chains, there is an all-encompassing term that singled-handedly answers the question: *cargo*. It could be said, of course, that vessels or stacking vehicles flow, but those movements can be also considered cargo flows (in a general sense) as they are directly or indirectly associated with them. Transportation of passengers (whom obviously cannot be considered cargo, at least not nowadays), on the other hand, is not properly part of maritime *supply chains*; neither can be considered *trade* in a strict sense, being rather a provision of a service.

An important distinction is that between raw materials, semi-manufactured products or spare parts, and finalized products, as they follow different business logics, even if their mode of transportation (for instance, a container) might be the same.

2.3.1.2. How it flows?

It could be tempting to answer this question with another all-encompassing term: *multimodally*. However, multimodal transportation does not comprise all kind of transportation (a pipeline being an example outside of the strict sense of the term), and transportation is not either the only way that cargo flows. Logistic processes like stacking, warehousing, or consolidation, are trade related physical flows; it would be inaccurate, however, to describe them as transportation processes. In addition, transportation routes and networks are part of the description about the mechanisms of physical flows in maritime trade; *the hub-and-spoke* structure being the most common one.

2.3.1.3. Why it flows

Physical flows in maritime trade occur for one of two reasons: *production* or *consumption*. Consumption flows are associated with final products, although in a strict logistics sense, the movement of finalized goods from wholesalers to retailers is still not consumption (they are instead *distribution*, which we consider here as part of production). Production flows are those related with raw materials, semi-manufactured or semi-processed goods, and the distribution of final products to end customers.

Consumption related physical flows take place when an economic actor chooses not to meet itself the demand for what it flows (e.g., a farmer chooses not to grow his own potatoes, but instead buys them at the market). Production related physical flows take place when an economic actor chooses not to perform itself a value aggregating process (e.g., a sportswear company that chooses not to manufacture itself the sneakers that it sells).

2.3.2. Information flows

2.3.2.1. What flows?

In maritime trade supply chains, there are two type of information flows: *data* and *information* (in the strict sense of the term). Data is defined as *'streams of raw facts representing events occurring in organizations or the physical environment before they have been organized and arranged into a form that people can understand and use'* (Laudon and Laudon, 2014, p. 46). Information, on the other hand, is *'data that have been shaped into a form that is meaningful and useful to human beings'* (*Ibid.*, p. 45). An example of data would be the GPS coordinates of a vessel or the temperature level of a refrigerated container; an example of information would be the item list in a cargo manifest or the incoterm in a commercial invoice.

2.3.2.2. How it flows?

Generally speaking, there are two basic mechanisms through which data information flows between actors in maritime supply chains: electronically or by means of paper-based documents. Paper-based documents are still the rule for certain trade related processes (bills of lading, letters of credit), though their electronic counterparts are gaining ground. Electronic means for transmitting data and information include data standards like EDI, although the use of internet-based solutions like e-mails or instant chats is already widespread.

2.3.2.3. Why it flows?

Information flows across maritime trade supply chains because it is needed as an input to physical or financial flows. Here the conception of information as a *resource* is relevant (Eaton and Bawden, 1991; Lewis *et al.*, 1995). Information functions a resource that is either needed for trade related processes or because it increases their efficiency. An example of needed information is the delivery of the original bills of lading to the carrier for downloading the cargo; an example of streamlining information is the estimated time of arrival (ETA) of a vessel at a seaport. In the first case, the cargo will not be delivered without the documents; in the second case, the ETA is a valuable decision-making input for berth allocation or optimal container stacking.

2.3.3. Financial flows

2.3.3.1. What flows?

Another case of an obvious and simple answer: *money*. Flowing of money can take a physical form, the interchange of paper cash or metal coins, but this is very rare in maritime trade supply chains. Instead, what flows is the *ownership* of money between physically separated entities. This is what takes place in a wire transfer from the importer's bank to the exporter's bank.

2.3.3.2. How it flows?

A general distinction is between *payments* and *credit*. Trade finance instruments like a letter of credit are both: a *payment* from the issuing bank to the confirming bank, and a *credit* from the issuing bank to the importer. Currently, most trade related financial flows take place on *open account* terms, which is a credit from the exporter to the importer (ICC, 2020). The processing of financial flows is done through data transfers, for instance, a SWIFT message between the importer's and the exporter's banks. Paper-based processes, however, are still used, like drawing a check; and the physical interchange of paper documents like letters of credit or bills of exchange is common.

2.3.3.3. Why it flows?

The logic behind financial flows is the same than that of physical flows: but it drives money in the opposite direction along the supply chain. This dynamic is what economic theory names the *Circular Flow Model* (Cohen, 1963; Leontief, 1991). Money flows from households to firms (as purchases of goods and services), from firms to firms (as supply chain or procurement related payments or credits), and from firms to households (as salary, dividends, bonuses, etc.). There is a causal relationship between financial flows and physical flows: one is the input or the output of the other.

2.3.4. Integrating the three flows

For a supply-chain (in fact, for any economic process) to work properly, the three flows have to be integrated to some extent. Being interdependent, a delay in one of the flows usually causes a corresponding delay in one or both of the other two. A disruption of any of them, on the other hand, might bring the whole system to a halt. Figure 2-1 shows a graphic representation of the three flows interrelation.

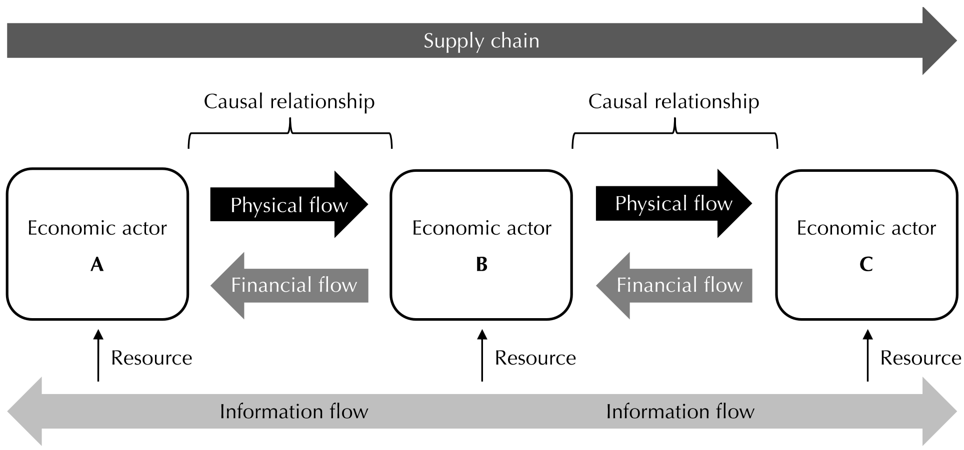

Figure 2-1. *Interrelation between the three flows*

As value aggregating processes are undertaken along the supply chain by different economic actors, there are physical and financial exchanges between them. Information, on the other hand, functions as a resource input for these value aggregating processes and their corresponding exchanges.

Table 2-1 summarizes the analysis presented in the previous sub-sections about the three anchoring constructs.

Table 2-1. *Summary of the three flows analysis*

	Physical flows	Information flows	Financial flows
What?	Cargo Raw materials Semi-manufactured Final products	Data Information	Money
How?	Multimodal Logistic processes Trade routes	Documents Electronically	Payments Credit
Why?	Production Consumption	Resource	Circular Flow Model

It was previously observed that a business model is generally understood as the way a firm creates, distributes and captures value. In this theoretical synthesis we aim to extend the business model concept by adding a new perspective:

A business model can be (entirely or partially) represented by a specific description of the physical, information and financial flows between a firm and other economic actors.

Each of the flows is associated with one or more of the value related processes: creation, distribution or capture. In the next section we discuss this affirmation in more detail.

2.4. Discussion

As previously exposed, the *Activity System* school understands business models as set of interdependent activities spanning firm boundaries (Gassmann *et al.*, 2016; Zott and Amit, 2010). These activities have a specific content, structure and governance. The *content* can be described by what type of flow is involved: physical, informational or financial. The *structure* can be depicted by the interdependencies and causal relations between the flows. And the *governance* identifies the actors from and to whom the flows take place. When any of these dimensions changes, it takes place a reconfiguration of the system; or in other words, we are witnessing *business model innovation*.

Digital transformation affects all physical, information and financial flows. Its greatest impact takes place on the mechanics of each flow, that is, the answer to the *"how?"* question. Instead, its influence in terms of the *"what?"* and *"why?"* questions is less apparent, though by no means non-existent (for instance, a digital technology like 3D printing might make unnecessary a physical flow: the *"why"* dimension). Of the three flows, naturally, it is information flows the ones more profoundly affected, because digitalization itself is built over IT infrastructures, and to digitize something is to represent it as data (more precisely, binary data).

The impact that digital transformation can have on the three flows is particularly significant for maritime trade supply chains. The content, structure and governance of these supply chains, depend on the type of technology used; therefore, when a technological innovation takes place, these elements change, sometimes radically, as happened with the container revolution (Stopford, 2009). Not only the ways in which the flows interact can be affected as a result of digital transformation, but also the functions performed and roles played by the actors across maritime supply chains. Finally, the whole industry network structure might be modified, as the three flows change their mechanisms.

Understanding the way that digital transformation might impact the mechanisms of physical, information and financial flows is relevant for theoretical and practical reasons. From a theoretical perspective, this understanding amounts to explanatory theory: an explanation of *'how and why some phenomena occur'* (Gregor, 2006, p. 624). Such clarifications are based on human-made conceptual constructs (Bacharach, 1989), which in turn are derived from empirical observations. For new phenomena such as digital transformation, explanatory theories provide a rather stable perspective over what could otherwise be perceived as complex or fuzzy.

From a practical perspective, understanding the mechanisms by which digital transformation affects the three flows in maritime supply chains, can be useful in managing disruptive situations like the ones generated as a consequence of the COVID-19 pandemic. For instance, it could help firms or organizations to choose the IT tool that, according to this understanding, would be more effective in addressing these situations. From a higher decision-making level, it could also be the basis of policies and strategies, or IT infrastructure investments. Finally, as digital transformation affects the whole supply chain industry, grasping its underlying mechanisms provides firms and organizations with clarity to adapt and, if necessary, design new business models.

As was briefly mentioned in the introductory chapter, this dissertation is structured around the three flows here studied. The most immediate purpose of this chapter is, therefore, to provide a general theoretical background for the three succeeding chapters, each of which addresses a research subject particularly associated with a specific flow.

Chapter 3 studies how business models might evolve in the context of seaports, as a result of the impact of Industry 4.0 technologies, such as internet of things (IoT) and blockchain. Seaports are by and large the most important nodes in the global networks where physical flows take place. This does not mean that the influence that digital transformation, like the one embedded in Industry 4.0 technologies, only affects physical flows in seaports. As it will be seen, physical flows are affected due to their dependency on information flows, which are the ones directly impacted by such technologies.

Chapter 4 addresses this topic from a different perspective: how digital transformation increases efficiency and reliability of information flows, enhancing sustainability in the shipping industry. Distributed ledger technology (DLT), most commonly known as blockchain, has the potential of enabling independent actors across the maritime supply chain to access, consume and even "re-cycle" information (as a resource). This would itself traduce in performance gains for the whole network in terms of both physical and financial flows.

Chapter 5 delves into a persisting problematic in international trade: the trade finance gap (Auboin and DiCaprio, 2017). This gap consists in the difference between the volume of trade finance that banks on other financial entities are willing to supply through instruments like letters of credit, documentary collections, etc., and the volume actually needed by importers to undertake international trade transactions. Reasons for this gap are varied and complex but, as it will be explained, information flow deficiencies are part of the problem. Digital transformation might be, therefore, part of the solution.

2.5. Concluding remarks

This chapters intends to expose an explanatory theory in order to build an understanding of how digital transformation affects maritime trade supply chains and its business models. It also aims to provide a common theoretical background to the research conducted in the succeeding chapters. Through a theoretical synthesis methodology, we break down this topic into three anchoring constructs: physical flows, information flows and financial flows.

As a conceptual basis for this, we cover literature from Management Science, Maritime Studies, and Information Systems Research. This cross-disciplinary approach looks to broaden the perspective of the analysis and increase the research's generalizability. Management Science introduces the business model concept; Maritime Studies sheds light over the context of the research, that is, maritime supply chains; and Information Systems Research provides a theoretical understanding of digital transformation phenomena.

For each one of the anchoring constructs, we enquiry about their nature *(what?)*, underlying mechanisms *(how?)*, and driving forces *(why?)*. Physical flows are, in the context of maritime supply chains, cargo flows; they take place through multiple modes and routes of transportation, but also include logistics processes that dot not amount to transportation; and they are driven either by production or consumption. Information flows carry data and information (in a strict sense); their mechanisms, inside maritime supply chains, are either paper documents or electronic-based communications; and, most crucially, they take place because information functions as an input (resource) for physical and financial flows. Finally, financial flows are money flows; they take the form of either payments (e.g., wire transfers) or credits (e.g., letters of credit); and they are driven by an underlying logic that economists explain through a *Circular Flow Model*. Table 2-1 above provides a summary of this.

The three flows are interdependent, though not in a single way. Physical flows and financial flows are linked by causal relationships of economic nature; and information flows function as inputs for decision making and processes that involve the other two flows in maritime supply chains. Figure 2-1 above depicts a basic illustration of this interdependencies.

Looking at the theoretical synthesis results in the context of the maritime trade industry, we offer a final reflexion. Digital transformation is yet far from reaching its full disruptive potential. Actors like seaports' authorities, terminal operators, large or medium-sized carriers, banks, and the myriad of SMEs involved in international trade processes, benefit from understanding the mechanisms associated with digital transformation, as well as the areas more directly affected by it. This chapter, and each of the research studies presented in the three following ones, aim to contribute to this understanding. Moreover, because digital transformation not only exercises its impact on maritime trade processes and IT infrastructures, but also in its actor's business models; this dissertation wishes to provide useful insights for strategy discussions and, above all, to give inspiration to entrepreneurs that would bring true disruption through their start-ups.

Chapter 3.
Digital transformation in seaports*

3.1. Introduction

More than a quarter of a century has passed since the United Nations Conference for Trade and Development (UNCTAD) classified seaports into a generation scale, which at that time reached up to the third generation (3G) (UNCTAD, 1994). The extent and pace of technological evolution that has taken place until today has added two new generations (4G and 5G) to this scale, a phenomenon that has taken place in parallel with a substantial increase in the volume of international trade and, most particularly, containerized shipping (Rodrigue and Notteboom, 2015). At the same time, as a result of decreases in information and communication (ICT) and transportation costs, as well as the positioning of Asian countries —with their abundant supply of cheap labour— as global manufacturing centres, value chains have become globalized and sophisticated networks (Gereffi, 2018). And at the centre of those networks, as one of their core nodes, have stood seaports (Lam and Yap, 2011; Zuidwijk, 2018).

As Asia —especially China— became the "World's Factory" (Zhang, 2006), containerized shipping concentrated there, and the size of their seaports

* This chapter is based on a research paper published as the following journal article: Henríquez, R., Martínez de Osés, F. X., and Martínez Marín, J. E. (2022) 'Technological drivers of seaports' business model innovation: An exploratory case study on the port of Barcelona'. *Research in Transportation Business & Management*, In Press. DOI: 10.1016/j.rtbm.2022.100803. The research paper is in turn an extension of the conference paper entitled "IoT-Driven Business Model Innovation: A Case-Study on the Port of Barcelona in the Context of the Belt and Road Initiative", which was presented at the 16th International Conference on e-Business Engineering (ICEBE 2019), in Shanghai, October 11-13, 2019. The conference proceedings were published in the book *Advances in E-Business Engineering for Ubiquitous Computing*. Springer: Berlin.

increased[1]. When analysing the role of seaports in global supply chains, maritime research and policy discussions focused on characteristics as structural connectivity (Lam and Yap, 2011; UNCTAD, 1999), emphasising aspects like port-hinterland relations (Notteboom and Rodrigue, 2008) or their suitability for being transhipment hubs (McCalla, 2008).

The prominence of infrastructure resources, geographic location, and shipping volumes as key factors for assessing a seaport's generation level has, however, given way to an increasing focus on technological capabilities; particularly those related with the Industry 4.0 paradigm. Instead of *structural* connectivity, concepts like *strategic* connectivity —associated with knowledge-intensive interorganizational exchanges between ports—, have been proposed (Hollen, 2015). Adoption of technologies like the internet of things (IoT) or blockchain, are nowadays among the main factors in evaluating a port's level of development (ESCAP, 2021; Jahn and Saxe, 2017). 5G ports have now become Ports 4.0 (Acciaro *et al.*, 2020b; Jahn *et al.*, 2018).

This increased focus on technological resources and capabilities as drivers of a port's development has been recognized in both grey literature (ADB, 2020; EPRS, 2020; Jahn and Saxe, 2017) and academic studies (Inkinen *et al.*, 2021; Lam *et al.*, 2020; Parola *et al.*, 2021). Moreover, the COVID-19 pandemic has raised awareness on the importance of digitalisation adoption in supply chains in general (PwC, 2020) and seaports in particular (Deloitte and ESPO, 2021; ESCAP, 2021; Notteboom *et al.*, 2021). Despite this recognition, explanatory theory (Gregor, 2006) on the interrelation between technology and business models is scarce in maritime research and port studies (Del Giudice *et al.*, 2021). Although many innovation studies have analysed and described the

[1] In 2004, Rotterdam was still the world's largest port in terms of containerized (TEU) units. That year it was overtaken by Singapore, which was successively overtaken by Shanghai. As of 2020, Rotterdam is # 10 and the top 9 are located in East or South Asia (7 of them in China) (World Shipping Council, 2021).

implementation of new technologies in the maritime industry and seaports, with its many benefits, challenges and opportunities (Acciaro *et al.*, 2020b; Ahmad *et al.*, 2021; Pu and Lam, 2021; Yang *et al.*, 2018), few of them have addressed the mechanisms that underpin the inter-relationship between technology adoption and business model innovation in these contexts (among these few: Agrifoglio *et al.*, 2017; Ferretti and Schiavone, 2016).

Scholars have called for studies exploring the impact of new technologies on supply chains and seaports (Dutta *et al.*, 2020; Peña Zarzuelo *et al.*, 2020; Scully and Höbig, 2019), looking to develop explanatory theory of this impact's mechanisms. Parola *et al.* (2021) call for research that would investigate barriers to the adoption and diffusion of digital technologies across maritime supply chains. However, a theoretical explanation of the way in which technologies affect business models is needed in order to understand what drives or impedes its adoption. While explanatory theory has been developed in this regard from a general perspective (Chesbrough, 2007; Teece, 2018), the topic needs also studies conducted in specific industry contexts, among them the maritime industry and seaports.

This chapter, therefore, aims to aims to offer explanatory theory on the mechanisms through which Industry 4.0 technologies (like IoT and blockchain) affect business models in a seaport context, and more particularly the evolution towards a "Smart Port" model. To this end, it elaborates a conceptual model that seeks to explain the relationship between the adoption of Industry 4.0 technologies and the evolution of a seaport's business model. This conceptual model is then assessed in the light of an exploratory case study conducted on the port of Barcelona. The research extends previous work on this topic by the authors (Henríquez, Martínez de Osés, and Martínez-Marín, 2020).

The research question that this chapter intends to give an answer is expressed in the following way:

RQ*$_2$*: How Industry 4.0 technologies might drive business model innovation in a seaport context?

The answer to the question is in line with the exploratory nature of this study: the authors do not seek to validate hypotheses that would provide a definitive explanation, but rather to plant theoretical seeds into the ground for subsequent research.

The rest of the chapter is structured as follows: Section 3.2. reviews literature from management science and maritime studies, including port models and technologies, as well as research on Industry 4.0 technologies and business models. Section 3.3. presents a conceptual model for explaining the relationship between Industry 4.0 technologies and seaport business model innovation. Section 3.4. explains the research methodology. Section 3.5. develops a case study of the port of Barcelona, focusing on its technological development in the last 5 years. Section 3.6. discusses the conceptual model in light of the exploratory case study presented, and Section 3.7. concludes the chapter, discussing contributions, managerial implications, limitations and suggestions for future research.

3.2. Literature review

This section covers previous research on the building blocks over which the conceptual framework presented in the Section 3.3. is to be built. It delves on literature from management science, maritime studies and information systems. Given the abundance of literature on concepts like business model innovation, Industry 4.0, and technologies like IoT or blockchain, the purpose is not so much to offer a complete picture, as to provide enough theoretical background to construct the propositions that comprise the conceptual framework.

3.2.1. Business model innovation and technological change

Management science has analysed the inter-relationship between technology and business for several decades, with many studies revolving around the phenomenon of innovation. One of the first useful distinctions utilised was that between *technology push* and *market (demand/user) pull* (Howells, 1997; Raisbeck, 1982; Zmud, 1984), according to which innovation can be predominantly driven either by science applications inventiveness or by the ever-increasing need of solving real-life problems (Johnson *et al.*, 2014).

Another classification of innovation is based on the level of impact that a new technology creates: incremental, disruptive or architectural innovation. *Incremental* innovation is related with improving the ways things are done, while keeping the core elements of a technology (e.g.: fastest or greener cars). *Disruptive* innovation, in contrast, changes the core elements and requires a new way of doing things (e.g.: digital photography). *Architectural* innovation, on the other hand, does not change the core concepts/components behind a technology, but modifies their linkage (Albert and Siggelkow, 2021; Henderson and Clark, 1990).

Innovation is also distinguished according to the *locus* in which takes place. A first general distinction has been that between product and process innovation (Bonanno and Haworth, 1998; Fritsch and Meschede, 2001; Li *et al.*, 2006; Utterback and Abernathy, 1975; Wang, M. *et al.*, 2021). *Product* innovation introduces novel devices or services into the market (e.g.: the container box). *Process* innovation is about modifying the way goods and services are produced, sold, distributed, etc (e.g.: containerization). A more recent concept in this *locus* distinction has been *Business model* innovation, understood as a change that affects how an organization creates, distributes and captures value (e.g.: vertical integration in large transportation companies) (Chesbrough and Rosenbloom, 2002; Gassmann *et al.*, 2016; Osterwalder and Pigneur, 2010; Zott and Amit, 2007).

The inter-relationship between technology and business models has been the subject of abundant academic theory (Chesbrough, 2007; Chesbrough and Rosenbloom, 2002; Hedman and Kalling, 2003; Pateli and Giaglis, 2014; Tongur and Engwall, 2014). A mainstream idea has been that business models mediate the way that technology affects firms' performance, such that the adoption of the same technology (whether related to products or processes) can turn out into very different performance outcomes, depending on which business model is adopted by the organization (Baden-Fuller and Haefliger, 2013). Another concept used to explain this interrelationship is that of *dynamic capabilities* (Teece, 2018); here, performance is dependent on how a firm can adapt, align and implement both its technology and business model, and answer to internal or external pressures. Thus, even the adoption of technology *A* and business model *B* by two firms can result in different performance levels, depending on their respective deployment of dynamic capabilities.

All these concepts and classifications are useful for explaining the relationship between the adoption of new technologies and the evolution of business models in a particular context, like that of a seaport (Del Giudice *et al.*, 2021). They provide largely complementary perspectives to analyse what are complex and mutually influencing processes. For the purposes of this research and the elaboration of a conceptual model, we give special attention to the above-mentioned notion of *architectural innovation*.

The concept of architectural innovation was introduced in the early nineties by Henderson and Clark (1990), who defined it as an innovation that changes the way the core components of a product or process are linked together, without changing or substituting them. The essence of architectural innovation is, therefore, the *'reconfiguration of an established system to link together* *existing components in a new way'* (Henderson and Clark, 1990, p. 12). A closely related distinction is that between *component* knowledge, that is, knowledge of the core components of a system; and *architectural* knowledge: knowledge of how these components are integrated into a coherent whole.

As it shall be elaborated upon in the conceptual model, both component knowledge and architectural knowledge are key factors in explaining the dynamics between emerging technologies and the evolution of ports' business models.

3.2.2. Industry 4.0, internet of things (IoT) and blockchain in the supply-chain industry

Industry 4.0 is a paradigm that was originated in Germany (Kagermann and Helbig, 2013), in the context of developments christened as the fourth industrial revolution (Schwab, 2016). It encompasses a series of technologies surged in the last two decades, including artificial intelligence, machine learning, robotics, 3D printing, internet of things (IoT) and blockchain technology, among others. The main industrial sector where Industry 4.0 has been connected with is that of manufacturing (Arnold *et al.*, 2016). However, in recent years it has also been applied to logistics, supply-chain and transportation (Hahn, 2020; Tjahjono *et al.*, 2017). A key concept behind Industry 4.0 is that of *Cyber-Physical Systems*, understood as a convergence of physical and virtual worlds, with both dimensions mutually interacting (Lee *et al.*, 2015). Capabilities such as real-time reaction, interoperability, as well as horizontal and vertical integration of operation systems are among of the features of Industry 4.0; and data is one of its most important resources (Ibarra *et al.*, 2018).

Among the frontier technologies (UNCTAD, 2021a) associated with Industry 4.0, the internet of things (IoT) and blockchain are particularly relevant for seaports (Sanchez-Gonzalez *et al.*, 2019; Yoon *et al.*, 2020). In the case of IoT, two elements define its essence: sensorization and interconnection. On the one hand, there has been significant progress in terms of the accuracy and reliability of devices for capturing data about physical events, like geolocation or temperature. On the other hand, these devices are increasingly interconnected through ICT networks. The combination of these two elements opens a wide array of features, uses cases and business models (Chen *et al.*, 2014). In the case of a seaport, many of its processes are dependent on the availability of reliable data. This means that IoT, by improving the way that data is captured, transmitted and consumed, can increase the efficiency of existing logistic process (like stacking or truck pick-up allocation) or even allowing new ones like container tracking (Choi *et al.*, 2017; Gnimpieba *et al.*, 2015).

Blockchain, or more properly, distributed ledger technology (DLT) has been mainly related with uses cases in the financial industry, like cryptocurrencies. However, its applicability in logistics and supply chains is also clear (Azzi *et al.*, 2019; Cole *et al.*, 2019; Kouhizadeh *et al.*, 2021; Scully and Höbig, 2019). At its core, blockchain is a decentralized database where events can be digitally registered, in such a way that data is immutable and any new addition to the database has to be congruent with the latest state of the ledger. The data thus registered can provide the input of events automatically triggered by software-controlled processes (aka *smart contracts*), like ordering a payment when a cargo is received. The greatest benefit for supply-chains that blockchain technology brings is that it can serve as a decentralized depository of data about logistic events, facilitating collaboration and transparency, and streamlining interdependencies between logistic processes (Bai and Sarkis, 2020; Pournader *et al.*, 2020).

Something that Industry 4.0 and its associated technologies have in common is that they streamline —and in some cases automate— the interaction between physical and information flows. Sensorization and IoT translate physical events into data streams; blockchain provides a trusted depository of data that can trigger physical actions. Because a seaport is at its core a space where interconnected physical and information flows take place, these technologies have the potential of significantly improving performance and competitiveness. It is not surprising, therefore, that they have been related with the now popular concept of a "smart port" (Ahmad *et al.*, 2021; Yang, 2019; Yang *et al.*, 2018).

