Essays on
Financial Intermediation, Innovation, and Growth

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For Anna

Vorwort

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Tübingen, September 2020 *Markus Merz*

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Acronyms

AAR	Average Abnormal Return
CAAR	Cumulative Average Abnormal Return
CHIPS	Clearing House Interbank Payment System
CVC	Corporate Venture Capital
DDM	Dividend Discount Model
DLT	Distributed Ledger Technology
DNS	Deferred Net Settlement
FCCU	Fourth Corner Credit Union
GP	General Partner
IOU	I Owe You
IVC	Independent Venture Capitalist
LP	Limited Partner
NCIA	National Cannabis Industry Association
OTC	Over-The-Counter
PE	Private Equity
R&D	Research and Development
RTGS	Real-Time Gross Settlement
SAFE	Secure and Fair Enforcement
SMEs	Small- and Medium-Sized Enterprises
SIC	Standard Industrial Classification
SWIFT	Society for Worldwide Interbank Financial Communication
TARGET	Trans-European Automated Real-Time Gross Settlement Express Transfer System
UTXO	Unspent Transaction Output
VC	Venture Capital

Symbols

α	Valuation parameter
θ_i	Firm i's innovative efficiency
π	Patent value
Π_i	Expected profits of firm i
σ	Innovative efficiency parameter
τ_1	Fixed indirect costs for a technology solution provider
τ_2	Fixed direct costs for a technology solution provider
τ_3	Variable direct costs for a technology solution provider
τ_4	Variable indirect costs for a technology solution provider
ω_i	Financial resources of firm i
c	Economy-wide transaction costs without correspondent banks
$\hat{c}$	Economy-wide transaction costs with correspondent banks
$\bar{c}$	Economy-wide transaction costs with DLT
c_1	Fixed indirect costs for banks
c_2	Fixed direct costs for banks
c_3	Variable direct costs for banks
c_4	Variable indirect costs for banks
$\bar{c}^A$	Costs for administrator (A)
$\hat{c}^B$	Costs for correspondent bank (B)
c^D	Costs for domestic bank (D)
c^F	Costs for foreign bank (F)
d_t	Dividend yield in t
D_{t+1}	Expected cumulative dividends
ROE_t	Return on equity in t
g	Implied growth rate
i	Indicator for large (L) or small (S) firm
j	Number of correspondent banks
k_e	Cost of equity
m	Number of foreign banks
n	Number of domestic banks
p_i	Probability of winning the R&D contest
P_t	Value of marijuana portfolio in t
SG_t	Sustainable growth rate in t
V	Volume for all cross-border payments
x_i	R&D investment of firm i

Chapter 1
Introduction

Over the last few decades, research has largely found that a more developed financial system results in higher economic growth (see, e.g., Levine 2005; Popov 2018 and Berger et al. 2019 for comprehensive surveys of the literature on finance and growth). The financial system fosters economic growth by providing payment and transaction services, enabling a more productive allocation of society's capital, and offering risk management tools (Allen et al. 2019). The financial system thus stimulates the formation of capital (Pagano 1993) and spurs technological innovation (King and Levine 1993; Comin and Nanda 2019). Both capital accumulation and innovation have long been recognized as key drivers for economic growth (e.g., Lucas 1988; Rebelo 1991; Grossman and Helpman 1991; Aghion and Howitt 1992). Figure 1.1 offers a schematic overview of the financial system's role in an economy.

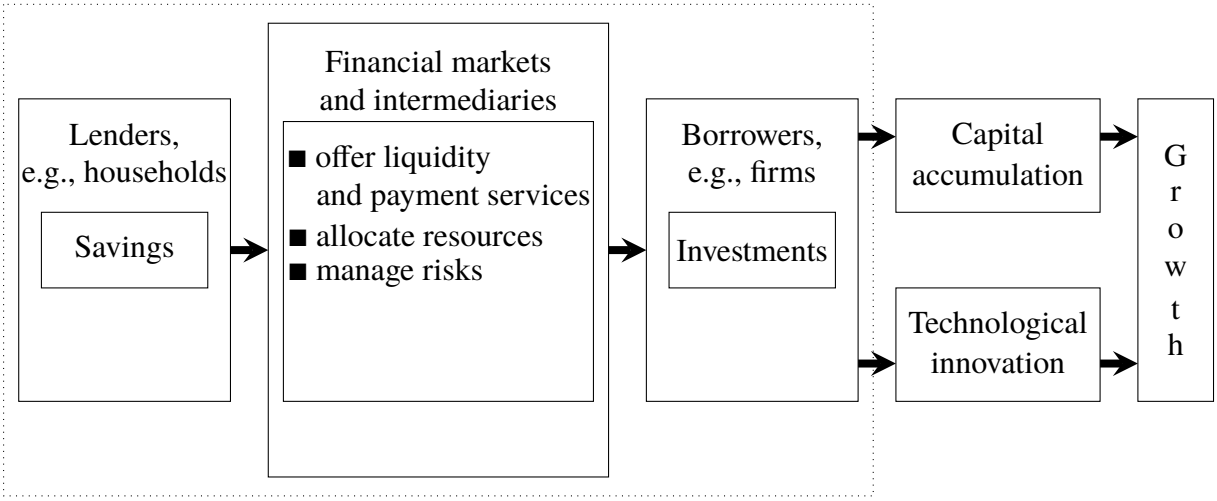


Fig. 1.1: The functions of the financial system

Lenders of capital are primarily households that have saved surplus funds. Financial markets and intermediaries transform these savings into funds, which for example can be used for investments by firms. When markets are perfect and complete, financial systems which use resources to research projects, scrutinize managers, or design arrangements to ease risk management and facilitate transactions are superfluous. In such a frictionless world, borrowers and lenders transact directly. The allocation of resources is Pareto efficient and intermediaries do not improve welfare. However, as soon as one takes into account the presence of frictions, such as the costs of acquiring information, enforcing contracts and making transactions, financial markets and intermediaries more efficiently allocate economic resources both across borders and across time (Merton and Bodie 1995).

Overall, empirical evidence indicates that the impact of the financial system on growth through increased productivity and optimized resource allocation is more significant than capital accumulation (Beck et al. 2000). Specifically, access to financial services, e.g., credit, savings, and insurance, increases entrepreneurship and firm innovation (Klapper et al. 2006; Aghion et al. 2007; Ayyagari et al. 2011). Financial development is not only important for individual firm growth or household welfare but also for the aggregate (economy-wide) growth. A well-developed financial system directs funds to their most productive use, fosters innovation and competition and improves governance across the economy (Kerr and Nanda 2009; Brown et al. 2013). Clearly, a well-developed financial system is beneficial for firm and economic growth.

This dissertation provides insight on the function and infrastructure of the modern financial system. In general, it examines the aggregate economic welfare and specifically looks at the different channels and mechanisms through which financial markets and institutions affect the real economy at the firm level. The dissertation is made up of two parts. The first part (Chapter 2, "Access to Banking and its Value for SMEs - Evidence from the U.S. Marijuana Industry" and Chapter 3, "Contemporaneous Financial Intermediation - How DLT Changes the Cross-Border Payment Landscape") specifically deals with the two functions, financing as well as payment and transaction services and how they affect firm growth. For centuries, these financial services were essentially performed by banks alone (Quinn and Roberds 2008; Greenwood and Scharfstein 2013). In developed countries, however, financial systems have recently undergone a dramatic transformation. In particular, the application of digital technology - with online banking, big data and cheap data processing - has not only transformed banks but also has created new competitors (FinTechs) in their core business. FinTechs frequently offer clients faster and more flexible solutions at good rates, such as instantaneous payment services, reliable information tracking, and new borrowing technologies (Ventura et al. 2015; Schwienbacher 2016). In this context the role of traditional banks in developed countries must be reevaluated. Here, the necessity of banks for financing and payment and transaction services for small- and medium-sized enterprises (SMEs) is examined in Chapter 2 (forthcoming as Merz and Riepe 2020). The unique example of the U.S. marijuana industry, a young industry without access to banking but situated in a highly financially developed environment, was utilized. Furthermore, the potential of Distributed Ledger Technology (DLT) is examined in Chapter 3 (Merz 2020, currently under review at the journal Information and Management). DLT is a novel and fast-evolving approach to record and share data among members of a decentralized network. This technology could revolutionize the cross-border payment system, a system traditionally relying on intermediary banks.

The second part (Chapter 4, "Innovative Efficiency as a Lever to Overcome Financial Constraints in R&D Contests" and 5, "Identifying Corporate Venture Capital Investors: A Data-Cleaning Procedure") focuses on the connection between finance and innovation-led growth. Innovations typically result from investment in research and development (R&D). Like any

investment, R&D projects require financial resources. Raising external financing, however, is associated with several difficulties inherent to R&D projects (Hall and Lerner 2010). Not every planned innovation can be realized making R&D projects highly uncertain. This uncertainty makes it hard for financiers to quantify the risk of an investment (Knight 1921). Additionally, often neither the innovator nor the financier knows the true potential of the project which exacerbates adverse selection (Stiglitz and Weiss 1981) and moral hazard problems (Holmström 1989). This background makes it especially challenging for innovative start-ups to access financing as they do not have creditworthiness and lack prior examples of technological capabilities (Hottenrott et al. 2016). Not surprisingly, it has been repeatedly found that large firms have higher R&D budgets (Acs and Audretsch 1988; Foster et al. 2019). In reality, however, despite their higher R&D expenditures large firms often do not win innovation contests. This raises the question of innovative advantage, i.e., when are entrepreneurial firms more capable at generating innovations. In order to clarify the origin of this apparent contradiction, a theoretical model is presented in Chapter 4 (published as Merz 2019) which explores the innovative advantages of small firms over large firms. In order to compensate the success of small firms in innovation contests, large firms have begun to develop their own venture capital (VC) programs, commonly referred to corporate venture capital (CVC). Recently, there has been a high research interest in CVC, but due to non-standardized definitions and data-cleaning procedures comparability and replicability is difficult. Here, in Chapter 5 (published as Röhm et al. 2020) a common definition of CVC and a data-cleaning procedure is proposed.

Taken as a whole, this dissertation provides a more thorough understanding of the modern financial system's function and its utilized infrastructure in developed countries.

Part I

Banks, The Allocation of Resources and Growth

Chapter 2
Access to Banking and its Value for SMEs - Evidence from the U.S. Marijuana Industry

Abstract This paper examines how legally restricted access to banking services affects small and medium-sized enterprises in a highly developed country. Using a mixed-method approach, we examine the unique situation of the U.S. marijuana industry. The industry benefits from the superior institutional environment in terms of legal protection and the labor market of the United States. However, due to conflicting state and federal laws it has no legal access to banking. We find significant value effects around three major events that affected future access to banking. These results indicate that banking access remains desirable for the marijuana industry. A survey taken by marijuana SMEs provides insights into what banking services are considered most valuable. We find that marijuana SMEs have problems to obtain financing and handle their transactions largely in cash, resulting in transaction inefficiency and high security concerns. Thereby, we shed light on the value of banks for SMEs in developed countries. We complement the literature on financial transaction services by highlighting the value for SMEs in developed markets.

2.1 Introduction

Banks are a vital lifeline for the economy (Bernanke 2008). They supply capital to firms and facilitate the exchange of goods and services (Levine 1997; Levine et al. 2000; Levine 2005; Song and Thakor 2010). In addition, they offer safekeeping depository services (Donaldson et al. 2018). While in developed countries capital markets and other non-bank financial intermediaries also fulfill these functions, a large number of studies have shown that access to bank financing is crucial for firms. This holds particularly true for SMEs. For example, Jayaratne and Strahan (1996), Bertrand et al. (2007), and Krishnan et al. (2014) examine the effects of gradual improvements in the availability of loans due to bank branching deregulation in the United States. They find evidence that this bank deregulation results in increased productivity of small firms and fosters economic growth. Gan (2007), Jiménez et al. (2012), Chodorow-Reich (2014), and Huber (2018) come to a similar conclusion based on the effect of bank distress or a change in monetary policy on the local economy. Fracassi et al. (2016) and Berg (2018) show that the ability to obtain loans increases firms' survival probability, sales, and job creation. Beck et al. (2008) and Robb and Robinson (2014) also provide evidence that access to bank financing is crucial for SMEs. Similar results are also found for developing countries (compare, e.g., Levine 2005 or Ayyagari et al. 2013 for an in-depth overview). While all of these studies find that banks are crucial for financing, the other banking services remained unconsidered. Specifically,

payment and financial transaction services are known to be an essential banking function (Kohn 1999; Donaldson et al. 2018). In their theory of banking, Donaldson et al. (2018) even cite safe-keeping depository services as a fundamental aspect of banks. However, there is only a limited number of empirical findings from developing countries, most of which focus on the Kenyan mobile money market. In this famous example, financial transaction services from M-Pesa are considered. This service enables customers who have limited or no access to a bank account to send, receive and store money. Overall these studies show the importance of access to payment and financial transaction services. Vaughan (2007), for example, reports that individuals use the mobile payment service to store money safely when traveling across Kenya. Jack and Suri (2014) provide evidence that access to financial transaction services affects the risk-sharing behavior of households. In particular, when faced with a financial shortage, households with access to transaction services are more likely to receive support from their network of family and friends. Plyler et al. (2010) and Beck et al. (2018) find that access to financial transaction services is not only welfare-enhancing on the household level, but also growth-enhancing for SMEs. Additionally, Beck et al. (2018) show empirically that access to financial transaction and payment services also influences access to external lending. Today, considerably less is still known about the value of bank-based transaction services in highly developed countries. Examples of firms in developed countries without any banking access are hard to find.

Our study aims at filling this knowledge gap by using the unique situation of the U.S. marijuana industry. While this industry has access to all other well-developed institutions, such as the legal system and the labor market, federal law inhibits the marijuana industry from using the traditional banking system (see Hill 2015). In addition, in the United States, new alternative financial intermediaries from the digital world (FinTechs) now exist (Ventura et al. 2015; Mills and McCarthy 2016). These intermediaries frequently offer clients faster and more flexible solutions at good rates, such as instantaneous payment services, reliable information tracking, and new borrowing technologies. This calls into question whether in this setting traditional banks still play a significant role. To understand the perceived importance of banking access for the U.S. marijuana industry in general, we apply an event study. We conduct event studies on three major occasions that affect the marijuana firms' probability of gaining legal access to banking services. Using a mixed-method approach, the event study results are complemented by a detailed survey among marijuana SMEs (microbreweries serve as a control group). With our survey, we reassess the legally restricted access to banking for unlisted firms and uncover specifically the SMEs' perspectives on the business challenges that arise from the legally denied access to banking in a developed country. Based on the literature, we expect that traditional banks are still perceived as important by the marijuana industry with particular desirability of the SMEs for bank financing. Although in developing countries it has been shown that transaction services are beneficial, in the United States, alternative transaction methods to traditional banks exist. Therefore, using

the results of the survey, it will be identified if transaction services by traditional banks are still considered relevant.

2.2 The marijuana firms and the banking system

In the United States, marijuana is considered a Schedule I drug. This means that according to the Controlled Substance Act, under federal law, it is illegal to possess, use, buy, sell, or cultivate marijuana. This prohibition also includes providing banking services to marijuana firms. Despite its federal controlled substance status, several states have legalized medical and recreational possession, use, sale, and cultivation of marijuana on a state level. In January 2014, Colorado became the first state where licensed and regulated retail stores could sell recreational marijuana to consumers. This jump-started a new industry. Washington State, Alaska, and Oregon soon followed suit. As of December 2019, eleven states have legalized recreational marijuana. About 70% of the U.S. population now lives in states where retail and/or medical marijuana is allowed. According to Marijuana Business Daily™ (2019), industry sales in the United States increased from about $2.7 billion in 2014 to up to $14 billion in 2019. Figure 2.1 shows the legal status of marijuana sales in each state.

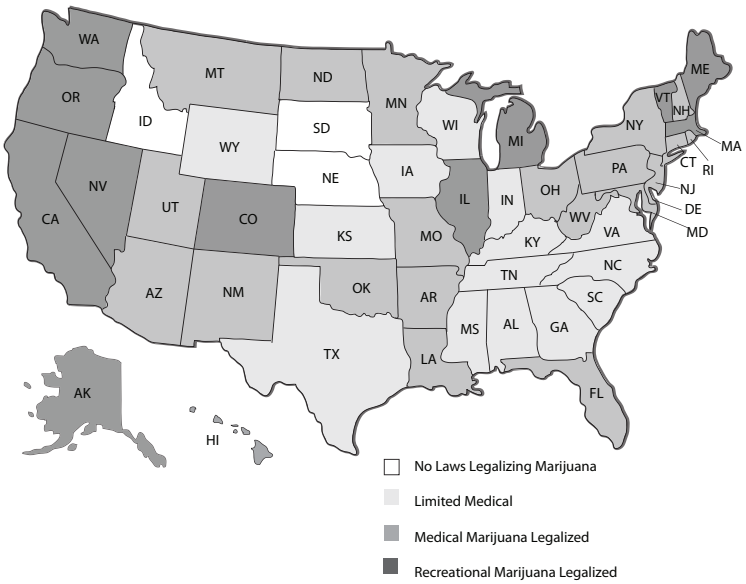


Fig. 2.1: Marijuana laws by state, as of December 2019

Although marijuana is legalized to some extent in several states, the Department of Justice has made clear that "[p]ersons who are in the business of cultivating, selling or distributing marijuana, and those who knowingly facilitate such activities, are in violation of the Controlled Substance Act, regardless of state law" (Cole 2011, p. 2). In other words, even in the face of contrary state law, individuals, firms, and financial institutions that violate the Controlled

Substances Act can be prosecuted under federal law. While a marijuana firm operates according to the legal requirements of a single state, federal law directly affects banks. Although the United States' dual banking system allows for both federal- and state-chartered institutions, the vast majority of financial institutions are federally insured.[1] With the benefit of federal insurance comes the burden of federal regulation.

There are additional legal requirements that intensify the legal threat to financial institutions. As outlined in the Bank Secrecy Act (1970) and the Money Laundering Control Act (1986), federal law requires all financial institutions to report any illegal activity to federal officials and to prevent wrongdoers from accessing the banking system. In the words of Hill (2015, p. 617), these requirements lead to the problem that "a financial institution that knowingly processes transactions for marijuana-related businesses commits the crime of money laundering." Any wrong-doing directly causes civil and criminal penalties for financial institutions that range from costly fines to the closing of the institution. Anecdotal evidence in the Marijuana Business Daily™ (2015, p. 7) indicates that "most banks [...] will not move forward until the government issues actual new rules or changes the law."

On February 14, 2014, the Department of Justice and the Department of the Treasury's Financial Crime Enforcement Network took a step towards easing the ban on marijuana firms from the banking system. They jointly issued Guidance Fin-2014-G001 on how banks should handle marijuana-related clients (Cole, 2014; Department of the Treasury Financial Crimes Enforcement Network, 2014) and announced their general intent to not prioritize the punishment of banks engaging in business relationships with legal marijuana firms. The clarification was perceived by market participants as a first step towards enabling banking access for marijuana firms (Hill, 2015) and gave hope that the legal restrictions would soon be abandoned altogether.

After the issuance of the Guidance Fin-2014-G001, the Fourth Corner Credit Union (FCCU) was founded with the mission to provide banking services to marijuana firms. Despite initially appearing promising, the U.S. District Court's ruling in Denver on January 5, 2016, ended the FCCU's attempt to receive a Master Account for electronic money transactions and payment services with the Federal Reserve, hindering a fast change in the legal situation. In their ruling, the court prioritized the federal law over the Guidance Fin-2014-G001 and reiterated that banks are not legally allowed to have clients from the marijuana industry. The Court's decision not only immediately affected the FCCU, but also had declaratory power for all other financial service providers in the United States.

On September 25, 2019, in a new attempt to harmonize federal and state law, the Secure and Fair Enforcement (SAFE) Banking Act was passed with a resounding 321-103 vote in the federal House of Representatives. While the passing of the SAFE Banking Act in the House was a first step enabling banking access, concerns that marijuana businesses violate federal laws were not fully addressed. "Ultimately, the only federal action that could provide equitable financial

[1] Even banks that operate under state charter rather than national charter use the Federal Reserve system for transferring funds and are generally supervised by the Federal Reserve, the National Credit Union Administration, or the Federal Deposit Insurance Corporation.

services to the industry is a change in federal treatment of [...] marijuana" (Lawrence, 2019, p. 31). In addition, the initial euphoria of the marijuana industry about the landmark House vote was dampened shortly afterwards because it remains unclear how the measure might fare in the Senate and if President Trump would sign it into law.

2.3 Data and method

2.3.1 Empirical strategy

To explore the importance of banking services for marijuana firms, e.g., financing and financial transaction services, we apply a mixed-method approach. To measure the necessity of banking services for the marijuana industry as a whole, we use the event study method. As events, the issuing of the Guidance Fin-2014-G001 regarding marijuana enforcement, the U.S. District Court's unexpected ruling in 2016 as well as the U.S. House of Representatives vote on the SAFE Banking Act in 2019 were selected. All events mark milestones in the marijuana industry's fight to gain legal access to the banking system. We expect to find positive (negative) abnormal returns for events that increase (decrease) the likelihood of banking access if market participants perceive banking services as important for the marijuana industry. To specifically understand the perspective of SME members of the marijuana industry on the importance of legal bank access, a detailed survey was conducted. As a control, similarly sized microbreweries were used. Similar to marijuana firms, microbreweries face multiple regulations at the federal and state level with respect to producing, distributing, and selling their products (Anhalt 2016). However, in contrast to marijuana firms, microbreweries have legal access to banks. Additionally, they started growing in popularity in areas where and around the same time as marijuana firms were legalized (Elzinga et al., 2015; Brewers Association, 2017). Both microbreweries and marijuana firms belong to sin industries and thus share a number of other characteristics. Hong and Kacperczyk (2009) and Durand et al. (2013) show that in general sin firms have similar investors, receive less coverage from analysts and face greater litigation risk. We expect that if banking services are perceived as valuable for sin firms, respondents from the marijuana industry should more often than microbreweries identify the lack of bank-related services as challenging. With the survey, we specifically examine the desirability of a) transaction and payment services and/or b) bank lending for these industries. Based on the literature that has established the crucial role of access to bank financing, we expect that our respondents have a particular desire for bank financing.

2.3.2 Event study

For the event study, we identified all listed U.S. firms that engage in marijuana-related business activities based on the Bloomberg Weed Index, firms mentioned in the 2014 and 2015 Viridian Cannabis Industry Report, and firms mentioned by Weisskopf (2019). It was manually verified that all firms conduct business in the marijuana industry. Overall, 87 firms from the marijuana industry that are listed on a stock exchange were identified. Thomson Reuters Datastream provides the corresponding stock prices for the marijuana firms. All time series are adjusted for non-trading days. We deleted penny stocks below 10 cents and illiquid stocks that are traded on less than 20% of all trading days within the respective estimation window. We also deleted stocks with less than 30 non-zero daily returns per year or missing return observations in the 20 days before the respective event (Brown and Warner, 1985). Additionally, we do not consider returns above 100% or equal to -100% on a single trading day and the subsequent reversals. Applying all of these criteria yields a sample of 28 firms for the first event, a sample of 28 firms for the second event and a sample of 30 firms for the third event. Overall, 52 unique marijuana firms are considered. Some firms are considered in more than one event. A detailed list of all firms included in the samples by marijuana industry activities and by stock exchange listings is provided in Tables 2.11 and 2.12 in Appendix A.1.

All samples consist of firms within several marijuana industry activities, such as growers, providers and manufacturers of equipment or growing facilities, and more indirectly, firms that provide supplementary goods or services. While some of the firms were newly founded, other firms in the sample previously operated in other industries before becoming marijuana firms, such as suppliers. With the exception of the producers, each sample's distribution closely resembles that of the marijuana industry. In all samples, a high number of firms is engaged in pharmaceutical research that includes marijuana firms which distribute their products for medical purposes. While medical marijuana is legal in many states, only a limited number of states allow recreational use (compare Figure 2.1). The marijuana producers are underrepresented in our samples and in the stock market in general, most probably due to their limited bank access.

