Investigating the FinTech ecosystem: A Technological Innovations Systems (TIS) study using System Dynamics

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Abstract

Although FinTech innovations are argued to foster financial market efficiency, financial inclusion and contribute to the Sustainable Development Goals set by the United Nations, FinTech innovations only slowly diffuse over time. This indicates that a technological innovation system (TIS) needed for widespread development, diffusion, and utilization of FinTech innovations has not been fully established yet. For this reason, this study uses the TIS approach in combination with qualitative system dynamics (SD) modelling to investigate the FinTech ecosystem and to identify systemic drivers and barriers for FinTech TIS development. This study finds that participation in FinTech support programs created by governmental regulators should not be taken for granted. Governmental regulators lack technical knowledge about FinTech activities which is needed in order to change existing financial market regulations in favour of FinTech entrepreneurs. Consequently, regulators use these support programs to acquire this technical knowledge but this study shows that the demand for and effectiveness of support programs will only decrease over time. This indicates that it only becomes more difficult for regulators to change existing financial market regulations to foster FinTech development. However, the future for FinTech innovations looks bright once the TIS around FinTech innovations has been fully established. Furthermore, this study shows that the long-term battle for relevance and scale in the financial market will be between financial incumbents and cross-sectoral technology players. FinTech start-ups currently seem to have their 15 minutes of fame, but this will only last until their capabilities have been fully absorbed by these financial incumbents and cross-sectoral technology companies.

Keywords: FinTech innovations, ecosystem dynamics, qualitative system dynamics, technological innovation system

Table of Contents

1. Introduction

The rise of information technology (IT) and rapid diffusion of mobile technology over the recent decade has led to plenty of new products and services. The infusion of new digital technologies in the financial sector is widely known as FinTech (Zhang-Zhang, Rohlfer, & Rajasekera, 2020). FinTech is the umbrella term for all products and services that use cutting-edge technologies coming from the IT sector to renew and improve financial services, such as robo-advising, mobile payments, blockchain, and crowdfunding platforms (Thakor, 2020). FinTech entrepreneurs aim to foster consumer welfare by making financial services currently offered by financial incumbents cheaper, faster, and more accessible (Hu, Ding, Li, Chen, & Yang, 2019; Thakor, 2020). As a result, Hua, Huang, and Zheng (2019) argue that FinTech innovations contribute significantly to financial market efficiency. Besides, Arner, Buckley, Zetzsche, and Veidt (2020) state that FinTech innovations are the main drivers of financial inclusion. Financial inclusion, in turn, supports the Sustainable Development Goals set by the United Nations (Arner et al., 2020).

Nevertheless, Suurs and Roelofs (2014) explain that although radical innovations often offer new sustainable development opportunities, lock-in effects provide incumbents advantages over new entrepreneurs and therefore cause new innovations to diffuse only slowly over time. This slow diffusion rate also applies for new FinTech innovations. Ernst and Young (2019) show that globally, on average, only 64% of consumers use at least one FinTech service or product. This is surprisingly low as FinTech innovations are argued to increase financial market efficiency, foster financial inclusion, and even contribute to the Sustainable Development Goals. Geels, Hekkert, and Jacobsson (2008), however, explain that the slow diffusion rate of new technologies can be explained by the fact that incumbent technologies are supported by the institutional environment in which these incumbent technologies evolved. The fact that although expected benefits are high FinTech innovations only slowly diffuse, shows that the development, diffusion, and utilization of a new technological innovation does not only depend on the technological innovation itself but also on the social system surrounding the innovation (Foxon & Pearson, 2008). To overcome these lock-in effects, a technological innovation system (TIS) must be developed around a new technology. Carlsson and Stankiewicz (1991) define a TIS as a “dynamic network of agents interacting in a specific economic/industrial area under a particular institutional

infrastructure and involved in the generation, diffusion, and utilization of technology" (p.93).

The TIS approach is frequently used in innovation studies that investigate the dynamics of new emerging technologies (Markard, Hekkert, & Jacobsson, 2015). The TIS approach focuses on getting a deeper understanding of the innovation system centred around a new technology (Markard et al., 2015). The TIS approach generates useful insights in the processes that require stimulation to achieve successful development, diffusion, and utilization of new sustainable technological innovations (Planko, Cramer, Hekkert & Chappin, 2017). To generate these insights, first, the actors, institutions, technological infrastructures, and interactions involved in the innovation system must be identified (Wieczorek & Hekkert, 2012). Thereafter, seven 'system functions' must be identified (Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2008). These system functions are argued to be necessary for widespread development, diffusion, and utilization of new technological innovations (Bergek et al., 2008). The seven system functions are (1) entrepreneurial activities, (2) knowledge development, (3) knowledge diffusion, (4) guidance of the search, (5) market formation, (6) resource mobilization, and (7) creation of legitimacy. A TIS gradually builds over time and its development over time can be accelerated by reinforcing feedback loops, but also hindered by balancing feedback loops, formed by interacting system functions, the so-called 'motors of (sustainable) innovation' (Suurs, 2009). The TIS approach therefore allows for identifying systemic drivers and barriers for the development, diffusion, and utilization of an innovation. Moreover, these motors of innovation indicate to what extent a TIS around a certain innovation has been developed since Suurs (2009) explains that the four respective motors of innovation can be seen as stages of TIS development.

This shows that a TIS is a dynamic system which arises from the interactions between actors, institutions, and infrastructures and that there are complex and dynamic underlying mechanisms, 'motors of innovation', that drive and hinder TIS development (Köhler, Raven, & Walrave, 2020). As a result, the TIS approach demands taking a systemic view. The TIS approach therefore lends itself for system dynamics modelling. System dynamics (SD) is a methodology that aims to understand and explain the complex dynamics of a system by modelling the system's underlying structure (Sterman, 2000). SD tries to uncover feedback processes that help to explain the observed behaviour within a system

(i.e. relatively low development, diffusion, and utilization of FinTech innovations) (Sterman, 2000). Causal loop diagrams visualize interrelationships between variables and bring out systemic drivers and barriers causing the observed behaviour of a system.

Consequently, this study uses the TIS approach in combination with qualitative SD modelling to investigate the FinTech ecosystem and to identify systemic drivers and barriers of the development, diffusion, and utilization of FinTech innovations. The TIS approach is suitable for this study since Planko et al. (2017) argue that the TIS approach deals with the formative phase of building an innovation system around a new technology. The fact that a large part of society has still not adopted a FinTech product or service (Ernst & Young, 2019), indicates that a TIS has not completely developed around FinTech innovations yet. A fully developed TIS around FinTech innovations is important to take full advantage of the benefits that FinTech innovations bring to consumer welfare and the financial market.

This study therefore has practical relevance for civil society since the outcomes of this study will help to further accelerate the widespread development, diffusion, and utilization of FinTech innovations. Moreover, this study will contribute to the existing FinTech literature which is still argued to be under-theorized (Hornuf, Klus, Lohwasser, & Schwienbacher, 2020). Zhang-Zhang et al. (2020) urged future researchers to investigate the FinTech ecosystem in more depth. The TIS approach requires a thorough investigation of the actors, institutions, technological infrastructure, and interactions in the FinTech ecosystem and this study will therefore contribute to an even more in-depth understanding of the FinTech ecosystem. Furthermore, Drasch, Schweizer, and Urbach (2018) and Hornuf et al. (2020) asked for more studies that examine the effect of FinTech on the financial market because of FinTech's potential benefits for financial market efficiency. The combination of the TIS approach with qualitative SD modelling will help in gaining a deeper understanding in what drives and hinders TIS development around FinTech innovations. These systemic drivers and barriers provide more insights into what the effect of FinTech will be on the existing financial market. Additionally, Basole and Patel (2018) expected power to shift from traditional financial incumbent institutions to FinTech start-ups. Gomber, Kauffman, Parker, and Weber (2018) also expected FinTech start-ups to disrupt the whole financial market. Arner, Buckley, and Barberis (2016), on the other hand, expected multiple players to provide financial services in the new FinTech ecosystem. The findings of this study will further support or discredit these expectations about the future FinTech ecosystem.

The research objective for this study is therefore to contribute to the undertheorized FinTech literature by using the TIS approach in combination with the SD methodology to investigate the FinTech ecosystem and to identify processes that explain drivers and barriers for technological system innovation needed for the widespread development, diffusion, and utilization of FinTech innovations. The data in this study consists of scientific literature. This study focuses on recent literature published in the last four years since no relevant literature before 2017 was identified during the search process for the integrative review. The following research questions need to be answered to realize the research objective:

1. What actors, institutions, technological infrastructures, and interactions involved in the TIS surrounding FinTech innovations are identified in scientific literature from 2017-2021?
2. What TIS system functions around FinTech innovations are identified in scientific literature from 2017-2021?
3. What reinforcing and balancing feedback processes, identified in scientific literature from 2017-2021, are involved in the interactions between the TIS functions surrounding FinTech innovations?
4. To what extent do variables and feedback processes identified in scientific literature from 2017-2021 explain the drivers and barriers for the development, diffusion, and utilization of FinTech innovations?
5. To what extent has the TIS around FinTech innovations been developed?

The remainder of this study is structured as follows. The second section describes the roots of the TIS approach, explains more about the SD methodology, and extensively discusses the structural dimensions, system functions, and motors of innovation involved in the TIS approach. The third section contains an explanation of the methods used for data collection and data analysis. This section also addresses research ethics. The fourth section provides the results of this study and answers the first three research questions. The fifth section concludes by answering the last two research questions and discusses the theoretical and practical implications of this study. The fifth section ends by discussing the limitations and by providing suggestions for future research.

2. Literature review

This literature review starts by discussing the roots that the TIS approach has in evolutionary economics and explains more about the TIS approach. Paragraph 2.2 elaborates on the links between the TIS approach and system dynamics. Paragraph 2.3, 2.4, and 2.5 respectively discuss the structural dimensions of the TIS approach, the seven system functions necessary for TIS development, and the motors of innovation that accelerate the TIS development through feedback mechanisms.

2.1 TIS Framework rooted in evolutionary economics

The TIS literature is a research strand within evolutionary economics. Whereas innovation was long thought of as a linear process which started with basic research, followed by applied research and development (R&D), and ended with production and diffusion (Godin, 2006), the TIS literature takes another view (Suurs, 2009). The TIS literature argues that innovation is a continuing interactive process between 'system functions' that reinforce and balance each other through feedback mechanisms (Suurs, 2009). The TIS approach has its roots in evolutionary economics. Within evolutionary economics, change unfolds by the interplay of variety, retention, and selection (Suurs & Roelofs, 2014). Suurs and Roelofs (2014) describe that different actors create variety by introducing new technological innovations. Yet, through inertia of institutions and technological infrastructures, incumbent technological innovations remain present. Selection takes place within the internal and external environment. The internal environment (i.e. firms) selects which new innovations it wants to develop and adopt whereas the external market environment also makes a selection of the available technological innovations. The TIS approach stresses that the development, diffusion, and utilization of a new technological innovation does not only depend on the innovation itself but is also heavily influenced by the social system surrounding the new technological innovation (Foxon & Pearson, 2008). Due to the significant influence of the social system surrounding the technological innovation, a TIS must be developed to support the development, diffusion, and utilization of a new technological innovation (Suurs & Roelofs, 2014). Carlsson and Stankiewicz (1991) argue that a TIS is a "dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilization of technology" (p.93).

The TIS approach incorporates a systems perspective to investigate how a supporting TIS develops around new innovations (Walrave & Raven, 2016). The TIS approach analyses the actors, institutions, and technological infrastructures present and the dynamic processes resulting from these 'structural dimensions' (Bergek et al., 2008). Thereafter, the TIS approach analyses seven functions of innovation systems (Planko et al., 2017). The TIS functions can be found in Table 1 above. The interaction between these system functions creates motors of innovation. These motors of innovation, through feedback mechanisms, accelerate the development of a TIS (Suurs, 2009). Yet, besides identifying these drivers of TIS development, the TIS approach also aims at identifying the systemic barriers that hinder the development of a TIS. These systemic barriers are especially important since policies must be devised to counteract them (Suurs & Roelofs, 2014).

Technological Innovation System (TIS) functions	
1.	Entrepreneurial activities
2.	Knowledge development
3.	Knowledge diffusion
4.	Guidance of the search
5.	Market formation
6.	Resource mobilization
7.	Creation of legitimacy

Table 1. TIS functions (Bergek et al., 2008)

2.2 TIS approach and system dynamics

As described in the foregoing, the TIS approach incorporates a systems perspective and aims to analyse the dynamics of emerging technological innovations. According to Walrave and Raven (2016), the TIS approach contains causal relations, delays, and feedback structures which are elements related to SD. The SD approach uses systems thinking, modelling, and feedback control theory to understand the dynamics of complex issues through examining the interactions within the system (Sterman, 2000). SD assumes that underlying feedback structures allow for explaining the dynamic behaviour of a social system (Rouwette & Franco, 2015). As a result, SD tries to uncover these feedback processes since these help to explain the observed behaviour of a system (Sterman, 2000). There are two types of feedback loops, reinforcing (positive) and balancing (negative) feedback loops. Reinforcing feedback loops cause the development of variables included in the loop to amplify and therefore lead to exponential growth or exponential decay (Sterman, 2000). Balancing feedback loops, on the other hand, resist change and therefore cause the system to maintain its status quo (Sterman, 2000). SD focuses on the causal factors internal to the social system and assumes external influences are less important, since an important premise of SD is that the dynamic behaviour of the system can be explained through the

interacting elements within the system (Rouwette & Franco, 2015).

The TIS approach tries to identify the systemic drivers and barriers for the development of a TIS. By using the SD methodology to model the 'motors of innovation', the interactions between the seven system functions, the TIS approach tries to identify reinforcing and balancing feedback loops. The identified feedback loops, in turn, provide increased understanding into what drives or hinders the development of a supporting TIS around FinTech innovations.