3.2.3. Fifth generation port (5G), Port 4.0, and Smart Port

The term "smart port" is an additional member in a family that includes "smart city", "smart buildings", etc. These terms refer in a general way to enhanced or outright new capabilities, enabled through digitalization, that allow for improved coordination, resource efficiency, and sustainability (Camero and Alba, 2019; Eremia *et al.*, 2017). However, in a more proper sense, "smart port" is a concept to be understood in the context provided by the classification of seaports into generations and, more precisely, the fifth-generation port (5G). In the same vein, a smart port can be equated with the novel concept of Port 4.0.

3.2.3.1. 5G Port

A fifth-generation port (5G) has been characterized as a "globalized e-port", with a prominent place as a hub in global supply chains, and featuring top ICT systems. It is, moreover, focused on community and customer-centric capabilities, with a constant strive to create new value for all its stakeholders (Inkinen *et al.*, 2021; Lee and Lam, 2015, 2016). This enhanced orientation towards customers and community implies a significant degree of business model innovation (BMI). In the context of seaports, BMI has been associated with the evolution from a "landlord" to a "port developer" role across four areas: organization, management, technology and co-creation; as well as the development of new value-creation activities (Hollen *et al.*, 2013).

3.2.3.2. Port 4.0

A Port 4.0, on the other hand, is described as an extension of the Industry 4.0 paradigm to sea and inland ports, comprising the development and implementation of data-driven innovation (Acciaro *et al.*, 2020b; Inkinen *et al.*, 2021). A key value for a Port 4.0 is integration; a value that should be created along four dimensions: 1) *Terminal* integration (e.g., crane automation, paperless processes, sensorization); 2) *Port-terminal* integration, which includes automatic data exchange between port actors; 3) *Port-stakeholder* integration, which extends automatic data exchange to external entities like city authorities; and 4) *Network* integration, which envisions automatic data exchange with the wider supply chain (Jahn *et al.*, 2018).

In the descriptions of a 5G port or a Port 4.0, a common feature is the emphasis on information flows, rather than physical flows. Or rather, on how improvements in information flows have beneficial consequences for physical flows, not only inside the port itself, but in the whole supply chain. Another feature is the characterization of a port as both a *node* in a global network *and* itself a *network* (or ecosystem) of actors. Lee and Lam put it this way: *'A port is a kind of organic system in a national socio-economic-political system as well as the globalized economic system'* (2016, p. 187). They add shortly after: *'As a social and economic organization, a port evolves continuously, adapting to changing economic and trading patterns, new technologies, legislation and port governance system'* (*idem*). These two ideas are at the core the conceptual framework presented in the next section: 1) a port as a networked, organic entity, interconnected with a broader socio-economic system; and 2) the interaction between physical and information flows as a key component in defining a port's role and activities.

3.2.4. Characteristics of a smart port

A set of characteristics associated with the concept of a smart port can be found in the literature on smart ports, 5G ports, Ports 4.0 or, more generally, in maritime studies on port competitiveness or their processes towards digital transformation. Some of these traits are rather abstract constructs, while others refer to specific use cases or functionalities, and each of them offers a partial view on what smartness means in the context of a seaport. Below we refer to each of them.

3.2.4.1. Customer centricity

Lee and Lam (2015, 2016) and Inkinen *et al.* (2021) consider this to be the main feature associated with seaports at the top of the generational ladder. These ports focus on the needs of direct customers and all stakeholders as the main driver behind their day to day operations, as well as their medium and long term strategic approach (ESCAP, 2021).

3.2.4.2. New value creation

In line with customer centricity, smart ports are constantly looking to create new value for their customers and stakeholders (ESCAP, 2021; Lee and Lam, 2015, 2016). Hollen *et al.* (2013) identify this search for new ways of creating value as an example of business model innovation.

3.2.4.3. Port developer

Hollen *et al.* (2013), in a case study on the port of Rotterdam, observe an evolution from a landlord model, focused only on shipping traffic handling and land exploitation, to a more entrepreneurial approach (port developer) through co-creation with the private sector; an approach similarly observed by Lee and Lam (2015) in the port of Singapore.

3.2.4.4. Enhanced port community systems

Port community systems (PCS) have been implemented so far by ports standing on different steps of the generational ladder (Deloitte, 2017;

UNCTAD, 2021b), but not all of them feature an equivalent level of sophistication. Case-studies on the ports of Hamburg (Kapkaeva *et al.*, 2021) and Rotterdam (Simoni *et al.*, 2022) identify the enhancement of information flows through more sophisticated PCS as the core element of a successful digital transformation strategy.

3.2.4.5. Tracking, tracing and event management

A study from the Asian Development Bank on smart ports (ADB, 2020) identifies the development of data capture functionalities —including track and trace, and management of business processes upon event's information— as one of the incremental steps in the transformation towards a smart port. Track and trace functionalities are associated especially with blockchain technology and IoT (Ahmad *et al.*, 2021; Scully and Höbig, 2019).

3.2.4.6. Strategic connectivity

The concept of strategic connectivity (SC) is proposed by Hollen (2015), referring to interactions among a seaport's internal stakeholders (intra-port SC), interactions between a port and its hinterland (hinterland-oriented national SC), with other national ports (ICT national SC), and with other ports abroad (international SC). The core idea behind the concept is that connectivity is not only enhanced through physical infrastructure, but also through strategic alignment, joint ventures with other ports, or ICT integration.

3.2.4.7. Integration with smart city

A specific phenomenon, close to the above referred strategic connectivity concept, is that of port-city integration under the "smart" paradigm. Acciaro *et al.* (2020a) study this integration in the context of Hamburg, noting that certain port-city governance models are more suited to create synergies between the city's and port's priorities, and that the generation of value for the city of Hamburg is a core element of the port's SmartPort strategy.

3.2.4.8. Emphasis on sustainability

Chen *et al.* (2019) study the concepts of green port and smart port, and conclude that they are mutually re-enforcing: smartness (particularly data-driven) contributes to sustainability; and the strife for more sustainable operations pushes toward the adoption of smart technologies. This mutual relationship between smartness and sustainability is also noted by ADB (2020), ESCAP (2021), and Lee and Lam (2016).

3.2.4.9. Competitive transhipment centre

Lee and Lam (2015) associate an enhanced capability of a port to attract transhipment cargo as a trait of a 5G port, a capability that is based on a customer-centric foreland strategy, in contrast with a two-dimensional price and quantity approach, proper of a 4G port.

3.2.4.10. Terminal integration, port-terminal integration, port-stakeholder integration, network integration

As observed before, these characteristics are associated with the concept of Port 4.0 (Jahn *et al.*, 2018) Each one of them can be respectively linked with the types of strategic connectivity mentioned by Hollen (2015). Peña Zarzuelo *et al.* (2020) refer to these levels of integration, based on data-sharing and connectivity, as one of the main challenges for the development of a Port 4.0.

3.2.4.11. Data-driven functions

A data-driven approach to define smartness in the context of a port is also found in the literature (Acciaro *et al.*, 2020b, ADB, 2020; ESCAP). Wang, S. *et al.* (2020) study data-driven models for improving the efficiency of ship traffic in ports, where data sharing through blockchain-technology enhances decision making in single-party, two-party and multi-party contexts. Inkinen *et al.* (2021) note that data sourcing and data-driven applications are at the core of the "virtual port" model, a construct that is itself associated with the smart port concept.

3.2.4.12. IoT-based management processes

The design and implementation of IoT-based functionalities supporting a diverse array of processes in a seaport is associated with the smart port concept (ADB, 2020; ESCAP, 2021; Parola, 2020; Yang, 2018). The core idea is that IoT enables real-time data-flows, which in turn enhance physical flows.

3.2.4.13. Real-time data interchange

The above mentioned real-time exchange of data between actors, enabled mainly through the deployment of IoT (Acciaro *et al.*, 2020b, Yang, 2018) and blockchain technology (Pu and Lam 2021; Wang J. *et al.*, 2021), is associated with the Industry 4.0 paradigm and smart ports.

3.2.4.14. Digitally-enabled port synchronization

In turn, real-time data collection and sharing makes possible an enhanced synchronization among actors in a seaport. This capability is also associated with the smart port concept (Ahmad *et al.*, 2021, Jahn *et al.*, 2018; Wang K. *et al.*, 2021), exemplified in use cases like smart gates for container pick up by trucks (Ahmad *et al.*, 2021) and digital twins (Wang K. *et al.*, 2021).

As previously mentioned, in order to provide a list of "smart port characteristics", we delved into maritime studies that either expressly analysed the smart port concept, treated the fifth generation (5G) port or Port 4.0 concepts, or in general studied port competitiveness and digital transformation in a seaport context. We did not limit our search to previous definitions of smart ports; instead, our goal was to gather a set of trails that would, in conjunction, provide a broad description of what "smartness" means in a seaport context.

Table 3-1 below shows the list of characteristics and the literature sources that associate them, directly or indirectly, with the concept of a smart port. Neither of them are meant to be exhaustive.

Table 3-1. *List of characteristics of smart ports*

Characteristics	Literature references
Customer centricity	ESCAP, 2021; Inkinen *et al.*, 2021; Lee and Lam, 2015, 2016
New value creation	ESCAP, 2021; Hollen *et al.*, 2013; Lee and Lam, 2015, 2016
Port developer	Hollen *et al.*, 2013; Lee and Lam, 2015, 2016
Enhanced port community systems	Lee and Lam, 2015, 2016; Kapkaeva *et al.*, 2021; Simoni *et al.*, 2022
Tracking, tracing and event management	ADB, 2020; Ahmad *et al.*, 2021; Scully and Höbig, 2019
Strategic connectivity	Hollen, 2015
Integration with smart city	Acciaro *et al.*, 2020a; Lee and Lam, 2015, 2016
Emphasis on sustainability	ADB, 2020; Chen *et al.*, 2019; ESCAP, 2021; Lee and Lam, 2015, 2016
Competitive transhipment centre	Lee and Lam, 2015, 2016
Terminal integration	Jahn *et al.*, 2018; Peña Zarzuelo *et al.*, 2020
Port-terminal integration	Jahn *et al.*, 2018; Kapkaeva *et al.*, 2021
Port-stakeholder integration	Jahn *et al.*, 2018; Lee and Lam, 2016; Peña Zarzuelo et al., 2020
Network integration	Jahn *et al.*, 2018; Peña Zarzuelo *et al.*, 2020
Data-driven functions	Acciaro *et al.*, 2020b; ADB, 2020; ESCAP, 2021; Inkinen *et al.*, 2021; Wang, S. *et al.*, 2020
IoT-based management processes	ESCAP, 2021; Parola *et al.*, 2021; Yang *et al.*, 2018
Real-time data interchange	Acciaro *et al.*, 2020b; Pu and Lam, 2021; Wang J. *et al.*, 2021, Yang *et al.*, 2018
Digitally-enabled port synchronization	Ahmad *et al.*, 2021; Jahn *et al.*, 2018; Wang K. *et al.*, 2021

The above list is not meant to be taken as a set of "requirements" for a seaport to be considered "smart". In fact, the authors consider that smartness is a matter of degree and not a binary status (in the sense that a port would either be "smart" or "not smart"). Seaports could then be considered to have a more or less advanced degree of smartness, according to how many and to which extent they feature the above characteristics or functionalities.

3.3. Theoretical conceptual model

This section is divided into three sub-sections. The first one elaborates a concept of a smart port as a synthesis of the related concepts of a 5G port and a Port 4.0, delving into the list of characteristics shown in Table 3-1, and exploring what "smartness" could mean for a seaport. The second one explains two mechanisms through which Industry 4.0 technologies might drive business model innovation in a seaport. To that effect, it develops a series of propositions, which are depicted as a conceptual model in the third sub-section. This model provides a theoretical answer to the research question, an answer that is in turn assessed in the light of the case study results.

3.3.1. A smart port concept

3.3.1.1. Smart port characteristics in its dimensions as a network and as a node in a global network

As previously observed, a smart port can be understood along two fundamental dimensions: as an organic ecosystem, being itself a network (Lee and Lam, 2016); and as a node in the global supply network (Zuidwijk, 2018). Each of these dimensions incorporates the characteristics listed in Table 3-1. Table 3-2 below classifies those characteristics according to the dimensions.

Table 3-2. *Characteristics of a smart port according to dimensions*

	5G Port	Port 4.0
Port as a network ecosystem	• Customer centricity • New value creation • Port developer • Enhanced port community systems • Tracking, tracing and event management	• Terminal integration • Port-terminal integration • Data-driven functions • IoT-based container management processes
Port as a node in the global supply network	• Strategic connectivity • Integration with smart city • Emphasis on sustainability • Competitive transshipment centre	• Port-stakeholder integration • Network integration • Inter-port community systems • Real-time data interchange • Digitally enabled port synchronization

Some differences of perspective can be seen in the concepts of 5G port and Port 4.0 and their associated characteristics. While the latter emphasises mainly technological applications and functionalities, the former focuses more on the broad role that a port plays. The customer and community centricity of a 5G port is one of its distinguishing features; while the technical concept of integration is a key component of a Port 4.0. Likewise, at the essence of the Port 4.0 concept is the adoption of a set of frontier technologies and the pursuit of data-driven innovation; while what is mainly innovative about a 5G port is that it creates value for various stakeholders in novel ways.

At this stage, it can be said that the concept of a 5G port describes the role that it plays towards its internal and external stakeholders, having a *market* focus. Instead, the Port 4.0 concept is built upon a list of functionalities and activities, having a *technology* focus. These two dimensions, market and technology, are the basis of the above-mentioned distinction between *technology push* and *market pull*, and provide the structure of the conceptual model.

3.3.1.2. What does "smartness" mean in a seaport context?

Almost two decades ago, the construct of "smart business networks" (SBN) was proposed and studied by a group of scholars associated with the Rotterdam School of Management (Vervest *et al.*, 2004, 2005). The concept was said to emerge in part from a question described as follows:

> *In August 2003 a group of the School's researchers put the following question: imagine that, all over the port of Rotterdam, one could have instant wireless access to the state of all ships, trucks, containers and cargo and to anyone and anything related to this. If so, could one manage the processes better, faster, more effectively, and more efficiently? What could one do that was not possible before? What would be required to do so?* (Vervest *et al.*, 2004, p. 225).

Three things can be noted in the quoted description:

1) the context inside which the SBN construct surged was that of a seaport; 2) there's an immediate reference to a technology ("instant wireless access"); and 3) it can be clearly seen that smartness is linked to a series of performance qualities ("better", "faster", "more effectively", etc.) related to the interaction between information flows and physical flows.

In a different place (Vervest *et al.*, 2005), the authors describe "smart" in the following way:

> *We apply the word "smart" to an action that is novel and different, hence thought of as innovative. Smart actions create remarkable, "better than usual" results. Smart has a connotation with fashionable and distinguished, but also with short-lived. What is smart today will be considered common tomorrow. The word "smart" in smart business networks is therefore not an absolute but a relative term. Smartness is a property whereby the network can create "better" results than other, less smart business networks, or other forms of business arrangements. While intelligence in the communications systems and networks may have a more absolute meaning, smartness of business networks is relative, time-bound and situation-bound. To be smart in business is to be smarter than the competitors, just as an athlete considered fast means (s)he is faster than the others* (p. 20).

Delving into the previously quoted considerations, we propose the following understanding of what "smartness" means in a seaport:

First, the concept itself is indeed relative to time and situation circumstances. In this sense, the classification of ports into generations, precisely because it is time-bound (as years pass, new generations emerge), provides a practical way of determining what counts as a smart port: a port that is considered to be at the top of the generational ladder (currently, 5G), should be considered a smart port (or, put in a different way, a port with a high level of "smartness").

Second, smartness is very closely linked to technological capabilities and functionalities. While 20 years ago, these capabilities and functionalities were mainly about physical flows related infrastructures (i.e.: having the bigger gantry cranes or most advanced RTG container systems), now they are increasingly related to information flows (i.e.: IoT, sensorization, digital twins, real-time track and trace). Still, IT functionalities are "smart" in as much as they enable increased performance in physical flows (i.e.: more efficient handling of containers inside the yard through a digital twin; shorter pick-up times and less congestion for trucks through e-gates).

Third, smartness is about satisfying the demand for seaport services better than others. A port with the most advanced physical and technological resources and capabilities, but that does not effectively answer to what customers demand, cannot be considered "smart". An extreme hypothetical example would be, for instance, a port with a very high container handling capacity, very sophisticated IoT and event-management systems, but located in a small island in the middle of the Pacific Ocean.

These three features of "smartness" (relative, technology-linked, demand-oriented) are reflected in the conceptual model presented ahead. The technology linkage aspect is reflected in the technology push mechanism, the demand orientation aspect in the market pull mechanism, and the relativeness of the smartness concept in the time and situation boundedness of what counts as advanced technology and of what is demanded by the market.

3.3.2. Theoretical propositions

The research question of this chapter asks how the Industry 4.0 technologies might drive business model innovation in a seaport. Based on the theoretical background presented in the literature review, and following the approach adopted by previous studies on diverse industry contexts (Brem and Voigt, 2009; Geum *et al.*, 2016; Horbach *et al.*, 2012; Lubik *et al.*, 2013; Luong *et al.*, 2008), this sub-section elaborates an answer along two mechanisms of influence: technology push and market pull. Each one of them channels in a different way the influence that Industry 4.0 exercises towards the adoption of a smart port business model; and each one does so in three different areas of innovation: operations, strategy, and investments. The following propositions are an extended and more formal version of the conceptual framework developed by the authors in previous work (Henríquez, Martínez de Osés, and Martínez-Marín, 2020).

3.3.2.1. Technology push

To understand the influence that the adoption of Industry 4.0 technologies by a seaport has in its business model, it is useful to refer to the above-mentioned concepts of architectural innovation, architectural knowledge and *component* knowledge. Every innovative technology (IoT, blockchain, VR/AR, etc.) brings with it a set of required skills and competences about the devices used, which correspond with component knowledge. However, as the technologies are adopted, *architectural* knowledge —defined as *'knowledge about the ways in which the components are integrated and linked together into a coherent whole'* (Henderson and Clark, 1990, p. 11)— becomes necessary. This knowledge is not limited to technological knowledge, because the components of this "coherent whole" are not just devices, but also business processes, communication protocols, etc. The result is a requirement, for a seaport that adopts Industry 4.0 technologies, to develop new capabilities and tasks or to "reengineer them" (Agrifoglio *et al.*, 2017; Dutta *et al.*, 2020; Inkinen *et al.*, 2021; Lam *et al.*, 2020; Simoni *et al.*, 2022; Tsiulin *et al.*, 2021).

The first answering proposition to the research question can therefore be stated as follows:

> ***P_1:*** *Industry 4.0 technologies exercise a push towards architectural innovation in seaports, by requiring new capabilities and tasks.*

This proposition is divided into 3 ancillary propositions, according to three different areas where innovation takes place: innovation in operations, innovation in strategies, and innovation in investments.

Operations in a seaport are still, in essence, about handling physical flows (Lam *et al.*, 2020; Parola *et al.*, 2021). New data-driven functions like container tracking or automatic stacking are just more sophisticated ways of performing this handling (Ahmad *et al.*, 2021; Dutta *et al.*, 2020). As Industry 4.0 technologies like IoT or blockchain are adopted in the seaport, the port provides new data-driven services that aim to increase efficiency in the interaction between physical and information flows (Jahn *et al.*, 2018; Jahn and Saxe, 2017; Lam *et al.*, 2020; Wang, S. *et al.*, 2020).

Proposition P_{1a} is thus stated as follows:

> ***P_{1a}:*** *Industry 4.0 technologies generate new data-driven services that aim to streamline the interactions between physical and information flows in the ordinary operations of a seaport.*

Strategies should be aligned with the role that a seaport aims to perform towards internal stakeholders (carriers, shippers, terminal operators, customs authority, etc.), and external ones (city council, inland ports, etc.) (Jahn *et al.*, 2018; Wang, K. *et al.*, 2021). The increased amount of data generated by the adoption of Industry 4.0 technologies is expected to exercise a pressure towards more integration with these stakeholders (Ahmad *et al.*, 2021; Peña Zarzuelo *et al.*, 2020; Pu and Lam, 2021; Simoni *et al.*, 2022; Tsiulin *et al.*, 2021).

Proposition P_{1b} is thus stated as follows:

> ***P_{1b}:*** *Industry 4.0 technologies generate innovative strategies, oriented towards information integration of a seaport with its internal and external stakeholders.*

The adoption of Industry 4.0 technologies requires new ICT infrastructure, which in some cases is considerably expensive (Acciaro *et al.*, 2020b; Del Giudice *et al.*, 2021; Dutta *et al.*, 2020; Ferretti and Schiavone, 2016; Inkinen *et al.*, 2021). Seaports are therefore expected to increase their investments in ICT infrastructure as this adoption takes place.

Proposition P_{1c} is thus stated as follows:

> ***P_{1c}*:** *Industry 4.0 technologies generate new investments in a seaport's ICT infrastructure.*

3.3.2.2. Market pull

The place that seaports have in global supply chains is strategic. They concentrate physical and information flows across the supply chain like no other entities[2]. As previously expressed, seaports are important *nodes* in a global network (Inkinen *et al.*, 2021; Parola *et al.*, 2021). The adoption of Industry 4.0 technologies by other nodes in this network, and by other important players like big shipping companies, is therefore expected to generate a market pull over all the nodes, as they become more interconnected (Bavassano *et al.*, 2020; Lee and Lam, 2016).

The second answering proposition to the research question can be stated in the following way:

> ***P_2*:** *As Industry 4.0 technologies are adopted by the maritime industry as a whole, they generate a pull towards their adoption by seaports.*

As with P_1, P_2 is to be divided into 3 ancillary propositions, depending on the area where the *locus* of innovation is situated.

[2] This could be stated also regarding financial flows. It is no coincidence that some of the largest or historically relevant ports in the world (New York, Amsterdam, Singapore, Hong Kong, Shanghai) are also global financial centres; a phenomenon interestingly explained by Kindleberger (1973).

When shipping companies, city councils, customs authorities, etc. adopt digitalization technologies, this creates a pressure over seaports to offer data-driven services (Wang J. *et al.*, 2021). For instance, if a global shipping company offers IoT-based container tracking services, it will prefer to work with port terminals that support those services with their own data-driven capabilities (Choi *et al.*, 2017; Yang *et al.*, 2018).

Proposition P_{2a} is thus stated as follows:

P_{2a}: *Seaports offer Industry 4.0-based, data driven services, as internal and external stakeholders require their provision.*

Interconnection with a port's hinterland, inland ports, city authorities, or seaports located abroad, has been mostly focused on the right physical infrastructure (Lam and Yap, 2011; Notteboom and Rodrigue, 2008). However, as Industry 4.0 technologies are adopted across global supply chains, the need for coordination, IT standards setting, integration, etc. is increased. It is to be expected, therefore, that knowledge-based collaborations between a seaport and its external stakeholders (strategic connectivity) would increase (Hollen *et al.*, 2015; Peña Zarzuelo *et al.*, 2020).

Proposition P_{2b} is thus stated as follows:

P_{2b}: *Seaports increase their focus on strategic connectivity, as a result of market pull from external stakeholders.*

In the same vein, as other global players and seaports invest in new ICT infrastructures while adopting Industry 4.0 technologies, seaports need to keep up with those investments in order to remain competitive (Allam and Newman, 2018; Cepolina and Ghiara, 2013; Jardas *et al.*, 2018; Jović *et al.*, 2019); or as expressed by De Langen *et al.* (2018): *'to address the challenges of the growing and changing needs of production and supply chains and to adapt to the requirements of sustainable transport'* (p. 15).

Proposition P_{2c} is thus stated as follows:

P_{2c}: *Investments in Industry 4.0 technological infrastructure by the shipping industry, generate a competitive pull to catch up with other seaports.*

Table 3-3 summarizes the propositions above stated, showing the basic structure of the conceptual model. The adoption of industry 4.0 technologies in a seaport or in the whole maritime industry works as the independent construct (an approach followed by Pournader *et al.*, 2020); technology push and market pull work as the influence mechanisms; and levels of innovations in the areas of operations, strategies and investments are the dependent constructs.

Table 3-3. *Conceptual model propositions*

	Independent construct		Industry 4.0 technologies	
Dependent constructs	Influence mechanisms			
	Technology push		Market pull	
	P_1	Industry 4.0 technologies exercise a push towards architectural innovation in seaports, by requiring new capabilities and tasks	P_2	As Industry 4.0 technologies are adopted by the maritime industry as a whole, they generate a pull towards their adoption by seaports.
Operations	P_{1a}	Industry 4.0 technologies generate new data-driven services that aim to streamline the interactions between physical and information flows in the ordinary operations of a seaport.	P_{2a}	Seaports offer Industry 4.0-based, data driven services, as internal and external stakeholders require their provision.
Strategies	P_{1b}	Industry 4.0 technologies generate innovative strategies, oriented towards information integration of a seaport with internal and external stakeholders.	P_{2b}	Seaports increase their focus on strategic connectivity, as a result of market pull from external stakeholders.
Investments	P_{1c}	Industry 4.0 technologies generate new investments in a seaport's ICT infrastructure.	P_{2c}	Investments in Industry 4.0 technological infrastructure by the shipping industry, generate a competitive pull to catch up with other seaports.

3.3.3. Conceptual model depiction

Figure 3-1 depicts the conceptual model, summarizing the place of the propositions in relation to the independent construct, the influence mechanisms, the dependent constructs and the concept of smart port itself. The model sketches the influence exercised by the adoption of Industry 4.0 in other seaports and the shipping industry, through technology push and market pull mechanisms, over a seaport's operations, strategies and investments.

In turn, the innovations that take place in each of these three areas, might add up to one or more of the defining characteristics of a smart port presented in Table 3-2. In other words, innovations in operations, strategies and investments, whether market or technology driven, move a seaport towards the smart port concept.

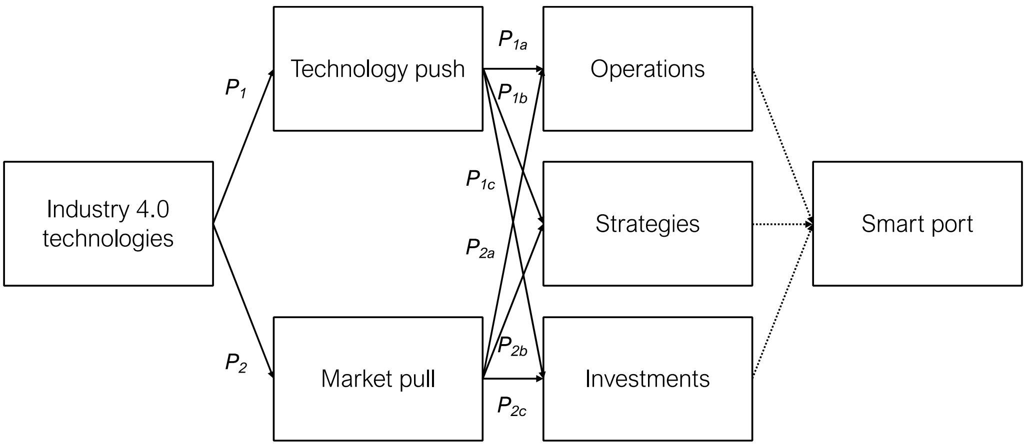

Figure 3-1. *Conceptual model*

3.4. Research method

3.4.1. Case study methodology

This study follows the exploratory research methodology by conducting a case study, as has been done recently by papers in maritime and supply chain research (Pantouvakis and Syntychaki, 2021; Vural *et al.*, 2020). Exploratory research and case studies have been considered appropriate for the analysis of contemporary phenomena, where empirical data from which to derive statistical inferences is not available, or not abundant enough (Benbasat *et al.*, 1987; Yin, 2009). Moreover, the research follows the *critical realism* epistemological approach, according to which there is an external, causally driven reality, independent of our empirical perceptions. This reality cannot be reduced either to the observable or the measurable *(positivism)*, or to the outcome of socially constructed meanings *(interpretivism)*. Critical realism provides a sound epistemological basis for case studies in general (Easton, 2010), and for information systems research in particular (Mingers *et al.*, 2013).