Table 2.1 reports the statistics for all events. The differences of the firms considered for the event studies are reflective of the strong growth of the marijuana industry between February 2014 and September 2019 (Marijuana Business Daily™ 2019). As a result, the findings offer insight into the marijuana industry at different stages. A typical (median) marijuana firm in our sample of the first (second/third) event has 7 (10, 27) employees, total assets of $1.52 ($3.70, $13.25) million and annual revenues of $120,000 ($530,000, $5,020,000). The market capitalization of the underlying stocks one day prior to the first (second/third) event window ranges from $21.53 ($7.01, $25.11) million at the 25th percentile to $176.99 ($22.85, $187.68) million at the 75th percentile with a median of $55.38 ($10.03, $37.72) million. The portfolio returns of each

Table 2.1: Descriptive statistics event study

	N	Mean	St. dev	P25	Median	P75
Event 1						
Number of Employees	23	38	72	4	7	38
Revenues [in million $]	28	$9.27	$23.79	$0.00	$0.12	$5.38
Total Assets [in million $]	28	$19.89	$65.40	$0.05	$1.52	$7.10
Market cap [in million $]	28	$184.61	$346.48	$21.53	$55.38	$176.99
Portfolio returns	239	0.86 %	2.78 %	−1.03 %	0.39 %	2.57 %
Event 2						
Number of Employees	28	46	109	4	10	21
Revenues [in million $]	28	$18.55	$62.86	$0.08	$0.53	$10.17
Total Assets [in million $]	28	$33.99	$78.25	$1.47	$3.70	$25.89
Market cap [in million $]	28	$123.51	$407.37	$7.01	$10.03	$22.85
Portfolio returns	239	−0.11 %	1.92 %	−1.39 %	−0.22 %	1.14 %
Event 3						
Number of Employees	30	63	78	6	27	78
Revenues [in million $]	30	$45.37	$148.50	$0.33	$5.02	$31.31
Total Assets [in million $]	30	$100.37	$241.10	$3.78	$13.25	$99.57
Market cap [in million $]	30	$224.13	$510.21	$25.11	$37.72	$187.68
Portfolio returns	239	0.01 %	1.96 %	−1.23 %	0.01 %	1.00 %

This table displays the statistics of the equally weighted portfolio of all marijuana shares that are used for the event studies. Number of Employees refers to the reported number of employees of the underlying firms at the time of the event. Note that for Event 1, a few firms did not report the exact number of employees. Revenues refer to the firms revenues in millions of USD that were disclosed in the financial report taken most closely to the event day. Total Assets refer to the firms total assets in millions of USD that were disclosed in the financial report taken most closely to the event day. Market cap refers to the market capitalization of the underlying stocks in millions of USD one day prior to the event window, respectively. Portfolio returns refer to the daily returns over the samples' estimation periods.

sample are small but mostly positive and the distribution of returns becomes less dispersed for later events.

The event study method closely follows Brown and Warner (1985). For the event study, we form an equally weighted portfolio of the identified marijuana firms. We use the market model to calculate the abnormal portfolio returns as well as the abnormal returns for all single stocks. We use different market benchmarks to mitigate any confounding effects of parallel market movements on the event day. We start with a beta factor of zero and a risk-free rate of zero percent. Furthermore, we estimate firm-specific model parameters with the S&P 500 Index as well as the S&P 600 Food, Beverage, & Tobacco Index as alternative market benchmarks. We discuss in detail only the results attained using the market benchmark of the S&P 600 Food, Beverage, & Tobacco Index since it measures the performance of similar sin industries. As previously mentioned, sin firms differ from other firms with respect to investors, analyst coverage and litigation risk (Hong and Kacperczyk 2009; Durand et al. 2013). We rely on different time frames preceding the three events. Due to the possibility that the issuing of the Guidance Fin-2014-G001 might have leaked into the market early, we start one trading day before the event in the earliest specification. For the court ruling, we base our main reasoning

on the event day and the days afterwards because the judgment surprised the market. Due to the fact that the vote on the SAFE Banking Act was announced one trading day before the actual event, we start at minus one. All the event windows go up to two days after because most firms are traded infrequently so it might take more than a day before the information is reflected in the prices. Overall, the results appear robust for the different event windows with smaller variations. All results remain qualitatively unchanged with respect to the different market benchmarks. This indicates that our findings can be traced back to abnormal movements in the marijuana firms' stock prices.

2.3.3 Survey design and sample

To understand the perspective of marijuana SMEs and to identify how these firms cope with the lack of legal access to banking in their day-to-day business, we developed a survey. The survey was designed based on the well-established "Survey on the access to finance of SMEs" by the European Commission and the European Central Bank. The questions are adjusted and complemented to address challenges specific to the marijuana industry. The survey contains objective questions (e.g., "Does your company currently have a business account with an U.S. American bank?"), that are complemented by subjective questions (e.g., "What in your opinion would be the biggest benefit of access to banking in regards to money transactions for your company?"). In addition, in order to limit bias stemming from socially desirable answers, we included questions that are constructed as "ideal experiments" (Hall 2008, p. 418). For example, to assess whether limited access to bank financing hinders firm growth we ask respondents for the first reaction in case of unexpected costs. The survey questions are provided in Appendix A.2.

The paper-based survey was conducted directly by visiting dispensaries in the Denver area as well as at the 2017 National Cannabis Industry Association's (NCIA's) Seed-to-Sale Show. One of the authors personally distributed 70 surveys to qualified personnel, for example, store managers or owners, to be sent back via mail. Here we received ten responses. At the 2017 NCIA's Seed-to-Sale Show, one of the authors personally surveyed managers and owners of marijuana SMEs. In order to limit a potential sample bias stemming from a fear to disclose illegal activity by marijuana SMEs, complete anonymity was promised to any potential respondent. Four out of five respondents were willing to participate in the survey.[2] In total, 58 marijuana SMEs participated in the survey. The survey sample includes very small firms (dispensaries) with direct customer contact as well as medium-sized firms that mainly supply other marijuana firms.

In the survey, most participants responded to all questions. Table 2.2 provides the summary statistics of the respondents and their firms. About 43% of the respondents were business owners

[2] Two additional responses were received by distributing the survey through an industry contact. Another two responses were received through follow-up calls via telephone.

Table 2.2: Summary statistics on respondents

	Marijuana firms N=58		**Microbreweries N=24**	
Position of respondent	**N**	**in %**	**N**	**in %**
Owner	25	43 %	16	67 %
Executive director	10	17 %	6	25 %
Non-executive director & other	23	40 %	2	8 %
Working experience in the firm				
Less than 1 year	14	24 %	1	4 %
1 year and more	44	76 %	23	96 %
U.S. state				
Colorado	42	72 %	10	42 %
California	7	12 %	7	29 %
Other	9	16 %	7	29 %
Industry sector				
Dispensary with integrated grow	26	45 %		
Infused product maker	12	21 %		
Wholesale grower	9	16 %		
Ancillary technology	6	10 %		
Ancillary services	5	8 %		
Owners of firms				
One owner	30	52 %	5	21 %
Multiple people	25	43 %	19	79 %
Venture capital enterprises	2	3 %	0	0 %
Public shareholders	1	2 %	0	0 %
Age of firms				
Less than 2 years	15	26 %	7	29 %
2-4 years	17	29 %	7	29 %
5-10 years	24	43 %	9	38 %
More than 10 years	2	2 %	1	4 %
Firm size by employee				
Micro firms	26	45 %	16	67 %
Small firms	23	40 %	7	29 %
Medium-sized firms	9	15 %	1	4 %
Annual turnover				
Up to $100 000	16	30 %	3	13 %
Over $100 000 and up to $1 million	16	30 %	15	65 %
Over $1 million and up to $5 million	12	22 %	5	22 %
Over $5 million	10	18 %	0	0 %
Average growth rate in the last 2 years				
Over 50 %	26	51 %	5	21 %
Between 20 and 50 %	14	27 %	7	29 %
Less than 20 %	8	16 %	5	21 %
Stayed about the same size	3	6 %	7	29 %
Did you (at least) break-even?				
Yes	37	64 %	17	71 %
Not yet	21	36 %	7	29 %

This table displays the summary statistics of the respondents and the marijuana firms/microbreweries the respondents work for. We report the respondents' position and their working experience in the firm. Additionally, we report the firm's characteristics such as location, industry sector, ownership structure, age, and size in terms of the number of employees, and annual turnover. Micro firms are firms with 1-9 employees, while small firms are those with 10-49 employees and medium-sized firms have 50-249 employees. We report the average growth rate over the last two years measured by turnover and whether the firms broke-even in the last year. We obtained 58 responses to our marijuana survey, but not all respondents provided information on the annual turnover and the average growth rate. We obtained 24 responses to our microbrewery survey, but not all respondents provided information on the annual turnover.

of marijuana SMEs, followed by non-executive directors such as store managers (~40%) and executive directors (~17%). Most respondents had worked in the firm for over a year. Given their position as well as their working experience in the industry, our respondents should be very knowledgeable about the business activities and their firms' access to banking services. Regarding the geographic scope, our sample is heavily focused on Colorado (72%) that is the oldest, most developed, and largest market for legal marijuana in the United States. Information from the remaining surveys indicates a similar, albeit less advanced, situation in other states. With around 45%, nearly half of our sample consists of dispensaries with integrated growing facilities. The other 55% of surveys come from SMEs that mainly do business with other marijuana firms.

About two-thirds of the marijuana sample firms have already broken even and consequently can rely on internal cash flow as a source of financing. Although 43% of our sample firms grew more than 50% in terms of turnover, their overall size remains small. Only 18% of the surveyed SMEs self-report revenues of more than $5 million.[3] Furthermore, the marijuana firms are on average young, because state licenses were only granted following legislation in 2010 for medical and after 2014 for recreational uses. Regarding the ownership structure, most marijuana SMEs are owned by a family or a single entrepreneur.

To better attribute our results to the marijuana firms' lack of access to banking and not to the overall characteristics of young SMEs, we conducted an online survey among U.S. American microbreweries as a control. Using the results of the subjective questions it is possible to explain differences in behavior between the control group and the marijuana firms (Bertrand and Mullainathan 2001). In total 24 microbreweries participated. Apart from access to banking services, the microbreweries in our control sample closely resemble the surveyed marijuana SMEs with respect to age, size, and geographical location (see Table 2.2). Most of the respondents were business owners or executive managers from Colorado (~42%). About two-thirds of the surveyed microbreweries have less than ten employees, and none of them self-reports revenues of more than $5 million. Thus, the microbreweries in our sample are on average smaller than the marijuana SMEs. As a result of their smaller size and also of their slightly shorter history, the microbreweries should be on average more financially constrained. Similar to most marijuana SMEs, microbreweries are owned by a family or a single entrepreneur.

2.4 Results

2.4.1 Event studies' results

Table 2.3 reports the event study results for the Guidance Fin-2014-G001. Column 1 depicts the average abnormal returns (AARs) per trading day, i.e., the portfolio returns. The according

[3] Bhue (2018) reports similar revenues for marijuana firms in Washington State.

Table 2.3: Event 1: Guidance Fin-2014-G001

Panel A: Market benchmark of S&P 600 Food, Beverage, & Tobacco Index

	Average abnormal returns	t-stats	Positive/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	0.92 %	0.40	13/15					
t-1	3.46 %	1.52	16/12	5.67 %	8.02 %	4.56 %	2.21 %	−1.23 %
Event day	3.44 %	1.51	14/14	1.25	2.04**	1.42	0.56	−0.38
t+1	1.12 %	0.49	14/14					
t+2	−2.35 %	−1.03	8/20					

Panel B: Market benchmark of S&P 500 Index

	Average abnormal returns	t-stats	Positive/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	0.91 %	0.40	13/15					
t-1	3.20 %	1.41	16/12	5.47 %	7.71 %	4.51 %	2.27 %	−1.14 %
Event day	3.41 %	1.50	14/14	1.20	1.96*	1.40	0.58	−0.35
t+1	1.10 %	0.48	14/14					
t+2	−2.24 %	−0.98	7/21					

Panel C: Zero-return benchmark

	Average abnormal returns	t-stats	Positive/ No change/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	1.86 %	0.81	15/2/11					
t-1	4.17 %	1.82*	18/2/ 8	9.32 %	10.61 %	6.44 %	5.15 %	0.77 %
Event day	4.38 %	1.91*	16/5/ 7	2.03**	2.67***	1.99**	1.30	0.24
t+1	2.06 %	0.90	14/2/12					
t+2	−1.29 %	−0.56	9/1/18					

This table displays the event study results for the Guidance Fin-2014-G001. The average abnormal returns (AARs) correspond to the excess returns with respect to three different benchmarks. In Panel A, the AARs are calculated against the S&P 600 Food, Beverage, & Tobacco Index as the market benchmark; Panel B uses the S&P 500 Index as a broad market benchmark; Panel C relies on the zero-return benchmark. Significance is calculated based on a two-sided t-test. Column 3 displays the number of individual marijuana firms that have abnormal positive (negative) returns on the specific trading day. The cumulative average abnormal returns are calculated based on five different event windows. The ***, **, and * represent significance at the 1%, 5%, and the 10% levels.

two-sided t-statistics are displayed in Column 2. Column 1 shows that the portfolio returns are positive on the event day and the day before. As the guidance was largely expected and involved many parties (see, e.g., Altman 2014), some investors had already traded based on this information. Apart from the portfolio returns, we also explore the individual securities to identify whether all firms are affected in a similar fashion or whether the aggregated results are dominated by a small number of marijuana firms. For the event day and the trading day before, we see that the vast majority of individual stocks show positive abnormal returns. When examining differences within the marijuana industry, positive abnormal returns on the event day were detected for all sectors, except for consulting firms. This result is logical because the

dominant role of consulting firms in the marijuana industry is brokering private financing. In this case access to banking could be perceived as negative.

In a second step, we accumulate the AARs over different event windows. The positive effect is especially strong for the event window of -1 to +1, where we find a significant cumulative average abnormal return (CAAR) of around 8% for the marijuana stocks. In Panel B and C of Table 2.3, the results are reported for the market benchmark of the S&P 500 Index and the zero-return benchmark. For both benchmarks, we still find significant CAARs for the event window of -1 to +1.

The event day is the same for all sample firms. To avoid bias in our results stemming from contemporaneous correlations among abnormal returns, we apply the standardized cross-sectional test by Kolari and Pynnönen (2010). The results remain qualitatively unchanged (compare Table 2.16 in Appendix A.3.1). This also holds true when applying parametric and non-parametric tests (compare Tables 2.17 and 2.18 in Appendix A.3.1). During the considered time period, there were no other confounding events that affected the stock market in general, the marijuana industry or any individual member of the marijuana industry sample. This thus indicates that the abnormal returns stem from the perceived substantial economic benefits that banking access would provide. In addition, the results are significant in economic terms. For the event window of -1 to +1, the average (median) marijuana stock increased its equity value by $14.8 million ($4.4 million). Even after accounting for general market trends, these gains remain economically substantial for the firms and their shareholders. Applying the dividend discount model (DDM) for the event day yields an implied growth rate of about 9.9%. To put this into context, we estimate the maximum sustainable growth rate according to Demirgüç-Kunt and Maksimovic (1998) as 9% for the marijuana industry portfolio. Thus, predicted legal access to banking services affects the marijuana industry's growth by about 0.9%.[4]

In Table 2.4, the event study results for the court ruling against the FCCU on January 5, 2016 are displayed. The portfolio returns around the event are positive on the days before the court ruling and the returns drop on the event day and turn negative. The significant positive AARs prior to the court ruling indicate the high hope for a positive court ruling and a fundamental change in the industry's access to banking. This hope was made clear in statements from industry representatives in the days before the court ruling. In contrast to the expectation of the industry, the FCCU's suit was rejected. Most marijuana stocks are traded on over-the-counter (OTC) markets at a low trading volume and frequency resulting in an often delayed trading. In addition, the local (Coloradan) court ruling slowly reached the industry and investors. For example, even the directly related Credit Union National Association only reported the judgment three days afterwards (Credit Union National Association 2016). These are possible explanations for the negative average abnormal return detected two days after the court ruling. When examining differences within the marijuana industry, negative abnormal returns on the days following the

[4] For more details on the estimations of the growth rates, see Appendix A.4.

Table 2.4: Event 2: The Fourth Corner Credit Union Case

Panel A: Market benchmark of S&P 600 Food, Beverage, & Tobacco Index

	Average abnormal returns	t-stats	Positive/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	3.60%	2.08**	16/12					
t-1	3.50%	2.02**	11/17	−3.78%	−0.17%	−3.67%	−7.28%	−4.80%
Event day	−2.48%	−1.43	12/16	−1.09	−0.06	−1.50	−2.43**	−1.96**
t+1	−1.19%	−0.69	12/16					
t+2	−3.61%	−2.08**	8/20					

Panel B: Market benchmark of S&P 500 Index

	Average abnormal returns	t-stats	Positive/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	3.71%	2.14**	14/14					
t-1	3.45%	1.99**	11/17	−3.50%	−0.14%	−3.59%	−6.95%	−4.35%
Event day	−2.60%	−1.50	14/14	−1.00	−0.05	−1.47	−2.31**	−1.77*
t+1	−0.99%	−0.57	11/17					
t+2	−3.36%	−1.93*	12/16					

Panel C: Zero-return benchmark

	Average abnormal returns	t-stats	Positive/ No change/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	3.44%	1.98**	13/6/ 9					
t-1	3.09%	1.78*	9/6/13	−4.76%	−0.92%	−4.01%	−7.85%	−5.15%
Event day	−2.70%	−1.56	11/4/13	−1.37	−0.31	−1.63	−2.61***	−2.10**
t+1	−1.31%	−0.76	6/6/16					
t+2	−3.84%	−2.21**	7/5/16					

This table displays the event study results around the court ruling against The Fourth Corner Credit Union. The average abnormal returns (AARs) correspond to the excess returns with respect to three different benchmarks. In Panel A, the AARs are calculated against the S&P 600 Food, Beverage, & Tobacco Index as the market benchmark; Panel B uses the S&P 500 Index as a broad market benchmark; Panel C relies on the zero-return benchmark. Significance is calculated based on a two-sided t-test. Column 3 displays the number of individual marijuana firms that have abnormal positive (negative) returns on the specific trading day. The cumulative average abnormal returns are calculated based on five different event windows. The ***, **, and * represent significance at the 1%, 5%, and the 10% levels.

court ruling are detected for all sectors except for consulting firms. In the case of the accumulated time frame 0 to +2, we find a statistically significant negative CAAR of about -7.3% resulting from the rejection of the FCCU's suit. In other words, the court ruling led to a value decline of about $9 million ($0.7 million) for the average (median) member of the marijuana industry. Although the second event has a less significant effect than the first event, the overall economic impact to the industry remains strong. Applying the DDM for the event day yields an implied growth rate of about 10.2%. In comparison, the estimated maximum growth rate is 11.3%. Thus, the perceived setback to gaining legal banking access reduced growth by about 1.1%. Panel B of Table 2.4 displays the results for the market model where the S&P 500 Index serves as the

benchmark. Panel C of Table 2.4 gives the results for the zero-return benchmark. Similar to our baseline case, we find significant cumulative average abnormal returns for the event window of 0 to +2 resulting from the legally denied access to banking. Again, our results remain qualitatively unchanged when applying parametric and non-parametric tests (compare Tables 2.19, 2.20 and 2.21 in Appendix A.3.2). Upon examination for confounding events, it was identified that the U.S. stock market in general was affected by turbulence in the Chinese stock market. In addition, there were concerns about the Chinese economy that led to a strong decline of mainly export-oriented firms in the S&P 500 Index during the event window.[5] Since the U.S. marijuana industry does not export to China, this event should not significantly affect the marijuana stocks. In other words, without the court ruling against the FCCU, marijuana stocks should have outperformed the market. Thus, the identified negative CAARs are significant. In order to confirm that spillover effects on marijuana stocks from our sample listed in the NYSE and NASDAQ were not the sole drivers of the negative returns, we reaffirm our results with a portfolio solely consisting OTC market stocks. In conclusion, our results can largely be traced back to the continued denied access to banking.

Table 2.5 illustrates the event study results for the U.S. House of Representatives voting on the SAFE Banking act in 2019. Column 1 shows positive portfolio returns on the day of the voting and negative returns on the days before and afterwards. The unclear pattern of the returns imminently around the vote appears rather surprising. It can, however, be understood by considering the news coverage of the vote. One day prior to the scheduled vote, there were rumors that the vote for the bill could be delayed. In addition, the vote was scheduled "under suspension of the rules", i.e., as a take it or leave it proposition that must be approved by a two-thirds majority in the House, making a success seem less likely. In the end, however the vote on the SAFE Banking Act took place and was passed with an overwhelming majority. In addition to the Democrats, surprisingly nearly half of the Republican caucus voted for the bill. The initial euphoria of the marijuana industry was subdued by the likely failure of the bill in the Senate (a positive vote in the House of Representatives and the Senate is necessary to pass a bill into a law). Moreover, while the SAFE Banking Act improves the status quo, it does not ensure financial services to the marijuana industry. This led to a significant negative portfolio return of -5.66% in the cumulative event window of +1 to +2. In Panel B and C of Table 2.5, the results are reported for the market benchmarks of the S&P 500 Index and the zero-return benchmark. For both benchmarks, we still find significant negative CAARs for the event window of +1 to +2. Again, our results remain qualitatively unchanged if we apply parametric and non-parametric tests (compare Tables 2.22, 2.23 and 2.24 in Appendix A.3.3). The results are also significant in economic terms. For the event window of +1 to +2 the average (median) value of marijuana firms declined by about $12.7 million ($2.1 million). Applying the DDM for the event day yields an implied growth rate of about 10.6%. In comparison, the estimated maximum growth rate

[5] For more information, see Koptis (2016) and NBC NEWS (2016).

Table 2.5: Event 3: The SAFE Banking Act

Panel A: Market benchmark of S&P 600 Food, Beverage, & Tobacco Index

	Average abnormal returns	t-stats	Positive/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	0.20%	0.13	9/21					
t-1	−2.48%	−1.70*	6/24	−6.16%	−3.45%	−0.97%	−3.68%	−5.66%
Event day	1.98%	1.36	14/16	−2.11**	−1.37	−0.47	−1.46	−2.75***
t+1	−2.95%	−2.02**	7/23					
t+2	−2.71%	−1.86*	8/22					

Panel B: Market benchmark of S&P 500 Index

	Average abnormal returns	t-stats	Positive/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	0.30%	0.21	9/21					
t-1	−2.05%	−1.41	8/22	−5.56%	−3.00%	−0.95%	−3.51%	−5.39%
Event day	1.88%	1.30	13/17	−1.91*	−1.19	−0.46	−1.39	−2.62***
t+1	−2.83%	−1.95*	7/23					
t+2	−2.56%	−1.76*	9/21					

Panel C: Zero-return benchmark

	Average abnormal returns	t-stats	Positive/ No change/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	0.28%	0.19	9/3/18					
t-1	−2.64%	−1.80*	4/4/22	−6.26%	−3.34%	−0.70%	−3.62%	−5.92%
Event day	2.30%	1.57	12/6/12	−2.14**	−1.32	−0.34	−1.43	−2.87***
t+1	−3.00%	−2.05**	5/6/19					
t+2	−2.92%	−2.00**	6/6/18					

This table displays the event study results around the voting by the U.S. House of Representatives on the SAFE Banking Act. The average abnormal returns (AARs) correspond to the excess returns with respect to three different benchmarks. In Panel A, the AARs are calculated against the S&P 600 Food, Beverage, & Tobacco Index as the market benchmark; Panel B uses the S&P 500 Index as a broad market benchmark; Panel C relies on the zero-return benchmark. Significance is calculated based on a two-sided t-test. Column 3 displays the number of individual marijuana firms that have abnormal positive (negative) returns on the specific trading day. The cumulative average abnormal returns are calculated based on five different event windows. The ***, **, and * represent significance at the 1%, 5%, and the 10% levels.

is 14.5%. Thus, the reiterated legally denied access to banking services lowers the marijuana industry's growth by about 3.9%. To ensure that our results can be traced back to the denied access to banking services, we again searched for confounding events. While the marijuana industry in general was only affected by this vote, three firms of our sample were also affected by firm-specific announcements. In particular, Kushco Holdings announced a secondary offering one day after the voting that negatively affected its stock. In contrast, CBDMD and United Cannabis both announced new partnerships on the event day and the day afterward, respectively. Still, the main results remain qualitatively unchanged if we exclude these three firms.

In summary, the event studies' results show that the marijuana industry perceives legal access to banking as crucial. More information about how typical marijuana firms, i.e., SMEs, cope with the restricted access to banking will be attained from the survey presented in the following section.

2.4.2 Survey results

2.4.2.1 Financial transaction management

Financial transaction and payment services are one of the most prominent economic functions of banks. Levine (1997) refers to them as "easing the exchange of goods and services." Financial transaction and payment services refer to the exchange of goods and services with the firms' customers, suppliers, investors, and with the tax authorities. Panel A of Table 2.6 provides evidence on how the surveyed marijuana SMEs and microbreweries handle their transactions with customers, suppliers, and other parties.

It is shown that marijuana SMEs handle most of their transactions with either cash or checks.[6] More than two-thirds report cash as their main source of revenue from customers and clients followed by checks (approximately one-third). Bank-based transactions do not play a major role in the revenues of most marijuana SMEs. Considering how they pay their suppliers, investors, and similar parties, all three forms of transactions are important. Checks, however, are used most often. Surprisingly, no firm listed alternative payment services like Bitcoins as their major transaction platform. In comparison, firms that do have access to banking, i.e., microbreweries, heavily rely on bank-based transactions. 79% of the microbreweries report bank-based transactions as their major source of revenues and none pay their bills in cash.

Although most marijuana firms rely predominantly on cash for transactions, over half of the surveyed firms have a bank account. This result is surprising as banks usually reject a client or terminate the business relations as soon as they become aware of the marijuana business activity. Although 12 SMEs indicate that they circumvented the rules by operating at least some transactions via their private or a third-party bank account, thirty SMEs report that they managed to open a corporate bank account. To the subjective question about whether they believe to have a long-term relationship 64% answered "yes". Based on additional comments by the respondents (e.g., "I hope that this time it is a long-term relationship"), this result is more an indication for the desire to have a stable banking relationship and less indicative of the current situation.

Still, and as indicated by the previous responses, these bank accounts are not used by most marijuana SMEs to handle their main payment transactions. One reason might be the permanent

[6] Note that there are several forms of checks, e.g., cashier's check, that do not require a bank account (compare, e.g., Stavins 2018 for an overview of the different payment instruments in the United States). The check can be cashed in at regular cash or retail stores. Although these non-bank money services are also subject to federal law and thus will not knowingly accept money from marijuana-related firms. However, if cash amounts are small, few questions are asked.