2.3 Structural TIS dimensions

The TIS approach first identifies the actors, institutions, and technological infrastructures and analyses the dynamic process between these structural TIS dimensions (Wieczorek & Hekkert, 2012). These structural dimensions can be seen as the building blocks of the TIS. These three structural dimensions are considered to be relatively stable over time, meaning that they are expected to change but at a slow rate (Suurs, 2009). An actor is any organization (e.g. civil society, start-up, MNC, government, or financial intermediary) that contributes to the development of TIS directly or indirectly (Wieczorek & Hekkert, 2012). The choices made and actions performed by actors influence the emergence of a TIS since these actors are the ones that develop, diffuse, and utilize these new technological innovations (Suurs, 2009). Consequently, the interactions and interrelationships between these actors have a considerable impact on the development of a TIS.

The second structural dimension comprises of institutions. North (1990) describes institutions as the rules of the game for society. These rules, in turn, shape human interactions. The TIS framework distinguishes formal (e.g. laws and regulations) and informal institutions (e.g. habits, routines, expectations, and/or patterns of behaviour) (Wieczorek & Hekkert, 2012). Formal institutions provide legislated and enforced rules whilst informal institutions can be either cognitive or normative. Suurs (2009) explains that the institutional configuration is frequently underdeveloped in the emerging phases of a TIS. The reasons Suurs (2009) provides for this are that (in)formal institutional structures are not yet in place when a new technological innovation emerges or that the current institutional structures are maladapted to this new innovation. In general, the informal institutional structures (i.e. expectations and visions) drive actors in the early stages of a TIS. Yet, the institutional factors indirectly influence the presence, willingness, and skills of the actors

involved and are predominantly the target of policies and business strategies (Suurs, 2009).

The third structural dimension comprises of the technological infrastructure (e.g. networks, knowledge, subsidies, and machines). According to Suurs (2009), these technological factors are key for the assessment of technological progress. These technological factors are both tangible as well as intangible. Technological factors also constrain and enable actors' actions and choices. Yet, technological factors and institutional structures are argued to mutually influence each other leading to significant feedback mechanisms (Suurs, 2009).

2.4 TIS system functions

Besides analysing the structural dimensions described in section 2.3, the TIS approach also focuses on system functions. Bergek et al. (2008) describe system functions as all the activities that play a role in the development, diffusion and utilization of a new technological innovation. The presence of these system functions is argued to be essential for the development of a TIS (Bergek et al., 2008). These system functions must be seen as sets of activities fostering a technological system innovation process. In total, there are seven system functions namely (1) entrepreneurial activities, (2) knowledge development, (3) knowledge diffusion, (4) guidance of the search, (5) market formation, (6) resource mobilization, and (7) creation of legitimacy.

Suurs (2009) defines entrepreneurial activities as all the projects aimed at proving the usefulness of a new technology in a practical environment. Entrepreneurial activities (e.g. demonstrations and experiments from new entrants and start-ups) are necessary since new technological innovations are often characterized by high levels of uncertainty. As a result, Suurs (2009) argues that entrepreneurs are at the heart of a TIS.

Knowledge development encompasses learning activities. These learning activities consist of R&D activities as well as activities that introduce the new technological innovation to users and networks by means of trials and experiments (Suurs, 2009).

The third system function is knowledge diffusion. Examples of knowledge diffusion activities are conferences and workshops which aim at facilitating knowledge exchange between the actors within the TIS (Suurs, 2009). Within a TIS, it is pivotal that knowledge is diffused among different actors. A shared understanding of the new technology among these actors encourages the gradual adjustment of technologies towards institutions and the other way around (Suurs, 2009).

Guidance of the search consists of all the activities that shape the expectations and requirements of actors towards a new technological innovation (Suurs, 2009). These activities can either be positive or negative. A positive guidance of the search indicates that there are positive signals towards the technology development (e.g. positive expressed visions or demand articulation by leading customers) (Wieczorek & Hekkert, 2012). However, in case guidance of the search expresses negative signals, this could be an indication that actors reject the technological development. Guidance of the search does not only influence actors within the TIS but also has considerable impact on actors outside the TIS (Suurs, 2009). Guidance of the search is an interactive activity in which multiple actors express their visions and expectations about a new technology.

The fifth system function is market formation. The market formation function covers all the activities that are needed to create demand for the new technology. According to Suurs (2009), it is practically impossible for new technologies to compete with the already widely-used existing technology. As a result, the creation of niche markets should help these technologies to further develop.

The sixth function is resource mobilization. This function emphasizes the importance of human, financial, and material resources within the TIS. Carlsson and Stankiewicz (1991) argue that a new technology cannot develop without the support of these capital factors. Examples of resource mobilization activities are specialized training programs, venture capital, and investments in natural resources (Wieczorek & Hekkert, 2012).

The last and seventh system function is creation of legitimacy. There are inevitably actors that resist the new technology since they have interest in the incumbent technology (Suurs, 2009). As a result, legitimacy creation activities such as lobbying and advocacy coalition formation must take place to neutralize the inertia caused by the incumbent technologies and institutions.

2.5 Motors of innovation

Suurs (2009) distinguishes four so-called ‘motors of innovation’. These motors of innovation describe how the abovementioned system functions interact in different phases of the TIS development.

The first motor is the ‘science and technology push motor’. A visualisation of the science and technology push motor can be found in Figure 1 below. The science and technology push motor involves two reinforcing feedback loops namely R1 and R2. R1

shows that positive research outcomes and expectations (i.e. positive guidance of the search) lead to governments providing financial resources such as subsidies and financial resources (i.e. resource mobilization) to the newly developed technology. This in turn drives the initiation of knowledge development and diffusion activities. Laboratory trials can be executed and conferences can be held to further strengthen the positive expectations and research outcomes of the technological innovation. However, R2 shows that at the same time firms and entrepreneurs are approached by the government (or another actor within the system context) to start projects that establish change to the technological innovation and surrounding institutions. Yet, technological innovations are characterized by high levels of uncertainty. As a consequence, the willingness of entrepreneurs and organizations to perform entrepreneurial activities depends on the first outcomes of the guidance of the search activities. If these entrepreneurs and organizations decide to perform entrepreneurial activities, this, in turn, further drives the positive expectations and the amount of resources allocated.

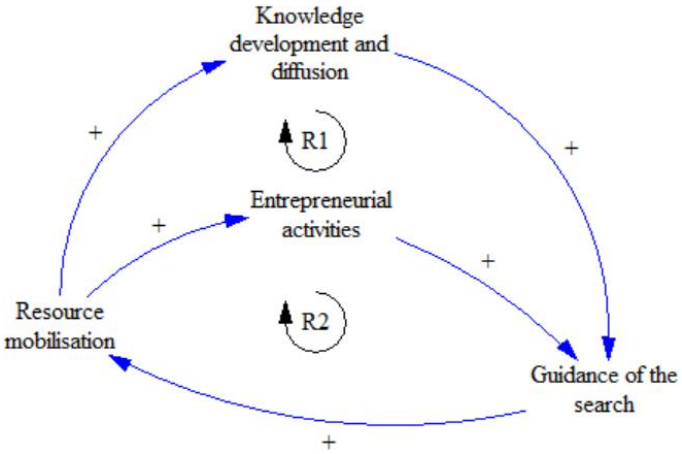

Figure 1. Visualisation of science and technology push motor based on Suurs (2009)

The second 'motor of innovation' is the entrepreneurial motor. According to Suurs (2009), the entrepreneurial motor is quite similar to the science and technology push motor. What makes the entrepreneurial motor distinct from the latter is the strong presence of entrepreneurial activities and advocacy coalitions (i.e. creation of legitimacy). Feedback loop R3, visible in Figure 2 below, starts with entrepreneurs initiating projects with a commercial aim to seize business opportunities or societal gain. Thereafter, these entrepreneurs start lobbying activities with governments to carry the financial risks by demanding financial resources. When resources are mobilized by the entrepreneurs, the projects are actually

executed. If the outcome of R3 is positive, this positively influences guidance of the search, leading to other actors initiating projects. This process is shown by R4. Moreover, this shows that R3 provides the (dis)incentive for R4. Feedback loop R3 and R4 are further strengthened by market formation activities. The science and technology push motor provides the basis for the entrepreneurial motor. Moreover, R5 shows that within the entrepreneurial motor, there is a strong interaction between entrepreneurial activities and knowledge development and diffusion activities.

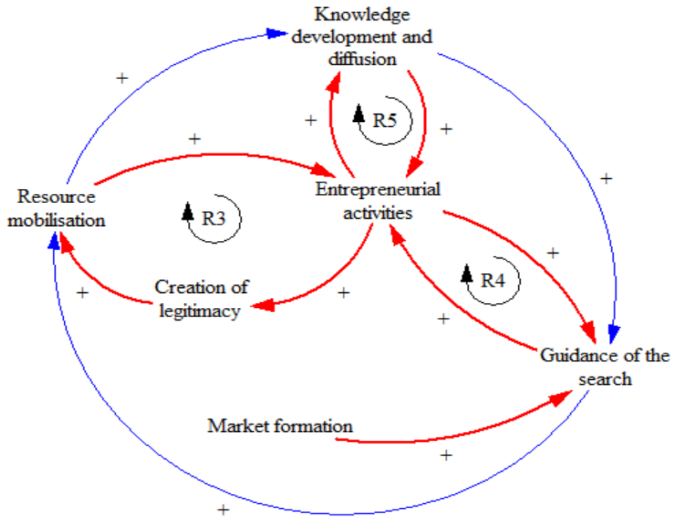

Figure 2. Visualisation of entrepreneurial motor based on Suurs (2009)

The third innovation motor is the system building motor (Figure 3 below). The key difference between the system building motor and the entrepreneurial motor is that actors within the system building motor intentionally co-operate to strengthen each other's activities (Suurs, 2009). Entrepreneurs start operating within networks. In this way, entrepreneurs are able to draw in new actors by knowledge diffusion activities. At the same time, entrepreneurs succeed in lobbying the government, leading to additional resources and positive guidance of the search. This leads to even more entrepreneurial activities (see respectively R6 and R7). R8 and R9 show that market formation activities reinforce R6 and R7. Suurs (2009) explains that this indicates that markets are intentionally shaped environments within the TIS.

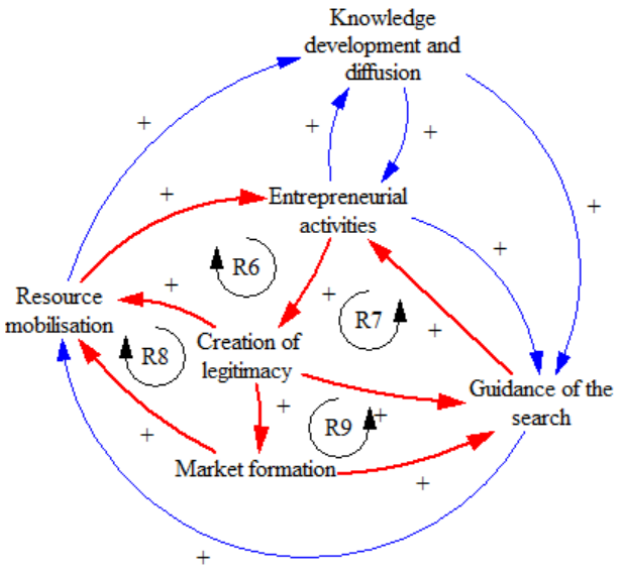

Figure 3. Visualisation of system building motor based on Suurs (2009)

The fourth 'motor of innovation' is the market motor (Figure 4 below). A characteristic of the market motor is that advocacy coalitions do not a play a role in this innovation motor. The reason for this is that markets are formed because of formal regulations and not because of politics (i.e. lobbying activities) (Suurs, 2009). Markets are now immediately created through business activities that support entrepreneurial activities such as marketing efforts (see feedback loop R10). In case a market is formed by these business activities, this increases the amount of allocated resources but also boosts the expectations of the technological innovation. Consequently, new actors will enter and start adopting the new technology (see R11 and R12 respectively). Market formation activities further reinforce R13 and R14.

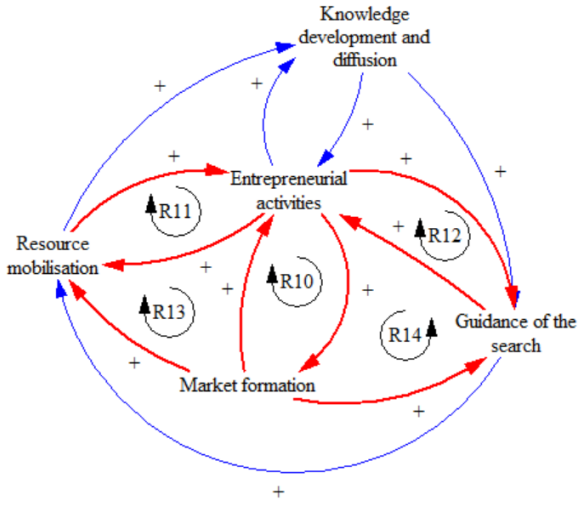

Figure 4. Visualisation of market motor based on Suurs (2009)

3 Methodology

As mentioned, the objective of this study is to contribute to the undertheorized FinTech literature by using the TIS approach in combination with the SD methodology to investigate the FinTech ecosystem and to identify processes that explain drivers and barriers for technological system innovation needed for the widespread development, diffusion, and utilization of FinTech innovations. To fulfil this research objective, an integrative literature review is conducted. The integrative literature review is used to identify the structural TIS dimensions (i.e. actors, institutions, technological infrastructures and their interactions), the TIS functions, and to identify variables and feedback processes that drive and hinder technological system innovation around FinTech innovations.

Section 3.1 explains how the data for this study, by means of an integrative review, is collected. Section 3.2 explains how the collected data is analysed. Section 3.3 discusses the research ethics incorporated in this study.

3.1 Data collection

An integrative literature review is a review method that reviews, critiques, and synthesizes literature for the purpose of developing a holistic understanding of a research topic (Whittemore & Knafl, 2005; Toracco, 2016). The broadness of integrative reviews allows researchers to capture the complexity of emerging phenomena (Hopia, Latvala, & Liimatainen, 2016) such as the emergence of a TIS around FinTech innovations. This complexity can be captured through integrative reviews because integrative reviews use multiple diverse data sources (Hopia et al., 2016). Toracco (2016) explains that integrative reviews generate new knowledge through the synthesis of extant literature. The synthesis of extant literature is a creative effort which aims at gaining a deeper holistic understanding of the research topic analysed (Toracco, 2016). Toracco (2016) discusses five ways of presenting synthesis which are in the form of (1) a research agenda, (2) taxonomy or other conceptual classification of constructs, (3) alternative model or conceptual framework, (4) meta-analysis and (5) metatheory. This study uses the third form of synthesis namely generating a deeper holistic understanding of the TIS development around FinTech innovations by constructing a qualitative SD model. De Gooyert (2016) argues that qualitative SD models in the form of a causal loop diagrams contribute significantly to theory development. De Gooyert (2016) explains that qualitative SD models are suitable for

synthesizing existing theories and help in gaining a deeper understanding of the complex dynamics behind the phenomenon of interest (i.e. TIS development).[1] This shows that synthesizing the results of the integrative review in the form of a qualitative SD model is suitable for the aim of this study which is identifying drivers and barriers for the widespread development, diffusion, and utilization of FinTech products and services.