Exploratory research is useful to study emerging technologies like those associated with the Industry 4.0 paradigm (Harikannan *et al.*, 2021; Menon and Shah, 2020; Shin, 2017; Tu, 2018; Zhu *et al.*, 2020). Rather than validating hypotheses or propositions, exploratory studies look to extend the theoretical and empirical ground over which future research might be based, including quantitative research with a positivist approach.

As previously said, this chapter does not adopt the positivist (or interpretivist) approach, but rather a critical realist one (though given its qualitative nature, its methodology is closer to interpretivism). In this sense, the evaluation of the conceptual model in view of the results provide by the case study —which is the core of the research methodology—, does not purport to validate the propositions presented (as a positivist approach would seek), but rather, to assess whether they provide useful insights for exploring and building explanatory theory.

The use of propositions or hypotheses has been considered an appropriate way of expressing theoretical frameworks in the context of exploratory research (Yin, 2009; Casula *et al.*, 2021), in contrast with grounded theory methodology, where no propositions should be stated (Glaser, 1978; Makri and Neely, 2021). In this study, the proposition-built conceptual model plays the role of an *'initial framing device (…) designed using the literature'* as Casula *et al.* put it (2021, p. 1708), and serves as a *'flexible conceptual framework'* (p. 1709).

3.4.1.1. Choice of port of Barcelona as the exploratory case study

The subject of the case study is the port of Barcelona. The choice of Barcelona was based on several reasons. First, the port of Barcelona has experienced a considerable level of innovation in operations, strategy and investments during the last decade, which makes it particularly suitable to explore innovative trends and influence mechanisms.

Second, one of the main enquiries of this study is how benchmarking might play a role when it comes to adoption of new technologies and business models in a seaport context. Benchmarking requires both an entity that does benchmarking and another entity, considered to be a model to follow, over which benchmarking is done. While several studies have been conducted on ports that are considered at the top of technological innovation —and are usually the reference of benchmarking— like Singapore (Lam *et al.*, 2020; Weeks *et al.*, 2017), Rotterdam (Hollen, 2015; Simoni *et al.*, 2022) or Hamburg (Ferretti and Schiavone, 2016; Kapkaeva *et al.*, 2021), the authors sought to complement those with a study on a port like Barcelona which, rather than being the reference of benchmarking, is itself a case of performing benchmarking by its authorities and players.

Finally, the availability of data facilitated the research, as port authorities have been very open in documenting their strategies and initiatives.

3.4.2. Data sources

3.4.2.1. Documentary sources

Given the exploratory nature of the research, and its early stage, data gathering was predominantly from documentary sources. Three sources were accessed: 1) the Documentary Centre of the Barcelona Port Authority, 2) internet sources, particularly from the website of Piernext, and 3) audio-visual material from the annual event "Smart Ports: Piers of the Future 2020", which took place (online) in Barcelona on November 17-18, 2020.

Among the documents reviewed in the Documentary Centre, the Port of Barcelona *III Pla Estratègic 2015-2020* (Port de Barcelona, 2015) and the recently adopted *IV Pla Estratègic 2021-2025* (Port de Barcelona, 2021a) were particularly relevant. PierNext is an initiative of the Barcelona Port Authority itself (as it will be mentioned in the case study section), so its website (https://piernext.portdebarcelona.cat) constitutes a very useful source. Finally, the videos of the conferences that were given during the above referred event, are helpful in building an updated view from experts and officials of various port authorities about the topics covered in this research; the videos and agenda of the event are accessible at its website (https://smartports.tv/2020). The use of material and data from internet sources has been considered especially suitable for case study research (Gallagher, 2019).

3.4.2.2. Semi-structured interview

On October 7, 2019, a semi-structured interview was conducted with a top official of the Barcelona Port Authority, whose responsibilities were related with the area of strategy and innovation. The interview lasted for about 90 minutes. Upon request of the interviewee, it was not recorded, but handwritten notes were taken.

The official in question was at the time of the interview the Director of Strategy and Innovation of the Barcelona Port Authority (BPA). He has been working in strategy roles at the BPA since 2006, and was directly involved in the research, discussions and implementation of both the 3rd and 4th Strategic Plans of the Port of Barcelona.

The authors chose to interview this official because the direct experience that he has on the strategy and management processes, as well as his ample knowledge on the port area, both in management and academic positions. It was considered that the official was one of the most suitable persons to be interviewed, since he could provide insights based on his own direct experience of the facts and events that comprise the subject of the case study: the approach that the port of Barcelona has been taken to technology, and the role this plays in operations, strategy and investments.

During 2020, other requests for interview were made, but largely due to the lockdown and limitations posed by the COVID-19 pandemic, no additional interviews could be conducted with relevant people from the port of Barcelona.

3.4.3. Data analysis

The data gathered about the subject of the case study is presented in Section 3.5. and discussed in Section 3.6. The exploratory case study was conducted as a way of evaluating the propositions that build the conceptual model presented in Section 3.3. The evaluation is done through content analysis, a technique for analysing documentary sources, which aims to provide new insights, increase a researcher's understanding of particular phenomena, or inform practical actions (Krippendorff, 2019; Weber, 1990). Each of the propositions is evaluated against a validation scale with four possible scores: not grounded (-), lowly grounded (+), moderately grounded (++), and highly grounded (+++). As previously observed, the assessment does not intend to "validate" in a positivistic way the conceptual model or to derive definite answers or conclusions, but instead to increase the understanding of topics under study and provide insights for subsequent research (Casula *et al.*, 2021; Marlow, 2005).

3.4.4. Research quality

Following recent exploratory case studies in the logistics field (Vural *et al.*, 2020), the research quality of this study is evaluated through the four criteria of rigor proposed by Halldórsson and Aastrup (2003) for qualitative research in logistic studies: credibility, transferability, dependability and confirmability.

This study's *credibility* (equivalent to internal validity in positivist research) is grounded on the "match" between the phenomena and constructions that emerge from the case study (derived from the data sources), and the theoretical propositions (presented in the conceptual model). To this end, the study evaluates the model through a discussion based on various sources of data. Given that the context of the case study is time and space bound, *transferability* (equivalent to external validity) of the findings is limited. Nonetheless, as noted by Halldórsson and Aastrup (2003), this does not mean that *'knowledge acquired in one context is of no relevance for other contexts or frames of time'* (p. 327); therefore, the extend of this transferability will be explained with more detail in sections 3.6. and 3.7., regarding representativeness of the case study and its limitations. *Dependability* (equivalent to reliability) is achieved since most of the data sources that ground the findings are stable documentary sources. In the case of the semi-structured interview, though not recorded, detailed written notes were taken. Finally, *confirmability* (equivalent to objectivity) is grounded in the case study itself: the research does not simply present the conceptual explorations of the authors, but confronts those with objective data sources.

3.5. Case study: the port of Barcelona

This section is structured into sub-sections, covering the 3 areas of innovation under study, as dependent constructs: operations, strategy, and investments. Previously, a short background about the port of Barcelona and its representativeness is presented. The data collected from the sources above mentioned is directly referred in each one of the sub-sections.

3.5.1. Background

The port of Barcelona is the third biggest Spanish port in terms of containerised cargo, measured in twenty-foot equivalent units (TEU), with a total volume of 2.96 million TEUs in 2020, behind Valencia (5.42 million TEUs) and Algeciras (5.11 million TEUs) (Statista, 2021). It terms of cruise passengers, at 2.9 million in 2019, it was the biggest port in Europe, 7th worldwide, and 2nd worldwide excluding the Caribbean area (behind Shanghai) (Ship Technology, 2019). In terms of port authority revenues, it was the biggest port in Spain in 2018 (€173.5 million), over Valencia (€140.3 million) and Algeciras (€83.5 million) (El Mercantil, 2019). After a sizable downturn in its cargo traffic volume in 2020, due to the COVID-19 pandemic, the port had its best first quarter ever in terms of containerised cargo, with a volume of 907,010 TEUs, a 25% increase in relation to Q1 2020 (Port de Barcelona, 2021b).

The port's direct hinterland is the region of Catalonia, in the northeast of Spain. Being located in the western Mediterranean Sea, the port serves also as a cargo gateway to southwestern Europe, especially southern France. As such, it has two main competitors in the region: Marseille and Genoa.

Table 3-4 shows the container throughputs of the main ports located in the western Mediterranean Sea for the year 2019:

Table 3-4. *Container throughputs for year 2019*

Place	Country	Volume (million TEU)
Valencia	Spain	5.44
Algeciras	Spain	5.12
Barcelona	Spain	3.32
Marsaxlokk	Malta	2.72
Genoa	Italy	2.64
Gioia Tauro	Italy	2.52
Marseille	France	1.45

Source: authors' elaboration from Notteboom (2020).

As observed, the port of Barcelona has a container volume typical of the main ports in the region (in fact, the average throughput for 2019 among the ports above listed was 3.32 million TEU, exactly the volume of Barcelona). Notwithstanding some significant differences among western Mediterranean ports (e.g. Algeciras and Marsaxlokk are mainly transhipment hubs, while the rest mainly serve their respective hinterlands), they are frequently compared as a group with the bigger ports in northern Europe (Rotterdam, Antwerp, Hamburg, and Bremerhaven) (Musso and Parola, 2007; Notteboom *et al.*, 2019).

3.5.2. Operations

In the semi-structured interview, it was emphasised that the mission of the port of Barcelona is to serve its hinterland, and that is the main criteria used to define which operations and services are offered. This mission has been unaltered since the 1st Strategic Plan (elaborated in 1998), although the sustainability component was added to the wording in the 4th Strategic Plan.

While the aim of serving the hinterland has been the same, the set of services, operations, activities, and the incorporation of new technologies, have clearly evolved throughout the years. Among the novel technologies and services provided in the port, the following have been highlighted:

3.5.2.1. Virtual gates

This is a service, based on OCR technology, which aims to increase efficiency and accuracy in the process of container pick-up from trucks. The service has been provided in the 2 container terminals (APM Terminals Barcelona and BEST) since the beginning of the last decade. In the Smart Ports 2020 conference, the CIO of the port described a vision for an enhanced, data-driven and even data-managed system where certain processes would be automatically managed by algorithms, based on data inputs captured through sensors, cameras, etc.

3.5.2.2. Digital Twins

The concept of a port digital twin has been discussed as a way of improving monitoring of port operations, safety and security, as well as the basis of AI-based predictive models (Wang, K. *et al.*, 2021). One startup supported by the port (3D Modelling Studio), has developed a solution for measuring and classifying waste, through the creation of a digital twin of the waste.

3.5.2.3. IoT and blockchain

Two IoT technological platforms have been tested in the port: GPS and LoRaWAN. However, the deployment of use cases like container tracking or AC systems monitoring is still under development. Blockchain technology has a few mentions in the 4th Strategic Plan, in the context of digitalization trends, but so far there is not a specific use case being developed in the port. The emphasis with both IoT and blockchain is that they would increase efficiency and reduce costs.

3.5.2.4. Electronic documentation

The port of Barcelona has been working on the implementation of electronic standards and processes since 2003 and developed its port community system (PCS) “Portic” in 1999. Digitalization and automatization in this area has been mostly focused on the processes of container picking. In February 2018, it was decided that container pickup requests had to be transmitted electronically, and as a consequence the level of use of electronic documents in this area quickly increased from 40% to 100%.

Apart from these specific use cases, in the semi-structured interview it was observed that the trend in the port’s services and operations is towards management of information flows. The Barcelona Port Authority is handling a global information flow, with increasing volumes of data, including data generated through sensors in the port's spaces. Services like Big Data analytics, predictive analytics, and information services based on an open data initiative are becoming part of what the port is to offer to its customers. Collecting data, informing, and managing data in real time will be core functions of the port.

3.5.3. Strategies

Something common to both the 3rd and 4th Strategic Plans of the port of Barcelona is that, in many passages, they make comparisons between the port of Barcelona and other ports in the Mediterranean zone, as well as those in the north of Europe (specially Rotterdam, Antwerp and Hamburg). There is a clear use of benchmarking as a strategic tool. However, the importance of factors and the weight of objectives changes clearly from one plan to the next. Most prominently, the 3rd plan emphasized growth as the main aspiration of the port, while the 4th plan mentions several times that growth in itself is not an end, and instead emphasizes sustainability as one of the key components in the port's mission and vision.

Regarding the positioning of the port, there is also a clear difference of emphasis between both plans. In the 3rd Strategic Plan, when analysing market trends and how the port should position itself, it is mentioned many times that the competition is not so much between ports, but between logistic chains and networks; and that the competition is for a bigger portion of traffic volumes. The concept of "network port" *(port en xarxa)* is a central one, comprising the development of transport logistic corridors and inland maritime terminals across the hinterland.

In the 4th Strategic Plan, instead, when it comes to the port's positioning, the emphasis is in the concepts of *diversification* of the offer, and *differentiation*. These two concepts were mentioned several times in discussion panels by the port's Head of Strategy, during the Smart Port 2020 event. The basic idea is that digitalization and the adoption of more sophisticated technologies will commoditize ports' services, so it is particularly important to develop innovative and diversified services as a way to differentiate from the competition. Interestingly, it is stated several times, both in the 4th Strategic Plan and by the Head of Strategy in the event, that human capital will be in the end the big differentiator. In other words, technology alone will not differentiate, but the skills and knowledge of the people that implement and use it.

In both the 3rd and 4th Strategic Plans the development of strategic alliances is mentioned, but the 4th plan is more detailed. In this area, as was also mentioned in the semi-structured interview, the port of Barcelona has been taking part in several initiatives with other ports, most specially ChainPort, led by the port of Hamburg.

The new vision of the port of Barcelona is to become a "SMART logistic hub", the "SMARTest logistic hub in the MED". The definition of what "smart" stands for is based in 5 pillars (which correspond with the "smart" word as an acronym): Sustainable, Multimodal, Agile, Resilient and Transparent.

3.5.4. Investments

Despite the evolution in the strategic emphasis from growth to differentiation, physical infrastructures that could cope with increasing traffic and logistic demands are the main focus of the port when it comes to investments needed. In the 4th Strategic Plan, when assessing the fulfilment of the 3rd Strategic Plan's objectives, it is stated that there was a moderated success, with two exceptions: the growth in traffic volume was not as large as expected, and the train infrastructure from Barcelona to Zaragoza was not concluded. The general observation is that there still remain several physical infrastructure works to be developed. The main investments to be made, therefore, as described in the strategic objective OESE4 "develop needed infrastructures", are related to building, remodelling or enlarging of physical infrastructures like the added dock *(moll adossat)*, the energy dock, the Catalonia container dock, etc.

Nonetheless, there is mention, both in the 4th Strategic Plan, PierNext website and Smart Port 2020 event, of the development of a 5G telecommunication network that would cover both the water and land spaces of the port. More recently, in March 2021 it was announced that Telefonica (the largest telecommunication provider in Spain) will deploy a 5G network in the port spaces managed by the Dutch-based port operating company APM Terminals (Blackman, 2021). The 5G network is identified in several places as the technological basis of the IoT and digitalization services to be provided in the port, with particular reference to the virtual gates and monitoring systems.

Another intended project in the ICT field is upgrading the Portic PCS, with the aim of making it 100% cloud oriented by 2022. It is also intended for the Barcelona Port Authority to adopt an open-data approach, where the data generated in the port could be shared with digital solution providers, creating new value and services.

What stands, however, as one of the most highlighted aspects of the approach that the port of Barcelona has towards investments and technology, is the development of an innovation hub to support tech start-ups. Pier01 is a space developed by the port (in a XIX century warehouse building) where several start-ups are supported to develop innovative products, most of them related with digital transformation in logistics.

Apart from Pier01 as a physical space, the port launched PierNext as a "digital knowledge hub" for knowledge sharing and collaboration between the port and its community. OpenPort, and the Port 4.0 fund (created by the Spanish government) are also supporting initiatives for the startup community. Even though, as was observed in the semi-structured interview, the port has no intention in the short run of becoming an investor in the start-ups that are surging in its ecosystem, there is a clear policy of collaborating with them. The idea is for the port to promote technological innovation, not by conducting itself R&D projects, but by supporting a strong startup community that would develop innovative solutions in the area of logistics. In other words, the trial-and-error ridden process of innovation is to be undertaken by start-ups, which are highly adaptable and lean, and not by the port's more rigid organization.

3.6. Discussion

As expressed in the introduction, the aim of this research is to provide insights into the inter-relation between Industry 4.0 technologies and business models in a seaport context. To that end, a conceptual model that purports to offer an initial explanation of this interrelationship was built around a set of propositions, and an exploratory case-study was conducted in order to assess them. This section, therefore, is structured along these propositions.

First, propositions P1 and P2 are evaluated; then, according to the specific innovation area (operations, strategies, investments) the corresponding pair of ancillary propositions is assessed. This is followed by a brief discussion of the role that factors like regulation, governance and funding might play in the adoption of smart port business models. Finally, we discuss what answer do the case study findings can provide to the research question posed at the beginning of this chapter, with special focus on the notion of smartness.

3.6.1. Technology push influence on innovation

From the content analysis performed over the data sources, it is difficult to perceive a significant influence of technology push forces in the port of Barcelona's business model. The port does not look for innovation *per se*, and in fact does not mention research and development as an activity that belongs to the role it plays, leaving it to the startup ecosystem. However, there is an important observation made in the 4th Strategic Plan, and also by the Head of Strategy in the Smart Ports 2020 event: the significance of human capital for creating an innovative and differentiated port offer. The value provided by this human capital consists of the skills, knowledge and implementation procedures for the new technologies adopted in the port.

It could be argued that this emphasis on the human capital as the true differentiator can be understood in the light of the concepts of component and architectural knowledge. It appears that the port authorities are aware of the importance of developing these kind of knowledge (even if they do not use the concepts themselves).

Proposition P_1 is therefore moderately grounded.

3.6.2. Market pull influence on innovation

In contrast with technology push influence, market pull forces are clearly and pervasively present as a driver of innovation in basically all the data sources. Benchmarking of other ports (particularly from northern Europe), comparisons with other ports' offers and the aim to become the leading logistic hub of in the Mediterranean are market-oriented perspectives and objectives. Moreover, the orientation towards customers' needs is a core aspect of the port's mission.

The adoption of technologies and use cases like IoT, OCR, virtual gates, etc. is seen as a way of diversifying and differentiating the port's value proposition and escape commoditization. The port's authorities seem very conscious of the increasing competitive forces that will affect supply chain operators, at a global level. There was a change of emphasis, from growth and capturing traffic as aims in the 3rd Strategic Plan, to a more sophisticated supply of services, including advanced technologies, in the 4th Strategic Plan. But what remains constant is the focus and orientation towards what the market is demanding.

Proposition P_2 is therefore highly grounded.

3.6.3. Technology and operations

From the discussions held in the semi-structured interview, as well as the content of the documentary sources, it can be seen that the port of Barcelona is envisioning and, in some cases, already performing data-driven functions. The virtual gate is a good example of a current data-driven service, which in the future is expected to depend more on the use of artificial intelligence, IoT and predictive analytics. It is, moreover, a clear example of how the management of information flows streamlines physical flows (i.e., the container pickup by trucks).

Proposition P_{1a} is then highly grounded.

While it is clear that the port looks to develop a data-driven or data-oriented set of services as a way of differentiating the port's offer, it does not appear from the data sources a strong demand from the port's community of these services. There is a mention to SMEs, as well as retailers from the Barcelona area as interested parties in the provision of data services; but the market pull forces appear more connected with the competition rather than the port's clients.

Proposition P_{2a} is then just moderately grounded.

3.6.4. Technology and strategies

The concept of integration with internal and external stakeholders, which is key in the Port 4.0 literature definitions above referred, is present in both 3rd and 4th Strategic Plans. The open data initiative to be followed by the Port Authority, which aims to facilitate the creation of added value from the data it collects and manages, can be said to be a form of information integration with external stakeholders. Nonetheless, this policy does not appear to be a consequence of the adoption of Industry 4.0 technologies like IoT. The integration with other ports and logistic operators is still more focused on physical infrastructures like railway lines, rather than information or IT integration.

Proposition P_{1b} is lowly grounded.

Regarding strategic connectivity, the collaboration with other ports through initiatives like ChainPort is a clear example. The Smart Port annual event itself is a collaboration with the ports of Hamburg, Antwerp, Rotterdam, Busan, Montreal and Los Angeles. Still, in the case of Barcelona, the main focus regarding collaboration with external stakeholders is on structural connectivity, particularly with those integrated in the network port *(port en xarxa)* concept, like inland ports and logistic centres.

Proposition P_{2b} is moderately grounded.

3.6.5. Technology and investments

In the particular case of the port of Barcelona, as mentioned, the main investments are those related to physical infrastructures. The 5G telecommunication network, however, is a case of an ICT infrastructure investment, as a way of boosting the development of IoT use cases. If the support of the startup ecosystem in Pier01 and the other initiatives is understood as a sort of "indirect" investment, then it can be said that there is an increasing focus, though still secondary, on ICT and knowledge intensive investments.

Proposition P_{1c} is moderately grounded.

As was observed in general regarding the market pull influence mechanism, there appears to be a clear focus by the port of Barcelona authorities in keeping up with the industry trends regarding new technologies. The expectation is that digitalization technologies will be widely adopted by the ports in the region, such that in order to be a leading port, Barcelona has to innovate and develop a skilled workforce. While, at least in the immediate future, most investments in the port of Barcelona are focused on the physical infrastructure, the market pull forces in terms of investment from other seaports or industry players are expected to accelerate ICT and knowledge intensive investments.

Proposition P_{2c} is highly grounded.

Table 3-5 summarizes the results of the conceptual model propositions' validation.

Table 3-5. *Conceptual model propositions' evaluation results*

Nº	Proposition	Evaluation
P_1	Industry 4.0 technologies exercise a push towards architectural innovation, by requiring new capabilities and tasks.	+ +
P_2	As Industry 4.0 technologies are adopted by the shipping industry as a whole, they generate a pull towards their adoption by seaports.	+ + +
P_{1a}	Industry 4.0 technologies generate new data-driven functions that aim to streamline the interactions between physical and information flows in the ordinary operations of a seaport.	+ + +
P_{2a}	Seaports offer Industry 4.0-based, data driven services, as internal and external stakeholders require their provision.	+ +
P_{1b}	Industry 4.0 technologies generate innovative strategies, oriented towards information integration with internal and external stakeholders.	+
P_{2b}	Seaports increase their focus on strategic connectivity, as a result of market pull from external stakeholders.	+ +
P_{1c}	Industry 4.0 technologies generate new investments in ICT infrastructure.	+ +
P_{2c}	Investments in Industry 4.0 technological infrastructure by the shipping industry, generate a competitive pull to catch up with other seaports.	+ + +

3.6.6. Regulation, governance and funding factors

While the main focus of this chapter has been on the technology push and market pull mechanisms as drivers of the smart port business model, it is appropriate to discuss other influencing factors that act as either hurdles or catalysts for the adoption of this model: regulation, governance and funding.

Appropriate regulation and governance have been considered key factors that either facilitate or impede the adoption of new technologies in the maritime industry (Acciaro *et al.*, 2020b; Bavassano *et al.*, 2020; Inkinen *et al.*, 2021; Lam *et al.*, 2020), especially in the case of blockchain technology, with its decentralized architecture (Ahmad *et al.*, 2021; Pu and Lam, 2021; Yang, 2019). Particular emphasis is being given, in this sense, to data ownership and privacy, where legal frameworks should strike the right balance between protecting privacy and stimulating information sharing (Ahmad *et al.*, 2021; Bavassano *et al.*, 2020). The governance model assumed by a seaport can also affect the way technology and business model innovation is adopted, though no conclusion has been reached as to whether a public, private or mixed model is preferable (Brooks *et al.*, 2017; Simoni *et al.*, 2022).

Regarding funding, De Langen *et al.* (2018), in a report prepared for the European Sea Ports Organisation (ESPO), point out the need to count with public funding beyond the budget of port authorities, especially in those cases where the societal value creation (the "value case") cannot be (fully) captured through the port's income (the "business case").

The data analysed in the case study do not offer much information on how these factors are considered in the context of the port of Barcelona. The 3rd Strategic Plan, when describing the role of the Barcelona Port Authority (BPA), states that *'the function of the APB (…) is the management of direct services, the regulation and control of concessioned and authorized services, and the coordination, efficiency measure and leadership of the whole port services'* (Port de Barcelona, 2015, p. 64), a description closer to the landlord governance model prevalent in European ports (Brooks *et al.*, 2017). Regarding funding, the 3rd Strategic Plan points out that the funding of investments made by the BPA is done with its own cash flow, and through complementary funding from the European Union. The 4th Strategic Plan, on the other hand, does not provide insights into either governance or funding issues. Neither the 3rd nor the 4th Plan discuss regulatory issues in relation to technology adoption.

This absence reflects a stance of the BPA that presumably gives low importance or priority to regulatory, governance and funding factors, at least when it comes to strategy planning. There is, however, an observation made in the 3rd Strategic Plan that might give some light on the approach to be taken regarding infrastructure investment funding. It is said that *'this funding of the expansion of the Port of Barcelona maintains a good level of balance between public and private investment; the public is destined basically to infrastructure, and the private to superstructures, facilities and manipulation equipment'* (Port of Barcelona, 2015, p. 66).

While it is not totally clear whether ICT would fall into the "infrastructure" or "superstructures" category, the emphasis on physical infrastructures that pervades both the 3rd and 4th Plans might point towards a categorization of ICT as superstructure, where private investment would play the leading role.

3.6.7. How smart is the port of Barcelona and what can be derived from its case study?

The research question of this study asks how Industry 4.0 technologies might drive the adoption of new business models by seaports. Another way of posing this question would be to ask whether the implementation of these technologies makes seaports to adopt smarter models.

This chapter seeks to explore answers to these enquiries by extracting insights from the example provided by the port of Barcelona. The main answer has been the evaluation of the conceptual model's propositions summarized in Table 3-5, which in the case of Barcelona points towards a primacy of market pull drivers over technology push ones. But another way of deriving insights is by answering the following question: how smart is the port of Barcelona?

Evaluating the port of Barcelona against the "smart port" characteristics listed in Table 3-1 and organized in Table 3-2, we find 4 main traits that point towards a significant level of smartness: 1) a conscious effort in understanding the needs of the port's clients and stakeholders (a customer centric focus); 2) an emphasis in generating value for its hinterland and the city of Barcelona (new value creation, integration with smart city); 3) supporting innovation by promoting a startup hub inside the port's ecosystem (port developer); and 4) the implementation of certain data-driven functionalities like virtual gates (data-driven functions, real time data interchange, digitally-enabled port synchronization). On the other hand, besides the said virtual gates, Industry 4.0 related functionalities are still more a matter of vision and planning, and less of actual implementation.