Table 2.6: Financial transaction management

Panel A: Handling of financial transactions

	Marijuana firms		Microbreweries	
How do you receive most of your revenue?	**N=44 ⋆**	**in %**	**N=24**	**in %**
Cash	31	70 %	1	4 %
Check	13	29 %	4	17 %
Via a bank	3	7 %	19	79 %
Via a non-bank (e.g., Bitcoin)	0	0 %	0	0 %
How do you pay most of your bills?	**N=45 ⋆**			
Check	18	40 %	9	38 %
Cash	16	36 %	0	0 %
Via a bank	15	33 %	15	63 %
Via a non-bank (e.g., Bitcoin)	0	0 %	0	0 %

Panel B: Access to banking of marijuana firms

Does your firm currently have a bank account?	**N=56**	**in %**
Yes, directly	30	54 %
Yes, indirectly (e.g., private account)	12	21 %
No	14	25 %
Perceived stability of bank relationship	**N=39**	
Long-term	25	64 %
Short-term	10	26 %
Terminable	4	10 %
Did the bank reject or close your account?	**N=56**	
Yes	31	55 %
No	25	45 %

⋆ Multiple answers possible

Panel A of this table displays the responses on the handling of money transactions by marijuana firms and microbreweries. We report how firms receive revenues and pay their bills. In panel B, we report how many marijuana firms currently have bank accounts and how often bank accounts were closed as well as their perceived stability of the banking relationship. Note that for some questions we received multiple answers.

threat that the bank discovers their status as marijuana firms and freezes or terminates their bank accounts. This threat also prevents marijuana SMEs from establishing a closer bank-client relationship that could overcome information asymmetries (Kysucky and Norden 2015). When directly asked, more than 50% of the respondents indicate that, due to their status as a marijuana firm, they had been rejected by a bank or their existing bank account had been terminated.

When asked for the most important and strongest benefit of having a regular bank account to handle transactions, most respondents name a reduction in risk (see Table 2.7). With an average score of 4.43 out of five, more than 80% expect that having a bank account would significantly reduce the risk of day-to-day business operations. With a regular transaction account, these firms would face lower risk of being robbed, of misappropriation by employees, as well as of crimes related to money laundering. This is in line with anecdotal evidence. To pay his taxes Jerred Kiloh from United Cannabis Business Alliance, for example “ha[s] to use a six-story parking

Table 2.7: Benefits of access to electronic payment services via banks

Row	Benefits	Mean score	% with 4 or 5 score	N	Significant differences in mean score vs. rows	H0: Mean score = 3
(1)	Reduced risks	4.43	83 %	46	2–5	***
(2)	Reduced time	3.83	63 %	46	1,5	***
(3)	More satisfied customers	3.83	35 %	46	1,5	***
(4)	Reduced costs	3.74	63 %	46	1,5	***
(5)	More satisfied suppliers	3.22	48 %	46	1–4	

This table reports the survey responses on the benefits of access to electronic payment services offered by banks. Respondents were asked to indicate the level of importance on a scale of 1 (not at all beneficial) to 5 (very beneficial). Column 3 reports the mean score where higher values correspond to larger benefits. Column 4 presents the percent of respondents who indicated the beneficial levels of 4 or 5 (somewhat beneficial and very beneficial). Column 5 displays the number of respondents. Column 6 reports the result of a t-test of the null hypothesis that the mean score for a given benefit is equal to the mean score for each of the other benefits, where only significant differences at the 5% level are reported. Column 7 reports the t-test of the null hypothesis that each mean score is equal to three (neither beneficial nor not beneficial). The ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

structure 500 yards from the [local] office of finance and walk through a homeless encampment with a duffel bag full of cash" (as cited in Chiang 2017, p. 13).

In addition to the reduction in risk, respondents state that a bank account would increase their operating efficiency by reducing time and costs, as well as improving customer satisfaction. The extra resources spent on counting money and handling transactions could be used to get additional funding. Currently, it is very labor and time intensive to ensure that each transaction is made correctly and on time. With an average of around 3.8 out of 5, the three effects are perceived as equally important, although the average is significantly lower than that of risk reduction. The lack of access to the bank transaction services appears to not be a relevant factor for the suppliers' satisfaction.

Overall, Tables 2.6 and 2.7 indicate the challenges of marijuana SMEs in handling financial transactions. The lack of legal access to banks makes these firms operate with cash and checks. These options cause a threat to the firms' security and reduce their operating efficiency, thereby hampering growth. Without widespread access to payment services, credit repayments to non-banks are also subject to theft, which decreases the creditworthiness of the firms.

2.4.2.2 Bank loans and credit lines

A second banking service that is typically crucial for SMEs is lending (see, e.g., Berger and Udell 1998; Robb and Robinson 2014). Bank lending includes standard loans and short-term liquidity facilities, such as overdrafts or credit lines. Unlike larger established firms, young SMEs lack access to public institutional debt and capital markets. The fluctuations in SMEs' profits

make free cash flow a less stable source of financing, making them more dependent on bank loans (Beck et al. 2008). However, irrespective of the size, firms rely heavily on credit lines or overdraft facilities to handle temporary fluctuations in the firms' cash flows. Figure 2.2 shows how marijuana SMEs cope with the lack of access to bank lending for their current and future business activities.

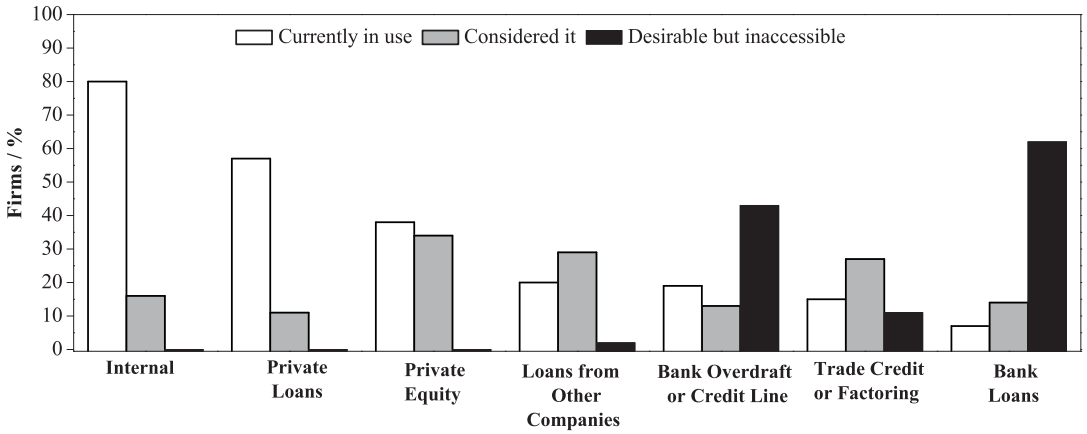


Fig. 2.2: Financing sources of marijuana SMEs

Figure 2.2 and Panel A of Table 2.8 show that most marijuana SMEs rely on internal funding as their major source of financing. Whenever available in a sufficient quantity, internal funding is usually an easy way of financing new and profitable operations. Most surveyed SMEs state that internal funds were available at least to some degree. However, firms that heavily rely on internal cash flow to finance investments tend to systematically underinvest and are classified as financially constrained (Almeida et al. 2004; Almeida and Campello 2007). This in turn holds back firm and ultimately economic growth (Beck et al. 2005; Ayyagari et al. 2008).

Figure 2.2 also shows that most marijuana SMEs finance their operations with private loans from friends, family members, wealthy private individuals, and private equity. Although private loans and private equity can have desirable features, they are usually more costly than traditional bank loans. According to Marijuana Business Daily™ (2016), these private loans are available for an average interest rate of 11%. In comparison, the U.S. Small Business Administration offers financing to SMEs not served by traditional banks and (only) charges between 5.75% and 8.25%. The more sophisticated financing instruments, such as factoring or trade credit, appear to be irrelevant for most marijuana SMEs.

Bank lending is not a major financing source for marijuana SMEs. Less than 20% have access to bank overdrafts or credit lines and less than 10% rely on bank loans, most likely via their private accounts. About 68% (43%) state that bank loans (overdraft facilities) are desirable but inaccessible (see Panel A of Table 2.8). The lack of bank funding is most probably the result

Table 2.8: Bank loans and credit lines

Panel A: Financing sources of marijuana firms

	Currently or previously in use		Considered it for the future		Desirable, but inaccessible		Not relevant	
Financing sources	**N**	**in %**	**N**	**in %**	**N**	**in %**	**N**	**in %**
Internal funds (N=56)	45	80 %	9	16 %	0	0 %	2	4 %
Private loans (N=56)	32	57 %	6	11 %	0	0 %	18	32 %
Private equity (N=56)	21	38 %	19	34 %	0	0 %	16	29 %
Loans from other firms (N=55)	11	20 %	16	29 %	1	2 %	27	49 %
Bank overdraft or credit line (N=54)	10	19 %	7	13 %	23	43 %	14	26 %
Trade credit or factoring (N=55)	8	15 %	15	27 %	6	11 %	26	47 %
Bank loans (N=56)	4	7 %	8	14 %	38	68 %	6	11 %
Issuing debt (N=55)	2	4 %	6	11 %	6	11 %	41	74 %
Public equity (N=56)	1	2 %	17	30 %	5	9 %	33	59 %
Most preferred external financing source (N=56)							**N**	**in %**
Bank loans							26	47 %
Equity capital (private or public)							16	29 %
Loans from other sources							8	15 %
None							6	11 %

Panel B: Financing sources of microbreweries

	Currently or previously in use		Considered it for the future		Desirable, but inaccessible		Not relevant	
Financing sources	**N**	**in %**	**N**	**in %**	**N**	**in %**	**N**	**in %**
Private loans (N=24)	16	67 %	1	4 %	1	4 %	6	25 %
Internal funds (N=24)	13	54 %	4	17 %	1	4 %	6	25 %
Bank loans (N=24)	10	42 %	8	33 %	2	8 %	4	17 %
Bank overdraft or credit line (N=24)	9	38 %	6	25 %	0	0 %	9	38 %
Trade credit or factoring (N=24)	4	17 %	4	17 %	1	4 %	15	63 %
Private equity (N=24)	3	13 %	8	33 %	0	0 %	13	54 %
Loans from other firms (N=24)	2	8 %	4	17 %	0	0 %	18	75 %
Public equity (N=24)	1	4 %	2	8 %	3	13 %	18	75 %
Issuing debt (N=24)	0	0 %	2	8 %	2	8 %	20	83 %

Panel C: Financial constraints of marijuana firms and microbreweries

	Marijuana firms		Microbreweries	
Reaction in case of unexpected costs	**N=56**	**in %**	**N=24**	**in %**
Raising capital	32	57 %	18	75 %
Cut back investments	12	21 %	3	13 %
Delay payments of suppliers	6	11 %	2	8 %
Lay off employees	3	5 %	0	0 %
Increase the price of products	2	4 %	0	0 %
Delay wage payments	1	2 %	1	4 %
Restricting growth opportunities	**N=58**			
Yes	40	69 %	6	25 %
No	18	31 %	18	75 %

This table reports the survey responses related to the financing of marijuana firms and microbreweries. Panel A and B display several financing sources that are used, considered, or desired by the firms. Panel C shows the first reaction in case of unexpected costs for marijuana firms and microbreweries. It further shows whether these firms see themselves as financially constrained.

of the legal situation. When directly asked, about 47% admit that bank loans are their most preferred source of new funding.

The surveyed microbreweries also heavily rely on internal funds and private loans. In comparison, however, bank loans are their third major financing source. 42% of the surveyed microbreweries state that they currently use bank loans and another 33% considers to apply for one (compare Panel B of table 2.8). Furthermore, about 38% currently use bank overdrafts or credit lines to finance their business.

Overall, the results in Table 2.8 show that marijuana SMEs lack access to bank lending but would prefer bank loans, credit lines and overdraft facilities to finance their future operations. The marijuana firms' inability to access bank lending causes the firm to be financially constrained. About 69% state that these financing obstacles hold back their firms' growth. In contrast, only a quarter of the microbreweries appear to be financially constrained and stated that they are restricted in their growth due to lack of funding. Consequently, marijuana SMEs suffer from their lack of access to bank financing.

2.4.2.3 Transaction services, bank lending, and other challenges

Our survey results indicate that the lack of legal access to banking services restricts marijuana SMEs in both financing and transactions. We now assess the relative importance of the two functions and explore their effects compared to other common challenges of SMEs. Panel A of Table 2.9 shows the perceived benefits of banking services. When asked about the most useful banking service, over 50% of the respondents state deposit and savings accounts. Thereby, the banks' service for storing and safeguarding money is perceived as highly important. The access to banks' lending (~26%) and money transfer services (~24%) appear to be equally important to marijuana SMEs.

Panel B of Table 2.9 displays the major challenges marijuana SMEs face, including the lack of access to banking services. Tax rules are the dominant concern of marijuana SMEs with 64% mentioning this as one of their main problems.[7] Access to finance is the second major concern (~50%). This is in line with the previously stated results. Financial transactions with customers and/or suppliers are only a minor concern. It appears that marijuana SMEs have adapted to the legal restriction by using cash payments. However, the frequent handling of large cash transactions increases security concerns dramatically. Security is the fourth most important concern of marijuana SMEs and is even ranked higher than concerns regarding the attraction of customers or finding sufficiently skilled employees and suppliers. These security concerns in turn negatively affect the creditworthiness of the firm because the credit repayment is subject to theft, intensifying the financing problems.

[7] Since marijuana is a Schedule I controlled substance, the IRS has used section 280E to disallow marijuana firms from deducting their ordinary and necessary business expenses. The result is that marijuana firms face much higher taxes than similar companies in other industries.

Table 2.9: Transaction services, bank lending, and other challenges

Panel A: Most useful banking service

Banking service (N=46*)	**N**	**in %**
Deposit/Savings account	24	52 %
Credit	12	26 %
Money transfer	11	24 %
Insurance/Foreign exchange	0	0 %

* Multiple answers possible

Panel B: Major challenges for marijuana firms

Row	**Challenges**	**Mean score**	**% with 4 or 5 score**	**N**	**Significant differences in mean score vs. rows**	**H0: Mean score = 3**
(1)	Tax rules	3.71	64 %	56	3–11	***
(2)	Access to finance	3.34	50 %	56	4–11	*
(3)	Bureaucracy	3.07	45 %	56	1,7–11	
(4)	Security concerns	2.81	36 %	58	1–2,8,10–11	
(5)	Competition	2.82	25 %	56	1–2,8,10–11	
(6)	Costs of production and labor	2.84	24 %	58	1–2,8,10–11	
(7)	Availability of skilled staff	2.60	23 %	57	1–3,10–11	**
(8)	Financial business transactions	2.23	20 %	56	1–6,10	***
(9)	Customer payments	2.25	16 %	44	1–3,10	***
(10)	Finding suppliers	1.75	9 %	56	1–9	***
(11)	Finding customers	1.88	7 %	56	1–7	***

This table reports the overall importance of different banking services. Panel A displays which banking service is perceived as the most useful for marijuana firms. Panel B reports the survey responses on the major challenges that marijuana firms faced in the last six months. Respondents were asked to indicate the level of difficulty of different challenges on a scale of 1 (not an issue) to 5 (very difficult). Column 3 reports the mean score, where higher values correspond to greater difficulty. Column 4 presents the percent of respondents who indicate difficulty levels of 4 or 5 (somewhat difficult and very difficult). Column 5 displays the number of respondents. Column 6 reports the results of a t-test of the null hypothesis that the mean score for a given challenge is equal to the mean score for each of the other challenges, where only significant differences at the 5% level are reported. Column 7 reports the t-test of the null-hypothesis that each mean score is equal to three (neither easy nor difficult). The ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

As a control, the major challenges of typical, young SMEs are illustrated by the example of U.S. American microbreweries in Figure 2.3. Bureaucracy is the dominant concern of microbreweries with 46% mentioning this as one of their main problems, followed by tax rules. This is consistent with the findings from marijuana SMEs. Although 38% of the surveyed microbreweries mentioned access to finance as the third major concern, they rated it on average significantly lower. With a mean value of 2.67 (compared to 3.34 for marijuana SMEs) access to finance appears to be rather a minor issue. This is also confirmed by the fact that finding customers is almost as challenging as getting financing for microbreweries. Looking at the handling of financial transactions and security concerns, the value of banking services becomes even more obvious. In contrast to the marijuana SMEs, none of the microbreweries rated customer payments or security as major concerns.

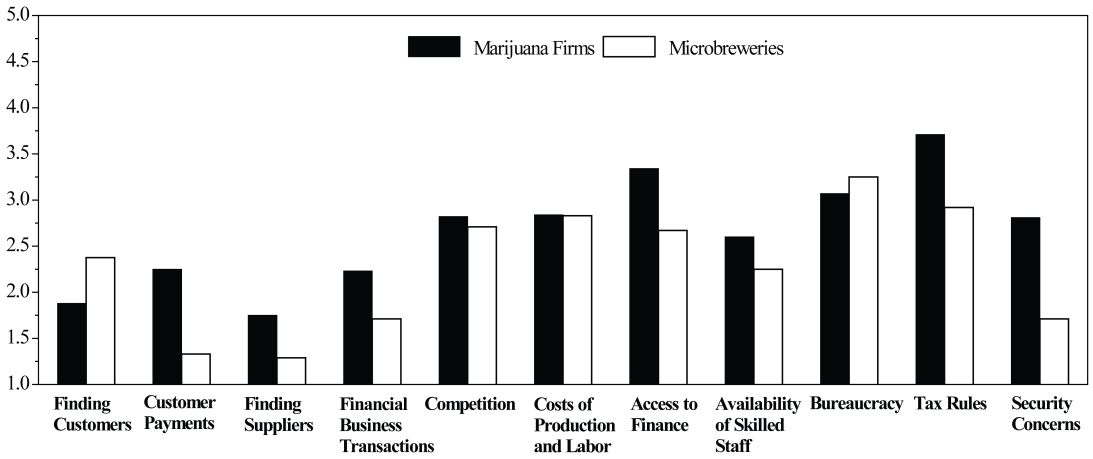


Fig. 2.3: Major challenges for marijuana SMEs and microbreweries

Table 2.10 reinforces the impressions from Figure 2.3. Compared to similar SMEs with legal access to banking services, marijuana SMEs have significantly more difficulties in handling transactions (with customers and other firms) and getting additional funding. In line with the previously stated results, the lack of legal access to bank-based transaction services increases security significantly.[8]

Table 2.10: Comparisons for challenges of marijuana SMEs and microbreweries

	Marijuana firms		Microbreweries		H0: Equality
Challenges	**Mean**	**St. dev**	**Mean**	**St. dev**	**of means**
Tax rules	3.71	1.45	2.92	1.18	**
Access to finance	3.34	1.43	2.67	1.63	*
Bureaucracy	3.07	1.43	3.25	1.26	
Security concerns	2.81	1.33	1.71	0.81	***
Competition	2.82	1.13	2.71	1.30	
Costs of production and labor	2.84	1.15	2.83	1.24	
Availability of skilled staff	2.60	1.21	2.25	1.03	
Financial business transactions	2.23	1.36	1.71	1.23	*
Customer payments	2.25	1.28	1.33	0.57	***
Finding suppliers	1.75	1.07	1.29	0.62	**
Finding customers	1.88	0.99	2.38	1.13	*

This table reports the mean score and standard deviation of survey responses on the major challenges that marijuana firms and microbreweries faced in the last six months. Respondents were asked to indicate the level of difficulty of different challenges on a scale of 1 (not an issue) to 5 (very difficult). The last column reports the result of a Welch t-test of equal means between the two different firm groups. The ***, **, and * indicate a statistical significance difference in means at the 1%, 5%, and 10% levels, respectively.

As shown by Ayyagari et al. (2008), only obstacles related to finance, crime, and policy instability directly affect firms' growth. It appears that microbreweries do not face these obstacles.

[8] As previously mentioned, the significant difference in tax rules results from the huge tax burdens marijuana firms face.

As a result, most microbreweries (~75%) stated that the current business environment is not restricting their growth. In comparison, 69% of the surveyed marijuana SMEs are hindered in their growth because they lack access to banking services.

In summary, our findings substantiate the importance of legal access to banking for young SMEs in developed countries. In particular, widespread access to banking services would alleviate the growth constraints for marijuana SMEs. Access to bank loans is needed to finance future operations whereas access to bank-based transaction services reduces the firms' risk, improves their operating performance, and increases the firms' creditworthiness.

2.5 Critical assessment and further research

In total, our empirical analysis gives significant insights into the value of banking services for developing industries in the United States, based on findings from the marijuana industry. In order to ensure that the results of the three event studies are not driven by any effects stemming from differences in the sample, we graphically analyzed the eight firms that are examined in all events and show that our results are also valid for this subgroup (compare Figures 2.4, 2.5 and 2.6 in Appendix A.3.4). In the event studies, we examine the value of legal banking access for the marijuana industry. Although we carefully selected events which affect the legality of the marijuana industry's access to banking, the changes in stock prices and the corresponding abnormal returns only reflect investors' changing expectations. Thus, it is only an indirect indicator for the valuation of legal banking access by the industry, which could be biased. For example, investors could incorrectly estimate firms' ability to cope with adverse regulatory developments, i.e., that the actual impact of the event is less positive/negative than investors expect. It is possible that our results are partly driven by other channels. For example, the banking announcement may proxy for the demand channel rather than the value of banking services. In the future a more accurate value of banking access could be attained by analyzing a binding law change. Alternatively, in future studies, abnormal returns from the events could be compared to abnormal returns surrounding other industry (non-banking) announcements related to the marijuana industry. However, the only important other industry (non-banking) announcements that took place during the examined time frames were votes on legalization in several states. For Colorado, these took place back in November 2012, a time when investor interest in marijuana was low. For several other states, the vote on legalization coincided with the presidential election in 2016, making it impossible to estimate meaningful abnormal returns.

With the survey, we specifically examine the perspectives of SMEs that are directly involved in the production and distribution of marijuana, on the business challenges that arise from the legally denied access to banking. As with all surveys, it is possible that our sample suffers from a bias. For example, respondents that maintain bank accounts illegally might be less likely to

participate in the survey out of fear that their activity will be disclosed. Although the bias should be limited because complete anonymity was ensured; four out of five asked respondents filled out the survey and of those a large number illegally uses a bank account. In addition, based on a later and larger survey with different questions, Berger and Seegert (2020) report very similar results to our work here. As a result, although the survey sample size here was small, the findings appear to be representative. Officially reported marijuana firm data from Washington State also substantiates the relevance of our results (compare, Bhue 2018). It is also possible that some respondents systematically overstate the value of legal access to banking due to social desirability or their short firm history. Several types of questions, i.e., subjective, objective, direct and indirect questions, have been used to limit this bias. In addition, all results are robust for the subgroup of respondents that have worked at least one year for the firms. In the survey, the high perceived value for bank-based financial transaction services is identified. Specifically, the heightened security risk as a results of large cash amounts is frequently cited. Now that marijuana has been legalized in over ten states, a larger multi-state study could be used to verify the general validity of the findings.

Based on the combined methods presented here, it can be discerned that the industry as a whole perceives legal banking access as highly desirable. Due to the inhomogeneity of the examined samples, it is not possible to directly link the worth of legal banking access identified in the event studies with the high valuation of bank financing transaction services by marijuana SMEs.

2.6 Conclusion

This study uses a mixed-method approach to analyze the real economic value of legal banking services for the U.S. marijuana industry. While this industry has access to the superior institutional environment of the United States, the conflict between federal and state laws prevents any legal banking access.

In an event study, we find statistically strong and economically significant value consequences around three events that are significant for determining the marijuana industry's future banking access. These results indicate that despite the superior institutional environment offered by a highly developed country, the marijuana industry still perceives widespread access to banking as crucial. In order to understand if financing and/or transaction services are perceived as desirable by the industry, we conducted a comprehensive survey. Microbreweries (a similar industry in size and revenues) were used as a control. As expected, in our survey more young marijuana SMEs than microbreweries identify financing as challenging. Many marijuana SMEs struggle to find financing comparable to that offered by banks: cheap and reliable. As a result, they more often cited being financially constrained. This indicates that widespread access to bank lending would

help marijuana firms grow. Surprisingly, after access to finance, security concerns were cited as one of the largest challenges facing marijuana SMEs. Contrarily, despite being in a similar industry segment, microbreweries do not consider security a concern. Without legal access to banking services marijuana firms are forced to use cash to complete financial transactions. These transactions are perceived as inefficient and significantly increase security concerns due to large levels of cash present in the firms. Our results indicate that in addition to access to financing, SMEs consider access to efficient payment and transaction services as substantially important for alleviating their financial constraints and stimulating their growth. The insights initially provided here are further supported by an ongoing larger study from Berger and Seegert (2020).

In summary, based on our results, even in highly developed countries, the services of traditional banks remain desirable. In line with the large body of existing studies, SMEs still rely on financing from banks. Additionally, the marijuana industry identifies transaction services as one of the most desirable bank functions. From studies largely done in Kenya, the importance of transaction services was previously identified. In these studies, however, the widespread and successful use of solely a transaction service was examined. In line with the results here, one critical aspect of transaction services is an increase of security due to a reduction of large cash amounts. In the United States similar transaction service providers exist. This fact in context with the research from Kenya, makes the marijuana industry's high valuation of bank's transaction services surprising. Based on the study here, this result cannot be conclusively explained. It is, however, possible that due to their long-standing presence, banks today play a too integral part in transaction processing within the United States, preventing widespread use of alternates.