3.1.1 Search strategy and inclusion/exclusion criteria

The database Web of Science is used to find relevant articles because Web of Science provides a complete overview of high-quality published articles that are strictly peer-reviewed (Gusenbauer & Haddaway, 2020). Besides, the database Web of Science is used for practical and accessibility reasons since Radboud University grants students free access to the Web of Science database. In order to collect a broad selection of journal articles on TIS development around FinTech innovations, the search terms applied in Web of Science were "FinTech" and "Innovation". Besides, all years were included in the search. The search was conducted on March 25th 2021 and after removing duplicates, the search led to the identification of 270 articles.

In order to select only the articles relevant for the scope of this study, seven steps with inclusion and exclusion criteria were applied. In the first step, from these 270 articles, only articles, papers in proceedings, and early-access papers were selected whereas other document types were excluded. Moreover, only articles, papers in proceedings, and early-access articles in the English language were included. These criteria led to the identification of 240 eligible articles.

The integrative review is used to identify the structural TIS dimensions, TIS functions, and feedback processes involved in the development of a FinTech TIS. Wieczorek (2012) made a short handout in which indicators for the seven TIS functions are provided. Consequently, in step 2, these indicators were used one at a time as an additional search term besides the search terms of "FinTech" and "Innovation". Appendix A shows this process. Appendix A lists the system functions and corresponding indicators, and shows how many articles and which articles satisfied these criteria. After step 2, 125 eligible articles were left that reported at least one TIS function.

[1] For studies using qualitative SD modelling with the aim of synthesizing existing literature to contribute to theory development, see Martinez-Moyano et al. (2013), Goh et al. (2012), or Repenning and Sterman (2002).

These 125 articles were examined in depth in step 3. After assessing all articles, two doubles were identified although having different stated writers and titles. After removing the doubles, 123 articles were left in the dataset. Moreover, 16 records turned out to be inaccessible in step 4. In order to gain access to these papers, Web of Science, RuQuest, Google Scholar and general Chrome searches were used. However, the decision was made to exclude these 16 articles as they were either impossible to find or inaccessible without having to pay for these articles. After step 4, 107 articles were left in the dataset.

In step 5, the remaining 107 articles were checked for their relevance to the research topic of interest. The aim of this study is to investigate the FinTech ecosystem and to identify variables and feedback processes that explain drivers and barriers for technological system innovation needed for the widespread development, diffusion, and utilization of FinTech products and services. As a result, the following criteria were used to assess whether the records were about this study's research topic:

- The term FinTech or financial technology needs to be mentioned more than 10 times. The record was removed if FinTech or financial technology was mentioned 10 times or less.
- The records need to be about FinTech. There are multiple new techs such as BigTech, InsurTech, RegTech, and Suptech but papers only covering these topics without addressing FinTech were excluded.
- FinTech needs to be a central element studied in the article, not an external effect to the examined phenomenon in the study.

After step 5, 95 articles were left in the dataset. In step 6, records were excluded with no empirical results on the basis of own conducted research. The reason for this is that this study looks at drivers and barriers present within the TIS of FinTech services and not at potential drivers and barriers. As a result, only records based on primary data were kept in the dataset. After step 6, 55 articles were left.

In step 7, the articles with non-generalizable results were excluded from the dataset. Results had to be generalizable to Europe or developed countries and had to be about FinTech in general. The reason for this is that there are multiple 'types' of FinTech. FinTech can be categorized into, for example blockchain, peer-to-peer lending, or cryptocurrency. However, results had to be generalizable to all 'types' of FinTech. After step 7, 23 suitable

articles were identified that met all criteria and were ready for data analysis. A full list of the final 23 articles can be found below in Table 2.

#	Author	Journal	Year
1	Abbasi, Alam, Du, and Huynh	Technological Forecasting and Social Change	2021
2	Najaf, Schinckus, and Yoong	Managerial Finance	2020
3	Butor-Keler and Polasik	Economics and Law	2020
4	Kabulova and Stankevičienė	Sustainability	2020
5	Zhang-Zhang, Rohlfer, and Rajasekera	Sustainability	2020
6	Alaassar, Mention, and Aas	Technological Forecasting and Social Change	2020
7	Choi and Lee	Sustainability	2020
8	Hommel and Bican	Sustainability	2020
9	Polasik, Huterska, Iftikhar, and Mikula	Journal of Economic Behaviour and Organization	2020
10	Fonseca and Meneses	Proceedings of the International Conference on Business Excellence	2020
11	Cojoianu, Clark, Hoepner, Pažitka, and Wójcik	Small Business Economics	2020
12	Hornuf, Klus, Lohwasser, and Schwienbacher	Small Business Economics	2020
13	Gazel and Schwienbacher	Small Business Economics	2020
14	Hendrikse, van Meeteren, and Bassens	Environment and Planning A: Economy and Space	2019
15	Chen, Wu, and Yang	Review of Financial Studies	2019
16	Dranev, Frolova, and Ochirova	Research in International Business and Finance	2019
17	Unsal and Rayfield	Disruptive Innovation in Business and Finance in the Digital World	2019
18	Tanda and Schena	Palgrave Macmillan Studies in Banking and Financial Institutions	2019
19	Svensson, Udesen, and Webb	Technology Innovation Management Review	2019
20	Basole and Patel	Service Science	2018
21	Drasch, Schweizer, and Urbach	Journal of Economics and Business	2018
22	Gozman, Liebenau, and Mangan	Journal of Management Information Systems	2017
23	Li, Spigt, and Swinkels	Financial Innovation	2017

Table 2. Full list of articles included in integrative review

To ensure reliability and validity, the selection process[2] for the integrative review was randomly checked by a second coder who was unfamiliar with the research topic. The second coder understood the inclusion and exclusion criteria and the same results were found. A visualization of the identification and selection process for the integrative review can be found in Figure 5 below.

[2] The article selection process can be found in the attached excel-file in the first tab.

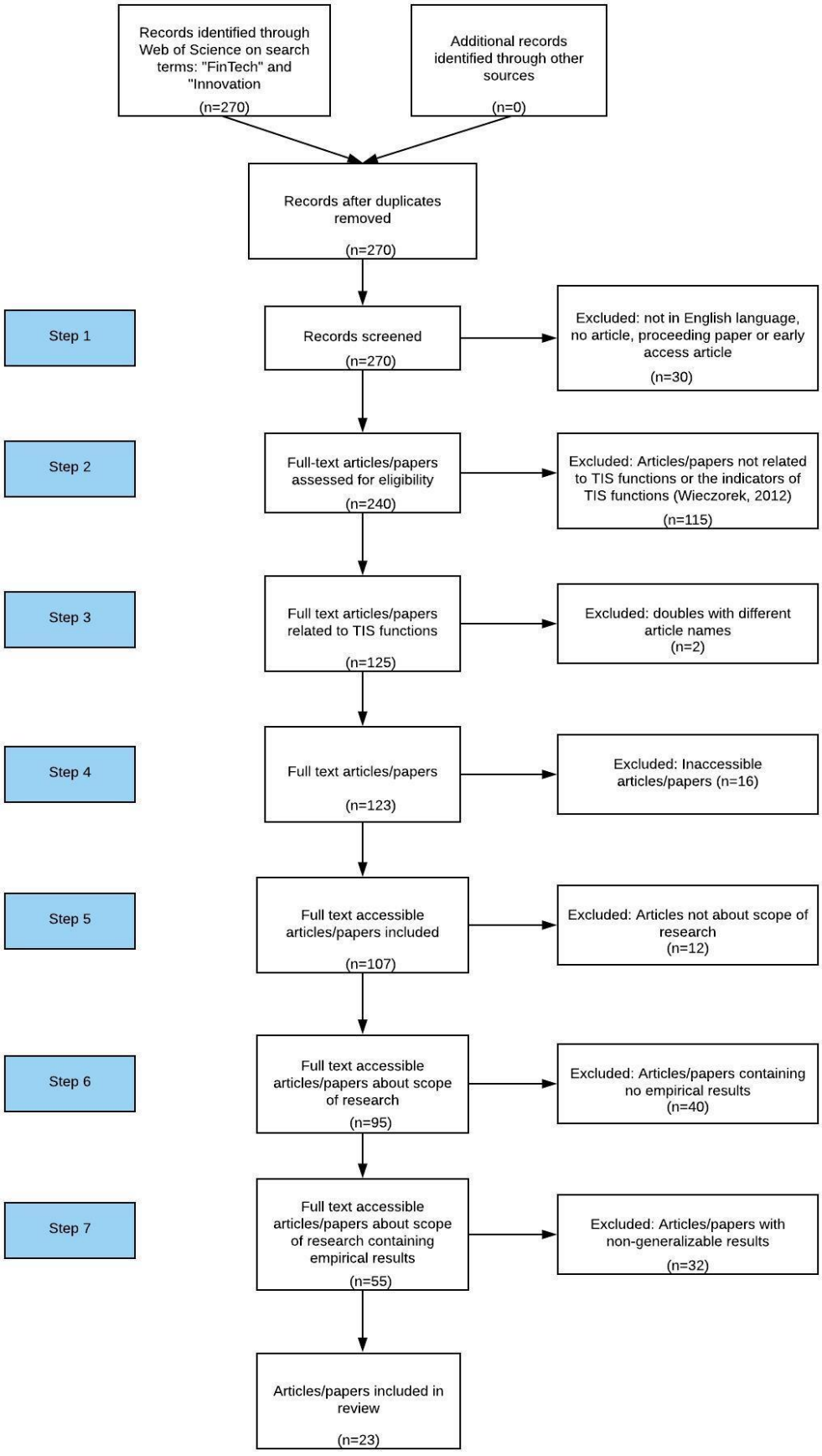

Figure 5. Identification and selection process for integrative review

3.2 Data analysis

To analyse the data of the integrative review, an evidence table was created with the following column names: 'study name', 'author and date', 'study design', 'sample size', 'study findings', 'implications of study', and 'limitations' to back up the SD model and to list the main data. Besides, the evidence table contains information about the TIS structural dimensions and system functions.[3] To achieve a complete evidence table, the 23 articles included in the final dataset were analysed in depth. At the beginning, the author scanned the whole text and read the abstract, introduction, and conclusions carefully to get a sense of the content of the articles. Thereafter, the author read the whole article sentence-by-sentence to complete the evidence table. When doing this, the short handout of Wieczorek (2012) was taken into account to ensure that the structural TIS dimensions and system functions were interpreted correctly. After analysing all 23 articles, the process was repeated one more time to edit and supplement the evidence table.

In addition, this study aims to generate an in-depth and holistic understanding of the TIS development around FinTech innovations by constructing a qualitative SD model. This qualitative SD model will be in the form of a causal loop diagram. To construct this causal loop diagram, the 23 articles were coded using the coding method of Davis et al. (2020). This coding method facilitates the transformation of textual data into word and arrow SD models. Consequently, the coding method of Davis et al. (2020) is suitable for realizing the aim of this study. The purpose of their coding method is to identify variables, interconnectivity, and feedback loops (Davis et al., 2020). The first step in their approach is to extract variables and causal relationships. This is done by checking the selected articles word-by-word and sentence-by-sentence (Davis et al., 2020). All causal relationships identified in the 23 articles were shaded in dark blue, whereas the variables were shaded in light blue.[4] All identified causal relationships were modelled in a SD software program called Vensim. This whole process was once again performed twice to ensure that no valuable information was overlooked. These modelling efforts led to the emergence of reinforcing and balancing feedback loops which were hidden in the textual data and were found by combining the content of the 23 articles.

[3] Evidence table can be found in the attached excel-file in the second tab.

[4] All identified causal relationships can be found in the third tab of the excel file. Likewise, the coded articles can be found in the attached WinRAR file.

After having modelled all identified causal relationships in Vensim, the exogenous variables were removed from the qualitative SD model to get to the essence of the model. The resulting model contains the main feedback loops identified in scientific literature.

Vennix (1996) explains that absolute valid models do not exist. As a result, model validation is often argued to be about the amount of confidence one has in the usefulness of the model with respect to its purpose (Barlas, 1996). The SD model built in this study is therefore perceived valid if the SD model identifies reinforcing and balancing feedback loops that provide an in-depth understanding of the systemic drivers and barriers for the development, diffusion, and utilization of FinTech products and services. Moreover, the SD model should provide more clarity about what stage TIS development is currently in since Suurs (2009) explains that the motors of innovation can be seen as stages of TIS development.

3.3 Research ethics

Although integrative reviews involve no direct collection of personal and confidential data from participants (Suri, 2020), multiple ethical considerations were taken into account when conducting this study. Wager and Wiffen (2011) argue that integrative reviews often form the basis for important policy decisions. Wagger and Wiffen (2011) therefore emphasize the importance of integrative reviews being accurate and unbiased. As a result, Wagger and Wiffen (2011) claim transparency about interests, accurate data extraction, and avoidance of plagiarism as essential when conducting integrative reviews.

The researcher hereby declares that the researcher can be considered as neutral and is not motivated by personal interests in the outcome of this study. Besides, to maximize accuracy and minimize biases, clear rules are defined before data extraction. These rules were defined in order to have evident search and sampling strategies to minimize the impact of publication and search biases (Suri, 2020). Wager and Wiffen (2011) advise the data extraction process to be checked by another independent researcher. As a result, the data extraction process in this study is randomly checked by the first supervisor of this study. Furthermore, to ensure the repeatability of this study, the methodological steps taken in this study are documented as careful as possible. In addition to the methodological steps described in this study, a spreadsheet is kept with the article selection process, an evidence table, and the identified causal relationships in the literature. Moreover, the

researcher avoids plagiarism by describing other researchers' findings in researcher's own words while always mentioning the source. Lastly, the integrative review contains only peer-reviewed records from the Web of Science data to make sure these records meet scientific and ethical standards (Kaminstein, 2017).