Assessing a specific level of smartness for the port of Barcelona is not possible, because there is simply not a scale for that[3]; all that can be said is that some of the characteristics and functionalities associated with the concept of a smart port are present.

Another way of questioning about smartness is through a comparative approach. Given that the implementation of Industry 4.0 related technologies is still fairly limited, does that mean, for instance, that the port of Barcelona is

[3] We deem to be highly questionable whether constructing one would be relevant or worthwhile.

less "smart" than ports that have already implemented more of these functionalities, like some ports in the north of Europe?

If being smart is simply understood as the adoption of certain Industry 4.0, data-driven functionalities, the answer is a clear yes. However, the case study gives indications that, at least in the case of Barcelona, the quest for smartness might not be focused on simply adopting a set of technologies, but on achieving a "match" between the resources and capabilities possessed (among them, technological ones) and what the market requires. In other words, an alignment between customer centric focus and technology sophistication. Determining to which extent has the port of Barcelona actually achieved this alignment is something that goes beyond the objective of this study.

A way of answering the research question of this chapter, in light of the findings of the case study, is as follows:

For a seaport, being smart is about understanding the needs of its hinterland clients and stakeholders, and addressing those with the right set of resources and capabilities, among them technological ones. The development and adoption of Industry 4.0 technologies by the maritime industry generates pressure on seaports to adopt them as a result of benchmarking of other ports, and of more demanding clients and stakeholders. Therefore, market pull forces are the main driver towards the adoption of smarter business models by seaports.

Given the exploratory nature of this study, the above answer cannot (and it is not intended to) be conclusive. As was pointed out in Section 3.4., the purpose of exploratory studies is not to validate propositions or hypotheses, but to extend the theoretical and empirical ground of a field or topic, providing basis for future research. According to Bacharat (1989) *'the primary goal of a theory is to answer the questions of how, when, and why, unlike the goal of description, which is to answer the question of what'* (p. 498). We have explored why and when do seaports adopt or implement Industry 4.0 technologies, and how those technologies might affect their business models. An increased understanding of these topics, even if it does not amount to definitive explanatory theory, can be the basis of further enquiries, whether positivistic or interpretivist. This is the contribution intended by this study.

A closely related issue is to which extent do the findings in the case study provide ground to the answer above given; how representative is the port of Barcelona of what is happening in the market?

Our answer is that no single port can be representative of what is happening in the market. What "smartness" mean for a seaport varies according to the circumstances and contexts it faces (as it is both situation and time-bound). In this sense, insights and conclusions derived from studying a specific seaport can be transferred to other ports with a similar context or set of circumstances, but not otherwise.

The port of Barcelona faces a similar set of internal and external circumstances than other ports in the Western Mediterranean, most particularly Marseille and Genoa: they are located in the same maritime route and serve an overlapping hinterland. In contrasts, other ports in the same region, like Algeciras or Marsaxlokk, are transhipment hubs; for them, what counts as being smart is expected to differ. Nonetheless, even for ports with different contexts, the insights gained from the case study can be equally relevant —if not properly transferable (Halldórsson and Aastrup, 2003)—, for instance, in order to determine how their own "smart" set of data-driven functionalities or technological capabilities should be different or similar.

In its report titled *Smart Ports in the Pacific*, the Asian Development Bank observes the following regarding smartness:

Any port can become smarter. There is no limit in terms of port size for the implementation of smarter solutions. But this does not mean that all ports require the same level of "smartness." The appropriate level of smart port maturity and sophistication should be designed according to the needs of each individual port (ADB, 2020, p. x).

We consider that only a piecemeal approach, that studies ports under different contexts and dynamics, can build an integral theory of what a smart port or smartness means for the whole market. This study intends to contribute to that endeavour with an individual piece.

3.7. Conclusion

This chapter has sought to add new insights on the interrelationship between Industry 4.0 technologies and the evolution of business models, specifically in the context of seaports. To that end, it built a conceptual model of the influence that Industry 4.0 technologies might have over innovation areas like operations, strategies and investments. In order to assess this conceptual model, it conducted an exploratory case study on the port of Barcelona. The main conclusion that could be extracted from the case study is that, at least in the context provided by the port of Barcelona, Industry 4.0 technologies influences business models predominantly through market pull mechanisms, as the port tries to keep up with developments in the industry, other ports, and their stakeholders.

3.7.1. Theoretical contributions

From a theoretical perspective, the chapter extends the literature on ports models, elaborating a definition of the smart port concept, derived from the related concepts of fifth generation (5G) port and Port 4.0. The chapter also contributes to the understanding of what "smartness" means in a seaport context, concluding than being smart is about finding a match between the market needs and the right set of technological functionalities, rather than by adopting a pre-defined set of technologies for its own sake. It also provides insights regarding the impact that technology push and market pull forces might have for seaports, concluding that market pull appears to be the main driver, according to the findings derived from the case study.

3.7.2. Managerial implications

From a managerial perspective, the chapter serves not only to evaluate the conceptual model that explains the influence of Industry 4.0 technologies on the adoption of a more sophisticated business model for a seaport, but also shows how prevalent is benchmarking and market pull when it comes to adopting new technologies.

Seaports should strive to become "smarter", not as a matter of pure benchmarking, but as a result of a better understanding of the market in terms of customers' needs, and an increased integration with stakeholders like cities, logistic operators, or even other ports. This understanding and integration then helps port authorities to find the match between what the market needs and the set of technologies to be implemented, strategies to be adopted, and investments to be made.

In order to define what "smartness" requires for a specific seaport, port authorities and other port stakeholders should not overuse benchmarking (which in many cases is done in reference to ports that face different contexts). Instead, they should also adopt a more pro-active stance and develop innovative use cases, not as a way of keeping pace with technologies generally adopted in the industry, but as a way of "striving for appropriate smartness" (ADB, 2020); that is: achieving a higher degree of match between what they offer and what is really valuable to their clients and stakeholders. This proactiveness is in fact observed by Cepolina and Ghiara (2013): *'Port authorities around the world are modifying their nature and their role, acquiring more and more an active role in the governance of logistics systems and often adopting managerial and entrepreneurial behaviors'* (p. 204).

Another way of becoming smarter is through catalysing the development of component and architectural knowledge (Henderson and Clark, 1990) of Industry 4.0 technologies; that is, by acquiring and furthering the skills and competences that these technologies require, and understanding their linkages.

3.7.3. Limitations and suggestions for further research

The research has several limitations. First, the case study covers only the experience of the port of Barcelona. This limits the transferability of the assessment to ports that face a similar context and set of circumstances. As previously mentioned, however, the limited representativeness of the case study does not preclude for its insights to be relevant in different contexts. Second, the data sources were limited, as was the possibility of conducting additional interviews with officials from the port authority, the port's stakeholders and the port community. This limitation reduced the possibility of triangulating findings from multiple sources, something that also decreases transferability. Third, the novelty of Industry 4.0 technologies, means that their implementation in the port of Barcelona is still relatively scarce, and they are more present in ideas and visions than in real and concrete use cases, limiting the analysis to what is found in statements, strategies and policies, rather than in actual developments. Finally, the nature itself of the research, as an exploratory study, implies a limited outcome in terms of explanatory theory generation. Nonetheless, the exploration conducted on the basis of a specific case study sets the grounds for more overarching theoretical understandings, under the piecemeal approach here proposed.

In line with this piecemeal approach, future studies can include experiences from other ports in the Mediterranean and North European regions, as well as in the Asian and American continents. Their strategies regarding innovation, their investments in technology infrastructures, and their definition of the right set of functionalities to be implemented, could be compared through a multi-case study research. Additionally, the influence that institutional initiatives like China's Belt and Road might have in the adoption of technologies and the development of strategic connectivity between ports, could be included in case studies. Moreover, the regulatory, governance and funding factors previously mentioned, can be made the focus of further research on the interrelationship between technology and business models in a seaport context. In other words, in the same way that technology push and market pull mechanisms have been analysed here as driving mechanisms, further studies can focus on how regulations, governance models and funding factors boost or hamper seaports in their strife for smartness.

Last but not least, both the inter-relation between Industry 4.0 technologies and seaports' business model, as well as what "smartness" mean in a seaport context, can be explored further through different theoretical lenses. One of such is given by affordance theory (Gibson, 1977) and the affordance actualization model (Strong *et al.*, 2014), used in IS research to investigate how organizations actualise and generate value out of digital technologies (Novales, 2022).

Chapter 4.
Digital transformation for a sustainable shipping industry*

4.1. Introduction

Ever since the Brundtland Report defined sustainability as '*development that meets the needs of the present without compromising the ability of future generations to meet their own needs'* (WCED, 1987), the topic has been increasingly present in academic research and policy discussions. Concepts like the triple bottom line (Elkington, 1998) —where the performance of an organization or industry is not only measured in economic terms, but also according to its social and environmental impact—, have entered the jargon of scholars, politicians, and executives. Throughout the last decade, the focus on climate change, socially inclusive economic growth, and corporate social responsibility has only increased. Environmental, social and governance criteria (ESG) are now taken on account for investments and asset valuations (Gregory *et al.*, 2020); and two years ago, 181 US CEOs, including some of the biggest global corporations, declared that the purpose of a corporation could no longer be limited to benefit its shareholders, but that it had also to generate value to all stakeholders, including customers, employees, the environment and the whole of society (Business Roundtable, 2019).

Given its significance for the global economy, the shipping industry has been anything but alien to this increased focus on sustainability, with a surging

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number of publications on sustainable shipping (Shin *et al.*, 2018). At the same time, the concept of sustainable business models (SBM) has gained ground in strategic management studies. However, studies about SBM in the context of the shipping industry are not easy to find.

In parallel to this focus on sustainability, the shipping industry has also given heightened attention to digitalisation. Among emerging technologies related to digitalisation of business processes, distributed ledger technology (DLT), better known as blockchain (we use the terms interchangeable throughout this chapter), has promised to bring about unprecedented levels of efficiency, coordination, and transparency.

While these three areas —sustainable shipping, sustainable business models and distributed ledger technology— have been researched in maritime and transportation studies, few papers have explored their interrelationship. On the one hand, how does DLT might have an impact on sustainable practices and business models has indeed been studied (Bai and Sarkis, 2020; Lund *et al.*, 2019; Upadhyay *et al.*, 2021); but despite its importance for global value chains —80% of all trade in goods is done by sea (UNCTAD, 2021b)— there is a gap in the literature on this topic inside the maritime context. On the other hand, there are already numerous studies on DLT use cases in the maritime shipping industry, but with some exceptions (Clott *et al.*, 2020), their focus is not on sustainability.

To address this gap, this chapter adopts an interdisciplinary perspective. It delves on concepts like "circular economy" from sustainability research and applies them in the context of information flows in the shipping industry and maritime supply chains. As a result, it proposes an original concept: information circularity, locating it inside a conceptual framework that purports to explore how DLT technology might positively influence sustainability practices and business models in the shipping industry.

The research question that this chapter addresses is the following:

RQ₃*: *What impact does DLT has on the adoption of SBM, as well as sustainable practices, in the shipping industry?

The relevance of this RQ is derived from the increasing need of understanding the drivers of sustainable practices and business models and the role that certain technologies, like DLT, might play in different contexts. Sustainable economies are the result of efforts and improvements in different dimensions, one of which is the availability of new technologies (Linnér and Wibeck, 2021). The RQ's value and purpose is therefore to explore and shed light on how a specific technology (DLT) might drive sustainability in a specific context (maritime shipping).

Accordingly, we adopt in this chapter a bottom-up exploratory approach. Instead of trying to provide a general explanation on how technology drives sustainability, the chapter looks to provide insights on concrete real case applications. In particular, how DLT technology would impact the adoption of SBM in the shipping industry and, in turn, sustainable shipping practices. To this end, we elaborate a conceptual model based on previous literature, and then make an initial assessment by conducting an exploratory case study about a real-life DLT-based information platform in the shipping industry: TradeLens.

The remainder of the chapter is organised as follows. Section 4.2. provides a background on the several theoretical dimensions of the research. Section 4.3. presents the research methodology. In Section 4.4., we develop our conceptual model. Section 4.5. presents an exploratory case study on TradeLens, a DLT-based shipping information platform. In Section 4.6., we discuss the case and assess the conceptual model provided. Section 4.7. concludes by presenting the contributions, managerial implications, limitations and suggestions for further research.

4.2. Theoretical Background

To address the research question, this chapter delves into theoretical constructs from the literature on information resource management (Cleveland, 1982; Eaton and Bawden, 1991; Ward and Carter, 2019), sustainable shipping management (Lirn *et al.*, 2014; Yuen *et al.*, 2019; Tran *et al.*, 2020), sustainable business models (Geissdoerfer *et al.*, 2017; Lüdeke-Freund *et al.*, 2017; Gallo *et al.*, 2018), and distributed ledger technology (Kouhizadeh *et al.*, 2019; Saberi *et al.*, 2019; Yang, 2019).

Reflecting the interdisciplinary approach of this study, this section is divided into several topics. These topics provide the theoretical bases upon which the conceptual model is then developed in Section 4.4.

4.2.1. Information as a resource

Whether or not information could be truly considered as a resource, was a debated topic in the 1980's and 1990's. A whole sub-field in Management Science, Information Resource Management (IRM), developed from the general concept of "information economy", which characterised information as a commodity (Cooper, 1983; Repo, 1989). IRM prescribed that resource management principles and techniques proper of different types of resources like property, energy or money, should be equally applicable to manage information. Other authors pointed out the crucial differences between information and other kind of assets, most prominently the fact that information was expandable, did not decreased with its use, and could be shared but not exchanged (Cleveland, 1982; Eaton and Bawden, 1991).

Above these divergences, IRM's central tenet that —like other resources— information (whether or not a commodity) needs to be acquired, stored, processed and distributed is generally acknowledged by the management literature (Lewis *et al.*, 1995; Ward and Carter, 2019). Stated more technically:

information follows a resource-like life cycle, which includes collection, transmission, processing, storage, dissemination, use and disposal (Burk and Horton, 1988).

For maritime shipping and supply chains, information acquires a special relevance as a resource for sound decision making. Choosing the most efficient type of hinterland transportation mode (Zuidwijk and Veenstra, 2015) or the optimal container yard stowage and order-picking (Gharehgozli *et al.*, 2016; Conca *et al.*, 2018), depends on real-time information about relevant facts such as a vessel's ETA. In turn, determining the optimal vessel's ETA for a port call (and therefore its sailing speed) depends on information about port congestion levels (Meng and Wang, 2014). While complex algorithm-based schedule design can cope (up to a point) with these uncertainties (Wang and Meng, 2012a, 2012b), an increase in information would traduce in higher efficiencies and easier decision making.

Therefore, information (or, more precisely, accurate, relevant and timely information) constitutes an input for decision making and business processes. Even if different than other resources like financial capital or raw materials, it shares with them a basic life cycle: it is obtained, it is used as an input for a process, and afterwards consumed. The later deserves some additional commentary.

That information is consumed does not mean that it decreases or is depleted with usage, like financial or physical resources. The fact that a vessel with 50 containers is to arrive at time t^1 will be known well after t^1. In fact, after the vessel has arrived, t^1 will be determined with full certainty and precision, and the information will not be lost after the fact. Nonetheless, the value of this information at t^0 is significantly superior than at t^{1+n}: knowing with a 90% probability degree that a vessel's ETA is between 01:25h and 01:45h of the next day, is far more valuable than knowing with 100% certainty that a vessel's ATA *was* 01:37h last week. In general, after the set of decisions and procedures for which information constitutes an input has been executed, the latter's value (not its amount) significantly decreases. It is in this sense that information can be said to be consumed as a resource.

4.2.2. Sustainable shipping

Literature on sustainable shipping has focused on the benefits of sustainable shipping for performance, under the above-mentioned triple bottom approach of economic, environmental, and social value (Lirn *et al.*, 2014, Shin and Thai, 2016). Recent studies have analysed how sustainable shipping should be achieved by maritime firms, identifying a set of critical factors and resources for sustainable shipping management (SSM) (Yuen *et al.*, 2019; Tran *et al.*, 2020).

The theoretical lenses generally used to analyse SSM are the resource-based view (RBV) from strategic management, the relational view (RV) and the knowledge-based view (KBV). In line with these approaches, intra-firm resources, inter-firm resources, and organizational learning, are identified as drivers of sustainable shipping (Yuen *et al.*, 2019). The RV, in particular, focuses on specific elements of intra-firm interactions that contribute to sustainability: contractual governance, interfirm relationship management, information sharing, and complementary resources and capabilities.

This "inter-firm" element —as opposed to the "intra-firm" aspect focused by the RBV— is gaining ground as the key basis for sustainable shipping. While a firm's internal resources and management directly contribute to sustainable shipping practices, it is at the inter-firm network level that sustainability is (or failed to be) properly achieved. Planning and decision making at the strategic, tactical and operational levels is required for greener shipping (Lu *et al.*, 2016), entailing in turn joint decision making between shipping actors, e.g.: liner shipping companies and port operators (Meng and

Wang, 2014). Furthermore, external sustainable collaboration at the inter-firm network level is positively correlated with intra-firm sustainable management and performance (Yuen *et al.*, 2019; Wu *et al.*, 2020).

4.2.3. Sustainable business models

The theoretical construct of a sustainable business model (SBM) has emerged in the last years as an offspring of the literature on business model innovation and sustainability. Some scholars consider research on SBM as a field in its own right, calling for an integrative research agenda (Lüdeke-Freund *et al.*, 2017). One of the central tenets behind the construct of SBM is derived from the sociological concept of "embeddedness" (Granovetter, 1985). It is realised that business models' basic elements (value creation, value delivery and value appropriation) are embedded in wider economic, environmental and social contexts (Upward and Jones, 2016). This embeddedness is reflected in the search for business models that are more concerned with environmental and societal well-being, and the surge of new theoretical constructs related to sustainability.

One of these emerging constructs is the notion of a "circular economy". Defined as a *'regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops'* (Geissdoerfer *et al.*, 2017, 766), the concept has gained notability in research and policy discussions, most prominently in China (Yuan *et al.*, 2006; Sarkis and Zhu, 2008) and the European Union (European Commission, 2015). The core idea is that a value chain should strive for circularity, where value aggregating processes do not follow a linear path of make-use-dispose, but instead a circular cycle where outputs can be turned into inputs for further processes. More specifically, the ReSOLVE model deconstructs circularity into 6 strategies: regenerate, share, optimise, loop, virtualise, and exchange (Ellen MacArthur

Foundation, 2015). Circularity, therefore, is a core building block of a sustainable business model.

Another business block of an SBM has to do with the "coordination" and "inter-firm" perspective based on the above-mentioned relational view. It is understood that true sustainable development is only possible through collaborative actions between actors and organizations at the network level, rather than at the individual firm level. Gallo *et al.* (2018) thus propose the construct of an associative sustainable business model as a sub-category of SBM, defining it as *'those business models deeply grounded in associative behaviours and partnerships to create value in the triple bottom line'* (Gallo *et al.*, 2018, p. 906).

4.2.4. Distributed ledger technology

Distributed ledger technology (DLT), most commonly known as blockchain technology, has caught the attention of businesses, governments and academics alike. It has generated massive expectations, many of them based on misunderstandings on what the technology is really about. Nonetheless, a second "slope of enlightenment" (to use the terminology of the Gartner cycle), where the true potential of DLT will manifest beyond the cryptocurrency frenzy, is predicted to be around the corner (Kietzmann and Archer-Brown, 2019).

At its core, DLT is a distributed database controlled by multiple nodes on a network, where certain events are registered in such a way that they cannot be modified or tampered with, and where any new event most be congruent with the last state of the system (Drescher, 2017). Bitcoin, the original DLT's use case, provides a good practical example of this: if the state of the Bitcoin ledger at time t^0 is that public key A has 100 BTC and public key B has 50 BTC, an event that modifies the system such that at time t^1 A has 50 BTC and B has 100 BTC is valid, while an event where A would have 80 BTC and B also have 80 BTC is not.

This functionality is not limited to registering crypto-currency transactions, but allows for the automatic execution of pre-defined processes in the form of smart contracts (SCon). SCon have been defined as automatable and enforceable agreements (Clack, 2018; Cummins and Clack, 2022), into which business logic or heuristic can be embedded. Thus, standardized business processes, even if they involve several untrusting parties, could be automated and more efficiently executed (Weber *et al.*, 2016).

The business impact of DLT is expected to span several industries, but most specially finance (Guo and Liang, 2016) and supply chain (Dujak and Sajter, 2019). In the specific context of maritime shipping, DLT is expected to streamline processes that are currently delayed due to paperwork problems, such as container movements, custom clearance, reducing document forges and fraud, as well as enabling tracking and tracing systems (Yang, 2019).

The technology has also been hailed as a sustainability enabler. Kouhizadeh *et al.* (2019) consider that DLT contributes to the circular economy by enhancing resource regeneration and closed loop processes. Moreover, due to its reliability and immutability, DLT would substantially increase transparency, traceability and security along the supply chain, allowing to confirm and verify that processes conform to sustainability standards (Saberi *et al.*, 2019).

4.3. Research Method

This study follows the exploratory research methodology through a case study. Both exploratory research and case studies have been considered appropriate for the analysis of contemporary phenomena, where empirical data from which to derive statistical inferences is not available (Yin, 2009; Sreejesh *et al.*, 2014). Moreover, the research follows the critical realism approach, which sustains that there is an external, causally driven reality, independent of our empirical perceptions; not to be reduced neither to the observable or measurable (positivism), nor to the outcome of socially constructed meanings (interpretivism). Critical realism provides a sound epistemological basis for case studies in general (Easton, 2010), and for information systems research in particular (Mingers *et al.*, 2013).

The subject of the case study is TradeLens, a DLT-based information infrastructure platform for the shipping industry. The choice of TradeLens was based on the fact that, in contrast with other blockchain related initiatives in shipping, it is already a functioning platform capturing real-life data.

Given the exploratory nature of the research, and its early stage, data gathering is limited to documentary sources. The first source is provided by a previous case study about TradeLens, conducted by Jensen *et al.* (2019). This case study is particularly relevant, as one of the authors, working under an industrial PhD framework, was able to immerse himself for several years into the conception and development of TradeLens, gaining first-hand experience on the discussions and perspectives that led to the platform in its current form. The second source is TradeLens Documentation, published at its website (TradeLens, 2021). This comprises detailed descriptions of the platform's functionality, business model, architecture, and technological basis. A final source was an interview with an IBM global trade business development executive about TradeLens, conducted by a website dedicated to blockchain news and knowledge (Unblocked Events, 2019).

The data gathered about the case study subject is discussed in Section 4.6., as a way of evaluating the propositions that build the conceptual model presented in Section 4.4. The evaluation is done through content analysis, a technique for analysing text-based sources, with the objective of providing new insights, increase a researcher's understanding of particular phenomena, or inform practical actions (Krippendorff, 2019; Weber, 1990). Each of the propositions presented is evaluated against a scale with four possible scores: not grounded (-), lowly grounded (+), moderately grounded (++), and highly grounded (+++). It is important to point out that, at this early stage of the research, the evaluation is preliminary and does not intend to derive definite conclusions, but rather to increase the understanding of the subject of study and provide insights for a subsequent research stage. Moreover, while it would be desirable to compare the case of TradeLens with other DLT solutions in the shipping industry, the truth is that TradeLens is currently the only applied solution that is properly operational (Quarmby, 2021).

4.4. Conceptual model

In line with the exploratory nature of this research, this section presents a series of theoretical explorations conducing to propositions, and the depiction of a conceptual model based on them. This conceptual model offers a theoretical answer to the research question, and provides a basis to discuss the results of the case study.

4.4.1. Information flows and circularity

Integrating the view of information as a resource and the concept of circularity, prompts to enquiry in which sense, if any, could information flows be said to be circular. The following analysis explores the issue in the context of supply chain and shipping processes.

The notion of circularity, as observed in the theoretical background, rests on the idea of resource processing that does not follow the linear path of make-use-dispose, but rather creates a loop where the output of a value aggregating process can be re-used as the input of other value aggregating processes.

Information, as a resource, can be the input or the output/by-product of business processes. The construct 'business process' is to be understood in terms of its physical, financial and informational dimensions. Thus, the delivery of a container by a truck is a physical business process that generates GPS data as a by-product. This by-product data can be then transformed, through data analytics, into information which would be the input for business decisions about optimal times for port picking-up scheduling (Wasesa *et al.*, 2017). In the same way, the request for a transportation service by a shipper is a business process that generates information about transportation demand as a by-product, which in turn can be the resource for a decision regarding capacity allocation and transport mode use by a logistic operator (Hofman, 2016). Whether as a by-product/output or as resource/input, information flows between actors in supply-chain and shipping processes, as shown in Figure 4.1.

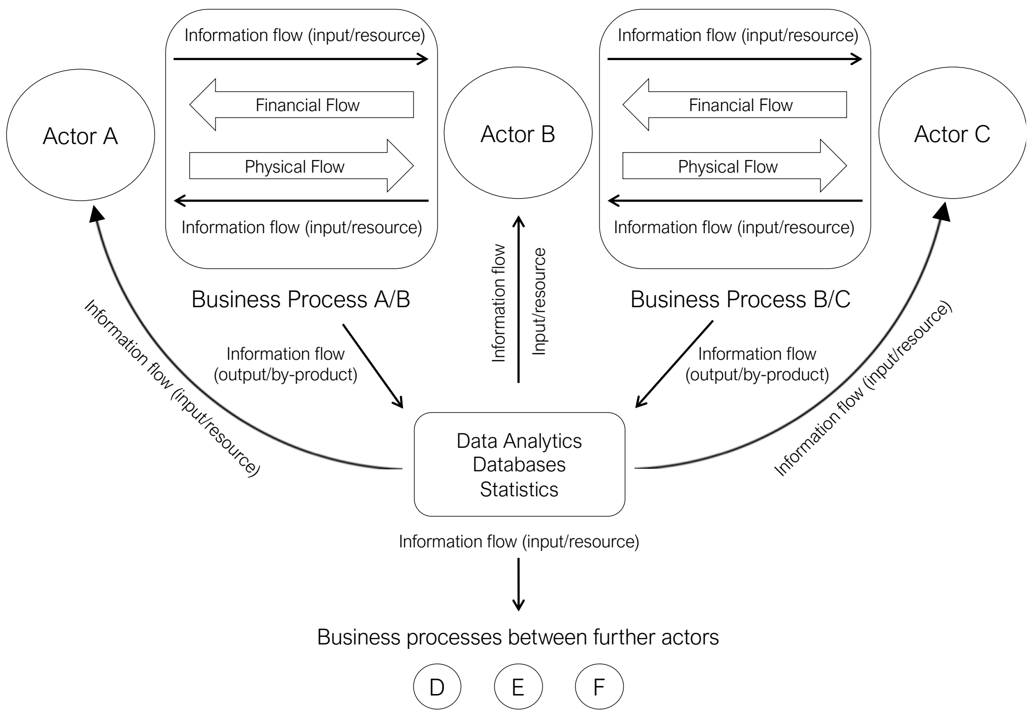

Figure 4-1. *Information as input/output of business processes*

When information that is generated as an output of a business process between *A* and *B* can be reused as an input of a successive (or parallel) business process between *B* and *C*, then information as a resource can be said to follow a circular path. In the same way, information/data outputs that are gathered into a database platform, can be acted upon and become the input of business processes between actors not involved in the originating ones. Such a path generates new value from information that had been previously consumed or generated as an output by the original actors.