Acknowledgements This chapter is adapted from my publication "SMEs with Legally Restricted Banking Access - Evidence from the U.S. Marijuana Industry" in the Journal of Business Economics in 2020. It was joint work with Jan Riepe from the Eberhard Karls University of Tübingen and was partly written during my stay at Cass Business School, London. We thank Thorsten Beck, Tobias Berg, Christoph Börner, Martin Brown, Ulf Brüggemann, Hans-Peter Burghof, Marc Deloof, Patrick Kampkötter, Werner Neus, Markus Nisch, Anh D. Pham, Andreas Pfingsten, Marc S. Rapp, David T. Robinson, Zacharias Sautner, Anna Staerz, Matthias Sutter, Tereza Tykvova, Theresa Veer, Laurent Weill, audiences at the Entrepreneurial Financial Management Conference 2017, Academy of Entrepreneurial Finance (Europe) Conference 2017, World Finance Conference 2017, Research Seminar of Rotterdam University 2017, Münsteraner Bankenworkshop 2017, the Finance Research Workshop of Cass Business School 2018, the HERMES Franco-German Doctoral Seminar 2019, three anonymous reviewers and the managing editor (Wolfgang Breuer) for very helpful and constructive comments.

A Appendices

A.1 Sample firms

Table 2.11: Sample firms

	Event 1	Event 2	Event 3
Industry sector	**Company name**	**Company name**	**Company name**
Producer		GROWBLOX SCIENCES	UNITED CANNABIS
		UNITED CANNABIS	
Industrial	AERO GROW INT.	AERO GROW INT.	AERO GROW INT.
	GREENGRO TECH.	TERRA TECH	GROWGENERATION
	GROWLIFE	TWO RIV. WATER FRMG.	KUSHCO HLDG.
	TERRA TECH		TERRA TECH
	TWO RIV. WATER FRMG.		TWO RIV. WATER FRMG.
Pharma/Research	22ND CENTURY GROUP	22ND CENTURY GROUP	22ND CENTURY GROUP
	ARENA PHARMA.	ARENA PHARMA.	ARENA PHARMA.
	CV SCIENCES	CARA THERAPEUTICS	AXIM BIOTECH.
	INSYS THERAPEUTICS	CV SCIENCES	CANNABICS PHARMA.
	NEUTRA	EMERALD BIOSCIENCE	CANNAPHARMARX
	PAZOO	INSYS THERAPEUTICS	CARA THERAPEUTICS
	PHARMACYTE BIOTECH.	NEUTRA	CV SCIENCES
	VERDE SCIENCE	PAZOO	EMERALD BIOSCIENCE
		ZYNERBA PHARMA.	INSYS THERAPEUTICS
			ZYNERBA PHARMA.
Consulting	CHUMA HLDG.	AMERICANN	AMERICANN
	DIRECTVIEW HLDG.	GROW CAPITAL	MARIMED
	GREEN TECH. SLTN.	MARIMED	MJ HLDG.
	ML CAPITAL GROUP		STWC HLDG.
Technology	AVT	DIGIPATH	DIGIPATH
	ENDEXX	LIFELOC TECH.	ENDEXX
	MCIG	MASSROOTS	LIFELOC TECH.
	NHALE	MYDX	TECHCARE
	TECHCARE	TECHCARE	
Real Estate	GENERAL CANNABIS	GENERAL CANNABIS	GENERAL CANNABIS
	ZONED PROPERTIES		INNOV. INDL. PROPS.
Consumer	FOREVERGREEN WWD.	CANNABIS SATIVA	CANNABIS SATIVA
	HEALTHIER CHOICES MAN.	EARTH SCIENCE TECH.	CBDMD (ASE)
	HEMP	FOREVERGREEN WWD.	EARTH SCIENCE TECH.
	VAPE HLDG.	HEALTHIER CHOICES MAN.	FOREVERGREEN WWD.
		ROCKY MOUNT. HIGH	

This table displays the firm samples for the event studies.

Table 2.12: Sample characteristics event study

Panel A: By industry sector

Industry sector	Event 1 [Number of firms]	Event 2 [Number of firms]	Event 3 [Number of firms]
Producer	0	2	1
Industrial	5	3	5
Pharma/Research	8	8	10
Consulting	4	3	4
Technology	5	5	4
Real Estate	2	1	2
Consumer	4	6	4
Total	**28**	**28**	**30**

Panel B: By listing type

Stock market	Event 1 [Number of firms]	Event 2 [Number of firms]	Event 3 [Number of firms]
OTC PINK	16	7	5
OTCQB	7	13	13
OTCQX	2	3	4
NASDAQ	2	4	5
NYSE	1	1	3
Total	**28**	**28**	**30**

This table displays the distribution of marijuana stocks by industry sector and by listing type. The industry sectors are adopted from Bloomberg. Producers are medical marijuana growers and recreational cultivators. Industrial firms are manufacturers of equipment or growing facilities used by the marijuana industry. Pharmaceutical research firms develop and/or research cannabis-based therapeutics and medicines. Consulting firms provide consulting, management, marketing, and/or financial services to the marijuana industry. Technology firms develop marijuana breathalyzers and/or provide software and technology solutions to the marijuana industry. Real estate firms acquire, lease, and/or develop real estate properties and growing facilities for the marijuana industry. Consumer firms are producers and manufacturers of hemp- or cannabis-based products, such as nutraceuticals, fibers, fabrics, and/or vaporization products.

A.2 Survey

Part A: Company Background Information

1. **In which U.S. state are your headquarters located?**

2. **In which year did your company start operating in the marijuana industry?**

3. **How long have you been with the company?**

4. **What is your position in the company?**

5. **How many people does your company currently employ in full-time equivalents?**

6. **Who owns the largest stake in the company?**

   - □ One owner (yourself or another single person)
   - □ Multiple people (e.g., a family or several entrepreneurs)
   - □ Another company
   - □ Public shareholders (it is listed on the stock market)
   - □ Venture capital enterprises or business angels
   - □ Other, please specify:

7. **Which sector of the marijuana industry is your company currently in? (If you have businesses in more than one, please choose the *one* in which you spend most of your time/ have the most active role.)**

   - □ Wholesale grower
   - □ Infused product maker (edibles, topicals, concentrates, etc.)
   - □ Dispensary or recreational store with integrated grow or processing
   - □ Dispensary or recreational store without integrated grow or processing
   - □ Testing lab
   - □ Ancillary services (i.e., law firms, consultants, accountants, education, etc.)
   - □ Ancillary technology or products (i.e., consumption devices, software, lighting, etc.)

8. What was the annual turnover of your company within the last year?

- □ Up to $100,000
- □ Over $100,000 and up to $500,000
- □ Over $500,000 and up to $1 million
- □ Over $1 million and up to $5 million
- □ Over $5 million and up to $10 million
- □ Over $10 million and up to $50 million
- □ Over $50 million

9. Over the past two years, how much did your company grow on average per year in terms of turnover?

- □ Over 50%
- □ Between 20% and 50%
- □ Less than 20%
- □ Stayed about the same size
- □ Became smaller

10. Did you (at least) break even last year?

- □ Yes
- □ No

11. How difficult have the following been for your company in the last six months?

	Not an issue				**Very difficult**
	1	**2**	**3**	**4**	**5**
Finding customers	☐	☐	☐	☐	☐
Customer payments	☐	☐	☐	☐	☐
Finding suppliers	☐	☐	☐	☐	☐
Financial business transactions (e.g., paying employees, vendors, etc.)	☐	☐	☐	☐	☐
Competition	☐	☐	☐	☐	☐
Costs of production and labor	☐	☐	☐	☐	☐
Access to finance (financing your business)	☐	☐	☐	☐	☐
Availability of skilled staff or experienced managers	☐	☐	☐	☐	☐
Bureaucracy (e.g., business license application)	☐	☐	☐	☐	☐
Tax rules	☐	☐	☐	☐	☐
Security concerns	☐	☐	☐	☐	☐
Other, please specify:	☐	☐	☐	☐	☐

Part B: Access to Banking and Financing of Your Company

1. **Which banking service would be most useful for your company?**

   □ Deposit/Savings account
   □ Money transfer
   □ Foreign exchange
   □ Credit
   □ Insurance

2. **Does your cannabis company currently have a business account with an U.S. American bank or credit union?**

   □ Yes, direct relationship with the bank/credit union
   □ Yes, via a third party (i.e., holding companies, financial intermediaries, etc.)
   □ No (please continue with question 4)

3. **How stable do you consider your company's banking relationship?**

   □ Terminable
   □ Short-term
   □ Long-term

4. **Have you ever been rejected by a bank, i.e., were unable to open a bank account, or the bank closed your account?**

   □ Yes, please specify:

   □ No

5. **How do you receive most of your revenue?**

   □ Cash
   □ Electronic funds transfer via a bank (e.g., direct deposit/debit)
   □ Check
   □ Electronic transfer via a non-bank third party (e.g., Bitcoin)
   □ Other, please specify:

6. How do you pay most of your bills?

- □ cash
- □ electronic funds transfer via a bank (e.g., direct deposit/debit)
- □ check
- □ electronic transfer via a non-bank third party (e.g., Bitcoin)
- □ other, please specify:

7. What in your opinion would be the biggest benefit of access to banking in regards to money transactions for your company?

	Not beneficial				**Very beneficial**
	1	**2**	**3**	**4**	**5**
Reduced cost of financial transactions	□	□	□	□	□
Reduced time of financial transactions	□	□	□	□	□
Reduced risk of financial transactions	□	□	□	□	□
More satisfied suppliers	□	□	□	□	□
More satisfied customers	□	□	□	□	□

8. Are the following sources of financing relevant to your company?

	Yes, currently or previously in use	**Yes, considered it for the future**	**No, interested but inaccessible**	**No, this is not relevant**
Private loans (e.g., from family and friends)	☐	☐	☐	☐
Loans from (related) companies	☐	☐	☐	☐
Debt securities issued (e.g., corporate bonds issued by your company)	☐	☐	☐	☐
Private equity capital (venture capital or business angels)	☐	☐	☐	☐
Public equity capital (stocks)	☐	☐	☐	☐
Credit line, bank overdraft or credit card overdrafts	☐	☐	☐	☐
Bank loans	☐	☐	☐	☐
Trade credit, factoring, or leasing or hire purchase	☐	☐	☐	☐
Internal funds (resulting for instance from savings, retained earnings or sales assets)	☐	☐	☐	☐
Other, specify:	☐	☐	☐	☐

9. What type of external financing would you prefer most to help your company grow?

- □ Equity capital (e.g., venture capital, business angels or stocks)
- □ Bank loans
- □ Loans from other sources (e.g., trade credit, related company, or family)
- □ Not applicable because of sufficient internal funds (e.g., savings, or sales assets)
- □ Other, please specify:

10. What would be your first reaction in the case of unexpected costs (e.g., replacement of storage furniture, new transport vehicles, etc.)?

- □ Raising capital (e.g., from owners)
- □ Cut back investments
- □ Close the business
- □ Delay wage payments
- □ Delay payments of suppliers
- □ Increase the price of products
- □ Layoff employees
- □ Other, please specify:

11. Is the current business financing environment (i.e., the limited access to banking) restricting growth opportunities for your company?

- □ Yes, please specify:

- □ No

A.3 Robustness tests - event studies

A.3.1 Event 1: Guidance Fin-2014-G001

Table 2.16: Event 1 with the standardized cross-sectional test by Kolari and Pynnönen (2010)

Panel A: Market benchmark of S&P 600 Food, Beverage, & Tobacco Index

	Average abnormal returns	t_{KP}	Positive/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	0.92 %	0.52	13/15					
t-1	3.46 %	1.83*	16/12	5.67 %	8.02 %	4.56 %	2.21 %	−1.23 %
Event day	3.44 %	1.84*	14/14	1.56	2.11**	1.83*	0.79	−0.48
t+1	1.12 %	0.53	14/14					
t+2	−2.35 %	−1.54	8/20					

Panel B: Market benchmark of S&P 500 Index

	Average abnormal returns	t_{KP}	Positive/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	0.91 %	0.52	13/15					
t-1	3.20 %	1.85*	16/12	5.47 %	7.71 %	4.51 %	2.27 %	−1.14 %
Event day	3.41 %	1.82*	14/14	1.49	2.06**	1.77*	0.80	−0.45
t+1	1.10 %	0.52	14/14					
t+2	−2.24 %	−1.50	7/21					

Panel C: Zero-return benchmark

	Average abnormal returns	t_{KP}	Positive/ No change/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	1.86 %	1.06	15/2/11					
t-1	4.17 %	2.58***	18/2/ 8	9.32 %	10.61 %	6.44 %	5.15 %	0.77 %
Event day	4.38 %	2.28**	16/5/ 7	2.58**	2.91***	2.51**	1.78*	0.30
t+1	2.06 %	0.98	14/2/12					
t+2	−1.29 %	−0.88	9/1/18					

This table displays the event study results for the Guidance Fin-2014-G001. The average abnormal returns (AARs) correspond to the excess returns with respect to three different benchmarks. In Panel A, the AARs are calculated against the S&P 600 Food, Beverage, & Tobacco Index as the market benchmark; Panel B uses the S&P 500 Index as a broad market benchmark; Panel C relies on the zero-return benchmark. Significance is calculated based on the two-sided standardized cross-sectional test by Kolari and Pynnönen (2010). Column 3 displays the number of individual marijuana firms that have abnormal positive (negative) returns on the specific trading day. The cumulative average abnormal returns are calculated based on five different event windows. The ***, **, and * represent significance at the 1%, 5%, and the 10% levels.

Table 2.17: Event 1 with the parametric test by Boehmer et al. (1991)

Panel A: Market benchmark of S&P 600 Food, Beverage, & Tobacco Index

	Average abnormal returns	t_{BMP}	Positive/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	0.92 %	0.56	13/15					
t-1	3.46 %	1.29	16/12	5.67 %	8.02 %	4.56 %	2.21 %	−1.23 %
Event day	3.44 %	1.69*	14/14	1.04	1.81*	1.59	0.46	−0.77
t+1	1.12 %	0.14	14/14					
t+2	−2.35 %	−1.34	8/20					

Panel B: Market benchmark of S&P 500 Index

	Average abnormal returns	t_{BMP}	Positive/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	0.91 %	0.57	13/15					
t-1	3.20 %	1.35	16/12	5.47 %	7.71 %	4.51 %	2.27 %	−1.14 %
Event day	3.41 %	1.56	14/14	0.96	1.77*	1.47	0.38	−0.77
t+1	1.10 %	0.14	14/14					
t+2	−2.24 %	−1.35	7/21					

Panel C: Zero-return benchmark

	Average abnormal returns	t_{BMP}	Positive/ No change/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	1.86 %	1.18	15/2/11					
t-1	4.17 %	2.38**	18/2/ 8	9.32 %	10.61 %	6.44 %	5.15 %	0.77 %
Event day	4.38 %	2.18**	16/5/ 7	2.49**	3.14***	2.48**	1.48	0.00
t+1	2.06 %	0.76	14/2/12					
t+2	−1.29 %	−0.75	9/1/18					

This table displays the event study results for the Guidance Fin-2014-G001. The average abnormal returns (AARs) correspond to the excess returns with respect to three different benchmarks. In Panel A, the AARs are calculated against the S&P 600 Food, Beverage, & Tobacco Index as the market benchmark; Panel B uses the S&P 500 Index as a broad market benchmark; Panel C relies on the zero-return benchmark. Significance is calculated based on the two-sided parametric test by Boehmer et al. (1991). Column 3 displays the number of individual marijuana firms that have abnormal positive (negative) returns on the specific trading day. The cumulative average abnormal returns are calculated based on five different event windows. The ***, **, and * represent significance at the 1%, 5%, and the 10% levels.

Table 2.18: Event 1 with the non-parametric rank test by Corrado (1989) and Corrado and Zivney (1992)

Panel A: Market benchmark of S&P 600 Food, Beverage, & Tobacco Index

	Average abnormal returns	t_C	Positive/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	0.92 %	0.94	13/15					
t-1	3.46 %	1.78*	16/12	5.67 %	8.02 %	4.56 %	2.21 %	−1.23 %
Event day	3.44 %	1.68*	14/14	0.90	2.23**	1.46	0.01	−1.18
t+1	1.12 %	0.39	14/14					
t+2	−2.35 %	−2.06**	8/20					

Panel B: Market benchmark of S&P 500 Index

	Average abnormal returns	t_C	Positive/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	0.91 %	1.07	13/15					
t-1	3.20 %	1.74*	16/12	5.47 %	7.71 %	4.51 %	2.27 %	−1.14 %
Event day	3.41 %	1.31	14/14	0.86	1.99**	1.21	−0.01	−0.94
t+1	1.10 %	0.39	14/14					
t+2	−2.24 %	−1.72*	7/21					

Panel C: Zero-return benchmark

	Average abnormal returns	t_C	Positive/ No change/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	1.86 %	0.93	15/2/11					
t-1	4.17 %	2.09**	18/2/ 8	9.32 %	10.61 %	6.44 %	5.15 %	0.77 %
Event day	4.38 %	1.69*	16/5/ 7	1.23	2.43**	1.50	0.21	−0.94
t+1	2.06 %	0.43	14/2/12					
t+2	−1.29 %	−1.76*	9/1/18					

This table displays the event study results for the Guidance Fin-2014-G001. The average abnormal returns (AARs) correspond to the excess returns with respect to three different benchmarks. In Panel A, the AARs are calculated against the S&P 600 Food, Beverage, & Tobacco Index as the market benchmark; Panel B uses the S&P 500 Index as a broad market benchmark; Panel C relies on the zero-return benchmark. Significance is calculated based on the non-parametric rank test by Corrado (1989) and Corrado and Zivney (1992). Column 3 displays the number of individual marijuana firms that have abnormal positive (negative) returns on the specific trading day. The cumulative average abnormal returns are calculated based on five different event windows. The ***, **, and * represent significance at the 1%, 5%, and the 10% levels.

A.3.2 Event 2: The Fourth Corner Credit Union Case

Table 2.19: Event 2 with the standardized cross-sectional test by Kolari and Pynnönen (2010)

Panel A: Market benchmark of S&P 600 Food, Beverage, & Tobacco Index

	Average abnormal returns	t_{KP}	Positive/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	3.60 %	1.40	16/12					
t-1	3.50 %	1.34	11/17	−3.78 %	−0.17 %	−3.67 %	−7.28 %	−4.80 %
Event day	−2.48 %	−0.95	12/16	−1.01	−0.05	−1.22	−2.03**	−2.34**
t+1	−1.19 %	−0.91	12/16					
t+2	−3.61 %	−1.93*	8/20					

Panel B: Market benchmark of S&P 500 Index

	Average abnormal returns	t_{KP}	Positive/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	3.71 %	1.46	14/14					
t-1	3.45 %	1.34	11/17	−3.50 %	−0.14 %	−3.59 %	−6.95 %	−4.35 %
Event day	−2.60 %	−0.99	14/14	−0.94	−0.04	−1.21	−1.93*	−1.94*
t+1	−0.99 %	−0.75	11/17					
t+2	−3.36 %	−1.69*	12/16					

Panel C: Zero-return benchmark

	Average abnormal returns	t_{KP}	Positive/ No change/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	3.44 %	1.32	13/6/ 9					
t-1	3.09 %	1.20	9/6/13	−4.76 %	−0.92 %	−4.01 %	−7.85 %	−5.15 %
Event day	−2.70 %	−1.03	11/4/13	−1.27	−0.26	−1.33	−2.18**	−2.53**
t+1	−1.31 %	−1.00	6/6/16					
t+2	−3.84 %	−2.07**	7/5/16					

This table displays the event study results around the court ruling against The Fourth Corner Credit Union. The average abnormal returns (AARs) correspond to the excess returns with respect to three different benchmarks. In Panel A, the AARs are calculated against the S&P 600 Food, Beverage, & Tobacco Index as the market benchmark; Panel B uses the S&P 500 Index as a broad market benchmark; Panel C relies on the zero-return benchmark. Significance is calculated based on the two-sided standardized cross-sectional test by Kolari and Pynnönen (2010). Column 3 displays the number of individual marijuana firms that have abnormal positive (negative) returns on the specific trading day. The cumulative average abnormal returns are calculated based on five different event windows. The ***, **, and * represent significance at the 1%, 5%, and the 10% levels.

Table 2.20: Event 2 with the parametric test by Boehmer et al. (1991)

Panel A: Market benchmark of S&P 600 Food, Beverage, & Tobacco Index

	Average abnormal returns	t_{BMP}	Positive/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	3.60 %	1.24	16/12					
t-1	3.50 %	0.87	11/17	−3.78 %	−0.17 %	−3.67 %	−7.28 %	−4.80 %
Event day	−2.48 %	−0.55	12/16	−1.34	−0.22	−1.07	−2.24**	−2.78***
t+1	−1.19 %	−1.09	12/16					
t+2	−3.61 %	−2.19**	8/20					

Panel B: Market benchmark of S&P 500 Index

	Average abnormal returns	t_{BMP}	Positive/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	3.71 %	1.35	14/14					
t-1	3.45 %	0.90	11/17	−3.50 %	−0.14 %	−3.59 %	−6.95 %	−4.35 %
Event day	−2.60 %	−0.62	14/14	−1.15	−0.15	−1.00	−2.03**	−2.38**
t+1	−0.99 %	−0.84	11/17					
t+2	−3.36 %	−1.89*	12/16					

Panel C: Zero-return benchmark

	Average abnormal returns	t_{BMP}	Positive/ No change/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	3.44 %	1.14	13/6/ 9					
t-1	3.09 %	0.65	9/6/13	−4.76 %	−0.92 %	−4.01 %	−7.85 %	−5.15 %
Event day	−2.70 %	−0.66	11/4/13	−1.62	−0.48	−1.22	−2.43**	−2.95***
t+1	−1.31 %	−1.17	6/6/16					
t+2	−3.84 %	−2.30**	7/5/16					

This table displays the event study results around the court ruling against The Fourth Corner Credit Union. The average abnormal returns (AARs) correspond to the excess returns with respect to three different benchmarks. In Panel A, the AARs are calculated against the S&P 600 Food, Beverage, & Tobacco Index as the market benchmark; Panel B uses the S&P 500 Index as a broad market benchmark; Panel C relies on the zero-return benchmark. Significance is calculated based on the two-sided parametric test by Boehmer et al. (1991). Column 3 displays the number of individual marijuana firms that have abnormal positive (negative) returns on the specific trading day. The cumulative average abnormal returns are calculated based on five different event windows. The ***, **, and * represent significance at the 1%, 5%, and the 10% levels.

Table 2.21: Event 2 with the non-parametric rank test by Corrado (1989) and Corrado and Zivney (1992)

Panel A: Market benchmark of S&P 600 Food, Beverage, & Tobacco Index

	Average abnormal returns	t_C	Positive/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	3.60 %	0.96	16/12					
t-1	3.50 %	−0.02	11/17	−3.78 %	−0.17 %	−3.67 %	−7.28 %	−4.80 %
Event day	−2.48 %	−0.64	12/16	−1.75*	−0.98	−1.19	−2.01**	−2.01**
t+1	−1.19 %	−1.04	12/16					
t+2	−3.61 %	−1.80*	8/20					

Panel B: Market benchmark of S&P 500 Index

	Average abnormal returns	t_C	Positive/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	3.71 %	1.07	14/14					
t-1	3.45 %	0.24	11/17	−3.50 %	−0.14 %	−3.59 %	−6.95 %	−4.35 %
Event day	−2.60 %	−0.53	14/14	−1.42	−0.82	−1.17	−1.78*	−1.81*
t+1	−0.99 %	−1.13	11/17					
t+2	−3.36 %	−1.43	12/16					

Panel C: Zero-return benchmark

	Average abnormal returns	t_C	Positive/ No change/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	3.44 %	1.01	13/6/ 9					
t-1	3.09 %	0.05	9/6/13	−4.76 %	−0.92 %	−4.01 %	−7.85 %	−5.15 %
Event day	−2.70 %	−0.61	11/4/13	−1.69*	−0.92	−1.17	−1.98**	−1.99**
t+1	−1.31 %	−1.04	6/6/16					
t+2	−3.84 %	−1.77*	7/5/16					

This table displays the event study results around the court ruling against The Fourth Corner Credit Union. The average abnormal returns (AARs) correspond to the excess returns with respect to three different benchmarks. In Panel A, the AARs are calculated against the S&P 600 Food, Beverage, & Tobacco Index as the market benchmark; Panel B uses the S&P 500 Index as a broad market benchmark; Panel C relies on the zero-return benchmark. Significance is calculated based on the non-parametric rank test by Corrado (1989) and Corrado and Zivney (1992). Column 3 displays the number of individual marijuana firms that have abnormal positive (negative) returns on the specific trading day. The cumulative average abnormal returns are calculated based on five different event windows. The ***, **, and * represent significance at the 1%, 5%, and the 10% levels.