4 Results

The results section starts in 4.1 with reviewing the structural dimensions (i.e. actors, institutions, technological infrastructure, and interactions) in the FinTech TIS. Thereafter, in paragraph 4.2 the seven system functions present in the FinTech TIS will be discussed in depth. The results section ends in paragraph 4.3 with describing the main feedback loops from the constructed SD model after having analysed the output from the integrative review.

4.1 TIS FinTech structural dimensions

The aim of paragraph 4.1 is to answer the first research question: *What actors, institutions, technological infrastructures, and interactions involved in the TIS surrounding FinTech innovations are identified in scientific literature from 2017-2021?*

4.1.1 Actors

The key FinTech ecosystem actors are FinTech start-ups, traditional financial incumbents, cross-sectoral technology companies, investors, governmental regulators, financial customers, and technology developers (Zhang-Zhang et al., 2020). Other FinTech ecosystem players that are mentioned are hackers (Najaf, Schinckus, & Yoong, 2020), small and medium enterprises (Abbasi, Alam, Du, & Huynh, 2021), and scholars (Zhang-Zhang et al., 2020). The division of roles between these FinTech ecosystem players is fuzzy and they seem to become even more mixed over time (Zhang-Zhang et al., 2020).

FinTech start-ups are currently active in 189 countries worldwide (Najaf et al., 2020). These FinTech start-ups focus on existing financial services in order to improve and renew these financial services traditionally offered by financial incumbents (Palmié, Wincent, Parida, & Caglar, 2020; Thakor, 2020). As a result, the active presence of FinTech start-ups disrupts the operations of traditional financial incumbent institutions (Zhang-Zhang et al., 2020). Butor-Keler and Polasik (2020) discuss the role of the big technology firms like Google, Amazon, Facebook, and Apple (GAFA) which entered the FinTech ecosystem because of the strong technological component in FinTech disruption. Zhang-Zhang et al. (2020) call these actors “cross-sector” players since these technology firms combine their knowledge about IT with financial services.

Furthermore, Najaf et al. (2020) show that public investors generally overestimate the market value of FinTech firms due to extravagant FinTech enthusiasm. Moreover,

FinTech ecosystem players invest in other ecosystem players, indicating the fuzziness of relations and roles within the FinTech ecosystem (Zhang-Zhang et al., 2020). The financial crisis of 2008 has led to increased interest from governmental regulators in the financial market. The reason for this is that operations of FinTech firms are considered way riskier than the operations of traditional financial incumbents (Najaf et al., 2020).

FinTech entrepreneurs make use of new technologies coming from the IT sector to respond to new financial customer needs (Basole & Patel, 2018). IT technologies are applied to existing financial services to improve and renew these services (Hendrikse, van Meeteren, & Bassens, 2019). This shows the important role for technology developers in the new FinTech ecosystem. Yet, Zhang-Zhang et al. (2020) argue that most cross-sectoral technology companies are also technology developers.

Theme	Key insights
Actors	- Key FinTech ecosystem players are FinTech start-ups, traditional financial incumbents, cross-sectoral technology companies, investors, governmental regulators, financial customers, technology developers, hackers, small and medium enterprises, and scholars. - Fuzzy roles and relations within FinTech ecosystem. - Entrance of cross-sectoral technology companies.

Table 3. Main takeaway related to TIS structural dimension: Actors

4.1.2 Institutions

In terms of *hard institutions*, existing regulations are still unable to meet demands of FinTech entrepreneurs (Butor-Keler & Polasik, 2020). Li, Spigt, and Swinkels (2017) explain that regulators have contradictory ideas about whether to lower regulatory costs for FinTech firms in order to encourage financial market innovation or to protect customers and create a level playing field with traditional financial incumbents by putting similar regulations in place. Nonetheless, the financial crisis of 2008 together with new technological innovations have led to increased regulatory supervision to protect customers and wider economies against instability and collapse of the financial system (Gozman, Liebenau, & Mangan, 2017). These new regulations demand financial market actors to report more and be more transparent to decrease hazards resulting from information asymmetries (Gozman et al., 2017). Besides, actors require government-issued financial market licenses to operate legally in the financial market (Zhang-Zhang et al., 2020). Traditional financial incumbents are therefore governed by strict regulations. As a consequence, there are multiple regulatory aspects that need to be considered by FinTech

entrepreneurs when trying to enter the financial market (Svensson, Udesen, & Webb, 2019).

Although these new regulations have been introduced after the financial crisis of 2008, Laahanen and Yrjänä (2019) explain that FinTech innovations develop way faster than regulators can keep up with. As a result, regulations from the technology sector are currently being applied to FinTech activities instead of financial market regulations (Butor-Keler & Polasik, 2020). The current financial market regulations, which are still standardizing the market and cannot keep up with FinTech's dynamic technological progress, hinder market entry for new FinTech entrepreneurs (Butor-Keler & Polasik, 2020). Lack of regulatory knowledge, legal uncertainty, and high regulatory compliance costs also form barriers for FinTech entrepreneurial activities (Alaassar, Mention, & Aas, 2020). Hommel and Bican (2020) explain that these regulations significantly affect FinTech success and their attractiveness to potential investors.

Likewise, FinTech firms operate internationally and have to operate in line with the regulations of the respective country they are operating in. As a consequence, many FinTech firms face regulatory requirement uncertainty which causes FinTech companies to withdraw from several markets (Najaf et al., 2020). To overcome these regulatory difficulties, national and global regulatory sandboxes are created by supervisory institutions (Alaassar et al., 2020). Governmental regulators create dedicated market environments which are called 'regulatory sandboxes' in order to support the development process of FinTech innovations (Butor-Keler & Polasik, 2020). A regulatory sandbox is a restricted experimentation space for FinTech entrepreneurs which enables these FinTech entrepreneurs to develop their business models with simplified market access (Butor-Keler & Polasik, 2020; Guo & Liang, 2016). These regulatory sandboxes allow regulators to understand FinTech firms' demands and in this way regulators learn how to support financial market development and competitiveness for FinTech firms (Butor-Keler & Polasik, 2020). Although financial regulations concerning FinTech are still lagging behind, new regulations such as the European General Data Protection Regulation (GDPR) and the Second Payment Service Directive (PSD2) came into force in 2018 and certainly encouraged FinTech development (Hommel & Bican, 2020).

Theme	Key insights
Hard institutions	- Existing financial market regulations are unable to keep up with FinTech's dynamic technological progress. - Regulators have to put in place regulatory sandboxes which are expected to help them change insufficient financial market regulations. - Some newly introduced regulations encourage FinTech development.

Table 4. Main takeaway from TIS structural dimensions: Hard institutions

In terms of *soft institutions*, it has always been the case that risk-taking firms in the financial market end up with the largest rewards whilst the general public is left with the associated consequences (Hendrikse et al., 2019). New FinTech ecosystem actors such as FinTech start-ups and cross-sectoral technology companies try to benefit from the inabilities of the financial incumbents to serve the modern financial needs of customers in order to gain these financial market rewards (Palmié et al., 2020). The current ongoing digital transformation changes financial consumer expectations and therefore raises new demands (Drasch et al., 2018). As a result, financial incumbents need to rethink their strategies to keep their prominent place within the financial sector (Tanda & Schena, 2019). To keep this prominent place, financial incumbents collaborate with FinTechs, hire Chief Digital Officers (CDOs), and start pursuing digital strategies (Hornuf et al., 2020). However, Hendrikse et al. (2019) argue that financial incumbents still lack innovative thinking. Financial incumbents have traditionally experienced low levels of innovation and low use of patents (Beck, Chen, Lin, & Song, 2016). Besides financial incumbents' inability to reform themselves, these traditional financial institutions experience incumbent inertia leading to unwillingness to change existing routines (Chen, Wu, & Yang, 2019). Hornuf et al. (2020) also explain that these incumbent financial institutions have to deal with ample regulatory requirements and suffer from IT legacy and a hierarchical organizational structure. As a result, multiple stakeholders need to be convinced by financial incumbents when desiring to implement organizational changes. FinTech start-ups, on the other hand, benefit from their agility and are therefore able to innovate faster (Fonseca & Meneses, 2020).

Furthermore, the general public is used to the bank-based model in which large financial institutions provide the complete financial product portfolio (Smedlund, 2012). Financial incumbents have therefore been associated with public trust, security, and robustness for a considerable amount of time (Romanova, Grima, Spiteri, & Kudinska, 2018; Fonseca & Meneses, 2020). Yet, financial decisions are nowadays made by financial customers via appropriate tools and applications, whereas in the past these decisions were

made by financial professionals (Basole & Patel, 2018). In the current platform and app-centric world, financial customers pick the product or service that fits best with their personal preferences from a variety of offerings by different companies (Hommel & Bican, 2020; Basole & Patel, 2018). The fact that FinTech start-ups and even cross-sectoral technology companies are now competing with the traditional financial incumbents raises public concerns about the safety of the disrupted financial market and what it implies for the security of financial market participants (Butor-Keler & Polasik, 2020).

Theme	Key insights
Soft institutions	- Financial incumbents suffer from incumbent inertia and lack innovative thinking whereas FinTech start-ups are agile and fast innovators. - Financial customers desire financial services to become more personalized and accessible, yet entrance of FinTech start-ups and cross-sectoral technology companies raises public concerns about the safety of the financial market.

Table 5. Main takeaway from TIS structural dimensions: Soft institutions

4.1.3 Technological infrastructure

The fourth industrial revolution is characterized by incorporating new technologies into business activities (Abbasi et al., 2021). FinTech start-ups are the most prominent players in the fourth industrial revolution (Abbasi et al., 2021). These innovative FinTech entities make use of core technologies coming from the IT sector such as blockchain, artificial intelligence, cloud computing, and big data (Dranev, Frolova, & Ochirova, 2019; Hendrikse et al., 2019). The reason for this is that the financial sector generates huge amounts of data due to its transaction-based nature (Zhang-Zhang et al., 2020). FinTech firms are therefore able to apply new information and communication technologies in the financial sector (Hendrikse et al., 2019). Consequently, FinTechs provide their products and services completely or in the majority of cases via the Internet since the provision of FinTech products and services requires no physical interaction (Puschmann, 2017). The latest IT revolution enables platformization of financial services due to new data-generating technologies via mobile phones (Langley & Leyshon, 2017). New FinTech entrepreneurial activities are therefore highly affected by the significant growth in mobile phone use (Slade, Williams, & Dwivedi, 2013). Yet, at the same time, this causes FinTechs to be highly vulnerable to cyberattacks and online fraud (Najaf et al., 2020; Gozman et al., 2017).

New knowledge from the IT sector fosters FinTech start-up entrepreneurial activities whereas new financial knowledge becomes more salient as FinTech firms start growing and

seek for capital since this stage requires transforming cutting-edge IT technologies into integrated FinTech solutions (Cojoianu, Clark, Hoepner, Pažitka, & Wójcik, 2020). Moreover, the financial crisis of 2008 pushed many former bank employees into entrepreneurial activities (Gozman et al., 2017). Najaf et al. (2020) argue that these former bank employees have become FinTech founders and therefore possess the knowledge to combine the latest IT developments with financial services. As a result, FinTechs, by making use of cutting-edge technologies from the IT sector, are said to operate more efficiently than the traditional financial incumbents (Zhang-Zhang et al., 2020).

Theme	Key insights
Technological infrastructure	- FinTech entrepreneurs apply IT technologies in the financial sector. - Most FinTech founders are former bank employees who are able to combine the latest IT developments with financial services.

Table 6. Main takeaway from TIS structural dimensions: Technological infrastructure

4.1.4 Interactions

The FinTech field is characterized by coopetition (Fonseca & Meneses, 2020). Besides cooperation and competition, Zhang-Zhang et al. (2020) argue that actors in the FinTech ecosystem also supply and complement each other. The relationships as well as the roles in the FinTech ecosystem are therefore deemed fuzzy (Zhang-Zhang et al., 2020).

FinTech start-ups, financial incumbents, and cross-sectoral technology companies compete with each other to best serve and meet the modern needs of financial customers (Palmié et al., 2020). Besides intensive competition among and between FinTech start-ups, financial incumbents, and cross-sectoral technology companies, FinTech ecosystem players enjoy mutual benefits when collaborating with each other (Gazel & Schwienbacher, 2020). These collaborations in the ecosystem occur in multiple forms such as strategic alliances, joint ventures, incubators, mergers and acquisitions, product-related partnerships, minority and majority investments, and/or outsourcing (Hommel & Bican, 2020; Drasch et al., 2020).

The most common collaboration in the FinTech ecosystem is between FinTech start-ups and financial incumbents. The collaborations between financial incumbents and FinTech start-ups are fuelled by new regulations such as the GDPR and PSD2 which have led to an enormous wave of new FinTech entrepreneurial activities (Svensson et al., 2019). These new FinTech start-ups differentiate themselves from financial incumbents with innovative cultures, personalized niche services and nimble organizations (Lee & Shin, 2018). Financial incumbents, however, need to maintain their legitimacy in the eyes of their customers and

therefore need to add new functionalities to their existing products and services (Svensson et al., 2019). Consequently, financial institutions require the technological know-how, agility, and specialist niche market operations from FinTech start-ups (Fonseca & Meneses, 2020). FinTech start-ups, on the other hand, need financial incumbents' market and regulatory knowledge, access to customers, security reputation, and funding (Fonseca & Meneses, 2020; Gozman et al., 2017; Hornuf et al., 2020; Drasch et al., 2018). As a result, Drasch et al. (2018) argue that FinTech start-ups and financial incumbents more or less depend on each other to effectively serve new customer demands and to play a prominent role in the new digital age. Moreover, Fonseca and Meneses (2020) argue that financial incumbents collaborate with FinTech start-ups to respond to the threats coming from cross-sectoral technology companies. FinTech start-ups as well as financial incumbents gain competitive advantages through collaborations since these collaborations allow for operational cost-savings, faster services, and allow both actors to better respond to the changing needs of financial customers (Fonseca & Meneses, 2020).