For information flows to follow the circular path so described, information sharing is an essential requirement. A data infrastructure that facilitates information sharing would therefore enhance information circularities. This prompts to question whether DLT could be such a data infrastructure, and how would that impact sustainability.

4.4.2. Conceptual model propositions

The key functionality of a DLT database, whether an open (permissionless) or restricted (permissioned) one, is that it provides a single source of truth for multiple actors in a business network. As parties interact, data and information can be registered in a distributed ledger, as long as it can be represented in code. The ledger, in turn, can be used and acted upon as an input source by any actor with access rights, regardless of its involvement in the interaction that generated it in the first place. A DLT platform, therefore, constitutes a transparent and reliable depository of output information from business processes, and a source of input information for new ones. This double role undergirds circular information flows among the parties in a network, becoming especially valuable for supply-chain and shipping, where multiple parties can use the same information as input for their decisions.

The first proposition of the conceptual model is thus expressed in the following way:

> ***P_1:*** *DLT enhances information resource circularity by providing a depository of output information from business processes, and a source of input information for new business processes.*

To some degree, in all industries, decision making has to be taken in coordination with other actors. In the supply chain and shipping industry, however, inter-firm coordination acquires a more prominent role as a basis of efficiency. This is due to the multitude of actors that take part in a single process (e.g. the transportation of a containerized cargo), and the cause-effect relations between steps in the process. Interfirm collaboration in the form of information sharing, constitutes in this manner an essential element of the value creation and value delivery dimensions of firms business models. Moreover, collaboration and associative behaviours between firms require that information inputs are reliable, secure, and accessible to all the parties.

DLT provides a secure and reliable database that serves as a unique input for coordination decisions, guaranteeing at the same time that all the parties involved in the collaborative action have access to it. Furthermore, because business logic can be embedded into DLT-based smart contracts (e.g. as pre-defined workflows), parties can automate at least part of these decisions or processes. The second proposition can thus be expressed as follows:

> ***P₂*:** *DLT positively impacts inter-firm collaboration and associative behaviours.*

As observed by the literature above referred, both circularity and associative behaviours constitute elements that underpin sustainable value creation, delivery and appropriation. In the case of information as a resource, information circularity and information sharing (which is in itself an associative behaviour) drive the adoption of sustainable shipping business models by increasing a coordinated creation, delivery and appropriation of value extracted from information as an input. Propositions 3 and 4 express that functionality:

> ***P₃*:** *Information circularity drives the adoption of sustainable shipping business models by enhancing coordinated value creation, delivery and appropriation.*

***P*$_4$:** *Information sharing, as an associative behaviour, drives the adoption of sustainable shipping business models by enhancing coordinated value creation, delivery and appropriation.*

Finally, the "inter-firm" dimension of sustainable shipping management observed through the theoretical lenses provided by the relational view (RV), as a basis for sustainable shipping, benefits from SBM that are based on information circularities and information sharing. In plainer terms, sustainable shipping practices, like planning and operations that strive for efficient physical flows with the lowest environmental footprint, find a solid basis in sustainable business models where information loops and is shared at the inter-firm level. The fifth proposition is thus stated in the following way:

***P*$_5$:** *A sustainable shipping business model based in information circularity and associative behaviours, provides a solid basis for sustainable shipping practices.*

4.4.3. Conceptual model depiction

Figure 4-2 portrays the conceptual model expressed in the above stated propositions. The model depicts the influence of DLT on information circularity and associative behaviours, which in turn constitute building blocks of sustainable shipping business models. Finally, a sustainable business model is a solid basis for sustainable shipping practices.

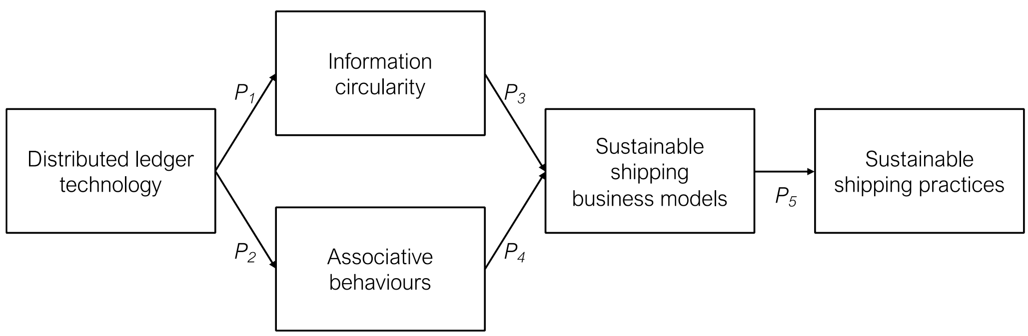

Figure 4-2. *Conceptual model*

4.5. Case Study: TradeLens

TradeLens (TL) is an information infrastructure platform developed by a joint venture between IBM and Maersk, formally launched on December 11, 2018 as a Maersk's subsidiary, with IBM as technology supplier (Jensen *et al.*, 2019). During both its development and operational phases, TL has caught considerable attention from pundits among the shipping and technology industries, as one of the first few real-economy use cases of blockchain. At the time of this writing, the platform claims to have more than 2.5 billion shipping events tracked, close to 24 million documents published, and more than 48 million containers processed (TradeLens, 2021). While blockchain constitutes a core component of TL's technology basis, it is not its unique or more important one (cloud computing is arguably the central element in the platform's architecture). However, the role that DLT (blockchain) plays in the overall system's functionality, visualised in conjunction with TL's architecture and business model, provides an insightful example of how DLT might contribute to sustainable business models for the shipping industry and global trade. This section, therefore, presents an exploratory case study into TL as a way of analysing the conceptual model in Section 4.4. against a real-life use case.

As Jensen *et al.* (2019) observe, TL's value proposition evolved from two initiatives: the information pipeline initiative and the paperless trade initiative. In order to break down information silos between global shipping actors (shippers, carriers, 3PLs, custom and port authorities, etc.), TL provides an infrastructure platform where information can be exchanged in a secure and transparent way. This is the main value provided by the information pipeline initiative. The paperless trade initiative, on the other hand, addresses the inefficiency problem generated by paper documents. Despite considerable digitisation of industries like media, retail, or travel/tourism, the shipping industry continues to rely on physical documents (BLs, packing lists, etc.); a circumstance that generates information flow delays which, in turn, affect physical and financial flows. To address these inefficiencies, TL aims to standardise and digitise trade related documents, enabling relevant supply chain actors to exchange and access them through a platform that guarantees traceability and immutability, thanks to blockchain technology.

The architecture of TL reflects a business model where collaboration and open innovation are at its core. The general structure is divided into 3 components: ecosystem, platform, and marketplace. The ecosystem comprises all the global supply chain actors that interact through the platform. The platform is where information and documents flow between the ecosystem actors. And the marketplace, built on top of the platform, allows applications to be developed by third parties, thus fostering open innovation and value co-creation. Figure 4-3 shows TL's general architecture.

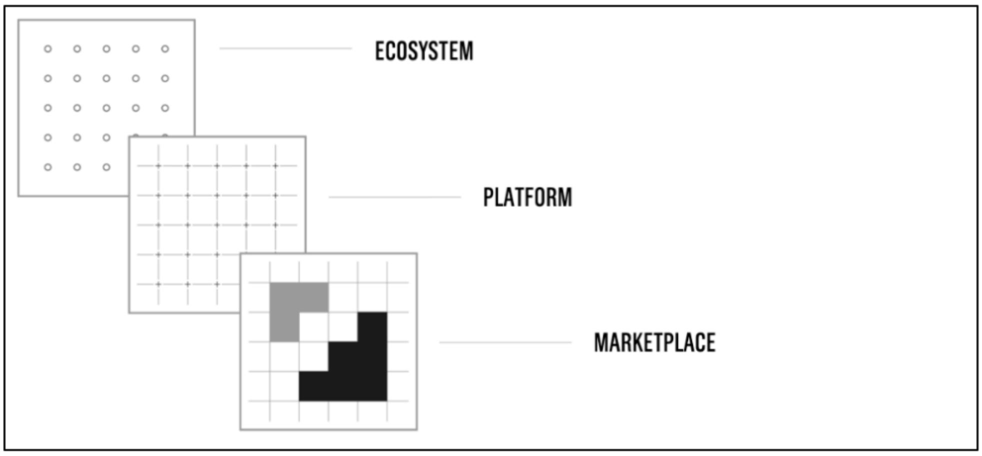

Figure 4-3. *TradeLens General Architecture*
Source: TradeLens (2021)

The platform has a layered structure where a blockchain network lies at the bottom, supporting the platform services (which are cloud-based) and the platform API. Shipping actors access the platform (and interact with each other) through APIs, through TL's proprietary application (TradeLens Core) or through third party apps. Information is stored at the platform in different persistence layers like object storage, document databases, relational databases, or the DLT-based database provided by Hyperledger Fabric. Which layer supports the information depends on the latter's type and how it is accessed (TradeLens, 2021). Figure 4-4 shows the Platform's architecture.

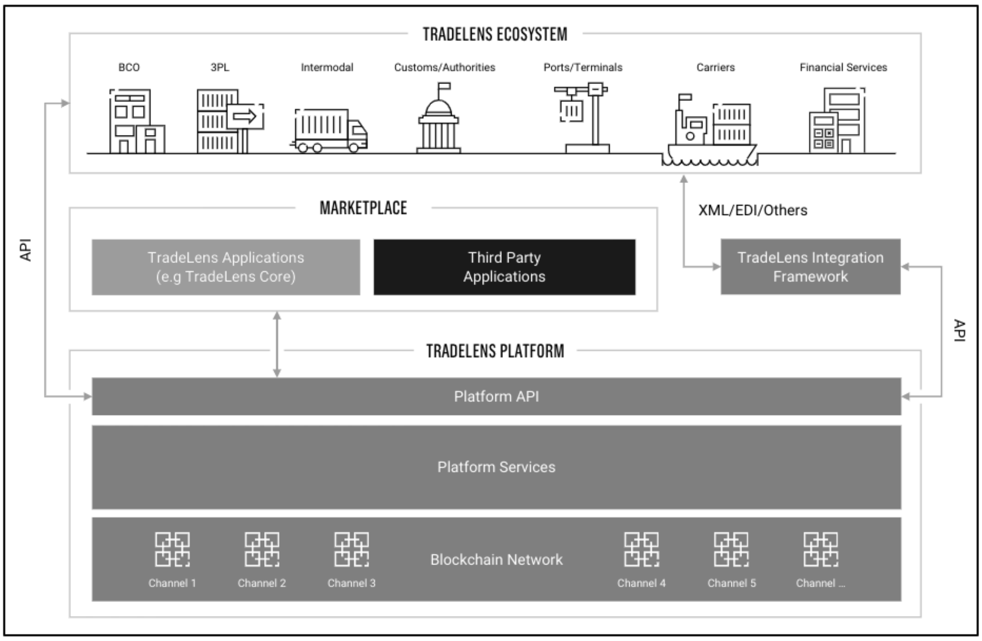

Figure 4-4. *TradeLens Platform Architecture*
Source: TradeLens (2021)

A central element of TL's functionality is the *event* model (related with the information pipeline initiative). More than 120 shipping events are supported, under a data model with two classes: consignment events and transport equipment events. Consignment events relate to cargo shipments, while transport equipment ones relate to containers, reflecting the two levels of containerized information flows, container level and cargo level (Van Baalen *et al.*, 2009). A consignment can involve multiple transport equipment (containers) or vice versa. An event represents a significant logistic milestone that has to occur in order for the cargo to get from origin to destination, including both the cargo level (e.g. booking) or transport equipment (e.g. load, departure, arrival, etc.). Events can involve a document. Here TL provides another classification (related with the paperless trade initiative) regarding two document types: structured and unstructured. Structured documents are generated from a JSON schema (template), while unstructured documents are based on pdf or image files. Unstructured documents might be a representation of a paper document or not.

The accessibility of information about events and/or documents is defined by the platform through a permission matrix. The *type* of data that can be accessed will depend on the role played by an actor in the overall shipping process. Thus, only actors involved in a specific shipment can have access to data over that shipment, and the type of data they can access depends on the role they play. For instance, an *export* customs broker has access to data about booking confirmation and shipping instructions, while an *import* customs broker has not; and the latter has access to data on arrival order and delivery notice, while the former has not. The permission matrix aims to ensure that *'no commercially sensitive information is available to competitors or other unauthorized parties'* (TradeLens, 2021).

What role does blockchain play in TL's overall system? As stated in TradeLens Documentation, *'blockchain is used to address trust challenges, provide a shared view of the truth, and provide an immutable audit trail'* (TradeLens, 2021); or, as expressed by the Head of Business Development for IBM Blockchain Global Trade Applications, Richard Stockley, in its interview: *'a common view of the most up-to-date information, as well as an auditable record of the changes that have occurred. This is where blockchain shines'* (Unblocked Events, 2019). Thus, data registered at the blockchain layer is tamper proof, verifiable, recoverable and auditable. The blockchain component is based on IBM Blockchain Platform, in turn based on Hyperledger Fabric. The latter has been described as a modular and extensible distributed operating system for permissioned blockchains (Androulaki *et al.*, 2018). One of the key characteristics of Fabric is that it partitions the blockchain network into channels that comprise a determined set of nodes, with consensus taking place inside the channel and not (generally) across channels. This feature is reflected in TL's blockchain layer, where information on events is accessible only by peers (or "Trust Anchors") included in a particular channel, which generally corresponds to a specific carrier. As mentioned, not all data is registered at the blockchain layer, but only that which creates trust challenges and requires auditability. All other data resides on persistence layers like document and relational databases, under a traditional cloud-based system.

Even though TL's documentation does not expressly mention the term "smart contract", it dedicates a section to what denominates "Actionable Doc Flows". These are pre-defined processes following a specific sequence of steps, where some of them are automatically handled by the TradeLens platform. Currently, only one Actionable Doc Flow is available (in Beta version): a doc flow from Shipping Instructions to a SeaWay bill of lading. Figure 4-5 presents a simplified version of it.

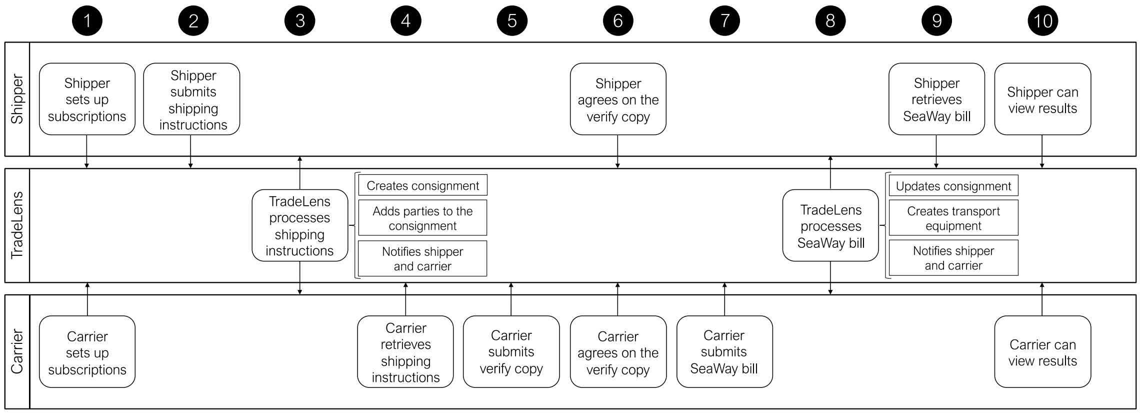

Figure 4-5. *Actionable Doc Flow*

Steps 3 and 8 are automatically processed by TL through code execution. In this sense, it could be argued that an Actionable Doc Flow is a (rather basic) smart contract between the shipper and the carrier, using TL as a coordinating tool.

In the end, the fundamental contribution made by blockchain to TL's platform and overall ecosystem is to provide a secure basis for information flows among shipping actors, enhancing trust between them. These information flows concern pre-defined shipping events upon which logistic decisions are to be taken in relation to a shipping process. The result is (or so it is claimed) a streamlined, transparent and secure global supply chain (Van Kralingen, 2020).

4.6. Discussion

The content analysis was performed over the documentary sources about TradeLens, in order to evaluate the coherence between the conceptual model and the findings of the use case. The following discussion, therefore, assess to which extent the conceptual model's propositions are reflected in TradeLens's structure, architecture, design and vision. Because the conceptual model is developed as an initial theoretical answer to the research question, its assessment against the use case constitutes the way in which this exploratory study addresses the research question.

The core functionality of TL is to facilitate information flows between the actors involved in the transportation of a cargo, from origin to destiny. When assessing the role played by blockchain technology, TL's documentation expressly asserts that the blockchain layer aims to address trust issues, provide a shared view of the truth as well as an immutable audit trail. Moreover, the data registered into the blockchain layer is structured in a series of pre-defined events that represent steps in the transport process. Information about these events is accessible by the relevant actors, according to the role they fulfil in the transportation network. Every event, as a logistical milestone, generates data that it is usually relevant for future events. This is so because many events are causally dependent on precedent ones.

To use the terminology presented in the conceptual model: the execution of a specific event in the logistic chain utilizes information about previous events as one of its inputs, and generates as an output information that, in turn, is the input of successive events. Because this information is traditionally dispersed and siloed between the many logistic actors, and is also paper-based for the most part, the possibility of it being re-used by actors other than those directly involved in the event that generates it is limited.

By registering events data into an immutable and shared source of truth, by means of a DLT (blockchain) database, TL extends the utilization of information on certain events as a resource or input for successive events by all the parties for whom it might be relevant. Thus, the positive impact of DLT technology on information circularities (P_1) is clearly reflected in TL's design and vision. Indeed, TL's blockchain based database works as both a depository and a source of information that is input and/or output of logistic events.

It is important to observe that this circularity does not take place exclusively at the blockchain layer; indeed, nothing precludes for some information residing at TL's Platform Service layer to function as input for decision making by different actors. Also, information about events registered at the blockchain layer can function as input for decision making not directly related with specific logistic events (e.g. resource planning or the choice of a specific transportation mode or company).

By providing a single depository and source of event's information, as well as automating (up to a point) certain business processes between actors involved in the transportation chain, TL enhances the collaboration and coordination between them. While the first example of a smart contract-based coordination (the Actionable Doc Flows) is still basic, the availability of structured information registered at the DLT layer (and also at the Platform Service layer) provides a basis for more sophisticated coordination.

On the other hand, TL's architecture, where an ecosystem of apps is to be built on top of the Platform, including third-party applications, is a catalyst for collaboration among shipping actors. Interaction with the Platform Service layer by means of these apps is done through APIs. The key role played by DLT in this case is to feed trusted information across all the layers, so that, for instance, a third-party app may provide functionalities that use information stored at the blockchain layer. In the end, by enabling the digitalisation and automation of cross-organizational shipping processes, TL positively impacts collaboration and associative behaviours between shipping actors (P_2).

The first two propositions aim to capture a direct relation between DLT technology and two phenomena: information circularity and associative behaviours. TL's technical profile (architecture, structure, design) can thus serve as a basis for assessing their groundedness. In contrast, the following ones (P_3 and P_4), express a relation between the former two phenomena and a mostly theoretical construct: a sustainable business model (SBM); and the final proposition (P_5) states a relation between two theoretical constructs, SBM and sustainable shipping. For this reason, the content analysis regarding the final 3 propositions focuses on statements about TL's vision and purpose, rather than its technical aspects.

In TL's website, an introductory video is available, where it is stated that TL enables transparency, efficiency and collaboration across the global supply-chain. The inter-firm cross collaboration element is stressed in several materials available on the website. In particular, the Solution Brief highlights, as TL's main objectives, the following ones: connecting the shipping ecosystem, drive true information sharing, fostering collaboration and trust, and spurring innovation (TradeLens, 2021).

Though it is not expressly mentioned, the corollary of these objectives is the emergence of new business models, were value creation, delivery and appropriation take place increasingly at the inter-firm level, something that will require a change of paradigms and mentality in the shipping industry. IBM's Richard Stockley puts it this way: *'The biggest inhibitors to the full realisation of technology generally –and blockchain specifically– is our own reptilian brains and the organisational structures we are anchored to. The challenge is to see that platforms allow a new way for enterprises to collaborate and differentiate'* (Unblocked Events, 2019).

The language used by TradeLens points toward new business models, though the sustainability element is barely mentioned. Nonetheless, the stress on two key aspects of SBM (information sharing and cross-collaboration) is clear, as well as the role played by DLT. Propositions P_3 and P_4 are thus moderately grounded in TL's vision and objectives.

P_5 expresses a positive relationship between SBM and sustainable shipping, as SBM would provide a solid basis for sustainable shipping practices. Among those practices, information sharing, sound contractual governances, interfirm relationship management, and the development of complementary resources and capabilities, are identified (Yuen *et al.*, 2019).

TradeLens's vision to provide a platform where actors in the shipping ecosystem can access and share information in a secure and transparent way, as well as develop cooperative behaviours, would constitute, if successfully adopted by the industry, a solid basis for sustainable shipping practices. Information sharing in itself would boost sustainability, for instance, when transport disruptions take place, because corrective inter-firm actions can be taken more quickly, saving resources and decreasing environmental footprint. Moreover, having a single source of information supports the development of complementary resources and capabilities. Finally, the possibility of developing pre-defined process flows like the Actionable Doc Flows (whether or not are those considered a true smart contract), would enhance interfirm relationship management and even provide a basis for contractual governance.

These practices, in turn, are supported by two building blocks of an SBM, reflected in TL: information resource circularity and associative behaviours. P_5 can thus be at least moderately grounded by TL case study.

Based on the foregoing assessment, Table 4-1 summarizes the result of the conceptual model propositions' evaluation.

Table 4-1. *Conceptual model propositions' evaluation results*

Nº	Proposition	Evaluation
P_1	DLT enhances information resource circularity by providing a depository of output information from business processes, and a source of input information for new business processes.	+ + +
P_2	DLT positively impacts inter-firm collaboration and associative behaviours.	+ + +
P_3	Information circularity drives the adoption of sustainable shipping business models by enhancing coordinated value creation, delivery and appropriation.	+ +
P_4	Information sharing, as an associative behaviour, drives the adoption of sustainable shipping business models by enhancing coordinated value creation, delivery and appropriation.	+ +
P_5	A sustainable shipping business model based in information circularity and associative behaviours, provides a solid basis for sustainable shipping practices.	+ +

4.7. Conclusion

This chapter's research question enquires what impact might distributed ledger technology (DLT) have on the adoption of sustainable business models and practices in the shipping industry. The approach utilized in this study to provide an (initial) answer to this question has been the following: first, building a conceptual model based on an interdisciplinary literature review, including information resource management, sustainable shipping, sustainable business models and DLT; second, conducting a case study on a real-life, operating information platform for the shipping industry that uses DLT as part of its technology stack; and third, assessing the propositions presented in the conceptual model in the light of the findings of the case study. This approach is proper of other exploratory case studies conducted in the context of maritime and supply chain industries, and PhD dissertations (Hollen, 2015; Wasesa, 2017).

As discussed in the previous section, the answer that can be provided is that the adoption of DLT inside the shipping industry can have a positive impact on sustainable business models and practices in two ways: first, by enhancing information circularity, and second, by facilitating inter-firm collaboration and associative behaviours among shipping players. This preliminary conclusion is, nonetheless, subject to the limitations proper of the exploratory nature of the study, as well as the novelty of the subject of research.

4.7.1. Theoretical contributions and managerial implications

This chapter presents a conceptual model that sketches the impact that distributed ledger technology (DLT) can have on sustainable shipping business models and practices. The model's theoretical base is grounded on the conception of information as a resource, provided by Information Resource Management (IRM) theory. From this foundation, the chapter presents the construct of information circularity, whereby information that is generated as output or by-product of business processes, is then re-utilised as a resource for subsequent or parallel business processes. This theoretical construct contributes to the IRM literature, as well as sustainability research, specifically on the concept of circular economies.

The research extends previous literature on blockchain technology and its impact on the circular economy, associative business models, and inter-firm coordination in general. It does so under the context of maritime shipping, extending both maritime literature and blockchain technology research. Moreover, the chapter presents a case study on a real-life deployment of blockchain technology in the context of maritime shipping. The theoretical lenses provided by IRM bring a new perspective about the functionality of DLT/blockchain. If data and information are treated as resources for business processes, it is more clearly understood how blockchain bolsters new business models by enhancing information flows between actors engaged in complementary processes along the supply chain.

The theoretical perspective presented, contrasted with the exploratory case study on TradeLens, offers a series of managerial implications, both for maritime shipping firms and regulatory bodies. Given the surge of DLT-based information infrastructures like TradeLens, shipping firms need to carefully analyse how they will take advantage of the new information flow dynamics that these platforms shall be enabling. Firms that are more effective in identifying and taking advantage of information flows interdependencies with the help of DLT-based tools, will gain competitive advantages and improve their sustainability performance ratings. On the other hand, the construct of information resource circularity offers a novel perspective to government and other regulatory bodies, which may enrich their discussions on sustainability policies, measures, standards and incentives. Moreover, they might gain new insights on the beneficial role that blockchain technology can play for circular economies and sustainability in the specific area of maritime shipping.

4.7.2. Limitations and future research

Finally, it is important to point out some limitations of this chapter, as well as potential avenues for future research. Two main limitations constrict the validity and generalisability of this research: one deriving from the research itself and the other from the subject of study. The case study research is currently in an early stage, where data sources are limited to documented material; furthermore, the content analysis assessment carries with it a significant dose of subjectivity.

The subject of the case study, DLT in the shipping industry, is still novel, with only a single real-life use case. This circumstance limits data triangulation with other use cases. However, as new blockchain based platforms become operational —like the Singapore-based Global eTrade Services (GeTS)—, the subject will broaden significantly, allowing new research opportunities, and the conduction of multi-case studies (Benbasat *et al.*, 1987).

Among these potential research avenues, cross-sectional and longitudinal case studies on different shipping information infrastructures, whether DLT-based or not, can be conducted. Issues like the impact of governance structure on adoption, or the inclusion of sustainability issues in their core mission can be analysed. On a more concrete level, specific input-output shipping information interdependencies, their impact on sustainability, and the utility of digital tools as sustainability performance enhancers, can be researched in more depth.

Chapter 5.
Digital transformation and trade finance*

5.1. Introduction

Trade finance —and in particular its traditional instrument, the letter of credit (LC)— aims to protect exporters and importers alike from the risk of non-completion[1]. Without an LC, many international trade transactions would be too risky to undertake. Lack of access to trade finance, therefore, translates into lost trade opportunities (Ahn *et al.*, 2011).

The importance of trade finance for international trade and economic development has gained increased attention in the last few years. International organizations have observed the persistence of a huge gap between supply and demand of trade finance —currently estimated at US$ 1.5 trillion— (ADB, 2017; WTO, 2016), with negative consequences for trade, most particularly for small and medium enterprises (SMEs), and for emerging and frontier economies (AfDB, 2017). The crisis generated by the COVID-19 pandemic, which disrupted supply chains, only made things worse, and new estimations project a trade finance gap of US$ 2.5 trillion by 2025 (Auboin, 2021).