A.3.3 Event 3: The SAFE Banking Act

Table 2.22: Event 3 with the standardized cross-sectional test by Kolari and Pynnönen (2010)

Panel A: Market benchmark of S&P 600 Food, Beverage, & Tobacco Index

	Average abnormal returns	t_{KP}	Positive/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	0.20%	0.09	9/21					
t-1	−2.48%	−1.64	6/24	−6.16%	−3.45%	−0.97%	−3.68%	−5.66%
Event day	1.98%	0.77	14/16	−1.73*	−0.99	−0.43	−1.54	−2.93***
t+1	−2.95%	−2.06**	7/23					
t+2	−2.71%	−2.87***	8/22					

Panel B: Market benchmark of S&P 500 Index

	Average abnormal returns	t_{KP}	Positive/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	0.30%	0.14	9/21					
t-1	−2.05%	−1.33	8/22	−5.56%	−3.00%	−0.95%	−3.51%	−5.39%
Event day	1.88%	0.74	13/17	−1.54	−0.85	−0.42	−1.46	−2.81***
t+1	−2.83%	−1.98**	7/23					
t+2	−2.56%	−2.74***	9/21					

Panel C: Zero-return benchmark

	Average abnormal returns	t_{KP}	Positive/ No change/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	0.28%	0.14	9/3/18					
t-1	−2.64%	−1.78*	4/4/22	−6.26%	−3.34%	−0.70%	−3.62%	−5.92%
Event day	2.30%	0.92	12/6/12	−1.82*	−0.99	−0.32	−1.56	−2.98***
t+1	−3.00%	−2.06**	5/6/19					
t+2	−2.92%	−3.02***	6/6/18					

This table displays the event study results around the voting by the U.S. House of Representatives on the SAFE Banking Act. The average abnormal returns (AARs) correspond to the excess returns with respect to three different benchmarks. In Panel A, the AARs are calculated against the S&P 600 Food, Beverage, & Tobacco Index as the market benchmark; Panel B uses the S&P 500 Index as a broad market benchmark; Panel C relies on the zero-return benchmark. Significance is calculated based on the two-sided standardized cross-sectional test by Kolari and Pynnönen (2010). Column 3 displays the number of individual marijuana firms that have abnormal positive (negative) returns on the specific trading day. The cumulative average abnormal returns are calculated based on five different event windows. The ***, **, and * represent significance at the 1%, 5%, and the 10% levels.

Table 2.23: Event 3 with the parametric test by Boehmer et al. (1991)

Panel A: Market benchmark of S&P 600 Food, Beverage, & Tobacco Index

	Average abnormal returns	t_{BMP}	Positive/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	0.20 %	- 1.08	9/21					
t-1	−2.48 %	-2.82^{***}	6/24	−6.16 %	−3.45 %	−0.97 %	−3.68 %	−5.66 %
Event day	1.98 %	0.68	14/16	-2.69^{***}	-2.06^{**}	−1.10	-2.08^{**}	-2.34^{**}
t+1	−2.95 %	−1.61	7/23					
t+2	−2.71 %	-2.79^{***}	8/22					

Panel B: Market benchmark of S&P 500 Index

	Average abnormal returns	t_{BMP}	Positive/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	0.30 %	−1.01	9/21					
t-1	−2.05 %	-2.49^{**}	8/22	−5.56 %	−3.00 %	−0.95 %	−3.51 %	−5.39 %
Event day	1.88 %	0.66	13/17	-2.49^{**}	-1.90^{*}	−1.10	-1.99^{**}	-2.21^{**}
t+1	−2.83 %	−1.56	7/23					
t+2	−2.56 %	-2.62^{***}	9/21					

Panel C: Zero-return benchmark.

	Average abnormal returns	t_{BMP}	Positive/ No change/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	0.28 %	−1.02	9/3/18					
t-1	−2.64 %	-2.98^{***}	4/4/22	−6.26 %	−3.34 %	−0.70 %	−3.62 %	−5.92 %
Event day	2.30 %	0.91	12/6/12	-2.78^{***}	-2.08^{**}	−0.97	-2.08^{**}	-2.46^{**}
t+1	−3.00 %	-1.65^{*}	5/6/19					
t+2	−2.92 %	-3.04^{***}	6/6/18					

This table displays the event study results around the voting by the U.S. House of Representatives on the SAFE Banking Act. The average abnormal returns (AARs) correspond to the excess returns with respect to three different benchmarks. In Panel A, the AARs are calculated against the S&P 600 Food, Beverage, & Tobacco Index as the market benchmark; Panel B uses the S&P 500 Index as a broad market benchmark; Panel C relies on the zero-return benchmark. Significance is calculated based on the two-sided parametric test by Boehmer et al. (1991). Column 3 displays the number of individual marijuana firms that have abnormal positive (negative) returns on the specific trading day. The cumulative average abnormal returns are calculated based on five different event windows. The ***, **, and * represent significance at the 1%, 5%, and the 10% levels.

Table 2.24: Event 3 with the non-parametric rank test by Corrado (1989) and Corrado and Zivney (1992)

Panel A: Market benchmark of S&P 600 Food, Beverage, & Tobacco Index

	Average abnormal returns	t_C	Positive/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	0.20%	-0.92	9/21					
t-1	−2.48%	-2.42^{**}	6/24	−6.16%	−3.45%	−0.97%	−3.68%	−5.66%
Event day	1.98%	0.20	14/16	-2.44^{**}	-1.94^{*}	−0.67	−1.42	-1.88^{*}
t+1	−2.95%	−1.15	7/23					
t+2	−2.71%	−1.51	8/22					

Panel B: Market benchmark of S&P 500 Index

	Average abnormal returns	t_C	Positive/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	0.30%	-1.07	9/21					
t-1	−2.05%	-2.49^{**}	8/22	−5.56%	−3.00%	−0.95%	−3.51%	−5.39%
Event day	1.88%	0.06	13/17	-2.58^{**}	-2.11^{**}	−0.82	−1.54	-1.92^{*}
t+1	−2.83%	−1.22	7/23					
t+2	−2.56%	−1.50	9/21					

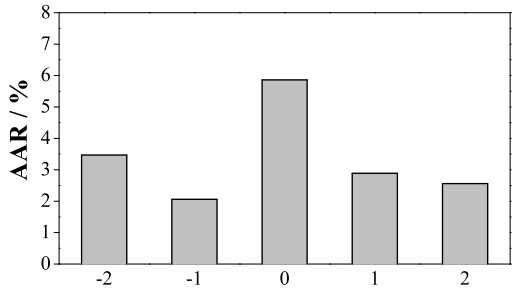
Panel C: Zero-return benchmark

	Average abnormal returns	t_C	Positive/ No change/ Negative	Cumulative average abnormal returns (-1,2)	(-1,1)	(0,1)	(0,2)	(1,2)
t-2	0.28%	−0.87	9/3/18					
t-1	−2.64%	-2.28^{**}	4/4/22	−6.26%	−3.34%	−0.70%	−3.62%	−5.92%
Event day	2.30%	0.28	12/6/12	-2.28^{**}	-1.77^{*}	−0.56	−1.32	-1.82^{*}
t+1	−3.00%	−1.07	5/6/19					
t+2	−2.92%	−1.50	6/6/18					

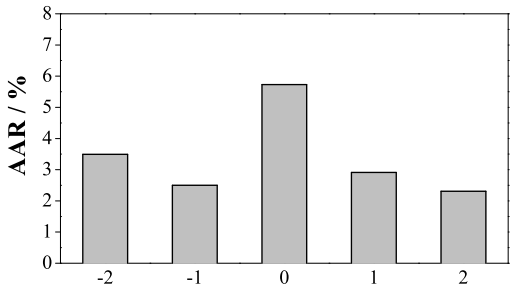
This table displays the event study results around the voting by the U.S. House of Representatives on the SAFE Banking Act. The average abnormal returns (AARs) correspond to the excess returns with respect to three different benchmarks. In Panel A, the AARs are calculated against the S&P 600 Food, Beverage, & Tobacco Index as the market benchmark; Panel B uses the S&P 500 Index as a broad market benchmark; Panel C relies on the zero-return benchmark. Significance is calculated based on the non-parametric rank test by Corrado (1989) and Corrado and Zivney (1992). Column 3 displays the number of individual marijuana firms that have abnormal positive (negative) returns on the specific trading day. The cumulative average abnormal returns are calculated based on five different event windows. The ***, **, and * represent significance at the 1%, 5%, and the 10% levels.

A.3.4 Event studies' results for the subgroup of eight firms that is examined in all events.

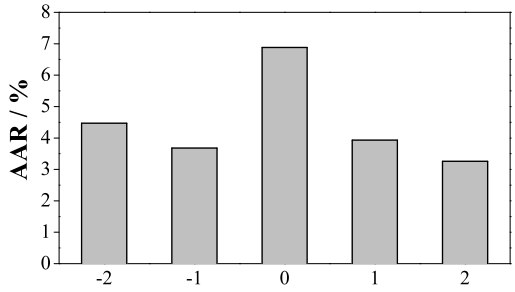
Fig. 2.4: Event 1 with the subgroup of eight firms that is examined in all events.



(a) Market benchmark of S&P 600 Food, Beverage, & Tobacco Index

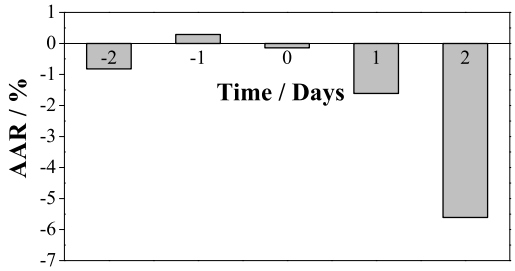


(b) Market benchmark of S&P 500 Index

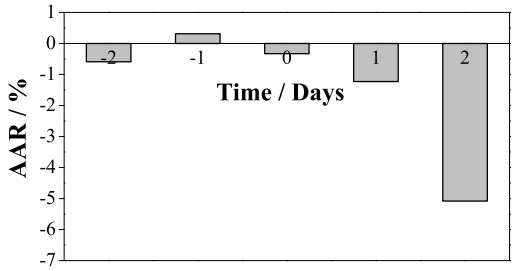


(c) Zero-return benchmark

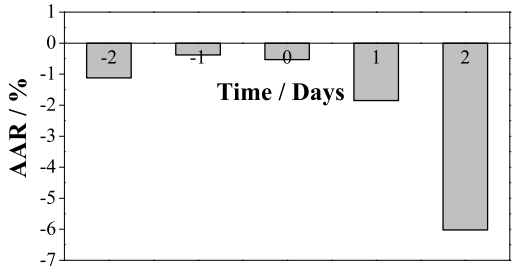
Fig. 2.5: Event 2 with the subgroup of eight firms that is examined in all events.



(a) Market benchmark of S&P 600 Food, Beverage, & Tobacco Index

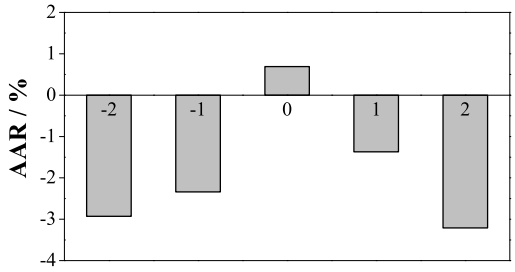


(b) Market benchmark of S&P 500 Index

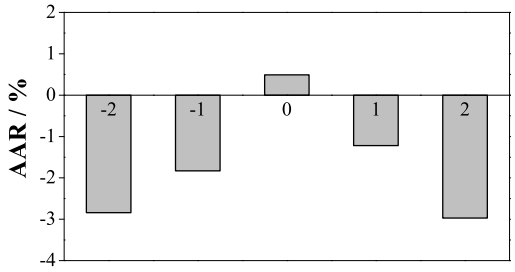


(c) Zero-return benchmark

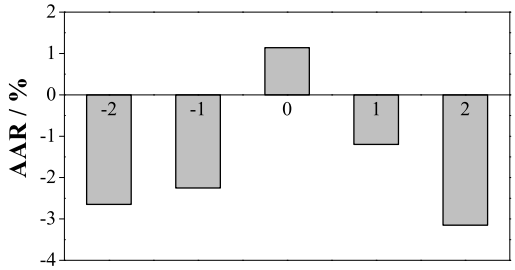
Fig. 2.6: Event 3 with the subgroup of eight firms that is examined in all events.



(a) Market benchmark of S&P 600 Food, Beverage, & Tobacco Index



(b) Market benchmark of S&P 500 Index



(c) Zero-return benchmark

A.4 Dividend discount model and a firm's maximum attainable growth rate

To estimate the implied growth rate of marijuana firms, the dividend discount model with a permanently constant expected growth rate is used, i.e., the Gordon growth model (Gordon 1959). The model relates the value of the marijuana portfolio P_t to its expected cumulative dividends D_{t+1}, the cost of equity k_e and the expected growth rate g.

$$P_t = \frac{D_{t+1}}{k_e - g}. \tag{2.1}$$

The implied growth rate can be estimated by rearranging equation (2.1):

$$g = \frac{P_t k_e - D_{t+1}}{P_t}. \tag{2.2}$$

Since many marijuana firms in our sample have not paid out dividends, the cumulative dividends D_{t+1} are hard to estimate. Empirical evidence, however, has shown that in the United States the so-called Fed model holds true (Bekaert and Engstrom 2010). The Fed model postulates that on average the dividend yield d_t on stocks equals the yield on nominal Treasury bonds. For the calculation, we assume the dividend yield to be the same as the yield on the nominal 10 year U.S. treasury bond at the event day. Thus, for the first (second/third) event, we get a dividend yield of 2.75% (2.25%, 1.73%). Equation (2.2) can be restated in terms of the dividend yield as:

$$g = \frac{P_t k_e - d_t P_t (1+g)}{P_t} \tag{2.3}$$

$$g = \frac{k_e - d_t}{1 + d_t}. \tag{2.4}$$

Our marijuana portfolio consists of firms listed on a major stock exchange and OTC-traded firms. Since firms listed on a major stock exchange have on average lower costs of equity than OTC-traded firms (Dhaliwal 1983), we use a weighted average for k_e. For the firms listed on major stock exchanges, we assume that the costs of equity equal those of the U.S. American Tobacco industry. Analogously, for the OTC-traded stocks, we use data from the Canadian marijuana industry. For the first (second/third) event, we computed a cost of equity of 12.94% (12.73%, 12.55%). Inserting k_e and d_t into equation (2.4) results in the presented implied growth rates.

According to Demirgüç-Kunt and Maksimovic (1998), a firm's maximum attainable and sustainable growth rate can be calculated as follows:

$$SG_t = \frac{ROE_t}{1 - ROE_t}, \tag{2.5}$$

where ROE_t is the return on equity, i.e., the ratio of net income to equity. To calculate the marijuana industry's sustainable growth rate according to equation (2.5), we use the reported

ROEs of the S&P 600 Food, Beverage, & Tobacco Index (8.28%, 10.16%, and 12.66%) for the years 2014, 2016 and 2019.

Chapter 3
Contemporaneous Financial Intermediation - How DLT Changes the Cross-Border Payment Landscape

Abstract Digital innovations in banking and payments recently have garnered a great deal of attention. Specifically, distributed ledger technology has the potential to fundamentally change the roles and responsibilities of stakeholders in the financial sector. DLT is a novel and fast-evolving approach to record and share data, e.g., payment transactions, among members of a decentralized network. Using transaction cost theory, the paper examines how DLT will change the cross-border payment infrastructure. DLT can reduce the overall transaction costs potentially resulting in the disappearance of correspondent banks.

3.1 Introduction

Banks have long been rationalized by their seemingly essential role as financial intermediaries in an economy. Traditionally, banks are thought to intermediate between non-banks, such as households and firms (e.g., Diamond and Dybvig 1983; Diamond 1984). However less regarded, but equally important banks also provide payment services.[9]

Cash is ill-suited for large payments, especially over a long distance. In this context, banks allow customers to transfer money in a safe and secure manner. Due to the globalization of both business and private transactions, and growing financial integration, transferring money across borders has become a pervasive issue.

For centuries, banks have dominantly carried out cross-border payments via correspondents, i.e., interbank intermediaries that complete transactions on behalf of banks in areas where they are not physically present (Society for Worldwide Interbank Financial Telecommunication 2016; Calomiris and Carlson 2017; Committee on Payments and Market Infrastructures 2018). Today, however, this model faces significant challenges. For example, banks must compete with faster, cheaper and more transparent (online) payment service providers (e.g., PayPal, TransferWise, WeChat Pay, Alipay, Amazon Pay, etc.). Many of these new intermediaries carry out transactions within their own ecosystem, instantly shifting money from one account to another. Surprisingly, according to Denecker et al. (2016), more than 95 percent of business-to-business and approximately 60 percent of consumer-to-consumer cross-border transactions are

[9] Strictly speaking, banks started as providers of payment services and then extended into financial intermediation services (Kohn 1999).

still processed by banks.[10] The authors cite proven security of banks for both money and data as the dominant reason.

Despite the longstanding dominance of banks, the competition remains fierce as cross-border payments are extremely profitable. About $136 trillion flow across borders annually (Bruno et al. 2019). Although this is only one-sixth of all global payments, it generates about 30 percent of the revenues that processors collect, totaling more than $230 billion per annum (Bruno et al. 2019). In order to insure their control, banks are continually working on improvements. For example the Society for Worldwide Interbank Financial Telecommunication's global payments innovation (SWIFT gpi) improves the speed, transparency and traceability of cross-border payments, but still relies on the correspondent banking system. More recently, however, banks have started to explore an innovation that could profoundly transform the cross-border payment infrastructure: Distributed Ledger Technology. DLT is decentralized and the network participants hold identical copies of a shared database that is updated algorithmically. The usage of DLT eliminates the need for third parties, i.e., correspondent banks, to manage and reconcile individual bank accounts. Although there are still significant legal, regulatory and operational barriers to the global implementation of such a system, DLT already has the potential to replace correspondent banks and dominate cross-border payments. In the presented research, transaction cost theory is applied to predict how DLT will increase the efficiency and resiliency of cross-border payments.

Empirical evidence is reported in literature that banks themselves rely on another layer of intermediation for a variety of functions (Craig and von Peter 2014; Calomiris and Carlson 2017). In a first step, this work rationalizes interbank intermediation theoretically. Specifically, the transaction cost model of Breuer (1993) is introduced and adapted to cross-border payments in order to show the current functions of correspondent banks. Subsequently, the impact of DLT on the presented market structure is analyzed. While in the field of cross-border payments DLT is highly discussed (He et al. 2017; Bank of Canada, Bank of England, and Monetary Authority of Singapore 2018; Newman et al. 2018) and has been implemented (Rapoport et al. 2014), academic reports are limited. Mills et al. (2016) and Casu and Wandhöfer (2018) are one of the few exceptions.[11] Mills et al. (2016), however, only touch on the topic in their broader work on payment, clearing, and settlement. Casu and Wandhöfer (2018) provide a more comprehensive analysis of the implementation of DLT in cross-border payments. Based on survey results of industry experts, they qualitatively evaluate the potential of DLT and several other network models. This work extends their analysis by explicitly examining potential effects on the design of payment infrastructure. It is shown that the economy-wide transaction costs can be reduced

[10] More recently, Rice et al. (2020) reinforce this finding stating that the overwhelming majority of cross-border transactions is processed by banks.

[11] The direct use of central bank digital currencies for cross-border transactions is also examined in literature (e.g., Koning 2016, Raskin and Yermack 2018 and Auer and Boehme 2020). Although this idea seems promising, economists have several reservations, e.g., privacy issues, or the limited operational capacity of central banks to deal with individuals (see, e.g., Kahn et al. 2019 for an insightful discussion on this topic). Additionally, Boar et al. (2020) found that the overwhelming majority of central banks see themselves as unlikely to issue any type of such a currency in the foreseeable future. Other studies examine the specific example of Bitcoin (Böhme et al. 2015; Narayanan et al. 2016) and its use as virtual currency (Rysman and Schuh 2017). Scalability and transaction speed, however, is limited in the Bitcoin system (Natarajan et al. 2017).

through DLT which will ultimately result in the disappearance of interbank intermediaries in cross-border payments. The work sheds light on how large-scale global payment transactions based on DLT affect established hierarchies and their utility (Swan 2015). The paper also relates and contributes to the broader literature on DLT and its economic implications (e.g., Abadi and Brunnermeier 2019; Catalini and Gans 2019).

3.2 The foundation of interbank intermediaries

3.2.1 The concept of correspondent banking

The ability to safely and securely transfer money both within and across borders is indispensable for a functioning economy. Until the middle ages, banks were municipally chartered institutions and could offer payments services only within their home city (Quinn and Roberds 2008). As a result, funds had to be physically transferred. A process that was often plagued by theft, confiscation, and loss at sea. As long distance trade increased, better suited transaction means were needed. The bill of exchange became available as a new payment instrument during the 13th century. Bills of exchange are written instructions from a drawer to a drawee, a correspondent in a different city, to give funds to a payee. Initially correspondents were often merchants, with time banks were used more frequently due to their ubiquitous network and ample liquidity. Starting in the 17th century, ongoing improvements in interbank relationships and the emergence of new payment instruments simplified inter-regional and cross-border payments (Quinn 1997; Quinn and Roberds 2008). By the end of the 19th century, certain banks began to specialize in mediation of long-distance transactions, i.e., correspondent banks (see, e.g., Calomiris and Carlson 2017 for an overview of the U.S. corresponding banking network at that time). Today most other banks rely on these correspondent banks to complete transactions on their behalf in areas where they are not physically present (Society for Worldwide Interbank Financial Telecommunication 2016; Rice et al. 2020).

The intermediary banking services are controlled by a few large correspondents, i.e., the market is typical for an oligopoly. According to the European Central Bank, in 2016, there were 401 correspondent banks involved in the Euro business that served 9,754 customer banks (European Central Bank 2016). Based on data from the Committee on Payments and Market Infrastructures (2019), it is estimated that the number of correspondent banks had decreased to about 361 by the end of 2018. Although the exact number of correspondent banks globally is publicly unknown (Committee on Payments and Market Infrastructures 2016, 2019), the total number is declining, i.e., the market is increasingly concentrated.

In the succeeding sections, for simplification correspondent banks will only be referred to as correspondents. The modern correspondent banking model consists of an international network of financial institutions, where the sender and the beneficiary bank employ an intermediary

(the correspondent) to sort and process cross-border payments. The sender and the beneficiary bank hold Nostro (Italian: ours, which refers to 'our account with you') accounts with the correspondent. Due to the absence of a direct account relationship, the correspondent provides Loro (Italian: theirs, which refers to 'their account with them') accounts on behalf of the sender and the beneficiary bank.[12] The financial information, to settle transactions by crediting and debiting the accounts, is exchanged via the SWIFT's network (Grant 1986; Society for Worldwide Interbank Financial Telecommunication 2016). The payment instruction flows through an entry posting system, which creates a debit to the sender's account and either a credit to the beneficiary's account if this is held with the same correspondent or a posting to the payment system queue for settlement over the national/regional payment system. The payment flows from one bank to another through a central bank clearing system. There are two main types of settlement systems: real-time gross settlement (RTGS) and deferred net settlement (DNS). While in a DNS system (such as the Clearing House Interbank Payments System, CHIPS in the U.S.) all unsettled transactions are gathered and processed in bulk, RTGS systems (such as Fedwire in the U.S. or the Trans-European Automated Real-Time Gross Settlement Express Transfer System, TARGET2 in Europe) process money in real-time.

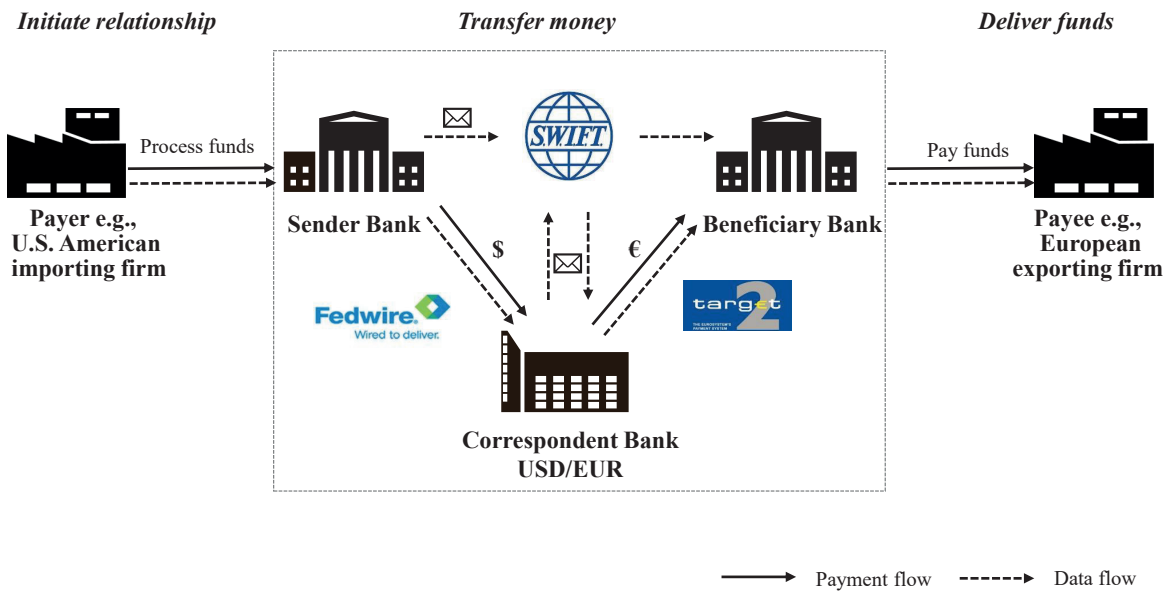


Fig. 3.1: Correspondent banking system today

To illustrate the payment processing via a correspondent, consider the following example. An U.S. American importer instructs its regional bank, i.e., the sender bank, to make a payment to a European firm (compare Figure 3.1). It is important to note that the payment instructions are exchanged separately from the "physical" flow of payments between the corresponding parties.