Although collaborations between FinTech start-ups and financial incumbents seem win-win situations, Hornuf et al. (2020) argue that not all collaborations between FinTech start-ups and financial incumbents are advantageous. Hornuf et al. (2020) explain that some FinTech start-ups as well as financial incumbents lack proper internal decision-making authorities to operate effectively in the transforming financial market. In addition, Hornuf et al. (2020) state that numerous financial incumbents terminate collaborations with FinTech start-ups because of having developed their own FinTech solutions. Drasch et al. (2018) further show that FinTech start-ups remain the owners of FinTech innovations in more than 90% of all collaborations with financial incumbents. This might indicate that FinTech start-ups do not want to sell their innovation or that financial incumbents are unable to integrate new FinTech innovations into their organization (Drasch et al., 2018). Besides inability, Drasch et al. (2018) argue that financial incumbents might avoid complicated and expensive efforts of trying to integrate FinTech innovations into their organization.

Besides collaborating with financial incumbents, FinTech start-ups also collaborate with each other and with cross-sectoral technology players. Dranev et al. (2019) show that FinTech start-ups acquire each other to expand their businesses and to at the same time invest in the development of FinTech technologies. Furthermore, Zhang-Zhang et al. (2020) state that also cross-sectoral technology companies are beginning to compete and

collaborate with other FinTech ecosystem actors. Cross-sectoral technology companies, in contrast to FinTech start-ups, enjoy the benefit of being more experienced, of having access to a large amount of resources and capabilities, and of enjoying economies of scale (Zhang-Zhang et al., 2020). Cross-sectoral technology companies are therefore able to offer their FinTech products and services directly to customers while these cross-sectoral technology companies at the same time supply hundreds of entities as technology developers (Zhang-Zhang et al., 2020). However, Hendrikse et al. (2019) emphasize that all collaborations need to comply with cartel competition rules and that it is vital to check these rules carefully.

Furthermore, multiple interactions in the FinTech ecosystem are stimulated by policy instruments such as innovation hubs, incubators, and accelerators but especially by regulatory sandboxes. Regulatory sandboxes provide safe experimentation spaces for FinTech start-ups, cross-sectoral technology companies and financial incumbents to test their services and products with substantive support from regulatory authorities without exhausting company resources (Butor-Keler & Polasik, 2020; Alaassar et al., 2020). As a result, regulatory sandboxes protect consumers and financial markets from potential risks (Magnuson, 2018) while protecting sandbox participants against capital losses due to regulatory uncertainties (Lee & Shin, 2018).

First, regulatory sandboxes facilitate the interactions between FinTech entrepreneurs and financial customers. In this way, FinTech entrepreneurs can learn about financial customers' needs and opinions. The regulatory sandbox, meanwhile, provides high security levels for the participating financial customers (Butor-Keler & Polasik, 2020). Second, regulatory sandboxes foster the interactions between governmental regulators and FinTech entrepreneurs. As a consequence of sandbox participation, FinTech firms are granted access to formal and informal networks. The (in)formal networks enable FinTech firms to obtain information and essential resources (Alaassar et al., 2020). On top of that, Alaassar et al. (2020) show that, even after sandbox participation, FinTech entrepreneurs enjoy from ongoing network opportunities and regulatory advice from regulators. Regulators, on the other hand, benefit from keeping an eye on the FinTech firms after having provided them unrestricted financial service licenses since the regulators are responsible for financial market stability (Alaassar et al., 2020). Third, regulatory sandboxes also stimulate interactions between (inter)national regulators. The reason for this increased interaction is the encountering of potential changes in existing regulations after their

interactions with sandbox participants. Finally, besides interaction between regulators, regulators also interact with industry partners, universities, and FinTech hubs to develop new ways of facilitating regulatory sandbox practices (Alaassar et al., 2020).

Theme	Key insights
Interactions	- The FinTech ecosystem is characterized by coopetition. - FinTech start-ups, cross-sectoral technology companies, and financial incumbents depend on each other to a smaller or bigger extent in the short-term. - Support programs facilitate interactions between and among actors in the FinTech ecosystem.

Table 7. Main takeaway related to TIS structural dimension: Interactions

The FinTech ecosystem actors and their interactions are visualized in Figure 6 below. The numerous collaborations and interactions show the importance of modularity, interfaces, and adaptability of business models in today's world (Drasch et al., 2018).

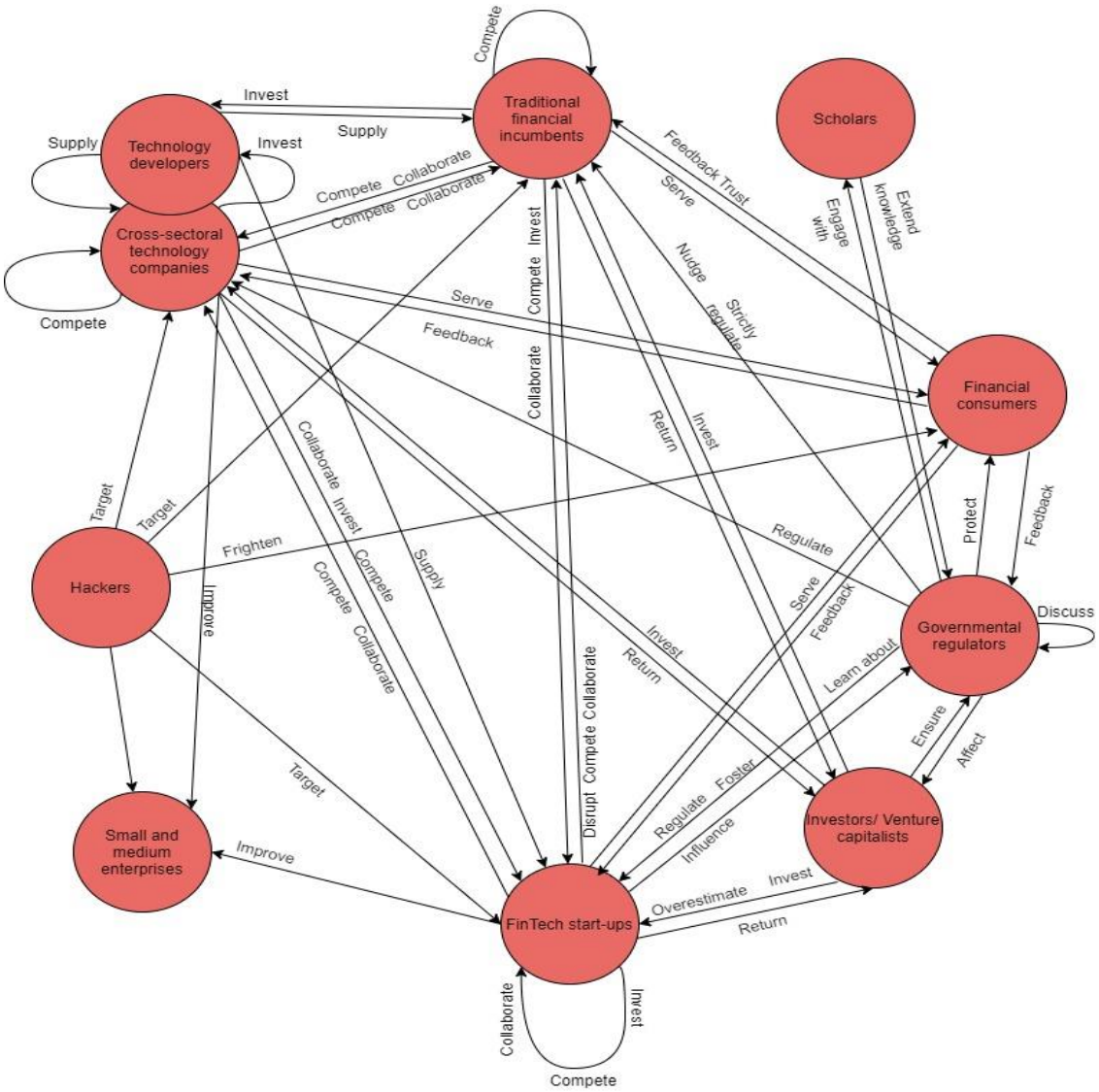

Figure 6. Extension of the FinTech ecosystem visualization presented by Zhang-Zhang et al. (2020).

4.2 TIS FinTech system functions

The aim of paragraph 4.2 is to answer the second research question: *What TIS system functions around FinTech innovations are identified in scientific literature from 2017-2021?* The key insights of the TIS FinTech system functions and main variables included in the SD model are listed at the end of every subparagraph.

4.2.1 System function 1: Entrepreneurial activities

FinTech entrepreneurial activities are most present in well-developed economies and markets with easy access to capital (Haddad & Hornuf, 2019). Although FinTech start-ups took the lead in business model innovation in the fourth industrial revolution based on consumer-oriented digitization (Puschmann, 2017), FinTech start-ups, financial incumbents, and cross-sectoral technology companies are now all intensively trying to capitalize on the novel demands by financial customers for new digital and customer-centric financial services (Kabulova & Stankevičienė, 2020; Drasch et al., 2018). These FinTech actors break down the traditional value chain of financial incumbents, leading to the unbundling of financial services (Basole & Patel, 2018). The focus on parts of the traditional value chain of financial incumbents allows FinTech entrepreneurs to establish niche market positions (Basole & Patel, 2018). Consequently, FinTech entrepreneurs, by serving niche markets, try to profit from offering existing financial services in a novel way with the use of new technologies from the IT sector (Basole & Patel, 2018).

FinTech start-ups, due to their agile organisational structure, are able to exploit these IT technologies faster than financial incumbents (Fonseca & Meneses, 2020; Hornuf et al., 2020). As a consequence, FinTechs are argued to be cheaper, faster, and more harmless than financial incumbents (Hommel & Bican, 2020). FinTech start-ups alter the established bank-based model by coordinating and restructuring financial information flows to create value (Gozman et al., 2017). FinTech start-ups are able to create this value through the mutually reinforcing and interdependent cooperative and competitive mechanisms of personalization, hybridization, disintermediation, financialization, and extension of access (Gozman et al., 2017). However, financial incumbents also undertake FinTech entrepreneurial activities in order to defend themselves against the FinTech start-ups (Chen et al., 2019). Chen et al. (2019) explain that financial incumbents that have invested substantially in R&D over time experience less harm from FinTech entrepreneurial activities because financial incumbents then have enough resources and capabilities to innovate their

current business. Moreover, Chen et al. (2019) state that financial incumbents enjoy technical economies of scale.

Furthermore, the strong technological component in FinTech development led to the entrance of cross-sectoral technology companies in the FinTech ecosystem (Zhang-Zhang et al., 2020). These cross-sectoral technology companies have access to technological expertise, large customer bases, and scale-based resources. The active engagement of financial incumbents and cross-sectoral technology companies emphasizes FinTech start-ups' need to use their speed, know-how, and streamlined decision-making to their advantage (Svensson et al., 2019).

Function	Key insight	Main variables
Entrepreneurial activities	- FinTech start-ups, financial incumbents, and cross-sectoral technology companies all undertake entrepreneurial activities to capitalize on novel demands of financial customers.	- FinTech innovations - Total market share cross-sectoral technology companies - Total market share financial incumbents, - Total market share FinTech start-ups.

Table 8. Main takeaway related to TIS system function: Entrepreneurial activities

4.2.2 System function 2 & 3: Knowledge development and diffusion

Most FinTech start-ups are founded by former bank managers who possess the knowledge and skills to combine the latest IT developments with financial services, yet require support to transform their ideas into successful FinTech innovations (Najaf et al., 2020). The reason for this is that most FinTech start-ups lack resources, face difficulties with legal and regulatory requirements and besides need to protect their ideas against other players (Butor-Keler & Polasik, 2020). As a result, regulatory sandboxes, innovation hubs, incubators, and accelerators are developed by governmental regulators to encourage innovative FinTech entrepreneurs to develop their product or service (Butor-Keler & Polasik, 2020). Regulatory sandboxes and innovation hubs are two forms of direct governmental support (Polasik, Huterska, Iftikhar, & Mikula, 2020). Regulatory sandboxes provide controlled environments in which new FinTech entrepreneurs can test their innovations with simplified market access without needing to exhaust all their company resources (Alaassar et al., 2020; Butor-Keler & Polasik, 2020). Regulatory sandboxes provide regulatory support but also nudge on compliance and operational issues which improves sustainability

of participants' businesses (Alaassar et al., 2020). Furthermore, financial centres are developing innovation hubs for FinTechs to ensure a prominent position for financial centres in the future (Hendrikse et al., 2020). Innovation hubs aid FinTech entrepreneurs in licensing requirements and regulatory uncertainties (Zetzsche, Buckley, Barberis, & Arner, 2017).

Besides regulatory sandboxes and innovation hubs, incubator and accelerator programs are initiated to support FinTech knowledge and diffusion activities (Gazel & Schwienbacher, 2020). Financial incumbents initiate FinTech incubators and accelerator programs to obtain financial shares in FinTech start-ups (Hornuf et al., 2020). Incubators and accelerators, in turn, aid FinTech start-ups by providing managerial, financial, or some other kind of assistance (Teece, 1992). Incubators target early-stage FinTech start-ups whereas accelerators help in scaling up FinTech start-ups (Gazel & Schwienbacher, 2020). Moreover, incubator and accelerator programs foster supportive environments in which FinTech start-ups have access to talent, resources, and services (Gazel & Schwienbacher, 2020).

The SWIFT Innotribe initiative is another approach to foster knowledge development and diffusion. SWIFT organizes a yearly Innotribe Start-up Challenge in which FinTech start-ups are connected with decision-makers, investors, and strategists from the incumbent financial service industry (Gozman et al., 2017). SWIFT, in this way, tries to stimulate knowledge development and diffusion by connecting entrepreneurs, networks, and ideas (Gozman et al., 2017). On top of this challenge, SWIFT organises networking events and multiple showcases for FinTech start-ups to reach external audiences (Gozman et al., 2017).