Causes behind this huge gap are various and complex. The main reasons usually mentioned by practitioners are the negative impact of regulations, insufficient liquidity in local banks, high transaction costs/ low profitability, and

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* This chapter is based on a conference paper entitled "A DeFi-based model for maritime trade finance", which was presented at the 8th International Conference on Maritime Transport (MT 2020), held (online) in Barcelona, on September 17-18, 2020. A slightly modified version of the paper was published as the following journal article: Henríquez, R., Martínez de Osés, F. X., Martínez Marín, J. E., and Tomás, C. (2021) 'Blockchain-based innovation in post-COVID-19 trade finance'. *International Journal of Finance, Economics and Trade*, **4** (2), 84-94. DOI: 10.19070/2643-038X-190011

[1] The risk of non-completion is based on the probability that either the importer does not pay for the merchandise, or the exporter does not ship it to the importer.

lack of trust issues (e.g. LC applicant insufficient creditworthiness, low country reputation, difficult contract enforcement, etc.) (ICC, 2017). Among the proposed answers to this problem are changes in banking regulations and compliance (making them risk based), and expansion of credit supply through multilateral banks and export credit agencies (ECA) (ICC, 2018). In parallel, during the last decade, there has been considerable technological developments in the financial industry, with a surge (and success) of so-called "fintech firms". Most particularly, blockchain-based decentralised finance (DeFi) has attracted attention as a non-conventional way of coping with financial needs.

Against this background it is thus valid to ask whether DeFi could provide an alternative solution for the trade finance gap (WEF, 2018, 2020); and if so, how could such a solution be designed and implemented. The research question that this chapter addresses is therefore expressed as follows:

> ***RQ$_4$**: How to design a DeFi business model that would address some of the causes behind the trade finance gap?*

Section 5.2. presents the theoretical background on the trade finance problematic, with particular mention of the context created by the COVID-19 pandemic, as well as on the topic of financial intermediation and business model innovation. Section 5.3. explains the research methodology. Section 5.4. discusses decentralised finance, offering a new conceptual approach. Section 5.5. describes the business model for a decentralised, blockchain-based trade finance system. Section 5.6. offers an *ex-ante*, preliminary evaluation of the model. Finally, Section 5.7. presents conclusions, limitations and suggestions for future research.

5.2. Theoretical background

The trade finance gap problem and its potential answer in the form of DeFi can be approached from diverse theoretical perspectives: management science, legal studies, micro and macroeconomy, etc. This reflects its complex nature, with causes and consequences spanning several areas. In this section, we shall begin by referring to the reasons behind the gap, as exposed in policy discussions, including the post-COVID-19 context.

Afterwards, the problematic and its likely solution will be analysed against the conceptual background provided by the theories of financial intermediation and of business model innovation. In the process, we shall also approach the concept of decentralised finance (DeFi) from a new perspective.

5.2.1. Causes of the trade finance gap

Several causes for the persisting trade finance gap has been observed in policy discussions. These causes may be divided into supply-related (affecting the capacity of banks or other financiers to provide capital for transactions) or demand-related (referred to the importing and exporting firms that transact with each other). Table 5-1 classifies the causes along this division criteria. In some cases, however, the same cause can be considered both as supply and demand related. Each cause is treated under the light of policy discussions and academic literature.

Table 5-1. *Classification of trade finance gap causes*

Trade finance gap causes	Supply-related	Demand-related
Increased capital ratio requirements in banking regulations	X	
Regulatory due-diligence requirements	X	
Minimal non-bank capital	X	
High processing costs	X	X
Document verification problems	X	X
Insufficient knowledge about trade finance	X	X
Firm related high level of risk		X
Country related high level of risk		X
Insufficient size of transactions		X

5.2.1.1. *Supply-related causes*

In the wake of the 2008/9 financial crisis, and its negative repercussions in the following years (e.g.: the sovereign debt crisis in some European countries), financial regulations were stiffened (Etürk, 2016; Walker, 2011). Among several areas covered by new banking regulations, two main ones stand: capital requirements and due-diligence procedures.

The Dodd-Frank Act in US, the Regulation (EU) Nº 575/2013 in the EU, and the Third Basel Accord (Basel III) on a global stage, increased the capital requirements for banks. These measures, aimed at lowering excessive risk taking by financial institutions in the previous years, had the negative effect of lowering profitability and decreasing liquidity for trade finance, as observed repeatedly in policy discussions (AfDB, 2017; ICC, 2017, 2018).

Consequences of capital requirements regulation on the level of financial supply, have been extensively studied in the financial literature, particularly in the context of discussions about the relationship between banks' liquidity and their risk taking (Adrian and Shin, 2010; Berger *et al.*, 2016; Horvath *et al.*, 2014; Kahn *et al.*, 2017). More recently, a couple of ECB workpapers analyse the short-term effects of capital requirements on credit supply: Mendicino *et al.* (2019) observe that, in the short run, rising capital requirements may have contractionary effects on credit supply and economic activity (what they name "transitional costs"), even if they generate positive effects in the long run by reducing systemic risk taking. Likewise, Behn *et al.* (2019) find a material impact of capital requirements on the supply of loans, though the effect is moderated by bank's initial balance sheets, with banks that are closer to the minimum capital requirements been more likely to reduce lending. These constraining effects of higher capital requirements and limited bank liquidity have also been pointed out in the specific case of trade finance (Ahn *et al.*, 2011; Auboin, 2011; Auboin and Blengini, 2019).

Due-diligence regulatory requirements, particularly those related to "Know your customer" (KYC) and anti-money laundering (AML) have also been correlated with constraining credit supply, based on results from banks' surveys (Auboin and DiCaprio, 2017; ICC, 2017, 2018). A necessary balancing between financial integrity and financial inclusion, with a risk-based approach to KYC and AML has thus been proposed (Gelb, 2016; ICC, 2017, 2018).

Other supply-related causes for the trade finance gap have been mostly pointed out in policy reports (AfDB, 2017; ADB, 2017; ICC, 2017, 2018; WTO, 2016). These include an insufficient involvement of non-bank investors in the secondary market; high-processing costs, especially for document verification, due to the still mostly paper-based nature of letters of credit; and insufficient knowledge about trade finance by local banks in emerging and frontier economies[2].

High processing costs are related to both supply-side and demand-side considerations for trade finance. For banks, higher processing costs mean lower profitability of trade finance instruments overall, which makes them to limit their credit supply in favour of other, less complex financial assets.

5.2.1.2. Demand-related causes

Demand-related causes for the trade finance gap are those that originate in the importing and exporting firms that require trade finance for their transactions. These can be taken as the answer to the following two, more specific questions: 1) what motivates the rejection of letter of credit applications? and 2) what limits importers/exports to seek trade finance in the first place?

[2] In a survey conducted by the African Development Bank Group, 36% of respondents stated that insufficient familiarity with trade finance instruments by the bank staff was a reason for not increasing the supply of trade finance (AfDB, 2017; DiCaprio and Yao, 2017).

DiCaprio and Yao (2017) observe three types of drivers for trade finance rejections: country-related, firm-related, and bank-related. The country-related reasons include high political and economic risk, underdeveloped finance system, and low contract enforceability. Niepmann and Schmidt-Eisenlohr (2014, 2017) find that in countries with higher risk and lower contract enforceability, LCs are used more than documentary collections (DC).

Bank-related rejections are those that take place among bank's themselves, more specifically, between the exporter's (confirming) bank and the importer's (issuing) bank. This aspect is closely related with country risks and is manifest in the ongoing decrease of correspondent bank relationships, as global banks move to lower risk economies (Auboin, 2021; DiCaprio and Yao, 2017; ICC, 2017). This phenomenon, admittedly, is more related to the supply-side of trade finance, but it is grounded in the economic environment where the importing firm is located.

Firm-related reasons for trade finance rejection are mainly due to insufficient collateral and creditworthiness, reflecting information asymmetries issues that limit credit availability (Stiglitz and Weiss, 1981). This affects predominantly small and medium enterprises (SME), for which is then increasingly difficult to join global supply chain networks.

Besides actual rejections, the demand-side of the trade finance gap is also affected by the high processing costs of instruments like letters of credits (LC), which include a fixed cost component for document handling and screening. The practical implication is that LCs become economically viable only for transactions that surpass certain size threshold (Niepmann and Schmidt-Eisenlohr, 2014). This, again, primarily affects SMEs, which on average engage in lower size transactions than large corporations (WTO, 2016).

5.2.1.3. Post-COVID-19 pandemic context

From the very outset, the COVID-19 pandemic caused a serious disruption in supply chains and international trade. By the end of 2020, the OECD estimated a 10.9% contraction in global trade (OECD, 2021). Given the complexity, diversification and interconnectedness of global value chains, the unavailability of intermediate products had a domino-like effect, affecting the whole chain (Vidya and Prabheesh, 2020).

Apart from the general disruption of international trade, financial flows were severely affected (Sansa, 2020), and trade finance in particular (OECD, 2021). Both supply-related and demand-related sides were impacted. On the supply-side, there has been a generalized increase in risk perception and consequent decrease in credit appetite, with international banks "re-shoring" lending and focusing on "safer" customers (Auboin, 2021). On the demand-side, there has been an increase in applications to documentary credits, ECA guarantees and payment deferrals (Auboin, 2021; OECD, 2021); with evidence showing that trade flows backed by letters of credit or documentary collections showed no significant decline (Demir and Javorcik, 2020). In addition, the lockdown created operational challenges that affected processes like the transmission of trade finance related documents (Auboin, 2021). This especially affected countries where digitalization is low, like most of Africa (Nyantakyi and Drammeh, 2020).

The reaction to these challenges, however, has been considerably more effective than in the case of the 2008 financial crisis. In particular, liquidity and credit provision from government entities, multi-lateral banks and ECAs has been crucial in propping up supply (Auboin, 2021; Berne Union, 2020; OECD, 2021).

Despite some recovery, the way ahead for trade finance looks arduous, as the above-mentioned decrease in supply and increase in demand are expected to persist. Key international suppliers like BNP Paribas, Société Générale and ABN-AMRO have restricted or closed whole trade finance segments, without any clear answer as to how this gap will be filled in the short term. Besides, specific challenges have surged, like the need to finance the transportation and international distribution of vaccines (Auboin, 2021).

Among the measures proposed for the post-COVID era are more direct support from governments in the form of grants and loan guarantees, securitization of loans by central banks (Boissay *et al.*, 2020), further liquidity provision by ECAs (OECD, 2021), and promotion of non-traditional trade finance solutions like factoring and forfeiting in countries with significant gaps (Auboin, 2021).

5.2.2. Financial intermediation

The traditional role of banks is to act as financial intermediaries, taking deposits from individuals (households) and channelling them to economic agents requiring capital (firms). This role of banks has been justified by a theory of financial intermediation based on transaction costs (Scholes *et al.*, 1976), asymmetry of information (Brealey *et al.*, 1977; Andolfatto and Nosal, 2009), risk management and participation costs (Allen and Santomero, 1997, 2001).

This traditional role, however, has undergone important changes in the last three decades. First, as observed by Allen and Santomero (1997), banks have concentrated in risk management activities, and the decrease for their clients of what the authors denominate "participation costs", i.e., the cost of *'learning how the market works, the distribution of asset returns and how to monitor changes through time'* (p. 1481). In other words, the main value adding function performed by banks have been not to act as financial buffers between depositors and borrowers, but as risk managers and financial know-how providers.

Technological changes have also significantly affected the role performed by banks. During the last two decades, with the surge of electronic marketplaces, a disintermediation process has taken place (Chircu and Kauffman, 2001; Lima and Soares de Pinho, 2008; Nellis *et al.*, 2000; Pati and Shome, 2006). Some authors describe an intermediation/disintermediation/ reintermediation cycle (Chircu and Kauffman, 1999, 2000) where some traditional intermediaries, after being disenfranchised as a consequence of technological innovations, find new ways to compete by leveraging these innovations. Financial disintermediation has been noticed in several fields, notably P2P lending (Berger and Gleisner, 2009; Bruett, 2007) and virtual currencies (Pflaum and Hateley, 2014).

Following the "functional perspective" of the financial system (Merton, 1995; Allen and Santomero, 1997), these trends could be understood as a sort of financial intermediation *reengineering*. The same underlying functions are performed in different ways and by different players as technology and economic forces evolve, thus generating new business models.

5.2.3. Business model innovation

During the last decade, business model innovation has been defined and explained by different (and competing) paradigms and schools (Gassmann *et al.*, 2016). One of them, the *Activity System* school (aka IESE/Wharton school), defines a business model as a set of activities, resources and capabilities (held within the firm or across its boundaries), that allow a firm to create value and appropriate a share of it (Zott and Amit, 2007, 2010). Therefore, a modification in the distribution of these activities, resources and capabilities aimed to generate and appropriate economic value, would traduce into business model innovation.

From a different perspective, the *Recombination* school (aka St. Gallen school) understands a business model as a "recombination of patters" for answering four key questions about a business: *who* is the customer? *what* is the supplied value? *how* is this value created and distributed? and *why* is the business profitable? (Gassmann *et al.*, 2016). One of the core tenets of this school is that most of business models are built out of repetitive patterns, whose recombination amounts to business model innovation (BMI) (Frankenberger *et al.*, 2013). BMI should be, therefore, a problem-solving undertaking where a business uses existing knowledge and technologies to generate and distribute value in innovative ways.

* * *

Delving into the afore described theoretical background, this chapter has two main research objectives. First, to discuss and understand the concept of decentralised finance under the framework provided by the concepts of financial intermediation and business model innovation. And second, to design a model for a decentralised finance system that could provide a solution, if only partial, to the trade finance gap problematic, taking into account the context created by the COVID-19 pandemic. These objectives will be dealt with in sections 5.4. and 5.5., respectively. Previously, however, the research methodology is discussed in the following section.

5.3. Research methodology

5.3.1. Research paradigm

The present study follows the *Design Science Research* (DSR) paradigm, frequently used in the Information Systems discipline (March and Smith, 1995; Hevner *et al.*, 2004). The goal of DSR is twofold: solving a practical problem and generating theory, both through the creation of an IT *artifact* (Beck *et al.*, 2013).

The IT artifact itself can be a *construct*, *model*, *method* or *instantiation*, and its creation follows two general stages: *design/building* and *evaluation* (March and Smith, 1995; Hevner *et al.*, 2004). Though traditional DSR suggests a sequenced procedure (first design/build, then evaluate), recent literature has questioned this structure as too rigid. It is observed that evaluation can be parallel and intermingled with the design stage (Beck *et al.*, 2013; Venable *et al.*, 2016), as well as that several design/evaluation iterations should be performed as the artifact is developed.

DSR begins by identifying a problem to be solved: in this case, the trade finance gap. A potential answer to this problem (among many) is aimed at through the development of a *model* (a *business* model). The model is developed in line with the DeFi paradigm, closely related to distributed ledger technology (blockchain).

The second general stage of DSR is the evaluation of the proposed artifact. The evaluation needs to cover two aspects, which correspond to the twofold goal of DSR: whether the artifact is *useful* in addressing the perceived problem, and whether the creation of the artifact generates *new knowledge*.

A full evaluation of an artifact should include its instantiation, i.e., the functioning artifact operating in the real world. For the research here undertaken, a full evaluation would imply an assessment on whether an instantiation of the proposed model effectively addresses the reasons behind the trade finance gap. In other words, a full DSR evaluation would require for an actual artifact to be already in the market.

However, as literature on DSR has observed, the evaluation of the artifact is conducted through several iterations, which cover not only its final instantiation, but also its preliminary design/blueprint in terms of models. In this sense, a distinction is made between *ex-ante* and *ex-post* evaluations

(Sonnenberg and Vom Brocke, 2012; Venable *et al.*, 2016). *Ex-ante* evaluations are made over the artifact's model before it is instantiated.

Given that the objective of this chapter is to design and propose a new business model for trade finance, the assessment to be presented in Section 5.6. constitutes an *ex-ante* evaluation of the corresponding blueprint. It represents the first step in the DSR which should be completed when an actual instantiation of the model is developed and introduced in the market (as a new system, or even as a startup). At that final stage, an *ex-post* evaluation can be conducted.

5.3.2. Business modelling

As previously mentioned, the artifact to be presented in this chapter is a *model*; more specifically, a *business* model. According to Aversa *et al.* (2015), who follow the *Cognitive* school (aka Cass School), a business model is first and foremost a cognitive representation of a particular way in which value is created, delivered and captured; and business modelling is a set of cognitive actions that aim to articulate that representation (Baden-Fuller and Morgan, 2010; Gassmann *et al.*, 2016). As a representation, a business model then simplifies and abstracts the details of concrete, real-life businesses activities. It does so, however, with the intention of facilitating change, in the sense that it is easier and more efficient to manipulate a conceptual model than to blindly execute changes in business activities following a trial/error process. The conceptual changing processes proposed by the authors, and followed here, are expressed as 6 modular operators: splitting, substituting, augmenting, inverting, excluding and porting.

The modelling process to be followed has two basic stages. First, the traditional way of providing trade finance through an LC will be depicted. This depiction amounts to a general level representation of value creation, delivery and capture. Then, some of the modular operators proposed by Aversa *et al.*

(2015) will be applied to the traditional model, in order to design a recombined way of creating, delivering and capturing value. As shall be seen, these operators correspond with the different uses of the DeFi concept, as it is defined in the following section.

5.4. What is decentralised finance (DeFi)?

5.4.1. Past and current definitions

The term "decentralised finance" has been used with differing meanings in academic and policy discussions. For instance, it was associated with the concept of fiscal decentralization or "fiscal federalism" (Oates, 1994; Wibbels and Rodden, 2006), as well as with the spatial decentralisation of financial markets and how this might influence flows of capital to SMEs (Klagge and Martin, 2005). In more recent years, however, the expression gained a more specific meaning in the context of the blockchain revolution. At the beginning, most of the uses of the expression, including its associated abbreviation (DeFi) were to be found in blockchain related websites like *Cointelegraph*, online publishing platforms like *Medium*, or initial coin offerings' (ICO) whitepapers; its use in academic papers being very scarce. This, however, changed in the last couple of years, where several academic papers have been providing definitions of DeFi (Gudgeon *et al.*, 2020; Schär, 2021; Zetzsche *et al.*, 2020; Amler *et al.*, 2021). The common element in these definitions is to identify DeFi with blockchain-based financial services; some of them limiting DeFi to solutions built in the Ethereum blockchain platform. An exception is the definition provided by Chen and Bellavitis (2020) whom, while acknowledging the close relationship between DeFi and blockchain technology, emphasise instead the disintermediation and decentralization aspects of the new finance solutions.

Without denying the clear relationship between what is referred as "DeFi" and blockchain technology-based systems, this study considers that the above definitions are too narrow. Correspondingly, in this section we discuss 4 alternative (but complementary) uses of the DeFi concept: DeFi as *disintermediation*, as *decreased concentration*, as *unbundling*, and as *alternative finance*.

5.4.2. DeFi as financial disintermediation

One of the virtues for which Bitcoin and blockchain have been hailed is that they would allow individuals to transact with each other without recurring to banks. Some of these discussions are ideologically dressed in anarchic or libertarian colours, where banks (especially central banks)[3] are at the root of all evils in the economy and society (Hayes, 2018; Schmid, 2019). In more concrete terms, it is observed that one of the virtues of Bitcoin and distributed ledger technology (DLT) is that it allows for considerably faster processing of payments, clearance and settlement: a *T+15'* system instead of the annoying *T+2* or *T+3* [4].

Besides payments, other financial functions traditionally performed by banks are being disintermediated (with or without the technological help of DLT): loans (P2P lending systems), and risk management (AI-powered credit scoring). In other words, some of the factors behind the justification for banking intermediation (asymmetries of information, transaction costs, risk management, participation costs) (Allen and Santomero, 1997), are being coped with through technological and business model innovation. This allows for the performance of those functions by entities different than banks or in a purely P2P basis. This disintermediation element is present in DeFi, understood in a more encompassing way than simply as blockchain-based financial services.

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[3] For instance, in the controversial, conspiracy theory-ridden documentary film *Zeitgeist* (2007), the US Federal Reserve is supposedly controlled by a secret sect of international bankers who conspire to subdue the whole world.

[4] *T+2* and *T+3* mean that a payment is cleared and settled 2 or 3 days, respectively, after it has been ordered. *T+15'* means that it is cleared and settled 15 minutes after.

DeFi as financial disintermediation corresponds with the *excluding* modular operator.

5.4.3. DeFi as decreased concentration in the financial system

As mentioned above, the term decentralized finance has been used to refer to capital markets that are geographically less concentrated (Germany) than others (UK) (Klagge and Martin, 2005). This level of spatial concentration in finance has its institutional, monetary and infrastructure counterparts. A financial sector can be more or less institutionally concentrated. Trade finance, for instance, is very highly concentrated: according to the ICC (2018), 90% of trade finance in the world, by transaction value, is provided by only 13 banks. Money creation is more or less concentrated between central banks and commercial banks (by virtue of fractional banking) in the monetary circuit (Lipton and Pentland, 2018). Financial ledgers are controlled by banks and central banks: they are purportedly being democratised by Bitcoin, where the ledger is being controlled by peer-nodes (in reality, there is a big concentration among a few Chinese mining pools) (Cong *et al.*, 2019; Lipton, 2018).

DeFi is therefore to be also understood as a process of decreasing spatial, institutional, monetary or infrastructure concentration. Bitcoin would be a good example of decreased concentration in the spatial (access to Bitcoin has mostly no geographic limits), institutional (digital exchanges trading have swarmed everywhere), and infrastructure senses. It is far less clear whether, with a few mining pools driving the increase in supply, Bitcoin is an example of monetary de-concentration.

5.4.4. DeFi as unbundling of financial functions

According to the above-mentioned functional perspective, over long periods of time, financial functions have been more stable than financial institutions: *'Institutions have come and gone, evolved or changed, but functional needs persist* *while packaged differently and delivered in substantially different ways'* (Allen and Santomero, 1997, p. 1466). Traditionally, banks have been the institutions that have performed these functions, as a one-stop place for most of financial services.

The Fintech revolution that has been taking place during the last decade (Gomber *et al.*, 2018), has brought the "unbundling" of financial services. This business phenomenon is closely related with the disintermediation of some of these functions, but it is not identical with it. Disintermediation refers to coping with problems related with financial functions (like transaction costs or asymmetries of information) without a bank or other intermediary. Unbundling refers to the provision of those functions by specialized players (fintech firms).

Rather than relying in a single a bank as the unique solution for their financial needs, individuals and firms are increasingly picking up different services (payments, micro-loans, mortgages, investment) from separate fintech companies or so-called "shadow" banks (Lee and Shin, 2018). The unbundling of functions is thus another element in our broad DeFi concept, corresponding with the *splitting* modular operator.

5.4.5. DeFi as alternative finance

One of the most salient phenomena brought about by blockchain technology, most particularly by the Ethereum platform smart contract-based ERC-20 digital tokens, is that of "initial coin offerings", better known simply as ICOs (Tasca *et al.*, 2018). During the second-half of 2017 and until the middle of 2018, all kind of startup projects, claiming to develop the next blockchain disruptive use case, tried to raise capital by selling so-called "utility" or "use" tokens, under a sort of pre-sale of services business model. However, by the second half of 2018 the amount of raised capital had substantially decreased, a trend that has continued to the present day.

Despite the overwhelming number of failed ICOs (many of them outright scams or Ponzi schemes), token-based alternative financing has been recognized as a potentially powerful tool that could lead to a new economic paradigm, from centralized platforms and business models to decentralised ones (Tasca, 2019). Apart from its current use in startup funding, token-based issuing events (now re-christened IEOs: "initial exchange offerings", or STOs "security token offerings"), might work as well as tools for deploying secondary markets for securities.

ICOs, IEOs and STOs can be understood as tools for alternative finance, defined as sources of financing different than traditional bank and market finance channels (Allen *et al.*, 2012). This characteristic of being capable to constitute an alternative source of financing is the last element in our DeFi conceptualization.

The alternative finance use corresponds with the *substituting* modular operator.

* * *

The former elements are meant as "badges" to identify instances of decentralised finance, and do not have to be all present for a financial system, method or tool to be considered as such. The purpose here is not to offer a complete and clear definition of DeFi; rather, it is to show several aspects where DeFi can be more effective and efficient than traditional finance in addressing the trade finance gap and in coping with financial needs, particularly those of SMEs in emerging and frontier economies.

5.5. A decentralised trade finance model design

In this section we develop a basic design for a decentralised trade finance model, aiming at answering the following general question: "how would a DeFi trade finance model look like?”. In line with the modelling process summarized in Section 5.3., this section is divided into three sub-sections, each one depicting how a specific use or element of DeFi (in the broad sense hereby provided) modifies the traditional trade finance business model.

5.5.1. The disintermediation element

International trade can be described in general terms as three inter-dependent flows: physical flows (merchandise/commodities), information flows (EDI, XML, documents), and financial flows (letters of credit, documentary collections, advance payments, etc.). Trade finance instruments like LCs can be described, more specifically, as an inter-dependent flow of documents and money, closely dependent too on cargo flows.

Figure 5-1, taken from Malaket (2016), depicts the traditional process flow for a documentary letter of credit.

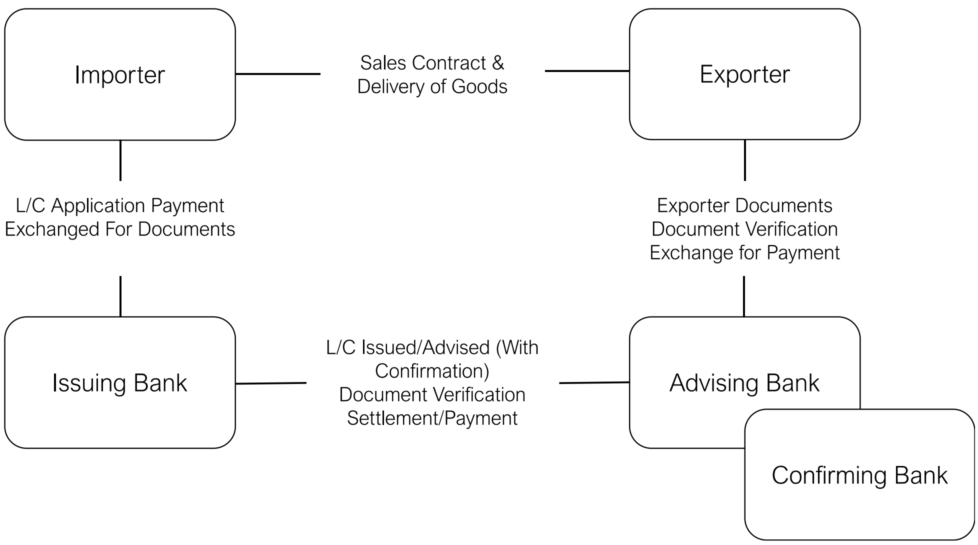

Figure 5-1. *Documentary letter of credit traditional workflow model*

The system works in a series of pair-based relationships: importer/exporter, importer/issuing bank, issuing bank/advising (confirming) bank, advising (confirming) bank/exporter. For each of these relationships, information (including documents) and money is exchanged. The validation and authentication of documents is done through the intermediation of the issuing bank and the advising (which can also be confirming) bank: the advising bank has to trust the issuing bank, and the exporter has to trust the advising bank, as to the authenticity of the LC.