[12] Note that this is the most simple structure. In principle, there could be additional correspondents involved on the sending and receiving sides.

The European firm has an account at Deutsche Bank with which the regional bank, e.g., the Bank of Colorado, has no banking relationship. However, both the Bank of Colorado and Deutsche Bank have a correspondent banking relationship with the Bank of America, i.e., they both hold Nostro accounts at the Bank of America. Like the Bank of Colorado, the Bank of America has an account at the Fed and thus receives the funds through the national payment system, e.g., Fedwire. The Bank of America provides Loro accounts for their bank clients that they can make and receive USD and foreign currency payments. Upon receiving the USD in its Federal Reserve account, Bank of America does a book-entry transfer to credit Deutsche Bank's USD Nostro account for the amount of the payment. Bank of America then converts the USD to Euro so it can send the payment to the German supplier's account at Deutsche Bank. Correspondents are used because accounts at the central bank governing the particular currency are required for a transfer. In this example, Deutsche Bank does not have an account at the Fed. As a result, Bank of America cannot "physically" move the USD to Deutsche Bank. Assuming the supplier would like to either withdraw the funds or use them to make a Euro payment, Bank of America must first do a separate foreign exchange transaction to convert the funds to Euro. To do this, the Bank of America will debit Deutsche Bank's USD Nostro account and then credit Deutsche Bank's Euro Nostro account for the Euro equivalent. Bank of America then sends the Euro amount via the European Central Bank settlement system, TARGET2, to Deutsche Bank, since Deutsche Bank has a TARGET2 account. Once Deutsche Bank has the funds, it can credit the supplier's account, and the supplier can make a Euro payment or withdrawal.

In terms of costs of cross-border payments, each bank in the payment process charges payment processing fees (Casu and Wandhöfer 2018).[13] Each bank also individually conducts know-your-customer, anti-money laundering and counter-terrorist-financing checks. In addition, network and liquidity costs are involved in maintaining correspondent relationships. Costs arise for each bank that is involved in the process of funding interbank accounts and managing exposures.

3.2.2 The theory of interbank intermediation

To better understand the formation of interbank intermediaries in cross-border payments, the model of Breuer (1993) is introduced and adapted. For this model cross-border transactions are defined as the transfer of a fixed amount of money from one currency-zone into another. Two banking systems with n domestic banks (D) and m foreign banks (F) are considered, the bilateral network and the corresponding banking system. In the bilateral network (compare Figure 3.2), on behalf of their clients, each domestic bank must handle the sorting and processing of payments directly with its foreign counterpart. In this system, there are $m * n$ possible interbank transactions.

[13] Note that in the end, these costs are passed on to the payer and/or payee depending on the charge code. The code OUR is used to denote that the payer covers all transaction fees, BEN indicates that the beneficiary bears all the costs and SHA indicates that payer and payee share the costs.

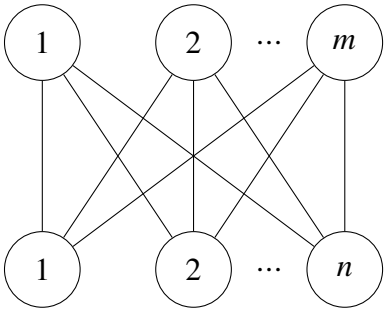


Fig. 3.2: Bilateral transactions

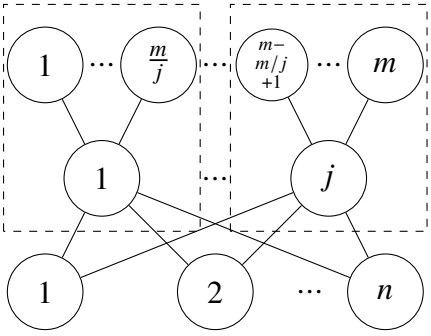


Fig. 3.3: Interbank intermediation

In contrast, the presence of j intermediary correspondents (B) results in $n * j + m$ transactions (compare Figure 3.3). In this case, all institutions forward payment instructions to correspondents that operate solely in a specific region (e.g., in one country, state or jurisdiction, etc.), to sort and process. In this system, the number of interbank transactions is reduced if the number of correspondents is sufficiently low, i.e., $j \leq \frac{m(n-1)}{n}$ holds true. In other words, as long as every correspondent j serves more than two foreign banks m, the correspondent system results in a lower number of interbank transactions. Note that the modeled structure implies that each domestic bank has access to all service-providing correspondents. As only "a few key players [account] for the majority of loro account turnover" (Committee on Payments and Market Infrastructures 2016, p. 15), this seems to be a reasonable assumption for the cross-border payment market. In contrast, each correspondent limits its service to a few foreign banks in a specific region, jurisdiction, or category of clients due to regulatory requirements and risk management considerations (Committee on Payments and Market Infrastructures 2016).[14]

To evaluate if the employment of correspondents and the resulting decrease in interbank transactions also reduces costs, further analysis is necessary. Therefore, it is important to consider the different types of transaction costs that arise for the banks when payments are processed.

In principle, transaction costs are classified according to their traceability (direct or indirect costs) and/or to their relationship with the transaction volume (variable or fixed costs) – compare Table 3.1. Each market participant faces market entry costs, c_1. These costs are volume independent (i.e., fixed) and cannot be attributed to a specific transaction. In case of cross-border payments, this could be, e.g., costs for a payment processor license. In addition, there are fixed costs that are directly attributable to the transaction, c_2. In the considered use case, these could be costs for establishing and managing counter-party bank relationships, directly with the correspondent or the foreign bank, respectively. There are also direct costs, c_3, that depend on the transferred money volume. Examples are foreign exchange costs or payment processing fees. With increasing payment orders, more processing fees accumulate. Finally, there are general

[14] Theoretically it is also possible to assume that each correspondent j has a relationship with all foreign banks. This would result in $m * j + n * j$ transactions. Depending on the number of correspondents, i.e., if $j \leq \frac{m*n}{m+n}$, this system could have a lower number of transactions in comparison to the bilateral system. However, such a system is not only inferior to the one depicted in Figure 3.3, but also at odds with reality.

Table 3.1: Different types of transaction costs

	Transaction volume independent costs	Transaction volume dependent costs
Costs not directly attributable to specific transactions	c_1	c_4
Costs directly attributable to specific transactions	c_2	c_3

This table is adapted from Breuer (1993) and displays the different transaction costs. Transaction costs can either be fixed (volume independent) or variable. Moreover costs can be distinguished into direct and general, i.e., not clearly attributable costs.

costs that depend on the total volume but are not attributable to a specific transaction, c_4. An example are the opportunity costs for trapped liquidity that banks are required to hold on their Nostro accounts to settle payments.

Every market participant is considered to have the same cost parameters and functions, i.e., is able to process the same amount of payments. This is done to rule out any biases stemming from specialized banks in the systems (i.e., more cost efficient banks). All market participants are banks and face similar regulatory costs (e.g., licensing fees or costs for know-your-customer checks etc.). In addition, all banks involved have volume dependent costs for funding interbank accounts as well as processing and managing exposures (Casu and Wandhöfer 2018).

As a result, the costs for a domestic bank in a bilateral system amount to:

$$c^D = c_1 + mc_2 + mc_3\left(\frac{V}{mn}\right) + c_4\left(\frac{V}{n}\right), \tag{3.1}$$

where V denotes the volume of all cross-border payments, $\frac{V}{mn}$ the volume for each transaction, and $\frac{V}{n}$ the volume per domestic bank. Respectively, the transaction costs for each foreign bank are given by:

$$c^F = c_1 + nc_2 + nc_3\left(\frac{V}{mn}\right) + c_4\left(\frac{V}{m}\right), \tag{3.2}$$

where $\frac{V}{m}$ denotes the payment volume per foreign bank. Consequently, in a bilateral system with n domestic and m foreign banks (compare Figure 3.2), the transaction costs sum up to:

$$\begin{aligned} c &= nc^D + mc^F \\ c &= [m+n]c_1 + 2mnc_2 + 2mnc_3\left(\frac{V}{mn}\right) + nc_4\left(\frac{V}{n}\right) + mc_4\left(\frac{V}{m}\right). \end{aligned} \tag{3.3}$$

In comparison, if j correspondents are involved (compare Figure 3.3), each domestic bank has transaction costs of:

$$\hat{c}^D = c_1 + jc_2 + jc_3\left(\frac{V}{jn}\right) + c_4\left(\frac{V}{n}\right). \tag{3.4}$$

Instead of directly processing payments to foreign banks, the domestic banks forward payment instructions to the specific correspondents. In turn the correspondent forwards the payment to the foreign bank. The costs for the foreign bank can be described by:

$$\hat{c}^F = c_1 + c_2 + c_3\left(\frac{V}{m}\right) + c_4\left(\frac{V}{m}\right). \tag{3.5}$$

In addition to the bilateral model, each correspondent bank also faces costs for their transmitting services:

$$\hat{c}^B = c_1 + \left[n + \frac{m}{j}\right] c_2 + nc_3\left(\frac{V}{jn}\right) + \frac{m}{j}c_3\left(\frac{V}{m}\right) + c_4\left(\frac{V}{j}\right). \tag{3.6}$$

As a result, in a system with j correspondents, n domestic, and m foreign banks, the overall transaction costs are given by:

$$\begin{aligned}
\hat{c} &= n\hat{c}^D + m\hat{c}^F + j\hat{c}^B \\
\hat{c} &= [m+n+j]c_1 + 2[jn+m]c_2 \\
&\quad +2\left[jnc_3\left(\frac{V}{jn}\right) + mc_3\left(\frac{V}{m}\right)\right] + nc_4\left(\frac{V}{n}\right) + mc_4\left(\frac{V}{m}\right) + jc_4\left(\frac{V}{j}\right).
\end{aligned} \tag{3.7}$$

To assess potential benefits of a correspondent banking system, the economy-wide costs with and without interbank intermediaries must be compared. Subtracting equation (3.7) from equation (3.3) reveals the cost differences between the two systems.

$$\begin{aligned}
c - \hat{c} &= -jc_1 - jc_4\left(\frac{V}{j}\right) \\
&\quad +2[mn - (jn+m)]c_2 + 2\left[mnc_3\left(\frac{V}{mn}\right) - \left[jnc_3\left(\frac{V}{jn}\right) + mc_3\left(\frac{V}{m}\right)\right]\right].
\end{aligned} \tag{3.8}$$

If the cost reduction in c_2 and c_3 through interbank intermediaries exceeds the additional costs c_1 and c_4, correspondents are beneficial. c_1 increases with the number of correspondents in the market. The general costs c_4 for processing payments increase with both volume and the number of involved correspondents because more liquidity is trapped on the respective Nostro accounts. For a sufficiently small number of correspondents, i.e., $j \leq \frac{m(n-1)}{n}$, interbank intermediaries result in lower network costs, c_2. Instead of maintaining business relationships with all counterparties, the domestic and foreign banks only interact with their correspondents. The network costs decrease as the number of domestic and foreign banks per correspondent increases. If the cost function c_3 is increasing at a decreasing rate, then correspondents can result in lower foreign exchange and payment processing fees. In other words, in this case correspondents have economies of scale. An example for such a cost function is $c_3(V) = aV^c$, where $a > 0$ and $0 < c < 1$. For this cost function, a lower c_3 is attained if there is a sufficient amount of foreign and domestic banks relative to the number of correspondents in the market. The sufficient

amount is defined as $\min\{m,n\} \geq \left[1+j^{1-c}\right]^{\frac{1}{1-c}}$.[15] If the number of correspondents (j) and the economies of scale parameter (c) are constant, then the cost saving increases with a higher number of foreign and domestic banks. Newman et al. (2018) cite processing payments (c_3) as the most significant cost in cross-border transactions. Although cited as important, opportunity costs for trapped liquidity (c_4) were found to be less significant than processing payment costs. The effect of the network management costs (c_2) was found to be low and that of market entry costs (c_1) is cited as negligible. In the case of a relatively high number of foreign and domestic banks compared to correspondents in the market, the positive effect of c_2 and c_3 outweighs the additional costs of c_1 and c_4. Since the correspondent banking market is best described by an oligopoly, i.e., the cross-border payment services are controlled by a few large correspondents, this holds true. Consequently, correspondents reduce the overall costs.

3.3 The downfall of interbank intermediaries

3.3.1 The digital transformation of correspondent banking

3.3.1.1 Distributed ledger technology

The previously described correspondent banking system was developed when communication was still costly, slow, and unreliable. Banks faced regulatory, as well as technical differences in national payment systems. As a result, there is limited transparency regarding the status of payments in this system. Depending on the parties involved, different requirements need to be met, e.g., some national payment systems (e.g., Fedwire and CHIPS in the U.S., or the Australian, Swiss and Japanese RTGS systems) do not use SWIFT messages (Casu and Wandhöfer 2018). The correspondent banking system is susceptible to payment delays as not all involved banks hold enough liquidity in the correct currency. As a result of the internet and the accompanied digitization, expectations by consumers for transparency, speed and reduced transaction costs have risen. In a world where online shopping enables real-time tracking and free delivery of physical goods within a few hours, customers struggle to accept opaque cross-border payments that take several days. Despite significant investments by SWIFT and other banks, the cross-border payment infrastructure remains suboptimal. From a financial stability perspective, the correspondent banking system is also a source of risk (Freixas and Parigi 1998; Allen et al. 2012; Del Prete and Federico 2019). Although, for simplification, banks use interbank credit

[15] Note that the derived relation would be most beneficial for a monopolistic correspondent that could evolve from the suggested cost function. As the cross-border market is clearly not controlled by a unique correspondent, the proposed cost function should be interpreted as a piecewise-defined function of an overall cubic cost function. Costs first increase at a decreasing rate (as advocated) and then increase at increasing rates after an optimal number and volume of processed payments is reached by a correspondent. If a cubic cost function is assumed, the existing oligopoly market structure can be rationalized.

lines to fulfill payment transactions for their customers, this is a potential contagion source in periods of financial stress (Afonso and Shin 2011).

To address these issues, recently, banks have begun to explore modern technological options (Thakor 2020). Here, specifically the potential of DLT to revolutionize long-distance transactions is examined. Technically speaking, DLT allows for a consensus record of state changes or updates to a synchronized ledger to be distributed across various nodes in the network. Important to note is that DLT is not a single well-defined technology, and that nomenclature is not standardized within literature (Perdana et al. 2020). In order to make the topic more clear and to show the terms used here, Figure 3.4 shows an overview. In general, it is differentiated between public (anyone can join) and private (members can join based on credentials) DLT systems (see Figure 3.4). In all cases, the crucial aspect of DLT, however, is that unlike the correspondent banking system where each financial institution in the payment chain updates its individual databases (i.e., the Nostro and Loro accounts), in a DLT system a central ledger is shared, replicated, and synchronized among the members of a decentralized network (Natarajan et al. 2017).

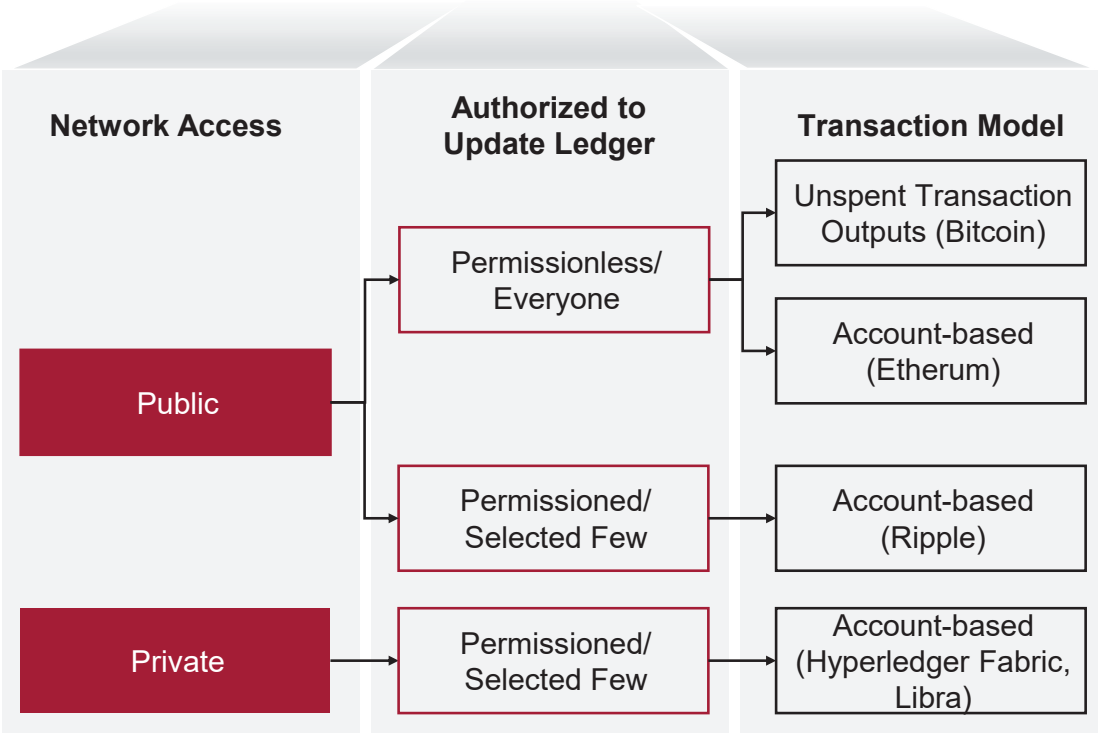


Fig. 3.4: Distributed ledger taxonomy

DLT systems are differentiated based on who is included in the group that updates the ledger. In the case of permissionless systems, all members can update the ledger. In permissioned

setups only certain members can update the ledger. The group governs and agrees by consensus on database updates, i.e., new transaction records. Thereby, the consensus is reached via a predefined cryptographic validation method, i.e., a set of rules. Such a consensus mechanism is necessary to establish whether a particular transaction is legitimate or not, and to ensure a correct sequencing of transactions done with the same assets. Every record has a timestamp and a unique cryptographic signature, making the ledger a verifiable, immutable history of all transactions in the network.[16]

Two different record-keeping models are commonly used in DLT systems, UTXO (unspent transaction output, sometimes referred to as store of value) and account-based (Kahn and Roberds 2009; Kahn et al. 2019). For a transaction to be deemed satisfactory in an account-based system, the payer has to be identified as the holder of the account from which the payment is made. The account balance of the payer is checked to ensure that the transaction amount is covered. The account value of the payer is then reduced and the money is added to the account of the payee. In the case of a UTXO-based system, information about the amount available from the payer for the transaction is stored in the unspent transaction output. This total value is used as the input for the transaction. In a second step, a new UTXO (total amount minus transaction amount) is sent back to a newly created address of the payer and the transaction amount is stored in a new output of the payee. The UTXO-model is often compared to a cash system. During a transaction, to cover the cost, several bills can be used (existing outputs) and in some cases change is returned (new output). In total each bill can only be used once (the original output no longer exists after the transaction).[17]

3.3.1.2 RippleNet - a new global payment system

Recently several banks, e.g., Royal Bank of Canada, Santander, UBS, etc., have begun to use a public permissioned account-based DLT system to transfer payments across borders. The banks use the closed-source banking software RippleNet that is sold by Ripple Labs, Inc. and is different from Ripple's own currency XRP (colloquially also referred to as Ripple). Access to this system is naturally permissioned, i.e., participating banks are pre-selected by an administrator, i.e., Ripple Labs, who controls network access and sets the rules of the database. RippleNet is a distributed database that contains information about user accounts, balances, and trades (Ripple 2017). A trade or payment is executed by making a valid change to the central ledger. Here an interledger protocol connects the different payment record systems of all participating banks from which it creates the central ledger. The central ledger is shared and maintained by all network members and represents every user's balance. Currencies enter and exit the Ripple network via gateways, i.e., banks (Rapoport et al. 2014). Analogously to traditional banks, these

[16] Note that many of the technical constructs are simplified here. For a more detailed and technical description, the reader is referred to Natarajan et al. (2017).

[17] For more details on the UTXO-model see, e.g., Sun (2018).

gateways accept currency deposits from customers and issue balances on the Ripple network. When a user wants to withdraw money from the Ripple network, the existing balance is redeemed. For security purposes, every user of RippleNet must hold a small amount of XRP. Within the network, payments can either be processed directly via XRP debit payments or indirectly via path-based currency-agnostic "I owe you" (IOU) settlement transactions (Moreno-Sanchez et al. 2016). In the case of IOU settlement transactions, banks can use fiat currencies (USD, Euro, etc.) to settle cross-border payments without any conversion to cryptocurrency. In this case, XRP is only used to pay the minute transaction fee imposed to prevent senseless transactions (Rapoport et al. 2014). To settle credit between sender and receiver, the most suitable route of credit between the sender's and receiver's banks is used (Moreno-Sanchez et al. 2018). Whenever a payment is made that involves two banks that are not connected by a direct trust line (i.e., Nostro accounts), the payment "ripples" through other trust relationships in the network. These trust relationships are banks that hold the specific currency pairs and function as market makers. By routing a payment through one (or several) market maker(s), banks can pay each other in currencies that they do not hold (or do not want to hold). The system automatically uses the most competitive exchange rates, i.e. the cheapest path. The money is simultaneously debited from the payer's account and credited to the beneficiary. For example, an American company A

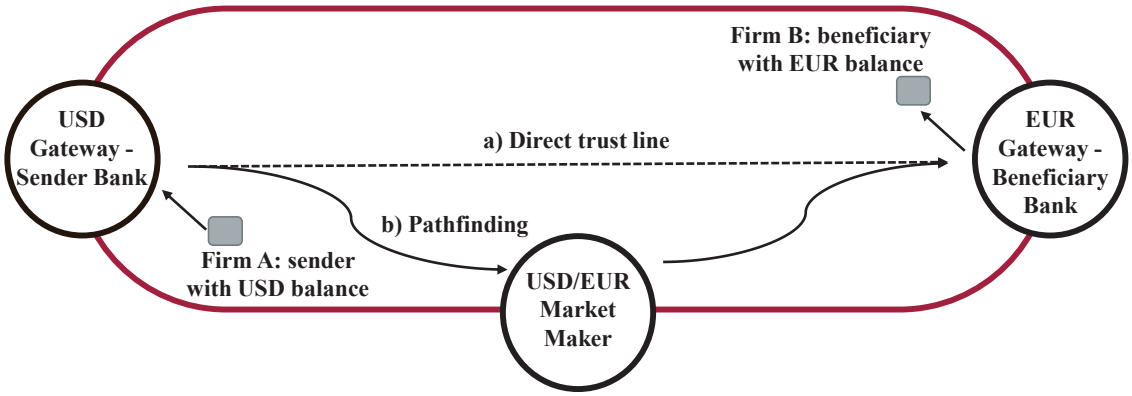


Fig. 3.5: Cross-border payments via RippleNet

would like to transfer money to a European firm B. After checking for liquidity and verifying the client's identification (legally required), the bank of the sender can simply send an IOU in USD to the beneficiary's European bank (compare Figure 3.5). At the same time, the beneficiary's bank must also put the transaction amount on hold. This step is necessary to accommodate the desire of the beneficiary to receive the money in Euros despite the transfer of USD. Once both banks have validated that the funds are on hold, the funds are released. A market maker becomes necessary if the beneficiary bank in Europe does not want to hold USD (compare Figure 3.5).

The market maker holds trust lines with the sender and the beneficiary bank and is paid a small fee (bid-ask spread) for the foreign exchange.[18]

RippleNet simplifies cross-border transactions enabling on-demand liquidity across multiple currencies for banks. It is capable of processing 1500 transactions per seconds and a typical payment only takes about 4-5 seconds between initiation and completion (Travis 2017). RippleNet integrates well into an already existing and highly regulated payment system. "In other words, while Ripple[Net] improves the underlying settlement infrastructure of global-payment systems, it does not affect the existing legal relationships between the participants of such systems" (Rosner and Kang 2016, p. 664). Banks must still continue to comply with financial regulations, anti-money laundering and know-your-customer rules. RippleNet also lowers some of the risks that current regulations seek to mitigate. For instance, the adoption of atomic (all or nothing) real-time settlement drastically reduces the risk of lost payments.

While from a technological perspective, RippleNet and other DLT systems are generally considered to offer secure, immutable, and transparent transactions, legal liability will simply not disappear (Zetzsche et al. 2018). Risks that are particularly pronounced due to the early level of RippleNet implementation are the lack of liquidity and the poor inter-connectivity of certain banks. Moreno-Sanchez et al. (2018) show that if banks are poorly interconnected, then it is possible that users can no longer access their funds even if the involved sender and beneficiary bank are not insolvent. In this case the issue of liability is unclear. The same holds true for the case of unintended third-party access (cyberattack) or the "garbage in, garbage out" dilemma, i.e., the spread of inaccurate stored data via DLT. In case of RippleNet, Ripple Labs controls the rules (Armknecht et al. 2015) and access to the database (Ripple 2017).[19] This allows the entities involved to be known. In turn, the particular entity could be directly liable for economic losses in the case of its breach. Nonetheless, the fundamental joint control of DLT will likely result in a joint liability of the network participants, including Ripple Labs (Zetzsche et al. 2018).