Functions	Key insight	Main variables
Knowledge development and diffusion	- Policy initiatives, from governmental regulators as well as other FinTech ecosystem actors, such as regulatory sandboxes, innovation hubs, incubator and accelerator programs, and start-up challenges support FinTech knowledge development and diffusion.	- Support programs/Policy initiatives - FinTech start-up success - Total market share of FinTech start-ups

Table 9. Main takeaway related to TIS system functions: Knowledge development and diffusion

4.2.3 System function 4: Guidance of the search

Governmental regulators nudge financial incumbents to follow an open strategy which allows for oligopolies in which new FinTech entrepreneurs are able to participate (Hendrikse et al., 2019). Governmental regulators in this way try to ensure a long-term stable financial system. Moreover, governmental regulators promote disruptive technologies potentially coming from cross-sectoral technology companies by providing regulatory assistance,

capital, and legitimacy since these disruptive technologies in turn will foster entrepreneurship and regional endowments (Hendrikse et al., 2019). These disruptive technologies allow FinTech entrepreneurs to develop platforms and apps which increase the efficiency of financial services (Hendrikse et al., 2019). This strategic coupling facilitated by win-win situations between incumbent financial institutions, small and big FinTech players, and governmental regulators creates a FinTech ecosystem (Hendrikse et al., 2019).

On top of that, governmental regulators spend considerable financial and human resources in the creation of support programs to foster FinTech innovations (Alaassar et al., 2020). Regulatory sandboxes, innovation hubs, incubators, and accelerator programs are all support programs created by governmental regulators or other FinTech market participants to foster FinTech innovations (Alaassar et al., 2020). These policy instruments show that regulators want to learn about FinTechs' market needs and want to play an active role in FinTech development (Alaassar et al., 2020). Butor-Keler and Polasik (2020) write that regulatory sandboxes have been announced and established around the world by more than 50 regulatory authorities.

Furthermore, the FinTech ecosystem players are guided by changing financial customer demands due to increased digitization (Drasch et al., 2018). The expectations of the public towards financial services change (Zhang-Zhang et al., 2020). Financial customers are more informed and demand more transparency about their financial assets (Ashta & Biot-Paquerot, 2018). Moreover, customers are argued to be more tech-savvy and therefore expect their financial service experience to be more responsive, personalized, and accessible (Maglio & Spohrer, 2013). Customers, nowadays, choose their FinTech products and services from various FinTech providers (Basole & Patel, 2018).

Function	Key insights	Main variables
Guidance of the search	- Governmental regulators desire oligopolies in the financial market to ensure a long-term stable financial system. - Governmental regulators spend considerable resources in policy initiatives to support FinTech development. - Financial customers expect financial services to be personalized, responsive, and accessible.	- FinTech start-up success - Support programs/Policy initiatives - Platform creation - Total market share FinTech start-ups - Total market share financial incumbents - Total market share cross-sectoral technology companies

Table 10. Main takeaway related to TIS system function: Guidance of the search

4.2.4 System function 5: Market formation

Although the FinTech ecosystem is beginning to consolidate, FinTech entrepreneurs can still tap multiple niche markets across the globe with novel financial products and services (Basole & Patel, 2018). In order to establish these niche market positions, FinTech start-ups focus on specific parts of the traditional value chain of financial incumbents (Basole & Patel, 2018). FinTechs in turn try to serve their niches with superior financial products and services compared to the offerings of financial incumbents (Alt & Ehrenberg, 2016).

Whereas digitalization has taken away the need for FinTech entrepreneurs to be geographically close to customers and investors, Gazel and Schwienbacher (2020) emphasize that the location of FinTech start-ups plays a large role in terms of survival. Cojoianu et al. (2020) argue that FinTech entrepreneurs must be actively aware of knowledge spillovers and the availability of high-skilled IT workers since these drive new ventures and access to capital. As a result, Gazel and Schwienbacher (2020) find that most FinTech start-ups are geographically clustered and that location is determined by cluster size and the presence of incubator and accelerator programs. Presence of business schools, on the other hand, has no influence on where FinTech entrepreneurs locate their business (Gazel & Schwienbacher, 2020). FinTech start-ups located in large clusters are less likely to fail, indicating the economic benefits of being part of such a FinTech cluster. Gazel and Schwienbacher (2020) argue that clusters benefit from accumulations of knowledge and resources, plenty of access to talent, and a prevailing entrepreneurial culture. Incubator and accelerator programs support start-ups in building up their resources which allow FinTech start-ups to start and grow their business (Gazel & Schwienbacher, 2020). Yet, FinTech clusters at the same time complicate the survival of new entrants which are just starting their operations due to the considerable competition among FinTech start-ups in the cluster (Gazel & Schwienbacher, 2020). Moreover, FinTech start-ups located in these large clusters are often approached by financial incumbents and cross-sectoral technology companies to collaborate (Gazel & Schwienbacher, 2020). Finally, Hommel and Bican (2020) argue that product imitation in the FinTech ecosystem is very rare due to the high complexity of IT and the fact that only firms with unique selling points will succeed.

Function	Key insights	Main variables
Market formation	- FinTech entrepreneurs establish niche market positions by breaking down the traditional value chain of financial incumbents. - FinTech start-ups locate in large clusters to enjoy from economic benefits. - Many FinTech start-ups which are located in these large clusters are approached by financial incumbents and cross-sectoral technology companies to collaborate.	- Size FinTech cluster - FinTech start-up success - Total market share of FinTech start-ups - Total market share of financial incumbents - Total market share of cross-sectoral technology companies

Table 11. Main takeaway related to TIS system function: Market formation

4.2.5 System function 6: Resource mobilization

FinTech entrepreneurial activities create the desired infrastructure for a new digital financial ecosystem (Arner et al., 2020). Choi and Lee (2020), however, emphasize that the creation of this new infrastructure involves high initial capital requirements. Yet, whereas financial incumbents benefit from technical economies of scale (Chen et al., 2019), regulatory expertise (Svensson et al., 2019), and ample financial resources (Chen et al., 2019), FinTech start-ups suffer from a liability of newness and therefore lack resources and face regulatory constraints (Butor-Keler & Polasik, 2020). Zhang-Zhang et al. (2020) argue that cross-sectoral technology companies also benefit from significant brand recognition, ample capital resources, and technological expertise to drive FinTech innovations. Haddad and Hornuf (2019) further argue that the trustworthy reputation of financial incumbents and cross-sectoral technology companies allows these companies to easily attract financial customers and therefore build competitive advantages over FinTech start-ups. As a result, resource mobilization is more important for FinTech start-ups than for financial incumbents and cross-sectoral technology companies which are not suffering from this liability of newness (Zhang-Zhang et al., 2020).

In terms of financial capital, FinTech portfolios bear more financial risks due to cyber-security risk, credit risk, and compliance risk, yet these FinTech portfolios have higher market values in comparison to non-FinTech firms' portfolios (Najaf et al., 2020). These higher market values indicate positive investors' perceptions about FinTechs' business prospects. Najaf et al. (2020) argue that these higher market values can be explained by their alternative business models as well as their financial incentives provided to investors due to their exposure to risks. However, FinTech start-ups might significantly contribute to fluctuations in the financial markets because of over-estimation caused by extravagant

FinTech enthusiasm (Najaf et al., 2020). As a result, FinTech start-ups receive considerable regulatory attention since these financial fluctuations might trigger a new financial crisis. Basole and Patel (2018) show that besides public investors, venture capitalists and corporate banks have invested billions of dollars in FinTechs. FinTech start-ups that are granted access to regulatory sandboxes possess prospective and innovative FinTech products and services. As a result, venture capitalists and business angels closely monitor regulatory sandbox participants leading to considerable financial capital investments (Butor-Keler & Polasik, 2020). Moreover, FinTech start-ups have started using new fundraising forms like crowdfunding and initial coin offerings (ICOs) to mobilize the required financial resources (Block, Colombo, Cumming, & Vismara, 2018). Hommel and Bican (2020) found that scalability and management team qualities were the most important funding criteria for investing in FinTech start-ups. Finally, Kabulova and Stankevičienė (2020) stress that not only equity investors monitor and invest in FinTech start-ups since financial incumbents and cross-sectoral technology companies also invest considerable amounts of money in FinTech start-ups.

In terms of human capital, Gozman et al. (2017) write that predominantly former bank managers founded FinTech firms since these bank managers had to change profession due to the financial crisis of 2008. Consequently, the FinTech founders possess the ability to combine the latest developments in the IT sector with financial services (Najaf et al., 2020). In addition, Chen et al. (2019) argue that all FinTech innovations developed by any actor in the FinTech ecosystem affect the financial sector through technological spillovers. Moreover, the geographical clustering of FinTech start-ups leads to knowledge spillovers and these clusters provide easier access to talent (Gazel & Schwienbacher, 2020). Yet, Tanda and Schena (2019) argue that the transformation of the financial sector has serious consequences for the human resources theme. The disappearance of physical branches and the increased application of IT technologies in financial services causes FinTech ecosystem actors to continuously acquire new skills and suitable training and education plans should therefore be developed (Tanda & Schena, 2019).

Function	Key insights	Main variables
Resource Mobilization	- Resource mobilization is more important for FinTech start-ups than for financial incumbents and cross-sectoral technology companies. - Corporate banks, venture capitalists, and public investors invest billions of dollars in FinTech. - FinTech ecosystem actors must constantly acquire new knowledge and skills to keep up with FinTech development.	- Access to resources, - Economies of scale - Investors' likelihood to invest - Financial incentives - Portfolio FinTech market value - Financial fluctuations

Table 11. Main takeaway related to TIS system function: Resource Mobilization

4.2.6 System function 7: Creation of legitimacy

The transformation of the new ecosystem around FinTechs changes which actors are seen as legitimate (Svensson et al., 2019). FinTech start-ups are argued to suffer from a liability of newness, meaning that these FinTech start-ups face difficulties with regard to legitimacy, visibility, and influence (Svensson et al., 2019). Moreover, the legitimacy of financial incumbents is no longer being taken for granted. Svensson et al. (2019) explain that organizational legitimacy and legitimacy for a new product or service are closely connected. As a result, actors within the FinTech ecosystem form alliances to create and gain organizational legitimacy (Svensson et al., 2019). FinTech start-ups and cross-sectoral technology companies are seeking for legitimacy whereas financial incumbents try to maintain their created legitimacy, indicating legitimacy needs for FinTech start-ups, financial incumbents, and cross-sectoral technology companies (Svensson et al., 2019). Svensson et al. (2019) mention that it is vital for FinTech start-ups to show that they are valuable. FinTech start-ups pursue legitimacy in order to increase credibility whereas financial incumbents try to secure their continuity (Svensson et al., 2019). FinTech start-ups need legitimacy to show that they comply with existing regulations and to reach customers who can validate their product or service (Svensson et al., 2019). Consequently, when forming alliances, FinTechs seek for a partner that is trusted by ample financial customers, which invests in new technologies, and provides regulatory support. Financial incumbents, on the other hand, seek for a partner that can provide new products and services that enhance customer experience and add value to the incumbent financial institution's platform (Svensson et al., 2019). Svensson et al. (2019) find that the joint accomplishments resulting from alliances boost the legitimacy of both FinTech start-ups and financial incumbents in the eyes of all FinTech ecosystem actors. These alliances between FinTech start-ups and financial incumbents foster business activities with venture capitalists, executive boards,

and shareholders and allow both players to operate effectively in the financial market with customers (Svensson et al., 2019). Moreover, sandbox regulators improve the legitimacy of FinTech entrepreneurs participating in the regulatory sandbox through press releases or presentations to external parties (Alaassar et al., 2020). These actions attract investors while at the same time facilitating network access for sandbox participants (Alaassar et al., 2020). Besides regulatory sandboxes, incubators also promote acceptance and legitimacy for FinTech entrepreneurs (Alaassar et al., 2020).

Function	Key insights	Main variables
Creation of legitimacy	-FinTech start-ups suffer from a liability of newness. - FinTech start-ups need to gain legitimacy whereas financial incumbents try to maintain their legitimacy in the financial market. - Cross-sectoral technology companies are seen as legitimate players but still need to gain legitimacy in the financial market.	- Legitimacy and acceptance, - Network access - Support programs/Policy initiatives - Financial incumbent-FinTech collaboration.

Table 12. Main takeaway related to TIS system function: Creation of legitimacy

4.3 System dynamics FinTech model

The main causal relationships found in the articles are modelled in a qualitative SD model to answer the third research question: *What reinforcing and balancing feedback processes, identified in scientific literature from 2017-2021, are involved in the interactions between the TIS system functions surrounding FinTech innovations?* A SD model visualizes the relationships between the main concepts from the FinTech ecosystem and therefore allows to identify feedback loops. Feedback loops explain the behaviour of a system and allow for identification of systemic drivers and barriers for FinTech TIS development (Sterman, 2000; Suurs, 2009). The complete qualitative SD model with the TIS system functions as its underlying basis can be found in Appendix B. The main feedback loops from the constructed SD model are explained below with the use of sub models.

Figure 7 below shows the main causal relationships and feedback loops around support programs (e.g. regulatory sandboxes, innovation hubs, and incubator and accelerator programs). Two main balancing loops cause the number of support programs to decrease over time. Balancing loop B1 shows that the supply of support programs will decrease over time when the risks associated with FinTech diminish. Support programs as well as collaborations between FinTech start-ups and financial incumbents lead to reduced FinTech

risks. Fonseca and Meneses (2020) explain that financial incumbents offer FinTech start-ups experience in risk management whilst Dranev et al. (2018) argue that these collaborations decrease cybersecurity risks. Moreover, Alaassar et al. (2020) explain that regulatory sandboxes prevent financial fraud. As a result, there will be less need for governmental regulators to create support programs over time.

Balancing loop B2, on the other hand, shows that the demand for support programs will also decrease over time. Support programs prevent FinTech start-ups from facing financial losses because of violating financial market regulations (Alaassar et al., 2020). Besides, support programs allow FinTech start-ups to quickly obtain financial market licenses and help them by removing legal and regulatory uncertainties (Butor-Keler & Polasik, 2020). As a result, these support programs foster the start and growth of FinTech start-ups. However, Basole and Patel (2018) argue that the FinTech market is already beginning to consolidate, meaning that fewer and fewer FinTech start-ups will enter the market over time. As a result, the demand and effectiveness of support programs will decrease over time. Moreover, even early stage FinTech start-ups are not entirely dependent on support programs because Hommel and Bican (2020) and Fonseca and Meneses (2020) explain that collaborations with financial incumbents provide FinTech start-ups with the same benefits as they gain from support programs.