Figure 5-2 shows the same documentary LC workflow, processed through a DLT platform.

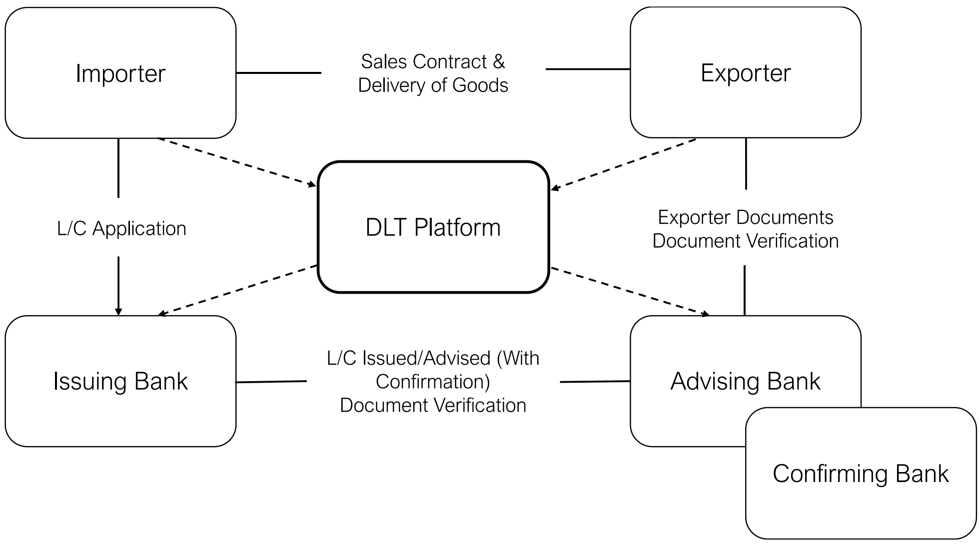

Figure 5-2. *Documentary letter of credit workflow with DLT-based solution*

DLT allows for this trust to be disintermediated and deposited in the platform itself. From the very first step of applying for an LC, the importer might use a frontend application through which relevant parameters (port of load, port of destination, sale price, etc.) are stored in the platform. Documents themselves are not to be stored, but rather their relevant parameters. This way, several of the authentication and verification functions performed by banks, which address the information asymmetry problem, are delegated (disintermediated) to the DLT platform.

5.5.2. The alternative finance element

In the traditional model for LCs, the delivery vs payment (DvP) dilemma is solved by bank guaranteeing payment against a compliant presentation of documents. The system works through a forward relay of information and documents, and a backwards relay interchange of documents for money, as depicted in Figure 5-3 (dashed lines represent information flows, dotted lines represent financial flows).

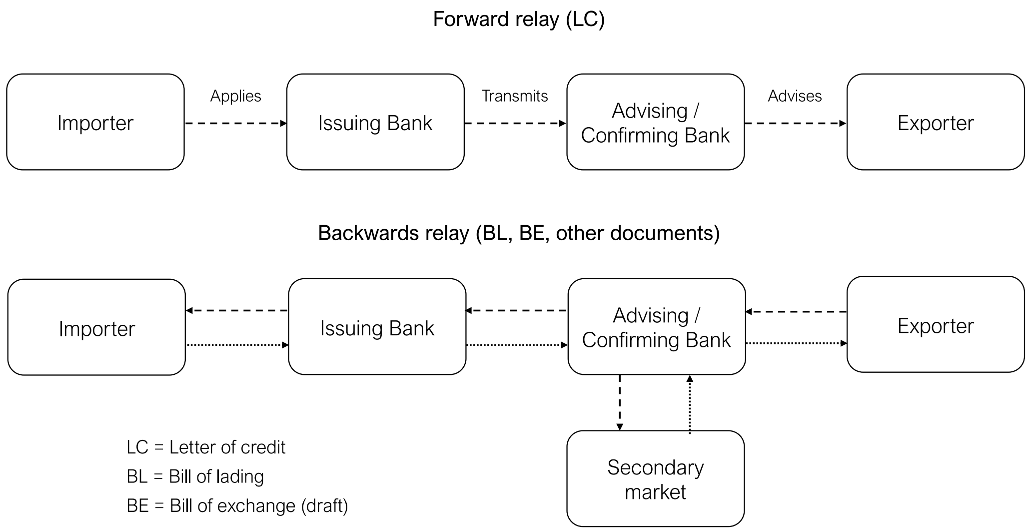

Figure 5-3. *Forward and backwards relays in documentary letter of credit*

In the forward relay, the importer applies for an LC; the issuing bank transmits the LC to the advising/confirming bank, which in turn confirms the authenticity of the LC (advises it) to the exporter. Then, in the backwards relay, the exporter presents relevant documents (BL, BE, and other documents like commercial invoice, certificate of origin, etc.) to the advising/confirming bank and receives payment; the advising/confirming bank forwards the documents to the issuing bank and gets reimbursed; and the issuing bank delivers the documents to the importer against reimbursement. The exporter gets paid by the advising/confirming bank either with funds from the bank itself, or by funds obtained through the negotiation of the LC in the secondary market.

Figure 5-4 depicts a modified version of the system (excluding the forward relay), showing how alternative finance comes into place.

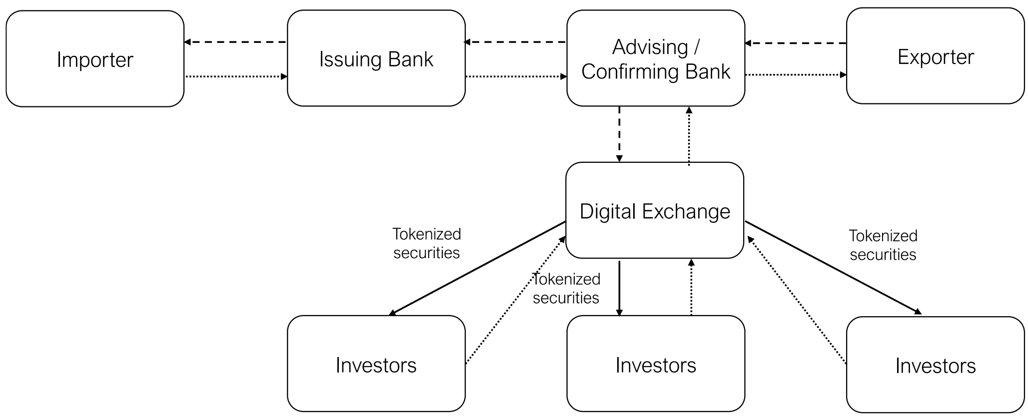

Figure 5-4. *Alternative finance system*

In the alternative finance system, the backwards relay interchange of documents for money works in a similar way. The novel element is provided by the tokenization of the LC, in order to expand its tradability in the secondary market. In other words, the LC becomes a digital asset with embedded intrinsic value (Tasca, 2019), in this case represented by the right to collect principal and interest from the importer, behaving very much like a bond.

LCs can be securitized either as single units or by fractioning them in sub-units, much like mortgage-backed securities (MBS). Each unit or sub-unit would be represented, as a digital asset, by a tradable token. For most LCs, securitization will require their slicing into smaller sub-units, given that the average value of an LC is considerably high[5].

The use of an alternative finance mechanism, P2P-based or not, is expected to increase liquidity for the trade finance system, as an expansion of the secondary market. One of the benefits of tokenized markets in relation to other secondary markets is the decrease of transaction costs, which in turn increases access of smaller players. Cryptocurrency digital exchanges (such as Coinbase, Binance or Kraken) have relatively simple onboarding mechanisms and very low transaction costs when compared with the costs of participating

[5] As reported by the ICC (2018), the average value of an LC in 2017 was US$ 537,000.

in the stock market. If the secondary market for LCs and other trade finance instruments can be tokenized, the supply of funds through additional retail investors should contribute to its expansion.

5.5.3. The unbundling element

As described above, the unbundling element in DeFi is manifested in the provision of financial services by separate players, who can specialize in a particular set of functions. In a traditional trade finance model, three financial functions are provided: the *administrative* function (collecting information and processing documents from importer, exporter, etc.), the *risk management* function (assessing the creditworthiness of the importer and the performance level of the exporter), and the *financial sourcing* function (providing funds).

Figure 5-5 shows a possible configuration of this unbundling, where issuing and advising/confirming banks outsource certain services to specialized entities. Document and information processing could be done by a frontend application provider. Risk management could be provided by a global bank with extensive knowledge in trade finance. And the source of capital would be digital exchanges, setting and monitoring tokenized secondary markets.

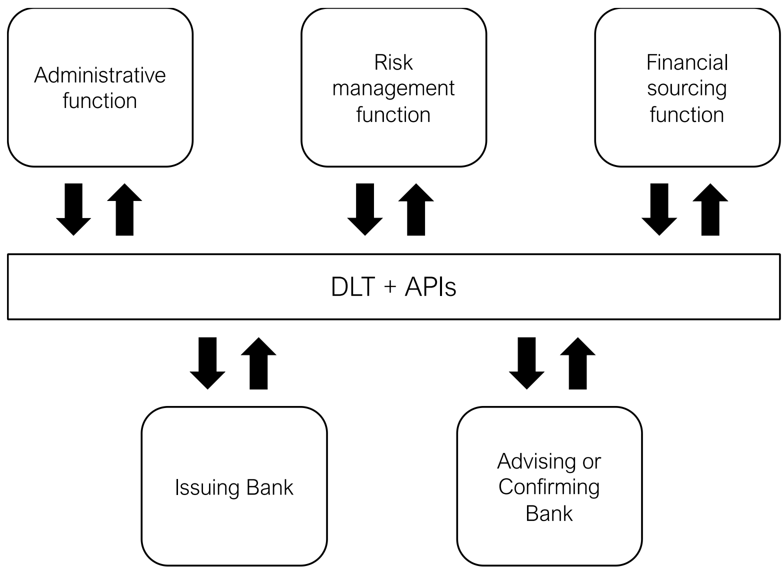

Figure 5-5. *Configuration of unbundled services for trade finance*

In this configuration, issuing banks retain their relationship with importers, and advising/confirming banks with exporters. But several services needed for the effective execution of the LC workflow are outsourced to more efficient entities. The fundamental role played by DLT/blockchain technology is to provide a single information infrastructure where several actors can obtain the same information inputs in order to perform their separate functions.

5.6. Evaluation

5.6.1. Preliminary considerations

Gregor and Hevner (2013) present a framework for evaluating DSR projects, composed of three maturity levels, as shown on Table 5-2 (reproduced from their research essay).

Table 5-2. *Design Science Research Contribution Types*

	Contribution Types	Example Artifacts
More abstract, complete, and mature knowledge	Level 3. Well-developed design theory about embedded phenomena	Design theories (mid-range and grand theories)
↕ ↕ ↕ ↕	Level 2. Nascent design theory—knowledge as operational principles/ architecture	Constructs, methods, models, design principles, technological rules
More specific, limited, and less mature knowledge	Level 1. Situated implementation of artifact	Instantiations (software products or implemented processes)

The contribution intended by this chapter is situated in Level 2 of the framework: it presents principles, in the form of elements (disintermediation, alternative finance, unbundling), for developing a DeFi trade finance business model. The artifact, at this stage, consist in the model presented in Section 5.5., plus the discussion about a theoretical construct (decentralised finance) contained in Section 5.4.

This *ex-ante* evaluation will cover two areas: practical assessment and theoretical contribution.

5.6.2. Practical assessment

The practical assessment of the artifact, represented by the business model, amounts to answering a simple question: *is it useful?* A question that in this case can be rendered more explicitly as: *does the model addresses the problems behind the trade finance gap?*

Following the classification in Section 5.2., the usefulness of the model in addressing supply-related problems and demand-related problems is considered in turn.

5.6.2.1. Addressing supply-related problems

The Basel III capital requirements and minimal non-bank capital investments, while having different origins (regulatory and economic), generate an important problem behind the trade finance gap: insufficient liquidity. This problem is addressed by the DeFi trade finance model through the alternative finance element: the development of a tokenized/securitized secondary market.

KYC/AML requirements, being related to regulatory issues, are not addressed by the model. High-processing costs and document verification problems are closely related. The still paper-based nature of the whole process has been identified as one key reason behind high processing costs. Most document verification issues arise out of archaic procedures and tasks. The digital transformation enhanced by DLT, in particular by the immutable registration of relevant parameters in a distributed database, would significantly reduce incongruencies between documents (LCs, BLs and BEs), which are the source of many delays and additional costs.

This increased efficiency provided by DLT would cover the whole lifecycle of the LC, from its issuance to its securitization, including execution, clearing and settlement of securities, as explained by Pinna and Ruttenberg (2016).

Finally, the unbundling of financial services would allow local banks who do not have sufficient knowledge about trade finance, to receive assistance from specialized providers in matters such as creditworthiness assessment and secondary market negotiation. Global banks who currently concentrate most of trade finance could provide creditworthiness assessments for LCs to be issued or confirmed by local banks in emerging and frontier markets, without taking part in the financing. This would decrease participation costs, as understood by Allen and Santomero (1997).

5.6.2.2. Addressing demand-related problems

High processing costs (partially caused by inefficient document verification procedures) affect SMEs by increasing transaction costs. In turn, this high transaction costs elevate the transaction-size threshold above which is economically viable to use an LC. All these problems would be addressed by DLT-based digital transformation, as already explained.

The insufficient knowledge about trade finance by importers and exporters can similarly addressed through the unbundling principle. For instance, a specialized frontend application service could guide the importer in the process of applying for an LC, and the exporter for making a compliant presentation under UCP 600 rules.

Firm-related level of risk reflects an asymmetry of information problem. A DLT-based system would help SMEs with good track record to signal its creditworthiness more easily to banks with whom they do not have previous experience. Indeed, all the relevant information about previous LCs would be accurately and immutable registered in a distributed database. These functionalities would be particularly beneficial to countries with low levels of digitalization, which will face higher hurdles in the post-COVID-19 era.

Country-related level of risk is not addressed by the model.

Table 5-3 presents the problems, the way they are addressed by the model, and the corresponding DeFi element.

Table 5-3. *Addressing trade finance gap problems with DeFi*

Trade finance gap causes	Addressed by	DeFi element
Increased capital ratio requirements in banking regulations (e.g.: Basel III)	Additional capital from investors in tokenized secondary market	Alternative finance
Regulatory due diligence requirements (e.g. KYC)	Not addressed by the model	Not applicable
Minimal non-bank capital	Additional capital from investors in tokenized secondary market	Alternative finance
High processing costs	Digitalization of processes	Disintermediation
Document verification problems	Digitalization of processes	Disintermediation
Insufficient knowledge about trade finance by local banks and by importers or exporters	Financial services provided by specialized firms or global banks / Reduced participation costs	Unbundling
Firm related high level of risk	Reduced information asymmetries	Unbundling
Country related high level of risk	Not addressed by the model	Not applicable
Insufficient size of transactions	Digitalization of processes	Disintermediation

5.6.3. Theoretical contribution

The theoretical contribution aimed at by this chapter is twofold. On the one hand, it discusses the theoretical construct of "decentralised finance", identifying previous usages and its current narrow meaning under the "DeFi" abbreviation, while developing a broader meaning. This is done by making explicit several elements implicit in the notion of decentralization, namely: disintermediation, decreased concentration, unbundling and alternative finance.

On the other hand, the research uses these elements in order to design a business model that addresses a real-life problem, in this case, the trade finance gap. This application looks to generate prescriptive knowledge or, following the theoretical taxonomy by Gregor (2006), theory for design and action.

5.7. Conclusion

This chapter has addressed a practical problem, the trade finance gap extensively discussed in policy circles, by inquiring whether a solution could be found in decentralised finance (DeFi). To this end, it has presented a theoretical background, including the academic and policy treatment of the trade finance problem, including the context created by the COVID-19 pandemic, as well as literature about the concepts of financial intermediation and business model innovation. Then, it has discussed the DeFi concept, offering a broader meaning, based on specific elements. These elements in turn have been used in the design of a DeFi business model that would address the trade finance gap. Finally, a preliminary evaluation of the model and the theoretical contribution has been offered.

Several limitations are present in this chapter. First and foremost, it represents a preliminary stage in the DSR process, where only a model is presented: it does not include methods or an actual instantiation. Second, all the data presented is obtained from secondary sources, also due to the early stage of the research. Also, the discussion is limited to documentary letters of credit, leaving out several other important trade finance instruments like documentary collections (DC), standby letters of credit (SLC) or factoring.

This opens opportunities for future research. A separate DeFi business model for DCs, SLCs or factoring could be designed. Also, more detailed analysis of the application of DLT to specific business processes related to trade finance can be conducted. For example, how information gathered during the origination phase of an LC and registered as relevant parameters in a DLT platform, could be useful for securitization processes in the secondary market.

Chapter 6.
Conclusion

6.1. Introduction

This doctoral dissertation focuses on the subject of how digital transformation influences business models in maritime trade supply chains. The main research question of the dissertation is stated in the following way:

> ***RQ***: *What is the impact of digital transformation on business models, in the context of maritime trade supply chains?*

As global value chains have become more complex and intermingled, maritime supply chain actors have been adopting novel technologies, processes, and business models, as a way to cope with a fast-changing industry (Salama, 2016; Salama, Martínez Marín, and Martínez de Osés, 2014). Potentially disruptive situations, like the COVID-19 pandemic crisis, are increasing awareness among industry players of the need to embrace digitalization sooner rather than later. Digital transformation has the potential to increase operational efficiency and to allow new value creation; in particular, it enhances information flows across the maritime network. Among the various ways that digital transformation takes place, technologies associated with the Industry 4.0 paradigm (like IoT or blockchain) are particularly suitable to underpin beneficial use cases in the maritime industry. While most of the focus inside the industry has been on the digitization of paper-based documents (a still pending issue), digital transformation goes much farther. If properly adopted, it will increase overall performance, changing business models and roles in the process.

However, for Industry 4.0 technologies and digital transformation to have a beneficial impact in maritime trade supply chains, industry players have to be careful in adopting the right business models (Gassmann *et al.*, 2014).

Technology is not an answer in itself, and if not aligned with appropriate ways of creating, delivering and capturing value, it might not provide any benefit or even be detrimental (Rai *et al.*, 2012).

6.2. Summary of main findings

In order to provide an answer to the dissertation's research main question, we undertook four separate and independent studies. In the first study, we aim to understand the way that digital transformation might affect business models in maritime trade supply chains. The corresponding sub-research questions is stated as follows:

> ***RQ₁:*** *How does digital transformation affect business models in terms of physical, information and financial flows?*

Chapter 2 intends to provide an answer to this question by conducting a theoretical synthesis from a cross-disciplinary perspective, including literature from Management Science, Maritime Studies and Information Systems Research. The synthesis is structured around three anchoring constructs: physical flows, information flows, and financial flows. For each one of this constructs, we ask questions about their nature *(what?)*, their underlying mechanisms *(how?)*, and their driving forces *(why?)*. We then describe the basic interrelation dynamics between them and provide a graphic illustration of the model. Physical and financial flows are interlinked by causal relationships; a financial flow takes place in response of a physical one, or vice versa. Meanwhile, information flows take place because information is an input for supply chain related processes and decision-making. Given the resource like nature of information flows in relation to physical and financial ones, disruptions in the former affect the latter two. From another perspective, the adoption of IT technologies that increase information flows' effectiveness, would positively affect physical and financial ones.

Chapter 3 presents a case study about the port of Barcelona that investigates what influence might Industry 4.0 technologies have over the evolution of seaports models. The sub-research question for Chapter 3 is stated in the following manner:

> ***RQ$_2$****: How Industry 4.0 technologies might drive business model innovation in a seaport context?*

This chapter presents a conceptual model that depicts the influence of Industry 4.0 technologies in seaports business models, and most specifically how it can lead seaports to adopt a "smart port" model. The model shows both the influencing mechanisms in terms of technology pull and market pull, and the seaport areas over which the influence is exercised: operations, strategies and investments. To evaluate the conceptual model, a case study analysis on the port of Barcelona was conducted. The case study findings were that, at least in the case of the port of Barcelona, market pull forces are a clear driver for Industry 4.0 technologies adoption, while technology pull forces are less apparent. The influence of these technologies is present in all the areas above mentioned, although with varying degrees.

Chapter 4 conducts an exploratory study on the impact that distributed ledger technology (DLT) has for the shipping industry; specifically, how it might drive adoption of more sustainable business models (SBM). The sub-research question for Chapter 4 is expressed as follows:

> ***RQ$_3$****: What impact does DLT has on the adoption of SBM, as well as sustainable practices, in the shipping industry?*

The methodology followed to provide an answer to this question is similar to that used in the previous chapter. First, a conceptual model is developed. The model is based in, among other theoretical pillars, the information resource management theory. This model is then assessed against the result of another case study, conducted in this case about TradeLens, a recently developed information infrastructure platform built over a DLT technological layer. The case study shows how DLT-based platforms can catalyse the adoption of sustainable practices and business models in the shipping industry. Most particularly, because DLT facilitates the generation of information circularities among industry players; that is, the re-use of information that is an output of business processes, as input for further processes.

Chapter 5 engages more directly with financial flows. Specifically, it enquires whether decentralised finance (DeFi), based on DLT (aka blockchain) technology, might provide a solution to the trade finance gap. Its corresponding sub-research question is the following:

> ***RQ_4:*** *How to design a DeFi business model that would address some of the causes behind the trade finance gap?*

The study conducts first a review of literature on the reasons that drive the unbalance between supply and demand of trade finance, and elaborates a classification of those causes, according to whether they are supply-related or demand-related. It also reviews recent literature on concept of decentralised finance, and presents a more encompassing definition of DeFi, understood along four dimensions. Then using Design Science Research (DSR) methodology, a business model for a DeFi-based trade finance system is designed and presented. A preliminary evaluation is then conducted, showing how the model might address some of the causes behind the trade finance gap.

6.3. Theoretical contributions

Chapter 2 provides an explanatory theory that furthers the conceptualization of the three flows in maritime trade supply chains: physical flows, information flows, and financial flows. This concepts function as the key constructs in providing a theoretical explanation on the impact that digital transformation has on processes and business models in the industry. The theoretical synthesis delves into the theory developed by the *Activity System* school regarding business models, and extends that theory by proposing that the components of such activity system, content, structure and governance, can be represented by a specific description of the physical, information and financial flows between a firm and other economic actors. It also extends the concept of business model innovation, describing it as a reconfiguration of the way the three flows are interrelated.

Chapter 3's theoretical contribution is mainly centred in explaining the mechanisms through which Industry 4.0 technologies influence the evolution of busines models in the context of seaports. The study extends the literature on ports models, elaborating a description of the smart port concept, built from the related concepts of fifth generation (5G) port and Port 4.0. It also provides insights regarding the impact that technology push and market pull forces might have for seaports, concluding that market pull appears to be the main driver. Finally, it contributes to the understanding of what "smartness" means in the context of a seaport.

Chapter 4 presents a conceptual model that sketches the impact that distributed ledger technology (DLT) can have on sustainable shipping business models and practices. The model's theoretical base is grounded on the conception of information as a resource, provided by Information Resource Management (IRM) theory. From this foundation, the chapter presents the construct of information circularity, whereby information that is generated as output or by-product of business processes, is then re-utilised as a resource for subsequent or parallel business processes. This theoretical construct contributes to the IRM literature, as well as sustainability research, specifically on the concept of circular economies. Moreover, the study extends previous literature on blockchain technology and its impact on the circular economy, associative business models, and inter-firm coordination in general. It does so under the context of maritime shipping, extending both Maritime Studies literature and blockchain technology research.

Chapter 5's theoretical contribution is twofold. On the one hand, the study develops a more encompassing meaning of the theoretical construct of "decentralised finance", building over previous usages and their current narrow meaning under the "DeFi" abbreviation. This is done by making explicit several elements implicit in the notion of decentralization, namely: disintermediation, decreased concentration, unbundling and alternative finance. On the other hand, the chapter uses these elements in order to design an artifact, in this case, a business model that addresses the trade finance gap problematic. This application purports to generate prescriptive knowledge or, following the theoretical taxonomy by Gregor (2006), theory for design and action.

6.4. Managerial relevance

Regarding the managerial relevance that each of the studies has, Chapter 2 provides an understanding of the mechanisms by which digital transformation affects the three flows in maritime supply chains, and this can be useful for managing disruptive situations like the ones generated as a consequence of the COVID-19 pandemic. As an example, it could help firms or organizations to choose IT tools that, according to this understanding, would be more effective in addressing these situations. It could also help them to develop policies and strategies, or undertake IT infrastructure investments. Moreover, as digital transformation affects the whole maritime supply chain industry, grasping its influencing mechanisms provides firms and organizations with clarity to adapt and, if necessary, design new business models.

Chapter 3 is based on a real-life case study about a seaport which has purposedly followed certain strategies in order to position itself as a competitive logistic hub. The research conducted serves not only to evaluate the conceptual model that explains the influence of Industry 4.0 technologies on the adoption of a more sophisticated business model for a seaport, but also shows how prevalent is benchmarking and market pull when it comes to adopting innovation. Seaport authorities and other port stakeholders might want, instead, to adopt a more pro-active stance and develop innovative use cases, not as an answer to pressures from the industry, but as a way of better addressing the needs of the markets and hinterlands they serve.

The theoretical perspective presented in Chapter 4, contrasted with the exploratory case study on TradeLens, provides managerial implications, both for maritime shipping firms and regulatory bodies. Shipping firms need to carefully analyse how they will take advantage of the new information flow dynamics that DLT-based information infrastructures like TradeLens bring to the market. Those firms that are more effective in identifying and taking advantage of information flows interdependencies with the help of these DLT-based tools, will gain competitive advantages and improve their sustainability performance ratings. In addition, the construct of information resource circularity offers a novel perspective to government and other regulatory bodies, which may enrich their discussions on sustainability policies, measures, standards and incentives. Moreover, they might gain new insights on the beneficial role that blockchain technology can play for circular economies and sustainability in the specific area of maritime shipping.

The main managerial relevance of Chapter 5 resides in the ideas that it might give to the entrepreneurial community (in fact, the study was in part undertaken with that in mind). There have been many policy discussions and recommendations regarding solutions for the trade finance gap, including boosting the action of multilateral banks and export credit agencies (Auboin and DiCaprio, 2017). The study hopes to convince entrepreneurs that, in addition to those entities, fintech start-ups have also an answer.

6.5. Generalizability, limitations, and further research

This doctoral dissertation provides several generalizable concepts and research insights. Chapter 2 provides a depiction of the interrelationship between physical, information and financial flows in supply chains (Figure 2-1), which is also applicable to other economic contexts. Chapter 3 offers an explanation of the influence of Industry 4.0 technologies in the context of seaports, that is also applicable for other actors in maritime trade supply chains, like liner companies. Chapter 4 explains how DLT technology can enhance information circularity and sustainability in the shipping industry; the same mechanism would operate in different industries, like manufacturing. Chapter 5 designs a business model template for a trade finance solution, based on broad concept of decentralised finance; this concept of DeFi could be also the basis of other fintech use cases, such as microcredits for agriculture.