Due to the inherently international nature of RippleNet's activities, both domestic and international laws must be considered. For example, regulators have concerns about the monopoly position of RippleNet in cross-border payments (European Securities and Markets Authority 2017). In addition, regulators must decide under which jurisdictions conflicts fall, e.g., which insolvency law to follow in the case of a bank's default (Rosner and Kang 2016). Therefore, regulators must coordinate and communicate to harmonize global standards and rules. Although the use of XRP could simplify issues due to international regulations, most banks do not yet use it as a vehicle currency. The digital currency is only worth what someone else is willing to pay for it. Ripple Labs owns about 60 percent of all XRP and controls the money supply in the network (Pick 2020). Users are forced to trust Ripple Labs with the fate of their money.

[18] For very exotic currencies XRP can be used as a vehicle currency. Most banks, however, opt not to use XRP (Pick 2020). Therefore, a detailed discussion of this feature is omitted here. For more information on XRP settlement see, e.g., Ripple (2017).

[19] As fairly mentioned by Rosner and Kang (2016), in principle, no single entity can change the RippleNet database. However, most of the validating servers are run by Ripple Labs, allowing it to change the database.

Overall, for a successful wide-spread implementation, it is vital that all network elements receive sufficient supervision. For securing trust in the new payment infrastructure, more research on the resiliency and weakness of the system is needed.

3.3.2 Implications for the correspondent banking system

In the following the transaction cost model of Breuer (1993) is used to illustrate how DLT systems, like RippleNet, affect the correspondent banking system. Instead of relying on several specialized correspondents, domestic and foreign banks use a shared network that is based on a permissioned DLT and transfer funds directly (compare Figure 3.6).

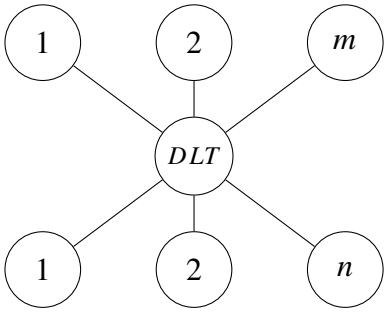


Fig. 3.6: Intermediation via DLT

In case of cross-border payments via DLT, the costs for a domestic and a foreign bank reduce to:

$$\bar{c}^D = c_1 + c_2 + c_3\left(\frac{V}{n}\right) + c_4\left(\frac{V}{n}\right) \tag{3.9}$$

$$\bar{c}^F = c_1 + c_2 + c_3\left(\frac{V}{m}\right) + c_4\left(\frac{V}{m}\right). \tag{3.10}$$

Instead of maintaining j counter-party relationships, each bank only maintains access to the Ripple network. This reduces the network costs for each bank to c_2. Similarly due to the fact that less parties are involved, the processing fees c_3 can be reduced, too. Instead of processing messages to j correspondents and keeping internal records to capture proprietary aspects of each currency transfer, both banks only face one-time costs, consisting out of the direct transfer costs and costs for validating transactions on the ledger. Like in the correspondent banking system, banks still have to provide sufficient funds in their account to process the payments.

Even though a lot of interbank intermediaries can be excluded in this system, at least one administrator (A) for the marketplace is needed. The administrator faces market entry costs τ_1 to set up the system. Additionally, the administrator has to verify all domestic and foreign banks (resulting in costs τ_2), ensuring that they have the ability to process payments. Once the information is digital, it can be easily verified and shared among all network members. Making

use of the distributed exchange capability, cross-border payments are automatically processed among network members, resulting in τ_3. The instant real-time settlement of transactions basically eliminates the time and cost of capital (τ_4) that is locked during a cross-border transfer. Still, the administrator faces τ_4 costs for the infrastructure, i.e., capacity costs that incur to be able to process all payments. Thus, the costs for the administrator can be described by:

$$\bar{c}^A = \tau_1 + (m+n)\tau_2 + n\tau_3\left(\frac{V}{n}\right) + m\tau_3\left(\frac{V}{m}\right) + \tau_4(V). \tag{3.11}$$

As a result, in a DLT system the following transaction costs incur:

$$\begin{aligned}\bar{c} &= n\bar{c}^D + m\bar{c}^F + \bar{c}^A \\ \bar{c} &= (m+n)c_1 + \tau_1 + (m+n)(c_2+\tau_2) + n\left[c_3\left(\frac{V}{n}\right) + \tau_3\left(\frac{V}{n}\right)\right] \\ &\quad + m\left[c_3\left(\frac{V}{m}\right) + \tau_3\left(\frac{V}{m}\right)\right] + nc_4\left(\frac{V}{n}\right) + mc_4\left(\frac{V}{m}\right) + \tau_4(V).\end{aligned} \tag{3.12}$$

To assess potential benefits of the DLT system, the economy-wide costs of the DLT system must be compared to those of the correspondent banking system. Subtracting equation (3.12) from equation (3.7) reveals the economy-wide differences between the two systems.

$$\begin{aligned}\hat{c} - \bar{c} &= jc_1 - \tau_1 + jc_4\left(\frac{V}{j}\right) - \tau_4(V) + [2jn + m - n]c_2 - (n+m)\tau_2 \\ &\quad + 2jnc_3\left(\frac{V}{jn}\right) - n\left[c_3\left(\frac{V}{n}\right) + \tau_3\left(\frac{V}{n}\right)\right] + m\left[c_3\left(\frac{V}{m}\right) - \tau_3\left(\frac{V}{m}\right)\right].\end{aligned} \tag{3.13}$$

Although the initial infrastructure required for a DLT platform is far more costly (τ_1) than a simple banking license (c_1), in relative terms considering the sheer number of existing correspondents j the technology is remunerative. While there is little data on the costs of public permissioned DLT systems, Brody et al. (2019) estimate an initial investment equivalent to approximately twenty-six German banking licenses, i.e., correspondent banks.[20] Currently, there are about 361 correspondent banks in the Euro business alone. For a sufficiently large number of correspondents (~26), the DLT system results in lower market entry costs. A DLT system reduces networking costs if onboarding (τ_2) is less expensive than it is for banks to establish counter-party relationships (c_2). There is limited information on both the onboarding costs in a DLT system and the banks' network costs. It seems plausible, however, that both the administrator and correspondents have economies of scale in establishing additional relationships (Maringer et al. 2019). While an administrator must accumulate knowledge about the regulatory environment and how to establish trustworthy relationships, correspondents potentially already possess unique proprietary knowledge. The exact relation between τ_2 and c_2 is hard to determine. Although c_2 may possibly be lower than τ_2, with an increasing number of correspondents the

[20] According to Haag and Steffen (2020), the German Federal Financial Supervisory Authority BaFin charges a fee of up to $25,000 for granting a banking license.

DLT system can result in lower network costs. Anecdotal evidence indicates that it is simply too costly for correspondents to establish and maintain banking relationship for certain geographic regions (Bräuning and Fecht 2017; Kobayashi and Takaguchi 2018). The number of correspondents has been steadily decreasing over the last years and the remaining correspondents have even pared back their relationships. This resulted in even higher cross-border payments costs in abandoned regions (Rice et al. 2020). In contrast, technologies such as RippleNet enable banks to exchange funds without dedicated pre-established networks for the target location of the transaction as long as both institutions are connected via the system.

Payment processing costs can be significantly reduced in the DLT system because failures of payments are minimized through the automatic real-time settlement (Ripple 2017). In the current correspondent system, complex interbank pricing rules create the need for manual invoicing, claims-handling and dispute management. This requires substantial manpower and valuable time for transaction execution. In addition, due to the presence of market makers, an universal intermediate currency (e.g., XRP) and cost beneficial path-settlements, foreign exchange costs can be reduced. Currently, managing cash reserves in multiple currencies makes optimizing payment flows challenging. The DLT system will reduce operational costs linked to the processing of payments, i.e., $\tau_3(\cdot) < c_3(\cdot)$ holds true. The main challenge for the administrator, e.g., Ripple Labs, is to ensure that the processing power to support an increasing number of transactions per second is available, i.e., the system is scalable. The required computing is energy intensive (Leopold and Englesson 2017; Truby 2018). Brody et al. (2019) cite ongoing maintenance (τ_4) as the most significant running cost for a public permissioned DLT system. In the case of correspondents, typically, opportunity costs for trapped liquidity (c_4) are a major cost factor. Nonetheless, given the required processing power and energy, maintaining a DLT system might still be more expensive. However, in case of a relatively high number of correspondents, the positive effect of τ_1, τ_2 and τ_3 outweighs the additional costs of τ_4. Consequently, in principle a DLT system results in an overall cost saving. The magnitude of improvement greatly depends on network effects that can only be created by on-board large banks around the world (Iansiti and Lakhani 2017). To achieve this, building and maintaining trust in the new payment system is vital.

3.4 Conclusion

Traditional correspondent banking networks are still prevalent for cross-border payments. Here, transaction cost theory was used to show the amenities of such interbank intermediaries. Subsequently, the effect of a DLT-based system on the cross-border payment market was analyzed. DLT has the potential to replace correspondents and dominate cross-border payments by reducing the overall transaction costs. DLT is a nascent technology that could form the basis of a

new cross-border commercial payments network. The speed of acceptance by banks around the world and the rate at which legal concerns are addressed will determine when DLT can be used to support trillions of dollars in payments.

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Part II
Access to Finance, Innovation and Growth

Chapter 4
Innovative Efficiency as a Lever to Overcome Financial Constraints in R&D Contests

Abstract Often the winner of an R&D contest seems unexpected or surprising, e.g., small firms win a disproportionate number of R&D contests despite having limited funds and on average lower market power. Here, different contest situations are modeled by considering variations in the innovative efficiency, patent valuation and financial resources of firms. It is found that small firms can be the Nash winner through highly efficient innovation despite financial constraints and low patent valuation. The results are helpful in understanding and predicting the probability of a firm's successful innovation.

4.1 Introduction

Give me a lever long enough and a fulcrum on which to place it, and I shall move the world.
– Archimedes

Since Schumpeter's discussion of the qualitative differences between the innovative activities of small entrepreneurial firms and large corporations, the relationship between firm size and innovation has attracted a great deal of theoretical and empirical research (see, e.g., Cohen 2010 for an in-depth overview). Until the 1980s, academics and policymakers attributed technological progress and innovation predominantly to large firms. Today, however, there are many examples of highly successful innovations stemming from small entrepreneurial firms.

One good example is the success of PayPal. In the 1990s internet use became very popular and companies such as eBay began to offer an online marketplace that enabled virtual strangers to conduct transactions with a mouse click. While purchases on such websites seemed instantaneous, the payment process still lagged behind. Slowly online transaction services started to appear that enabled people to exchange money instantly. However, these services were plagued by fraud issues. Although this was problematic for all service providers, Citibank, the largest U.S. bank at that time, and PayPal, a small start-up from California were the most significant players in the research and development contest to address digital fraud. In 2001, despite being much smaller, more financially constrained and having much less experience with financial transactions, PayPal was the first to patent a financial surveillance software called IGOR.[21] Thus PayPal succeeded, Citibank ended its online transaction service in 2003 and left the market completely. Like PayPal, many entrepreneurial firms beat a seemingly stronger opponent in

[21] Compare Levchin and Frezza (2002). Note that according to the U.S. patent law, software per se cannot be patented. However, the patent was granted for a business method invention.

R&D contests. This raises the question of innovative advantage, i.e., when are entrepreneurial firms more capable at generating innovations.

Creating innovation requires investment in R&D. Large and well-established firms have advantages in financial resources (Beck et al. 2005; Hottenrott et al. 2016). They have the financial reputation and records of past performances necessary to attract additional financing. Moreover, it has been repeatedly found that within many industries, R&D expenditures vary proportionally with firm size, i.e., larger firms have higher R&D expenditures (Acs and Audretsch 1988; Foster et al. 2019). Based on these findings, all else equal, large firms are more probable to win R&D contests (Kamien and Schwartz 1982; Schroth and Szalay 2009). In addition to being more endowed, there are several reasons why large firms may have greater incentives to innovate, and consequently value the patent more than small firms.[22] They can apply the innovation in a greater product output and reap rewards more quickly (Teece 1986; Gans and Stern 2003). If a functioning patent system is in place, established firms have greater incentives to preserve their current market position by patenting new technologies before potential competitors (Gilbert and Newbery 1982).

Regardless, many modern global corporations often find it difficult to compete with the R&D efforts of smaller firms. Holmström (1989) attributes the success of smaller firms to comparative advantages in conducting innovative research, i.e., a higher innovative efficiency. Large firms have more bureaucratic drag, organizational rules and routines, and are distracted by ongoing business activities (Haveman 1993). Additionally, due to the fact that R&D investments are uncertain, intangible, and can take a long time, project managers can more easily seek private benefits and disguise their suboptimal investment decisions.[23] This particularly holds true for large firms, because they pursue several research projects at the same time and face less significant financial constraints. In contrast, financially constrained firms, which are often small, only invest in their most promising projects (Zenger 1994; Almeida et al. 2013). There is also evidence that small firms more often benefit from unidirectional knowledge spillovers from universities (Kirchhoff et al. 2007). Thus, there are several reasons why small firms might have a higher innovative efficiency, i.e., a higher ability to transform investment into technological progress.

To understand whether innovative efficiency can be a lever with which small firms can potentially overcome their lower incentive to innovate (measured by the patent value) and limited funds, a contest model where two asymmetric firms compete for a patent is used.[24]

[22] Note that there are also claims for why small and entrepreneurial firms have greater incentives to innovate. Reinganum (1983), for example, argues that established firms have lower incentives to innovate when there is uncertainty about whether an innovation will cannibalize a portion of their profits.

[23] Private benefits from wasteful R&D investment come in many ways. For example, managers may gain insider profits by disclosing planned changes in R&D budgets (Aboody and Lev 2000). Moreover, having a large R&D budget represents power, which can help enhance managers' self esteem.

[24] Within the industrial organization literature, at least two other model types (races and tournaments) are often used. Here, however, the contest framework was selected because it offers a simple structure and empirical results can be easily included. As shown by Baye and Hoppe (2003), contest games are strategically equivalent to continuous-time patent-race games with negligible interest rates (see, e.g., Loury 1979), and (if restricted to a discrete strategy space) to research-tournament games (see, e.g., Taylor 1995; Fullerton and McAfee 1999).

Thereby, the three previously described, variable characteristics of firms are considered: patent valuation, innovative efficiency and financial constraints.

Prior work on strategic consequences of firm characteristics in contests focused on the effect of different patent valuations (e.g., Nti 1999) or innovative efficiency (e.g., Singh and Wittman 2001) or both (e.g., Harris and Vickers 1985; Baik 1994). Baik (1994) shows that a firm can overcome its relative innovative inefficiency through a higher relative valuation of the patent if financially unconstrained. In reality, however, a firm's willingness to invest is not a sufficient condition for actual investment in R&D, because they have limited funds. This holds particularly true for small entrepreneurial firms (Brown et al. 2012). Che and Gale (1997) and Grossmann and Dietl (2012) address this concern and incorporate financial constraints in their contest models. The model of Che and Gale (1997) is limited because they assume otherwise symmetric firms. In the case of Grossmann and Dietl (2012) asymmetric patent valuation is considered, but innovative efficiency is not addressed. Innovative efficiency, however, has been found to play a key role in R&D success. Shackelford (2013), for example, reports that small firms (5-499 employees) spend on average only $1.17 million per patent application, whereas large firms (>500 employees) spend on average $2.63 million per patent application. Akcigit and Kerr (2018) also document a significant decline in innovation intensity (patents as a share of sales or total employment) with firm size.

By considering the effect of all three firm characteristics, the work here provides a more complete analysis of the correlation between a firms' R&D expenditures and its resulting success in innovation. The next section presents the basic assumptions and the structure of the model. Then the case without financial constraints is analyzed. Subsequently the analysis is extended to the case of asymmetric firms with varying financial constraints. The article concludes with a summary of the main results and highlights policy implications and testable implications for future empirical research.

4.2 The basic model

A contest between two asymmetric firms *i (i=L,S)*, i.e., a large and a small firm, that are competing in R&D activities in order to attain a patentable product is considered. Because the patent system provides a legal monopoly over the technology to the winner, the innovation allows the first firm to extract profits π by selling it in a market where competitors are unable to replicate it. Only the winner of the contest profits and the loser suffers a loss given by the invested R&D expenditures which, however, is sunk as soon as the contest is over. Evaluation of the patent is different between the two firms due to differences in commercializing the new products. While the small firm values the patent at π, the large firm values the patent at $\alpha\pi$, where $\alpha > 0$. If the valuation parameter α is greater than one, the large firm values the patent more, while a

value of the parameter less than one implies the opposite. While some firms can fully realize the potential of an innovation or even have additional utility for other applications, other firms are limited in their financial and human resources to commercially exploit the innovation (Gans and Stern 2003). In addition, patents have different strategic values for firms, e.g., due to securing a firm's future market or due to restricting competitors' opportunities (Blind et al. 2009). With time the valuation parameter of a firm can vary, i.e., past successful R&D contests result in changes of strategic motives. For a single R&D contest, however, it is assumed, that the present commercialization capability and a firm's strategic motives largely predetermine the valuation parameter.

In order to win the contest, both firms invest x_i of their financial resources $\omega_i > 0$ in R&D activities. Thus, the maximum investment each firm can make is equal to its financial resources. Furthermore, the individual financial resources of the firms are common knowledge. It is publicly known that the large firm has more financial resources than the small firm ($\omega_L > \omega_S$) because it has access to capital market financing. The small firm must rely on internal and private funds.

The success probability of each firm is given by the logit-form contest success function (Dixit 1987). Firm i's probability of winning the contest, $p_i = p_i(x_L, x_S)$, equals the ratio between its own (effective) investment and the sum of all (effective) investments:

$$p_i(x_L, x_S) = \begin{cases} \frac{\theta_i x_i}{\theta_L x_L + \theta_S x_S} & \text{if } \max\{x_L, x_S\} > 0 \\ 0 & \text{otherwise,} \end{cases} \tag{4.1}$$

where $\theta_i > 0$ indicates the firm's innovative efficiency, i.e., the ability to transform the investment into technological progress. Put differently, the innovative efficiency parameter is a measure for a firm's present ability to generate patents per dollar of R&D investment. A firm's innovative efficiency existent in each R&D contest is predetermined by several characteristics, such as the organizational form (Holmström 1989; Seru 2014), managerial skills (Custódio et al. 2019), past innovation success (Cohen et al. 2013), and financial distress (Almeida et al. 2013).

For notational ease, equation (4.1) is considered in relative terms. The probability of success for the large firm is described by the following function:

$$p_L(x_L, x_S) = \begin{cases} \frac{\sigma x_L}{\sigma x_L + x_S} & \text{if } \max\{x_L, x_S\} > 0 \\ 0 & \text{otherwise,} \end{cases} \tag{4.2}$$

where $\sigma = \frac{\theta_L}{\theta_S}$ represents the innovative efficiency of the large firm relative to the small one. A value of σ greater unity implies that the large firm has a higher innovative efficiency than the small firm, and vice versa. Note that the described set-up is a special case of the more general model of Baik (1994).

Both firms maximize their expected profits:

$$\Pi_L = \alpha\pi\frac{\sigma x_L}{\sigma x_L + x_S} - x_L \tag{4.3}$$

$$\Pi_S = \pi\frac{x_S}{\sigma x_L + x_S} - x_S, \tag{4.4}$$

subject to the constraint that the investment in R&D activity does not exceed their financial resources, $x_i \leq \omega_i$. The expected profit functions (4.3) and (4.4) are concave, so the optimum is at the unique global maximum (if it lies between an infinitesimal positive number and ω_i) or at the boundary (ω_i).

Let $x_L(x_S)$ and $x_S(x_L)$ respectively denote the firm's reaction functions:

$$x_L(x_S) = \begin{cases} \frac{\sqrt{\alpha\pi\sigma x_S} - x_S}{\sigma} & \text{if } 0 < x_S < \alpha\pi\sigma \leq \frac{(\sigma\omega_L + x_S)^2}{x_S} \\ \omega_L & \text{if } \alpha\pi\sigma > \frac{(\sigma\omega_L + x_S)^2}{x_S} \end{cases} \tag{4.5}$$

$$x_S(x_L) = \begin{cases} \sqrt{\sigma\pi x_L} - \sigma x_L & \text{if } 0 < \sigma x_L < \pi \leq \frac{(\sigma x_L + \omega_S)^2}{\sigma x_L} \\ \omega_S & \text{if } \pi > \frac{(\sigma x_L + \omega_S)^2}{\sigma x_L} \end{cases}. \tag{4.6}$$

Of course each firm has the possibility to deviate and not invest at all in R&D (by definition this case is not covered by the reaction curves).[25] If both firms are financially unconstrained, the best response for the large firm is given by $x_L(x_S) = \frac{\sqrt{\alpha\pi\sigma x_S} - x_S}{\sigma}$ and for the small firm by $x_S(x_L) = \sqrt{\sigma\pi x_L} - \sigma x_L$. If a firm has less resources than it would ideally spend on R&D activities, it is considered financially constrained. In this case, it is optimal for a firm to invest all of its financial resources, ω_i. For all combinations of cases where both firms invest, a unique Nash equilibrium exists at the intersection of the reaction functions, where both equations (4.5) and (4.6) are simultaneously satisfied.[26]

4.3 The role of firm characteristics

4.3.1 Unconstrained firms

If both firms have the same effective investment ($x_S = \sigma x_L$), value the patent identically ($\alpha = 1$), and are not financially constrained, the firms' optimal R&D expenditures (x_i^*) and the corresponding expected profits (Π_i^*) in equilibrium are:

$$x_i^* = \frac{\pi}{4}; \quad \Pi_i^* = \frac{\pi}{4}. \tag{4.7}$$

[25] This case also cannot constitute a Nash equilibrium because each firm could theoretically increase its profits from zero to π by slightly increasing its R&D expenditures.

[26] See Yamazaki (2008) for a more rigorous proof of the existence and uniqueness of a Nash equilibrium.

In this case, both firms are equally likely to win the R&D contest ($p_i^* = 1/2$).

However, firms usually differ in their innovative efficiency and their valuation of the patent, i.e., α and σ are not equal to one. Thus, the optimal R&D expenditures (and consequently also the success probabilities) and the corresponding expected profits depend on a combination of these factors:

$$x_L^* = \frac{\alpha^2\pi\sigma}{(\alpha\sigma+1)^2}; \quad \Pi_L^* = \frac{\alpha^3\pi\sigma^2}{(\alpha\sigma+1)^2} \tag{4.8}$$

$$x_S^* = \frac{\alpha\pi\sigma}{(\alpha\sigma+1)^2}; \quad \Pi_S^* = \frac{\pi}{(\alpha\sigma+1)^2}. \tag{4.9}$$

In the following, the Nash winner is defined as the firm who has a probability of winning greater than 1/2. Thus, the large firm is the Nash winner if $\alpha\sigma > 1$, while the small firm is the Nash winner if $\alpha\sigma < 1$. As a result, if one firm has a significantly higher innovative efficiency, it is now possible that this firm is the Nash winner even if it values the patent less. Similarly, if a firm values the patent significantly higher, it can still be the Nash winner even if it is less efficient in innovating. Figure 4.1 illustrates the case for the situation where the small firm overcomes its relative lower valuation through a higher relative efficiency. The dotted line in Figure 4.1 illustrates the points that satisfy $\sigma x_L = x_S$, resulting in an equal winning probability. Therefore, if the Nash equilibrium is located above (below) the dotted line, the small (large) firm is the Nash winner.

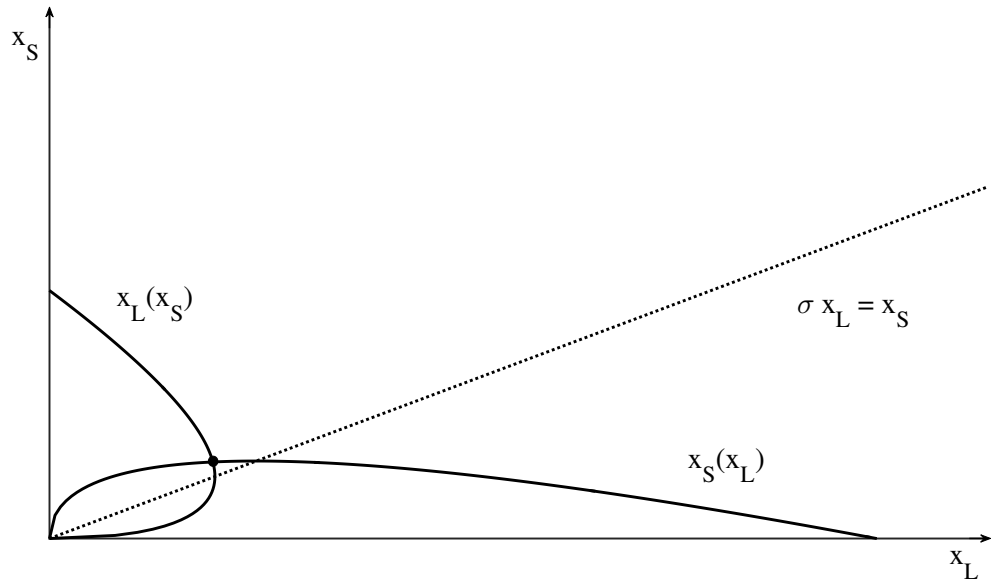

Fig. 4.1: Reaction functions when the small firm values the patent less but is significantly more efficient, i.e., $\alpha\sigma < 1$ holds true

Since the outcome of the contest crucially depends on the values of α and σ, comparative statics with respect to these parameters are analyzed. An increase of the valuation parameter α results in a shift to the right of the large firm's reaction function (cf. Figure 4.2). The valuation parameter is relative. Therefore, the small firm's reaction function remains unchanged.