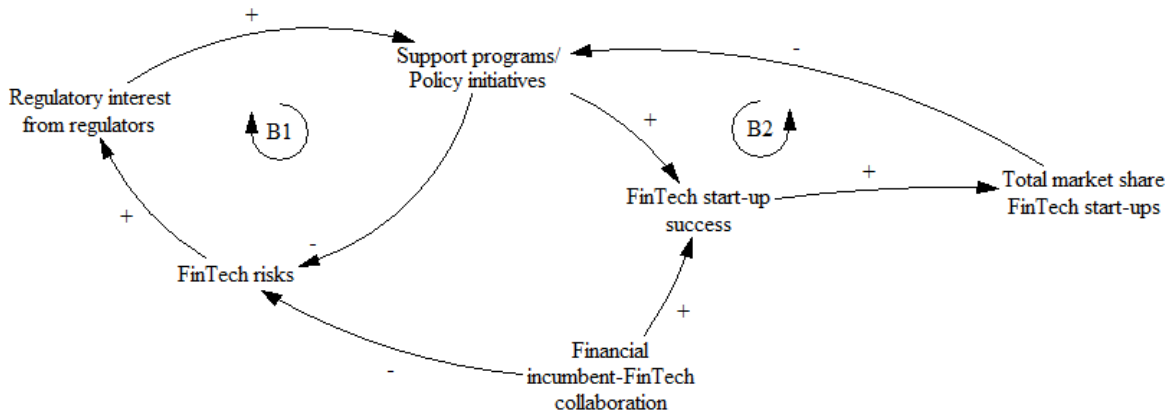

Figure 7. Sub model around support programs/policy initiatives

Figure 8 below shows the dynamics between FinTech start-ups, financial incumbents, and cross-sectoral technology companies. The main finding is presented by reinforcing loop R1 which reveals a “Success to the Successful” system archetype. System archetypes are common patterns of system behaviour which recur in different settings (Senge, 1990). The “Success to the Successful” archetype occurs when two parties compete for resources and support in a system that is set up for only one “winner” (Senge, 1990). The more support and resources one party receives, the higher the likelihood of success for this party (Kim, 1994). Reinforcing feedback loop R1 indicates that financial incumbents will have to compete with cross-sectoral technology companies for success in the FinTech market in the long run. However, reinforcing feedback loops R2 and R3 show that the total market share of FinTech start-ups will increase in the short-term because FinTech start-ups are able to benefit from support programs and collaborations with financial incumbents. Besides, FinTech start-ups operate in clusters which allows these FinTech start-ups to enjoy economic benefits (Gazel & Schwienbacher, 2020). Yet, balancing feedback loops B3 and B4 show that the market share of FinTech start-ups will stabilize in the long run. The reason for this is that most FinTech start-ups located in clusters are acquired or approached by financial incumbents and cross-sectoral technology companies to collaborate. The current market share from FinTech start-ups will therefore in the future shift to either financial incumbents or cross-sectoral technology companies, which, as shown by the “Success to the Successful” archetype, will compete for success.

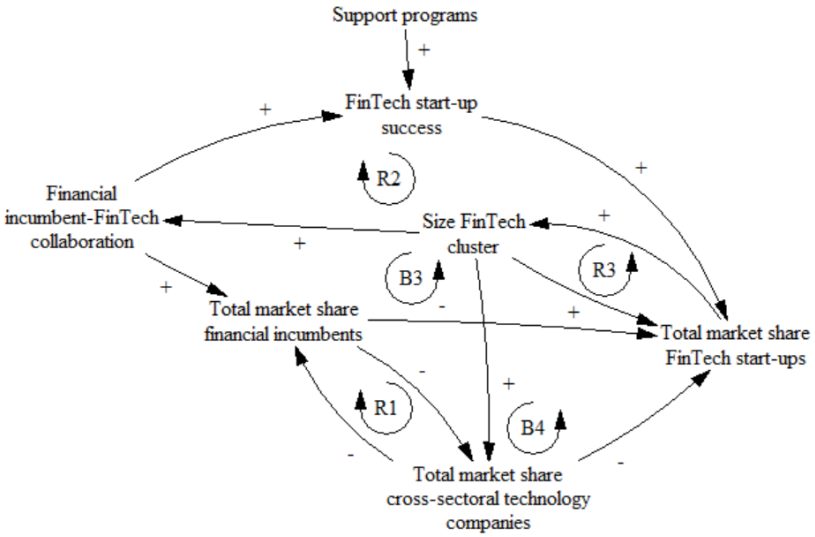

Figure 8. Sub model of dynamics between the different FinTech entrepreneurs

Figure 9 below shows how access to resources and legitimacy drive FinTech innovations. Reinforcing feedback loops R4 and R5 show that the number of FinTech innovations will only increase over time. Najaf et al. (2020) show that public investors are enthusiastic about FinTech development and Basole and Patel (2018) explain that these public investors, together with corporate banks and venture capitalists invest billions of dollars in FinTech development. Besides, Najaf et al. (2020) explain that financial incentives are provided to public investors due to FinTech's risky nature to make FinTech investments even more attractive. Reinforcing feedback loop R4 shows that platform creation further reinforces the number of FinTech innovations. Hommel and Bican (2020) explain that platforms enable economies of scale. The resulting cost advantages increase the amount of resources, which result in even more FinTech innovations (Hommel & Bican, 2020).

Besides economies of scale, FinTech platforms also increase the size of user networks (Hommel & Bican, 2020). FinTech platforms reduce information asymmetries which fosters legitimacy and acceptance. Alaassar et al. (2020) explain that more legitimacy and acceptance lead to easier network access which facilitates access to required resources. Network access in turn reinforces the level of legitimacy and acceptance (R6). As a result, FinTech platforms facilitate resource mobilization directly (R4) and indirectly via legitimacy and acceptance (R5). The more access to resources, the more FinTech entrepreneurs (i.e. FinTech start-ups, financial incumbents, and cross-sectoral technology companies) are willing to develop FinTech innovations. Moreover, besides FinTech platforms, support programs and collaborations between FinTech start-ups and financial incumbents boost the amount of resources and level of legitimacy and acceptance (relations not included in Figure 9).

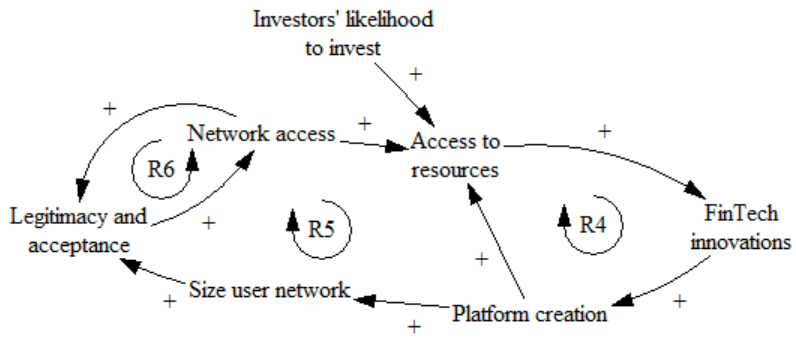

Figure 9. Sub model of dynamics around FinTech innovations

5 Conclusion and discussion

After the in-depth investigation of the FinTech ecosystem with respect to its structural dimensions and TIS functions, and the construction of a qualitative SD model, this final section will conclude and discuss the findings of this study. Paragraph 5.1 will answer the remaining fourth and fifth research questions before discussing the implications of this study's findings in paragraph 5.2. Paragraph 5.3 ends this study by elaborating on the limitations of this study and by providing suggestions for future research.

5.1 Conclusion

This study uses the TIS approach in combination with the SD methodology to identify variables and feedback processes that explain drivers and barriers for technological system innovation around FinTech innovations. Three research questions have already been answered in the results section. These three research questions prelude the fourth and fifth research question. The fourth research question was: *To what extent do variables and feedback processes, identified in scientific literature from 2017-2021, explain drivers and barriers for the development, diffusion, and utilization of FinTech innovations?*

The main systemic barrier hindering FinTech TIS development comes in the form of regulators lacking knowledge about FinTech activities to change regulations and the SD model (balancing loop B2 in Figure 7) shows that over time it will only become harder for regulators to acquire this knowledge. Governmental regulators lack technical FinTech knowledge which they need in order to change the, in the eyes of FinTech entrepreneurs, insufficient current regulations. To acquire this technical knowledge, governmental regulators create support programs in which they try to provide FinTech entrepreneurs with regulatory support. At the same time, these support programs allow regulators to learn about FinTech activities. However, the more the FinTech market consolidates, the less effective the support programs become for regulators as means for acquiring technical FinTech knowledge. Three reasons were identified in this study to support this claim. First, support programs are really helpful for FinTech start-ups in the early stages but FinTech clusters hinder new FinTech start-up market entry which causes fewer start-ups to enter the market over time. As a result, fewer start-ups will participate in support programs from governmental regulators which hinders regulators in acquiring the needed technical knowledge about FinTech activities. Second, cross-sectoral technology companies entering

the FinTech market have enough resources and therefore do not need the support programs from regulators. As a result, cross-sectoral technology companies will also not provide governmental regulators with the necessary technical knowledge about FinTech activities. Third, FinTech start-ups also increasingly benefit from collaborations with financial incumbents and these big cross-sectoral technology companies, making FinTech start-ups less dependent on support programs from governmental regulators.

Another observed barrier is that investors and the general public are still quite hesitant towards FinTech. The general public still needs to get used to all the changes in the financial market. Butor-Keler and Polasik (2020) argue that still a large part of society wonders what FinTech innovations imply for the security and stability of the financial market. Moreover, Hornuf et al. (2020) show that public investors perceive collaborations between financial incumbents and FinTech start-ups as value-reducing because these investors desire financial incumbents to develop their own FinTech innovations without the aid of FinTech start-ups. Although most FinTech innovations are offered business-to-business (B2B) instead of business-to-consumer (B2C), for TIS development around FinTech innovations, it is important that investors and the general public fully support the changes FinTech will make to the financial market.

Nonetheless, this study also identified drivers of TIS development around FinTech innovations. The multiple interactions and win-win situations between FinTech ecosystem actors are huge drivers of TIS development. The fact that FinTech start-ups, financial incumbents, and cross-sectoral technology companies all have distinct strengths and weaknesses drive collaborations between these actors in the short-term. FinTech start-ups require the financial and technological resources from financial incumbents and cross-sectoral technology companies whilst financial incumbents and cross-sectoral technology companies benefit from the human resources and agility of FinTech start-ups. In addition, FinTech start-ups and cross-sectoral technology companies need to gain legitimacy in the financial market whereas financial incumbents need to maintain their legitimacy. Moreover, FinTech start-ups and cross-sectoral technology companies need the regulatory and market knowledge of financial incumbents in the strictly regulated financial market.

Another observed driver is that not only governmental regulators create support programs but also financial incumbents and financial centres create sandboxes, innovation hubs, incubators, and accelerators to foster FinTech activities which indicates that even

incumbent players in the financial market try to contribute to FinTech development. The collaborations and support programs ensure that in the short-term FinTech start-ups, financial incumbents, and cross-sectoral technology companies all undertake ample FinTech activities which boost the number of FinTech innovations. However, Figure 8 shows that the active presence of FinTech start-ups will stabilize over time (balancing loops B3 and B4) and that in the long-term financial incumbents will compete for success in the FinTech market with cross-sectoral technology companies.

Furthermore, FinTech innovations create platforms which further reinforce the number of FinTech innovations. FinTech platforms benefit from economies of scale and therefore cost reductions which directly foster access to resources (reinforcing loop R4 in Figure 9). Besides, FinTech platforms diminish information asymmetries and therefore boost legitimacy and acceptance in the financial market. Increased legitimacy and acceptance facilitates access to external networks which fosters access to resources needed for even more FinTech innovations (reinforcing loop R5 in Figure 9).

As a result, it seems that if the TIS around FinTech innovations has fully developed, FinTech innovations will increase over time until market saturation. These FinTech innovations will make existing financial services more efficient by making these services cheaper, faster, and more accessible. The more efficient financial services will foster financial inclusion. Consequently, this provides a basis for answering the fifth research question: *To what extent has the TIS around FinTech innovations been developed?* Suurs (2009) argues that the motors of innovation can be seen as stages of TIS development. The science and technology push motor, entrepreneurial motor, system-building motor, and market motor are stages of TIS development. The interactions between the system functions discussed in paragraph 4.2 should create these four motors of innovation for successful TIS development.

The science and technology push motor is visible in the FinTech ecosystem. FinTech start-ups started innovating their business models by applying IT technologies to existing financial services (Puschmann, 2017). These FinTech start-ups have gained a small share of the financial market, indicating positive research outcomes (i.e. guidance of the search). As a consequence, support programs were developed by governmental regulators to foster FinTech development and to ensure financial market stability (i.e. resource mobilization). These support programs supported FinTech start-ups in additional knowledge development

and diffusion which caused FinTech start-ups to break down the value chain of financial incumbents. The rise of FinTech start-ups also fuelled entrepreneurial activities from financial incumbents and cross-sectoral technology companies. Financial incumbents had to undertake entrepreneurial activities to keep their prominent place in the financial market. Moreover, the strong technological component in FinTech innovations also motivated cross-sectoral technology companies to undertake entrepreneurial FinTech activities. The enormous amount of FinTech activities in turn led to financial incumbents and financial centres to also develop their own support programs.

The entrepreneurial motor is quite similar to the science and technology push motor, yet is characterized by the strong presence of entrepreneurial activities and the amount of legitimizing actions (Suurs, 2009). The FinTech start-ups, financial incumbents, and cross-sectoral technology companies are all undertaking entrepreneurial activities because they want to serve niche markets and achieve commercial and societal gains. However, FinTech start-ups and cross-sectoral technology companies need to gain legitimacy in the eyes of governmental regulators, investors and consumers whilst financial incumbents need to maintain their legitimacy in the eyes of these FinTech ecosystem actors. FinTech start-ups and cross-sectoral technology companies can gain legitimacy through the developed support programs and through collaborating with financial incumbents. Financial incumbents, on the other hand, maintain their legitimacy by adding proper functionalities to existing financial services which can be achieved by collaborating with these new FinTech entrepreneurs. Fonseca and Meneses (2020) explain that collaborations between FinTech start-ups and financial incumbents have increased over time and will keep increasing in the upcoming years. In addition, Zhang-Zhang et al. (2020) show that cross-sectoral technology companies have started collaborating with FinTech start-ups and financial incumbents. As a result, since Svensson et al. (2019) explain the importance of collaborations for gaining legitimacy and acceptance, it can be assumed that FinTech start-ups, financial incumbents, and cross-sectoral technology companies currently experience an adequate degree of legitimacy and acceptance to operate effectively in the FinTech ecosystem. For this reason, the entrepreneurial motor is also present in the FinTech ecosystem. However, the degree of legitimacy and acceptance of FinTech start-ups, financial incumbents, and cross-sectoral technology companies has not reached its optimal level which can be seen by the hesitance of the general public and investors towards FinTech development.