Each of the studies that comprise this dissertation have a number of limitations. Chapter 2 limits its theoretical synthesis on digital transformation to the three flows that take place in maritime supply chains, but it leaves out dimensions also affected by digitalization, like organizational change. Chapter 3 presents a case study on a single seaport, covering only a limited time frame. If focuses on operations, strategies and investments undertaken by the port authority; but does not include other stakeholders. Chapter 4 has a limited generalizability, given that the subject of the case study, DLT in the shipping industry, is still novel, with only a single real-life functioning use case. Moreover, the assessment of the conceptual model propositions presented in both Chapter 3 and Chapter 4 carries its dose of subjectivity.

The design research undertaken in Chapter 5 has various limitations as well. First, it presents a preliminary stage in the DSR process, where only a model is designed, without including an actual instantiation. Second, all the data presented is obtained from secondary sources, also due to the early stage of the research. Finally, the only trade finance instruments studied are documentary letters of credit, leaving out several other important mechanisms like documentary collections (DC), standby letters of credit (SLC) or factoring.

Future research can add new insights into the impact that digital transformation has on maritime trade. The case study conducted in Chapter 3 about the port of Barcelona should be extended to include other seaports, as well as other industry stakeholders like shipping lines. In the same vein, the case study presented in Chapter 4 can be conducted in relation to new DLT-based information infrastructures, as they become operational. The topic of sustainability in the shipping industry and its relationship with digital transformation can be addressed in the context of other Industry 4.0 technologies, like IoT or virtual reality. Regarding the model designed in Chapter 5, future research can include other trade finance instruments, as well as include supply chain finance solutions.

Ideally, digital transformation phenomena in the maritime industry and Industry 4.0's associated technologies will be the subject of future studies conducted through the Action Design Research (ADR) methodology (Sein *et al.*, 2011). The method extends DSR by incorporating the organizational context during the design, development and instantiation of artifacts. This way, use cases developed by start-ups in the area of digital transformation could be researched from the inside. Hopefully, the insights provided in this dissertation shall prod future entrepreneurs to develop innovative products and business models.

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Summary (English)

This doctoral research explores the inter-relationship between the contemporary phenomena known as digital transformation, and the adoption of certain business models in the context of the maritime trade supply chain industry. Most specifically, it enquires the impact that the former might have on the latter. The question's relevance is twofold. On the one hand, the pace of both technological and business innovation has accelerated during the last 15 years, especially for certain industries. On the other hand, while there has been some degree of innovation in maritime trade supply chains, the industry lags behind other economic sectors; still working with technologies, business models and processes that predate the contemporary globalization era. Thus, understanding how and why the adoption of certain technologies might generate new ways of creating, delivering and capturing value in maritime trade supply chains, becomes a significant undertaking from both a theoretical and practical perspective.

To address this enquiry, we have conducted four separate studies in this dissertation. In Chapter 2, we conduct a theoretical synthesis in order to provide a general theoretical background for the research conducted in the subsequent chapters. To this end, we begin by providing a literature basis, grounded in 3 disciplines: Maritime Studies, Management Science and Information Systems Research. The core approach is then built around the construct of the three flows present in maritime trade supply chains: physical, information and financial flows. For each one of the flows, we ask three basic questions: *what?* (describing the content of flow), *how?* (describing the mechanisms), and *why?* (understanding what drives the flow in question). For physical flows, we refer to its content with the encompassing term of "cargo", the mechanism as

multimodality and the driving cause as either production or consumption. For information flows, the content is either data or information (in a strict sense), the mechanism is paper-based or electronic, and the driving cause its role as a resource for decision making. Financial flows are about money, which flows either by means of payments or credits, under a Circular Flow Model as a driving logic. The chapter then offers a basic explanation of how the three flows are integrated: physical and financial flows are based on mutual interchanges between actors across the supply chain (moving in opposite directions), while information flows move in both directions, supporting the first two. Finally, the chapter aims to contribute to the understanding of the business model construct, observing that business models can be represented by specific descriptions of the physical, information and financial flows between a firm and other economic actors.

Chapter 3 is mainly concerned with physical flows. We investigate what impact does the adoption of Industry 4.0 technologies by seaports might have on their business models. To define these, we refer to the classification of seaports across a generational ladder: from 1st generation to 5th generation ports; referring as well to the novel construct of Port 4.0, and the commonly used "smart port" term. Delving into Maritime Studies literature, we provide a list of features and functionalities that would characterise a smart port, and offer a general explanation on what "smart" or "smartness" should mean in this context. We then develop a conceptual model expressed as a series of propositions, built around two influencing mechanisms taken from Management Science: technology push and market pull. Most specifically, the model purports to explain how Industry 4.0 technologies, through these mechanisms, influences seaports business models in three areas: operations, strategies and investments. To assess this conceptual model, we conduct an exploratory case study about the port of Barcelona, based on content analysis of documentary sources (specially the 3rd and 4th strategic plans) as well as a semi-structured interview. Our assessment shows a primacy of market pull and benchmarking influencing mechanisms, as the main way that adoption of Industry 4.0 drives business model innovation, at least for seaports with the characteristics and circumstances of Barcelona.

In Chapter 4 we turn to information flows. Most specifically, we explore the influence that distributed ledger technology (DLT) —most commonly known as blockchain— might have on the adoption of sustainable business models in the shipping industry. One of the core theoretical pillars of the study is the conception of information as a resource, provided by Information Resource Management discipline. Upon this conception we propose the construct of information circularity, which takes place where information that is generated as by-product or output or business processes is used as input/resource for further processes. We then develop a conceptual model depicting the relationship between DLT and sustainable shipping, expressed as 5 propositions. To assess the model, we conduct an exploratory case study about TradeLens, a DLT-based information platform for global supply chains, using content analysis technique. Our preliminary assessment finds that DLT, by allowing increased information circularity and associative behaviours between supply-chain actors, becomes a catalyst for sustainable shipping business models, which in turn drive sustainable practices in the shipping industry. The research extends previous literature on DLT technology and its impact on the circular economy, associative business models, and inter-firm coordination in general, under the context of maritime shipping.

Chapter 5 focus on financial flows. It presents a design science study on a problem known as the trade finance gap; understood as the difference between the total supply of and demand for trade finance in international trade on a global level. The main question addressed is how to design a new business model that would address the causes behind the said trade finance gap. As a first step, delving into academic and grey literature, we classify a set of causes behind the problematic, according to whether they are supply-related (that is, pertain to the capability of financial institutions to provide trade finance) demand-related (relating to the firms that need trade finance), or both. Delving into financial intermediation theory, we then analyse the novel concept of decentralised finance (DeFi), proposing a broader meaning than the prevailing one, which reduces it to functions based on blockchain technology and cryptocurrencies. Our broader meaning is constructed upon four perspectives: DeFi as disintermediation, as decreased concentration, as unbundling of financial functions, and as alternative finance. The chapter then presents a model of a DeFi-based system for trade finance, most specifically, for the processing of documentary credits. In it, we describe how the model differs and improves the most traditional trade finance instrument: the letter of credit. Most importantly, in line with the Design Science Research methodology, we evaluate how the model addresses the causes behind the trade gap problematic, as well as its theoretical contributions. The conclusion is that a DeFi based model for trade finance can decrease transaction costs, increase liquidity, and provide better information about firms in order to improve their creditworthiness assessment.

To conclude, this dissertation explores how digital transformation affects or impacts business models in maritime trade supply chains. It does so, by conducting studies on different contexts, each of them primarily focused on either physical, information or financial flows. From a theoretical perspective, the dissertation provides insights on the interplay between the three flows in maritime trade; with a special focus on how digital transformation, by affecting this interplay, drives or contributes to the adoption of new business models. Most specifically, Industry 4.0 technologies like IoT or DLT improve the way information flows interact with physical and financial flows. From a practical/managerial perspective, the research provides useful insights for business executives and policy makers, on how digital transformation should be faced at the strategic, tactical and operational level. By understanding how new technologies affect the ways in which value is created, delivered and captured, decision makers can design better business models, increasing competitiveness; or implement more adequate policies and strategies. Most importantly, the dissertation aims to serve as a source of ideas for those entrepreneurs who, through their startups, will design and develop innovative use cases and business models for the maritime industry.

Resumen (Castellano)

Esta investigación doctoral explora la interrelación entre los fenómenos contemporáneos conocidos como transformación digital y la adopción de ciertos modelos de negocio en el contexto de la industria de la cadena de suministro del comercio marítimo. Más concretamente, indaga sobre el impacto que los primeros pudieran tener sobre la segunda. La relevancia de la pregunta es doble. Por un lado, el ritmo de la innovación tanto tecnológica como empresarial se ha acelerado durante los últimos 15 años, especialmente para determinadas industrias. Por otro lado, si bien ha habido cierto grado de innovación en las cadenas de suministro del comercio marítimo, la industria va a la zaga de otros sectores económicos; sigue trabajando con tecnologías, modelos de negocios y procesos que son anteriores a la era de la globalización contemporánea. Por lo tanto, comprender cómo y por qué la adopción de ciertas tecnologías puede generar nuevas formas de crear, distribuir y capturar valor en las cadenas de suministro del comercio marítimo se convierte en una tarea importante tanto desde una perspectiva teórica como práctica.

Para indagar sobre ello, hemos realizado cuatro estudios en esta disertación. En el Capítulo 2, llevamos a cabo una síntesis teórica con el fin de proporcionar un marco teórico general para la investigación realizada en los capítulos siguientes. Para ello, comenzamos desarrollando una base bibliográfica, fundamentada en 3 disciplinas: Estudios Marítimos, Ciencias de la Gestión e Investigación de Sistemas de Información. El enfoque central se basa entonces en la construcción de los tres flujos presentes en las cadenas de suministro del comercio marítimo: flujos físicos, de información y financieros. Para cada uno de los flujos nos hacemos tres preguntas básicas: *¿qué?* (describiendo el contenido del flujo), *¿cómo?* (describiendo los mecanismos), y

¿por qué? (comprender qué impulsa el flujo en cuestión). Para los flujos físicos, nos referimos a su contenido con el término global de "carga", el mecanismo como multimodalidad y la causa impulsora como producción o consumo. Para los flujos de información, el contenido son datos o información (en sentido estricto), el mecanismo es en papel o electrónico, y la causa impulsora es su rol como recurso para la toma de decisiones. Los flujos financieros se refieren al dinero, que fluye ya sea por medio de pagos o créditos, bajo un modelo de flujo circular como lógica impulsora. Luego, el capítulo ofrece una explicación básica de cómo se integran los tres flujos: los flujos físicos y financieros se basan en intercambios mutuos entre actores a lo largo de la cadena de suministro (que se mueven en direcciones opuestas), mientras que los flujos de información se mueven en ambas direcciones, apoyando a los dos primeros. Finalmente, el capítulo tiene como objetivo contribuir a la comprensión del concepto de modelo de negocio, observando que los modelos de negocio pueden ser representados por descripciones específicas de los flujos físicos, financieros y de información entre una empresa y otros actores económicos.

El Capítulo 3 se ocupa principalmente de los flujos físicos. Investigamos qué impacto podría tener la adopción de tecnologías Industria 4.0 por parte de los puertos marítimos en sus modelos de negocio. Para definirlos, nos referimos a la clasificación de los puertos marítimos a través de una escala generacional: desde puertos de 1ra hasta 5ta generación; refiriéndonos también al nuevo concepto de Puerto 4.0, y al común término "puerto inteligente". Basándonos en la literatura de Estudios Marítimos, proporcionamos una lista de características y funcionalidades que caracterizarían a un puerto inteligente y ofrecemos una explicación general sobre lo que debería significar "inteligente" o "inteligencia" en este contexto. A continuación, desarrollamos un modelo conceptual expresado como una serie de proposiciones, construidas en torno a dos mecanismos de influencia tomados de las Ciencias de Gestión: el impulso tecnológico *(technology push)* y la atracción del mercado *(market pull)*. Más específicamente, el modelo pretende explicar cómo las tecnologías de Industria 4.0, a través de estos mecanismos, influyen en los modelos de negocio de los puertos marítimos en tres áreas: operaciones, estrategias e inversiones. Para evaluar este modelo conceptual, llevamos a cabo un estudio de caso exploratorio sobre el puerto de Barcelona, basado en el análisis de contenido de fuentes documentales (especialmente el tercer y cuarto planes estratégicos), así como una entrevista semiestructurada. Nuestra evaluación muestra una primacía de los mecanismos de influencia del mercado y la evaluación comparativa *(benchmarking)*, como la principal forma en que la adopción de la Industria 4.0 impulsa la innovación de modelos de negocio, al menos para los puertos marítimos con las características y circunstancias de Barcelona.

En el Capítulo 4 pasamos a los flujos de información. Más específicamente, exploramos la influencia que la tecnología de *distributed ledger* (DLT), más comúnmente conocida como *blockchain*, podría tener en la adopción de modelos de negocio sostenibles en la industria del transporte marítimo. Uno de los pilares teóricos centrales del estudio es la concepción de la información como recurso, proporcionada por la disciplina Gestión de Recursos de Información. Sobre esta concepción, proponemos el concepto de la circularidad de la información, que tiene lugar cuando la información que se genera como subproducto o resultado de procesos comerciales, se utiliza luego como entrada/recurso para procesos posteriores. Posteriormente, desarrollamos un modelo conceptual que representa la relación entre DLT y el transporte marítimo sostenible, expresado como 5 proposiciones. Para evaluar el modelo, realizamos un estudio de caso exploratorio sobre TradeLens, una plataforma de información basada en DLT para cadenas de suministro globales, utilizando la técnica de análisis de contenido. Nuestra evaluación preliminar encuentra que la DLT, al permitir una mayor circularidad de la información y comportamientos asociativos entre los actores de la cadena de suministro, se convierte en un catalizador para modelos de negocio sostenibles, que a su vez impulsan prácticas sostenibles en la industria del transporte marítimo. La investigación amplía la literatura previa sobre la tecnología DLT y su impacto en la economía circular, los modelos de negocios asociativos y la coordinación inter-empresarial en general, en el contexto del transporte marítimo.

El capítulo 5 se centra en los flujos financieros. Presenta un estudio de diseño sobre un problema conocido como la brecha de financiación del comercio *(trade finance gap)*; entendido como la diferencia entre la oferta y la demanda total de financiamiento en el comercio internacional a nivel global. La principal pregunta que se aborda es cómo diseñar un nuevo modelo de negocio que aborde las causas detrás de dicha brecha de financiamiento comercial. Como primer paso, basándonos en literatura académica y gris, clasificamos un conjunto de causas detrás de la problemática, según estén relacionadas con la oferta (es decir, que pertenezcan a la capacidad de las instituciones financieras para proporcionar financiamiento comercial) relacionadas con la demanda (relativas a las empresas que necesitan financiación comercial), o ambas. Adentrándonos en la teoría de la intermediación financiera, analizamos a continuación el novedoso concepto de finanzas descentralizadas (DeFi), proponiendo un significado más amplio que el prevaleciente, que lo reduce a funciones basadas en tecnología blockchain y criptomonedas. Nuestro significado más amplio se basa en cuatro perspectivas: DeFi como desintermediación, como disminución de la concentración, como desagregación de las funciones financieras y como financiación alternativa. Luego, el capítulo presenta un modelo de un sistema basado en DeFi para la financiación del comercio, más específicamente, para el procesamiento de créditos documentarios. En él, describimos cómo el modelo difiere y mejora el instrumento de financiación comercial más tradicional: la carta de crédito. Lo que es más importante, en línea con la metodología de Investigación de Diseño Científico *(Design Science Research)*, evaluamos cómo el modelo aborda las causas detrás de la problemática de la brecha de financiamiento comercial, así como sus contribuciones teóricas. La conclusión es que un modelo basado en DeFi para la financiación del comercio puede reducir los costes de transacción, aumentar la liquidez y proporcionar mejor información sobre las empresas para mejorar su evaluación de la solvencia.

Para concluir, esta disertación explora cómo la transformación digital afecta o impacta los modelos de negocio en las cadenas de suministro del comercio marítimo. Lo hace mediante la realización de estudios sobre diferentes contextos, cada uno de ellos centrado principalmente en los flujos físicos, de información o financieros. Desde una perspectiva teórica, la disertación proporciona información sobre la interacción entre los tres flujos en el comercio marítimo; con un enfoque especial en cómo la transformación digital, al afectar esta interacción, impulsa o contribuye a la adopción de nuevos modelos de negocio. Más específicamente, las tecnologías de Industria 4.0 como IoT o DLT mejoran la forma en que los flujos de información interactúan con los flujos físicos y financieros. Desde una perspectiva práctica/gerencial, la investigación proporciona información útil para los ejecutivos de negocios y los diseñadores de políticas sobre cómo se debe enfrentar la transformación digital a nivel estratégico, táctico y operativo. Al comprender cómo las nuevas tecnologías afectan las formas en que se crea, distribuye y captura el valor, los tomadores de decisiones pueden diseñar mejores modelos de negocio, aumentando la competitividad; o implementar políticas y estrategias más adecuadas. Lo que es más importante, la disertación tiene como objetivo servir como fuente de ideas para aquellos emprendedores que, a través de sus *startups*, diseñarán y desarrollarán casos de uso innovadores y modelos de negocio para la industria marítima.

Resum (Català)

Aquesta investigació doctoral explora la interrelació entre els fenòmens contemporanis coneguts com a transformació digital i l'adopció de certs models de negoci en el context de la indústria de la cadena de subministrament del comerç marítim. Més concretament, indaga sobre l'impacte que els primers poguessin tenir sobre la segona. La rellevància de la pregunta és doble. D'una banda, el ritme de la innovació tant tecnològica com empresarial s'ha accelerat durant els darrers 15 anys, especialment per a determinades indústries. D'altra banda, si bé hi ha hagut cert grau d'innovació a les cadenes de subministrament del comerç marítim, la indústria va darrera d'altres sectors econòmics; segueix treballant amb tecnologies, models de negocis i processos anteriors a l'era de la globalització contemporània. Per tant, comprendre com i per què l'adopció de certes tecnologies pot generar noves maneres de crear, distribuir i capturar valor a les cadenes de subministrament del comerç marítim es converteix en una tasca important tant des d'una perspectiva teòrica com pràctica.

Per indagar-hi, hem realitzat quatre estudis en aquesta dissertació. Al Capítol 2, duem a terme una síntesi teòrica per tal de proporcionar un marc teòric general per a la recerca realitzada en els capítols següents. Per això comencem desenvolupant una base bibliogràfica, fonamentada en 3 disciplines: Estudis Marítims, Ciències de la Gestió i Investigació de Sistemes d'Informació. L'enfocament central es basa llavors en la construcció dels tres fluxos presents a les cadenes de subministrament del comerç marítim: fluxos físics, d'informació i financers. Per a cadascun dels fluxos ens fem tres preguntes bàsiques: *què?* (descrivint el contingut del flux), *com?* (descrivint els mecanismes), i *per què?* (comprendre què impulsa el flux en qüestió). Per als fluxos físics, ens referim al seu contingut amb el terme global de "càrrega", el mecanisme com a

multimodalitat i la causa impulsora com a producció o consum. Per als fluxos d'informació, el contingut són dades o informació (en sentit estricte), el mecanisme és en paper o electrònic, i la causa impulsora és el seu rol com a recurs per a la presa de decisions. Els fluxos financers es refereixen als diners, que flueixen ja sigui per mitjà de pagaments o crèdits, sota un model de flux circular com a lògica impulsora. Després, el capítol ofereix una explicació bàsica de com s'integren els tres fluxos: els fluxos físics i financers es basen en intercanvis mutus entre actors al llarg de la cadena de subministrament (que es mouen en adreces oposades), mentre que els fluxos de informació es mouen en les dues direccions, recolzant els dos primers. Finalment, el capítol té com a objectiu contribuir a la comprensió del concepte de model de negoci, observant que els models de negoci poden ser representats per descripcions específiques dels fluxos físics, financers i d'informació entre una empresa i altres actors econòmics.

El capítol 3 s'ocupa principalment dels fluxos físics. Investiguem quin impacte podria tenir l'adopció de tecnologies Indústria 4.0 per part dels ports marítims als seus models de negoci. Per definir-los, ens referim a la classificació dels ports marítims mitjançant una escala generacional: des de ports de 1ra fins a 5ta generació; referint-nos també al nou concepte de Port 4.0, i al comú terme "port intel·ligent". Basant-nos en la literatura d'Estudis Marítims, proporcionem una llista de característiques i funcionalitats que caracteritzarien un port intel·ligent i oferim una explicació general sobre el que hauria de significar "intel·ligent" o "intel·ligència" en aquest context. A continuació, desenvolupem un model conceptual expressat com una sèrie de proposicions, construïdes al voltant de dos mecanismes d'influència presos de les ciències de gestió: l'impuls tecnològic *(technology push)* i l'atracció del mercat *(market pull)*. Més específicament, el model pretén explicar com les tecnologies d'Indústria 4.0, mitjançant aquests mecanismes, influeixen en els models de negoci dels ports marítims en tres àrees: operacions, estratègies i inversions. Per avaluar aquest model conceptual, duem a terme un estudi de cas exploratori sobre el port de Barcelona, basat en l'anàlisi de contingut de fonts documentals (especialment el tercer i el quart plans estratègics), així com una entrevista semiestructurada. La nostra avaluació mostra una primacia dels mecanismes d'influència del mercat i l'avaluació comparativa *(benchmarking)*, com la forma principal en què l'adopció de la Indústria 4.0 impulsa la innovació de models de negoci, almenys per als ports marítims amb les característiques i circumstàncies de Barcelona.

Al Capítol 4 passem als fluxos d'informació. Més específicament, explorem la influència que la tecnologia de *distributed ledger* (DLT), més comunament coneguda com a *blockchain*, podria tenir en l'adopció de models de negoci sostenibles a la indústria del transport marítim. Un dels pilars teòrics centrals de l'estudi és la concepció de la informació com a recurs, proporcionada per la disciplina Gestió de Recursos d'informació. Sobre aquesta concepció, proposem el concepte de la circularitat de la informació, que té lloc quan la informació que es genera com a subproducte o resultat de processos comercials, s'utilitza després com a entrada/recurs per a processos posteriors. Posteriorment, desenvolupem un model conceptual que representa la relació entre DLT i el transport marítim sostenible, expressat com a 5 proposicions. Per avaluar el model, realitzem un estudi de cas exploratori sobre TradeLens, plataforma d'informació basada en DLT per a cadenes de subministrament globals, utilitzant la tècnica d'anàlisi de contingut. La nostra avaluació preliminar troba que la DLT, en permetre una major circularitat de la informació i comportaments associatius entre els actors de la cadena de subministrament, es converteix en un catalitzador per a models de negoci sostenibles, que alhora impulsen pràctiques sostenibles a la indústria del transport marítim. La investigació amplia la literatura prèvia sobre la tecnologia DLT i el seu impacte a l'economia circular, els models de negocis associatius i la coordinació Inter empresarial en general, en el context del transport marítim.

El capítol 5 se centra en els fluxos financers. Presenta un estudi de disseny sobre un problema conegut com la bretxa de finançament del comerç *(trade finance gap)*; entès com la diferència entre l'oferta i la demanda total de finançament al comerç internacional a nivell global. La principal pregunta que s'aborda és com dissenyar un nou model de negoci que abordi les causes darrere d'aquesta bretxa de finançament comercial. Com a primer pas, basant-nos en literatura acadèmica i grisa, classifiquem un conjunt de causes darrere de la problemàtica, segons estiguin relacionades amb l'oferta (és a dir, que pertanyin a la capacitat de les institucions financeres per proporcionar finançament comercial) relacionades amb la demanda (relatives a les empreses que necessiten finançament comercial), o ambdues. Endinsant-nos en la teoria de la intermediació financera, analitzem a continuació el nou concepte de finances descentralitzades (DeFi), proposant un significat més ampli que el prevalent, que el redueix a funcions basades en tecnologia blockchain i criptomonedes. El nostre significat més ampli es basa en quatre perspectives: DeFi com a desintermediació, com a disminució de la concentració, com a desagregació de les funcions financeres i com a finançament alternatiu. El capítol presenta un model d'un sistema basat en DeFi per al finançament del comerç, més específicament, per al processament de crèdits documentaris. Hi descrivim com el model difereix i millora l'instrument de finançament comercial més tradicional: la carta de crèdit. El que és més important, en línia amb la metodologia de Recerca de Disseny Científic *(Design Science Research)*, avaluem com el model aborda les causes darrere de la problemàtica de la bretxa de finançament comercial, així com les seves contribucions teòriques. La conclusió és que un model basat en DeFi per al finançament del comerç pot reduir els costos de transacció, augmentar la liquiditat i proporcionar millor informació sobre les empreses per millorar-ne l'avaluació de la solvència.

Per concloure, aquesta dissertació explora com la transformació digital afecta o impacta els models de negoci a les cadenes de subministrament del comerç marítim. Ho fa mitjançant la realització d'estudis sobre diferents contextos, cadascun centrat principalment en els fluxos físics, d'informació o financers. Des d'una perspectiva teòrica, la dissertació proporciona informació sobre la interacció entre els tres fluxos al comerç marítim; amb un enfocament especial com la transformació digital, en afectar aquesta interacció, impulsa o contribueix a l'adopció de nous models de negoci. Més específicament, les tecnologies d'Indústria 4.0 com IoT o DLT milloren la manera com els fluxos d'informació interactuen amb els fluxos físics i financers. Des d'una perspectiva pràctica/gerencial, la recerca proporciona informació útil per als executius de negocis i els dissenyadors de polítiques sobre com cal enfrontar la transformació digital a nivell estratègic, tàctic i operatiu. En comprendre com les noves tecnologies afecten les formes en què es crea, distribueix i captura el valor, els prenedors de decisions poden dissenyar millors models de negoci, augmentant la competitivitat; o implementar polítiques i estratègies més adequades. El que és més important, la dissertació té com a objectiu servir com a font d'idees per als emprenedors que, a través de les *startups*, dissenyaran i desenvoluparan casos d'ús innovadors i models de negoci per a la indústria marítima.

About the author

Ricardo Henríquez Larrazábal was born in Maracaibo, Venezuela. He has a Master of Letters in Philosophy by the University of St Andrews, Scotland, (2000), a Specialization in International Maritime Trade by the Caribbean Maritime University, Caracas (2012), a Master of International Business by EAE Business School in Barcelona (2013), and a postgraduate Diploma in Port Operations Management by the Catalonia Polytechnic University (2014). From 2014 to 2017 he taught Strategic Management in the MBA program at EAE Business School.

Since 2017, Ricardo has been involved in several tech startup projects, including blockchain development companies in Dubai and Kazakhstan, and a fintech startup in Israel. At the beginning of 2020, he began to work on his own startup project, consisting of a digital solution for SMEs engaged in international trade. He has taken part on prestigious startup accelerator and incubation programs like Techstars (Tel Aviv, 2018) and F10 (Zurich, 2020). His main academic interest focus on the impact that new technologies have on business model innovation on different industrial sectors. Currently, he works from the Digital Hub Logistics in Hamburg, Germany.

PhD Portfolio

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2020 Annual Conference of the International Association of Maritime Economists (IAME), Hong Kong, 10-13 June 2020. Special Session S9: Innovations and net benefits for a Sustainable Shipping industry. Presentation: *DLT-based sustainable business models for the shipping industry*.

8th International Conference on Maritime Transport (MT 2020), Barcelona, 17-18 September 2020. Presentation: *A DeFi-based model for maritime trade finance*.

Workshops

9th ERIM/CentER PhD Workshop on Information Management Research. Erasmus University – Rotterdam School of Management. Rotterdam, April/May 2017.

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