The third motor of innovation is the system-building motor in which ecosystem actors are argued to intentionally cooperate to strengthen each other's activities. The FinTech ecosystem actors cooperate deliberately since all ecosystem actors have their own strengths and weaknesses. FinTech ecosystem actors intentionally shape a new FinTech market through the unbundling of financial services. As a result, FinTech entrepreneurs have been able to establish niche market positions and the system-building motor is sufficiently present in the FinTech ecosystem.

The fourth motor of innovation is the market motor. Lobbying activities do not play a role in the market motor since formal regulations are argued to form markets (Suurs, 2009). A FinTech market instead of a financial market is starting to form and consolidate. However, acceptable formal regulations are still lagging behind although efforts have been made by governmental regulators to change existing financial regulations in favour of FinTech development. Moreover, as explained earlier, it will become only more difficult for regulators to acquire the desired technical knowledge about FinTech activities. As a result, the market motor is not fully present in the FinTech ecosystem because a FinTech market has not been created yet through formal regulations.

In conclusion, the development of a TIS around FinTech innovations is well on its way but has not fully established yet. Before the FinTech TIS can fully establish and FinTech entrepreneurs can bring new advantages to the financial market, regulators must be encouraged and especially assisted in making the financial market regulations more favourable for FinTech entrepreneurs. Yet, attention must be paid that this is not at the expense of financial market security because this will otherwise only increase hesitation from investors and the general public towards FinTech development.

5.2 Discussion

The research objective of this study was to contribute to the undertheorized FinTech literature by using the TIS approach in combination with SD methodology to identify processes that explain drivers and barriers for technological system innovation needed for the widespread development, diffusion, and utilization of FinTech innovations. Although the research objective is very theoretical, the findings of this study have implications for both theory and practice. These theoretical and practical implications are discussed below.

5.2.1 Theoretical implications

This study contributes to the existing FinTech literature which is still argued to be under-theorized (Hornuf et al., 2020; Puschmann, 2017). Drasch et al. (2018) and Hornuf et al. (2020) urged future researchers to examine the effect of FinTech on the financial market more in depth, which Hua et al. (2019) argued to be important because of the potential benefits of FinTech for financial market efficiency. Li et al. (2017) tried to find out whether FinTech start-ups substitute or complement financial incumbents. Li et al. (2017) found complementarity, however, suffered from spurious results. This study supports the finding that FinTech start-ups complement financial incumbents at least in the short term. The results show that FinTech start-ups need financial incumbents to gain legitimacy, to mobilize resources and to benefit from financial incumbents' regulatory and financial market knowledge. Financial incumbents, on the other hand, need FinTech start-ups to maintain their legitimacy in the financial market and to benefit from the agility and know-how of these FinTech start-ups. This also immediately partially answers the question of Hornuf et al. (2020) who urged future researchers to find out why FinTech start-ups actually want to collaborate with financial incumbents. Moreover, this study contributes to the question of Butor-Keler and Polasik (2020) who asked whether the biggest challenge for financial incumbents comes from FinTech start-ups or from cross-sectoral technology companies. This study has shown that both FinTech start-ups and cross-sectoral technology companies for sure need to collaborate with financial incumbents in the short term because of incumbents' knowledge about strict financial market regulations, for legitimacy reasons, and because of the knowledge that financial incumbents possess about the demands and expectations of financial customers. However, FinTech start-ups depend more on financial incumbents than cross-sectoral technology companies do. Both financial incumbents and cross-sectoral technology players collaborate intensively with FinTech start-ups. As a result, it seems that FinTech start-ups are currently having their 15 minutes of fame but that the long-term battle for relevance and scale in the financial market will be between financial incumbents and cross-sectoral technology players who will by then have absorbed the capabilities of FinTech start-ups. Consequently, for the short-term, this study confirms the expectation of Arner et al. (2016) who expected multiple FinTech ecosystem actors to provide financial services. However, it refutes the expectation of Gomber et al. (2018) who expected FinTech start-ups to disrupt the whole financial market. FinTech start-ups perhaps

initiated financial market disruption but will not be the main actor causing this disruption. Consequently, this study also disagrees with the statement of Basole and Patel (2018) who argued that power will shift from financial incumbents to FinTech start-ups.

Besides investigating the effects of FinTech activities on the financial market, Zhang-Zhang et al. (2020) urged future researchers to analyse the FinTech ecosystem in more depth and include the role of cross-sectoral technology companies. The TIS approach facilitates getting a deeper understanding of the FinTech ecosystem and this study therefore lays a foundation for future studies investigating the FinTech ecosystem. Moreover, Figure 6 presented an extended visualization of the FinTech ecosystem created by Zhang-Zhang et al. (2020). With respect to the role of cross-sectoral technology companies, this study finds that cross-sectoral technology companies have the potential to disrupt the financial market due to their significant experience, resources bases, and brand recognition built in other sectors. As a result, if cross-sectoral technology companies with their monopolistic tendencies are able to fully absorb the capabilities of FinTech start-ups, they are likely to become one of the main players in the long-term FinTech ecosystem.

Additionally, this is the first study to introduce SD modelling to the FinTech literature base. SD modelling has shown to be a useful tool for understanding the complex dynamics in the FinTech ecosystem. Nevertheless, Köhler et al. (2020) argue that the wide literature is still failing to see TIS development as a dynamic process. Yet, the added value of SD modelling in identifying systemic drivers and barriers of FinTech TIS development in this study once again emphasizes the dynamics involved in TIS development. Consequently, the use of SD modelling helped to identify a significant systemic barrier of FinTech TIS development. Whereas Butor-Keler and Polasik (2020) and Alaassar et al. (2020) only highlight the positive effects of regulatory sandbox participation for FinTech entrepreneurs, this study finds that FinTech entrepreneurs are not dependent on regulatory sandboxes and that the demand for regulatory sandbox participation will only decrease over time. However, regulators are unable to acquire needed knowledge about FinTech activities when FinTech entrepreneurs do not participate in regulatory sandboxes. As a result, regulators are unable to change regulations in favour of FinTech entrepreneurs which hinders the widespread development, diffusion, and utilization of FinTech innovations. This study therefore shows that although regulatory sandbox participation is beneficial for regulators

as well as FinTech entrepreneurs, more attention should be given to ensuring participation of FinTech entrepreneurs in regulatory sandboxes.

5.2.2 Practical implications

The lack of technical knowledge of governmental regulators and the resulting inability to change regulations has been found to be the main bottleneck for further FinTech TIS development. Although regulators do everything they can to acquire this knowledge, it seems to become only more difficult over time. Governmental regulators' main aim is to ensure a stable and secure financial market. As a consequence, this implies that FinTech entrepreneurs should help regulators with changing the regulations. FinTech entrepreneurs should come up with regulation changes that are in favour of FinTech development as well as result in no harm for financial market stability and security. FinTech entrepreneurs must clearly explain how the changes support their activities and illustrate that there are no negative consequences for financial market stability. Regulators are sympathetic to FinTech development which can be seen by the enormous amount of resources invested in the creation of support programs. As a result, regulators will be willing to change regulations. However, regulators are currently unable to respond to the demands of FinTech entrepreneurs.

Furthermore, results have shown that investors and the general public are still quite hesitant towards FinTech innovations. This reinforces the importance of a stable and secure financial market even more. Consequently, it is important that regulators maintain a good relationship with FinTech entrepreneurs so that FinTech activities can be controlled and do not lead to harmful effects on the financial market. The prominent role of big cross-sectoral technology companies in FinTech stresses once again the importance of monitoring bodies since these technology companies with their power are able to disrupt the whole financial market. Good relationships between regulators and FinTech entrepreneurs will therefore lead to win-win situations for all parties. The general public will then benefit from more efficient financial services while not having to worry about the financial system collapsing.

Moreover, this study found that the long-term battle for relevance and scale in the financial market will likely be between financial incumbents and cross-sectoral technology companies. Kim (1994) argues that in a "Success to the Successful" situation, ways must be found to make financial incumbents and cross-sectoral technology companies collaborators instead of competitors. However, the monopolistic tendencies of cross-sectoral technology

companies are likely to hinder collaboration with financial incumbents in the long term. The regulatory and financial market knowledge built over time provide financial incumbents an advantage over cross-sectoral technology companies. As a result, it is extremely important for financial incumbents to absorb the capabilities of FinTech as soon as possible to keep their prominent place in the financial market. Cross-sectoral technology companies also try to benefit from these same capabilities of FinTech start-ups. However, financial incumbents with their experience in the financial market are at the moment still one step ahead of cross-sectoral technology companies and the "Success to the Successful" archetype shows that they can keep this competitive edge and prominent place in the future if they absorb the FinTech start-ups' capabilities. This implies that financial incumbents will benefit from seeing FinTech start-ups as partners instead of competitors.

5.3 Limitations and future research

The main limitation of this study is that there was no time for interviews or surveys which would have contributed to an even more in-depth analysis. It would have been interesting to delve deeper into the intentions of several central FinTech actors. Interviews with regulators could lead to increased information about what hinders them in changing existing financial regulations and whether they are willing to intensively cooperate with FinTech entrepreneurs. Moreover, it would have been interesting to investigate what the intentions are of FinTech start-ups, financial incumbents, and cross-sectoral technology companies. Interviews and future research could further exploit whether these actors are also willing to collaborate with each other in the long-term or that these actors want to gain a monopoly position in the financial market. As a result, this study urges future researchers to further delve into the intentions of individual FinTech ecosystem actors and to investigate what their stance is towards other actors in the FinTech ecosystem.

Furthermore, this study focused on FinTech in general. However, Lee and Shin (2018) have distinguished multiple types of FinTech (i.e. wealth management, lending, capital market, crowdfunding, payments, and insurance). As a result, it would be interesting for future researchers to apply the TIS approach specifically to these specific types of FinTech to see whether the same results will be found.

In addition, although an integrative review has been conducted as carefully as possible, there are some methodological limitations. First of all, the integrative review is

based on 23 articles and since scholarly interest in FinTech rises quickly, there will be already new high-quality published articles that are not included in this study. Second, this study only used Web of Science to identify proper articles and did not search for additional records outside Web of Science due to time constraints. As a result, this study can be used as a basis for further research and new knowledge can be added to gain an even deeper understanding of the FinTech ecosystem. Third, the constructed SD model has not been validated by experts operating in the FinTech field. However, the constructed SD model is perceived valid since the model is able to identify systemic drivers and barriers for FinTech TIS development and is able to provide clarity about the stage TIS development is currently in. As a result, the use of SD has shown to be of value for investigating FinTech ecosystem dynamics. This study therefore invites future researchers to build further on the SD model constructed in this study and encourages researchers to use SD when investigating ecosystem dynamics. Fourth, Suri (2020) argues that a researcher's belief system influences the way evidence from selected articles is interpreted. As a result, it could be that other researchers' findings have been unconsciously misinterpreted although the researcher of this study did his best to interpret all evidence as objectively as possible.

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Appendices

Appendix A – Inclusion criteria based on TIS functions and corresponding indicators

Function	Indicator	Amount of articles	Numbers in excel
1.Entrepreneurial (activities)		8	10,28,54,61,99,101,112,205
	New entrants	6	37, 44, 94, 146, 157, 172
	Experiments	1	218
	Start-ups	19	18,28, 33,36,37,48,92,96, 102,152,192, 200,202,205, 209, 210, 213, 214, 225
	Diversification (activities)	6	67, 111, 124, 144, 233, 234
2. Knowledge development		9	4,5,18,26,51,75,103,124,127
	R&D projects	2	95, 135
	Demonstration projects	0	-
	Patents	8	2, 5, 22, 35, 95, 120, 133, 139
	Journal publications	1	77
	Reports	13	12,17, 38, 40, 59, 75, 82, 109, 113, 118, 126, 148, 199
	Prototypes	0	-
3. Knowledge diffusion		2	5,87
	Workshops	0	-
	Conferences	1	239
	Network activities	29	3,4,5,40, 43, 53, 69, 99, 103, 104, 112, 117, 122, 126, 127, 137, 143, 149, 160, 168, 179, 180, 185, 193, 200, 202, 222, 225, 234
4. Guidance of the search		0	-
	Visions	0	-
	Expectations	10	28,41,52,56,122,139, 146, 155,199, 220
	Policy documents	2	77 & 226
	Demand (articulation)	10	46, 59, 89, 106, 117, 131, 143, 145, 173, 220
5. Market formation		4	76,132,142,168
	Niche (markets)	4	46, 101, 103, 181
	Tax (regime)	3	51, 64, 77

	Environmental standards	0	-
6. Resource mobilization		1	11
	Human capital:	0	-
	Education	4	58,108,159, 199
	(Specialized) training programs	0	-
	Financial capital:	24	**6**,**18**,20,**28**,29,**36**,45,**48**,58,69,77,91,100,107, 115, 126,134,**168**,183,196, 209,213, **214**, 235
	Venture capital	8	**36**,**48**,58,69,**168**,196,**214**, 235
	Public seed money	0	-
	Private investments	2	100, 169
	Physical capital:	0	-
	Natural resources	0	-
	infrastructure	16	13,25,32,**35**,51,94,113,114,131, 135,141,149,180,199,**205**,225
7. Creation of legitimacy		3	**28**,60,**164**
	Interest groups	0	-
	Advocacy coalitions	0	-
	Lobby activities	0	-

The green numbers in bold in the last column show the 23 included articles in the integrative review. These numbers correspond with the numbers in column K of tab 1 in the excel file.

Appendix B – Qualitative SD model about FinTech ecosystem