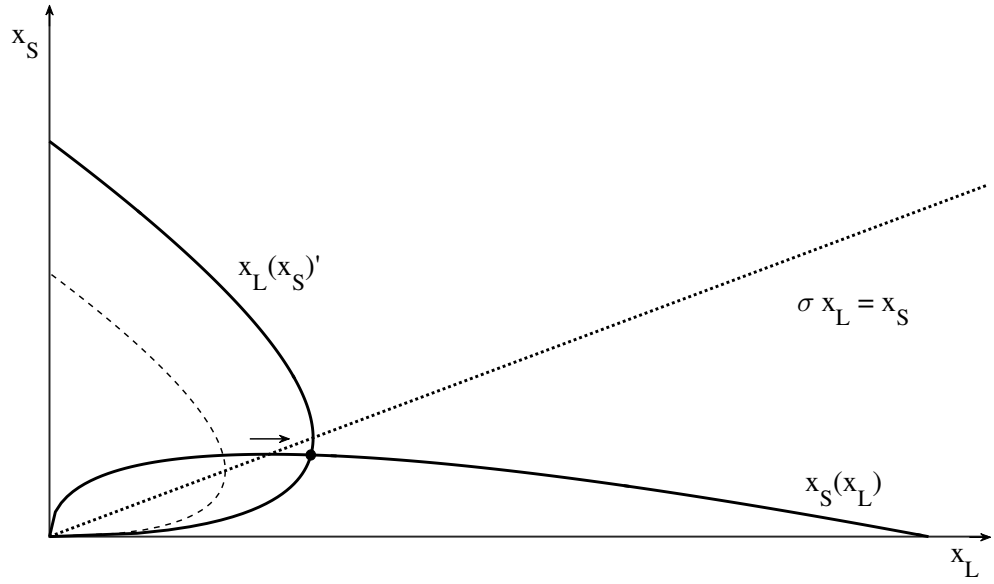

Fig. 4.2: Shift of the large firm's reaction function when the valuation parameter α increases, i.e., the large firm values the innovation higher

Intuitively, the large firm is willing to spend more in R&D activities, the more it values the patent. A higher valuation parameter α in turn can result in higher or lower R&D expenditures for the small firm:

$$\frac{\partial x_L^*}{\partial \alpha} = \frac{2\alpha\pi\sigma}{(\alpha\sigma+1)^3} > 0 \tag{4.10}$$

$$\frac{\partial x_S^*}{\partial \alpha} = \frac{-\alpha\pi\sigma^2+\sigma\pi}{(\alpha\sigma+1)^3} \begin{Bmatrix} >0 \\ =0 \\ <0 \end{Bmatrix} if \begin{Bmatrix} < \\ \alpha\sigma = 1 \\ > \end{Bmatrix}. \tag{4.11}$$

In the case $\alpha\sigma < 1$, the small firm has an advantage and increases its R&D expenditures with increasing α. Once an equal success probability is reached, the small firm is no longer at an advantage and will no longer increase R&D expenditures. In the case $\alpha\sigma > 1$, the large firm is stronger and the small firm decreases its R&D expenditures with increasing α. Thus, firms increase their R&D expenditures (and their success probability) as long as they maintain an overall advantage. The opposite holds true for a lower valuation parameter.

An increase of the relative innovative efficiency parameter from σ to σ' results in a shift to the right (upward) of the large firm's reaction function above curve $\sigma' x_L = x_S$. However, below

curve $\sigma x_L = x_S$ the large firm's reaction function shifts to the left (downward). A graphical illustration is given in Figure 4.3.

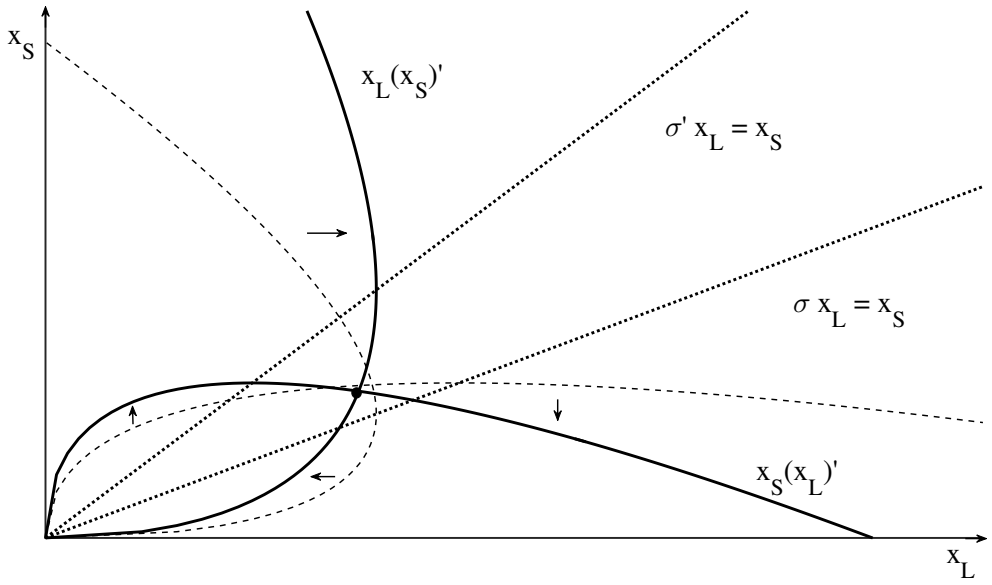

Fig. 4.3: Shifts of reaction functions when the innovative efficiency parameter σ increases

In the case of $\alpha\sigma' < 1$ (i.e., above curve $\sigma' x_L = x_S$), where the small firm is strong, the large firm responds to an increase in the relative innovative efficiency by increasing its own R&D expenditures. Although the large firm's innovative efficiency increases relative to the small firm, it remains an overall disadvantage. The small firm will also increase its R&D expenditures. In the case of $\alpha\sigma > 1$ (i.e., below curve $\sigma x_L = x_S$), where the small firm is weak, the large firm responds to an increase in its innovative efficiency by decreasing its own R&D expenditures. Since the increase in the efficiency parameter worsens the small firm's situation, it will respond accordingly by decreasing its R&D spending. Overall, each firm's R&D expenditure increases with increasing σ until σ reaches $1/\alpha$, and then decreases with increasing σ.

$$\frac{\partial x_L^*}{\partial \sigma} = \frac{-\alpha^3\pi\sigma + \alpha^2\pi}{(\alpha\sigma+1)^3} \begin{Bmatrix} >0 \\ =0 \\ <0 \end{Bmatrix} if \begin{Bmatrix} < \\ \alpha\sigma = 1 \\ > \end{Bmatrix} \tag{4.12}$$

$$\frac{\partial x_S^*}{\partial \sigma} = \frac{-\alpha^2\pi\sigma + \alpha\pi}{(\alpha\sigma+1)^3} \begin{Bmatrix} >0 \\ =0 \\ <0 \end{Bmatrix} if \begin{Bmatrix} < \\ \alpha\sigma = 1 \\ > \end{Bmatrix}. \tag{4.13}$$

In addition, a higher (lower) relative innovative efficiency parameter always increases the success probability of the large (small) firm.

4.3.2 Financial constraints

In addition to the valuation parameter and the innovative efficiency, a firm's financial constraints are considered. In the following the small firm is considered financially constrained, i.e., it can only invest its financial resources ω_S, that is assumed to be under the theoretically optimal R&D expenditures without financial constraints, $\omega_S < x_S^*$.[27] In this case, the firms' optimal R&D expenditures are:[28]

$$x_L^{**} = \frac{\sqrt{\omega_S}}{\sigma}\left(\sqrt{\alpha\pi\sigma} - \sqrt{\omega_S}\right) \tag{4.14}$$

$$x_S^{**} = \omega_S, \tag{4.15}$$

and the corresponding expected profits are:

$$\Pi_L^{**} = \left(\frac{\sqrt{\alpha\pi\sigma} - \sqrt{\omega_S}}{\sqrt{\sigma}}\right)^2 \tag{4.16}$$

$$\Pi_S^{**} = \frac{\sqrt{\pi\omega_S}}{\sqrt{\alpha\sigma}} - \omega_S. \tag{4.17}$$

Whether the large or the small firm is the Nash winner or loser now depends on a combination of the relative patent value, the relative innovative efficiency and the financial resources of the small firm, ω_S. For $\alpha\sigma \geq 1$, the large firm is always the Nash winner, given that the small firm

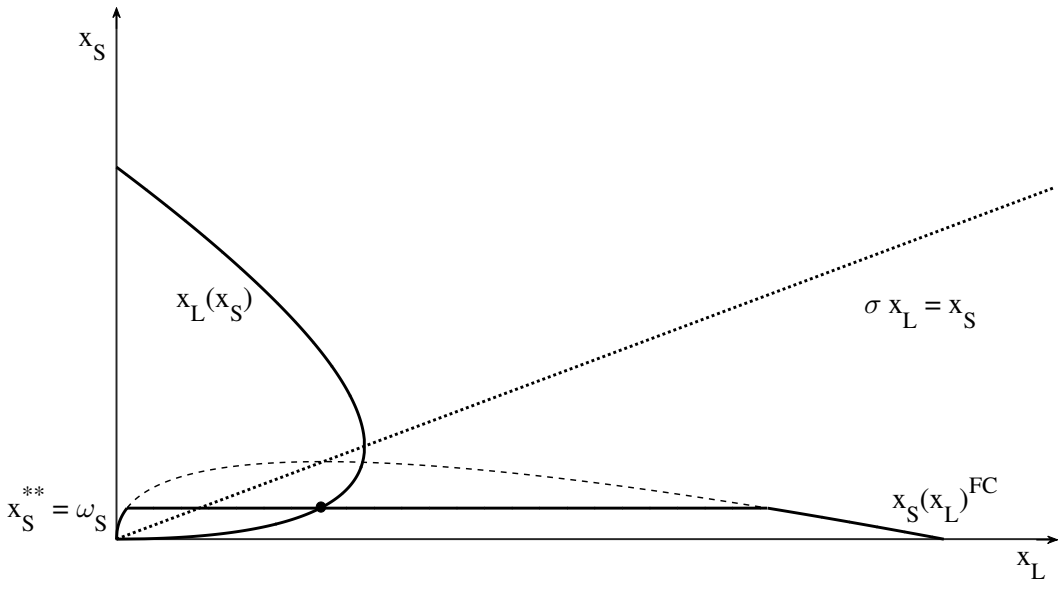

Fig. 4.4: The small firm has an overall disadvantage ($\alpha\sigma > 1$) and is financially constrained

[27] Note that the case where the large firm is financially constrained could also be examined, but would provide no further insight as the large firm is always relative to the small firm.

[28] In order to guarantee a positive investment for the large firm, $\alpha\pi\sigma > \omega_S$ and the non-binding constraint $x_L^{**} \leq \omega_L$ must be fulfilled.

is financially constrained. In this case, the small firm has a comparative disadvantage that is amplified further by its financial constraints (cf. Figure 4.4).

For $\alpha\sigma < 1$, the small firm has a comparative advantage that results in a higher success probability without financial constraints. Thus, the Nash winner is determined by how financially constrained the small firm is. The equal winning probability is described by the points that satisfy $\sigma x_L = x_S$. For an equal winning probability the financial resources of the small firm must equal:

$$\hat{\omega}_S = \frac{\alpha\sigma\pi}{4}. \tag{4.18}$$

If the small firm has less financial resources than $\hat{\omega}_S$, i.e., it is extremely financially constrained, the large firm becomes the Nash winner (cf. Figure 4.5).

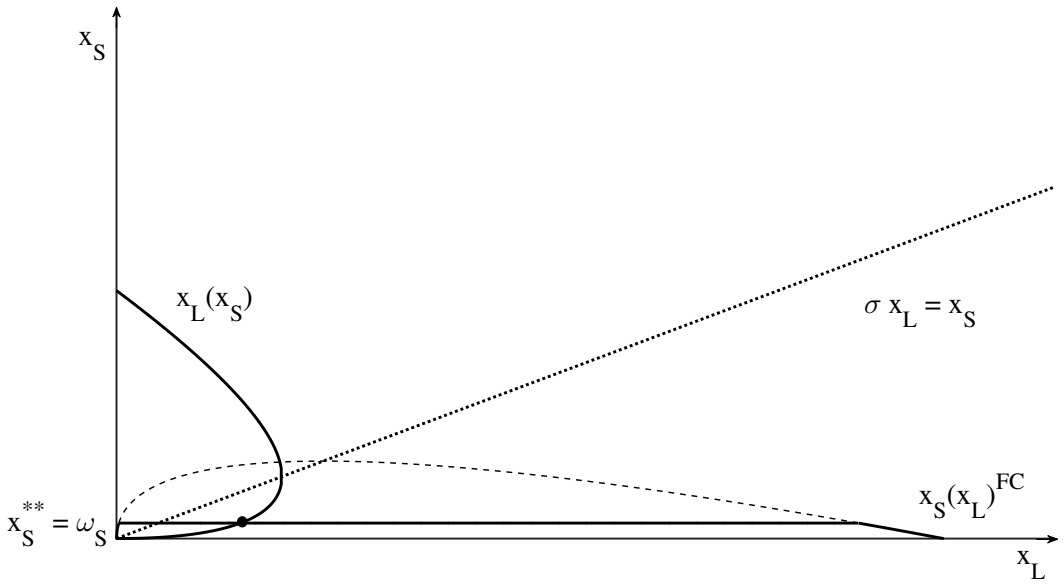

Fig. 4.5: The small firm has an overall advantage ($\alpha\sigma < 1$) but is extremely financially constrained

Although the large firm has a comparative disadvantage, the limited financial resources set this disadvantage off and decrease the small firm's success probability significantly. However, if the small firm's financial resources exceed $\hat{\omega}_S$, it becomes the Nash winner. Thus, if it can overcome the lower valuation of the patent with a higher innovative efficiency, the small firm is the Nash winner despite facing financial constraints (cf. Figure 4.6).

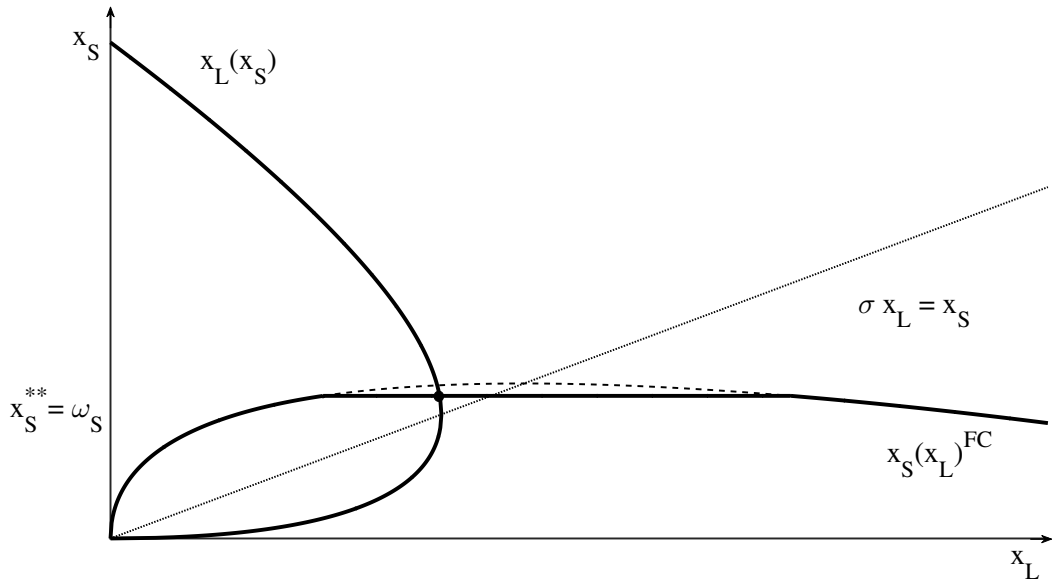

Fig. 4.6: The small firm has an overall advantage ($\alpha\sigma < 1$) but is weakly financially constrained

Overall, all else equal, more financial resources lead to an increase in the small firm's R&D expenditures and its probability of winning until the theoretical optimal expenditures x_S^* are reached.

$$\frac{\partial x_S^{**}}{\partial \omega_S} = 1 > 0. \tag{4.19}$$

The effect of an increase in ω_S on the large firm's R&D expenditures requires further analysis.

$$\frac{\partial x_L^{**}}{\partial \omega_S} = \frac{\frac{\sqrt{\alpha\pi\sigma}}{\sqrt{\omega_S}} - 2}{2\sigma} \begin{Bmatrix} > 0 \\ = 0 \\ < 0 \end{Bmatrix} if \begin{Bmatrix} < \\ \omega_S = \hat{\omega}_S \\ > \end{Bmatrix}. \tag{4.20}$$

If the small firm has financial resources that are below $\hat{\omega}_S$, the large firm raises its R&D expenditures with increasing financial resources of the small firm. Intuitively, the large firm is willing to spend more in R&D activities as long as it remains the Nash winner. Whereas the opposite is true for $\omega_S > \hat{\omega}_S$.

In all cases, more financial resources of the small firm result in a decrease of the large firm's expected profits. In this case, the large firm becomes less likely to win the contest.

$$\frac{\partial \Pi_L^{**}}{\partial \omega_S} = \frac{1}{\sigma} - \frac{\sqrt{\alpha\pi\sigma}}{\sigma\sqrt{\omega_S}} < 0. \tag{4.21}$$

The profits of the large firm decrease with increasing financial resources ω_S since if the large firm invests in R&D activity $\alpha\pi\sigma > \omega_S$ holds true (compare equation 4.14). Consequently, the second term of equation (4.21) is always larger than the first term ($\frac{\sqrt{\alpha\pi\sigma}}{\sqrt{\omega_S}} > 1$).

The expected profits for the small firm will change with increasing financial resources accordingly:

$$\frac{\partial \Pi_S^{**}}{\partial \omega_S} = \frac{\sqrt{\hat{\omega}_S}}{\alpha\sigma\sqrt{\omega_S}} - 1 \begin{Bmatrix} > 0 \\ = 0 \\ < 0 \end{Bmatrix} if \begin{Bmatrix} < \\ \alpha\sigma\sqrt{\omega_S} = \sqrt{\hat{\omega}_S} \\ > \end{Bmatrix}. \tag{4.22}$$

The expected profits of the small firm increase for $\alpha\sigma\sqrt{\omega_S} < \sqrt{\hat{\omega}_S}$. Intuitively, this holds true in the case of $\alpha\sigma < 1$, where the small firm is strong. An increase in its financial resources raises its success probability in all cases because it has an overall advantage. The small firm's expected profits will increase until it reaches its optimal R&D expenditures x_S^*, i.e., it is financially unconstrained. A graphical illustration is given in Figure 4.7.

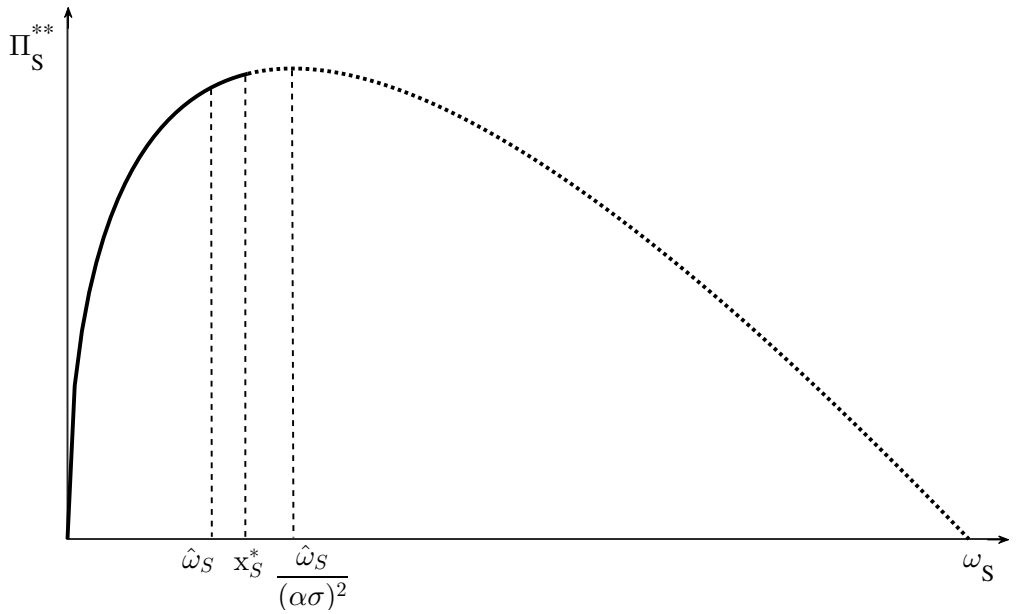

Fig. 4.7: Financial resources and expected profits of the small firm when it has an overall advantage ($\alpha\sigma < 1$)

If the small firm is weak ($\alpha\sigma > 1$), an increase of its financial resources can result in higher expected profits (compare area A in Figure 4.8). This is only the case for $\omega_S < \frac{\hat{\omega}_S}{(\alpha\sigma)^2} = \frac{\pi}{4\alpha\sigma}$, where the marginal revenues exceed the constant marginal costs. This means that an increased winning probability offsets the additional R&D expenditures.

If the small firm's financial resources ω_S are larger than $\frac{\hat{\omega}_S}{(\alpha\sigma)^2}$, its expected profits decrease. Due to the fact that the small firm is financially constrained $\sqrt{\omega_S} < \sqrt{x_S^*} = \frac{\sqrt{\alpha\sigma\pi}}{\alpha\sigma+1}$ holds true. Rearranging this relation yields:

$$(\alpha\sigma + 1)\sqrt{\omega_S} < \sqrt{\alpha\sigma\pi} \tag{4.23}$$

$$\frac{\alpha\sigma + 1}{2}\sqrt{\omega_S} < \sqrt{\hat{\omega}_S}. \tag{4.24}$$

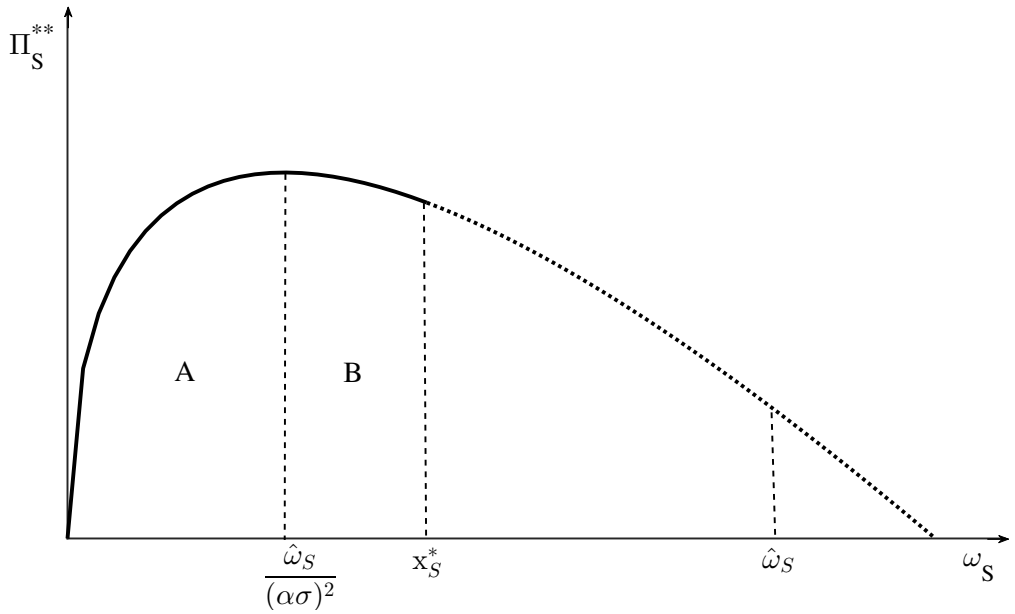

Fig. 4.8: Financial resources and expected profits of the small firm when it has an overall disadvantage ($\alpha\sigma > 1$)

The expected profits of the small firm decrease for $\frac{1+\alpha\sigma}{2}\sqrt{\omega_S} < \sqrt{\hat{\omega}_S} < \alpha\sigma\sqrt{\omega_S}$. In Figure 4.8, this holds true for all financial resources in area B. In the case of $\alpha\sigma > 1$, where the small firm is weak, the additional R&D expenditures are larger than the potential gains. The marginal revenues are below the constant marginal costs. In this case, a more constrained small firm would be preferential as a larger firm will increase R&D expenditures as a result of higher spending by a smaller firm.

Although generally large firms have more financial resources, on an individual R&D project level it is possible that both firm types are comparably financially constrained. In this case, it is optimal for both to invest their financial resources.

$$x_L^{***} = \omega_L \tag{4.25}$$

$$x_S^{***} = \omega_S. \tag{4.26}$$

As an example, the situation where the small firm has an overall advantage ($\alpha\sigma < 1$) is depicted in Figure 4.9. Equilibria, i.e. any intersection between two financially constrained investments, only exist within the shaded lens. The Nash winner is determined by a firm's financial resources and its innovative efficiency. If both are financially constrained, the expected profits in equilibrium are given by:

$$\Pi_L^{***} = \alpha\pi\frac{\sigma\omega_L}{\sigma\omega_L + \omega_S} - \omega_L \tag{4.27}$$

$$\Pi_S^{***} = \pi\frac{\omega_S}{\sigma\omega_L + \omega_S} - \omega_S. \tag{4.28}$$

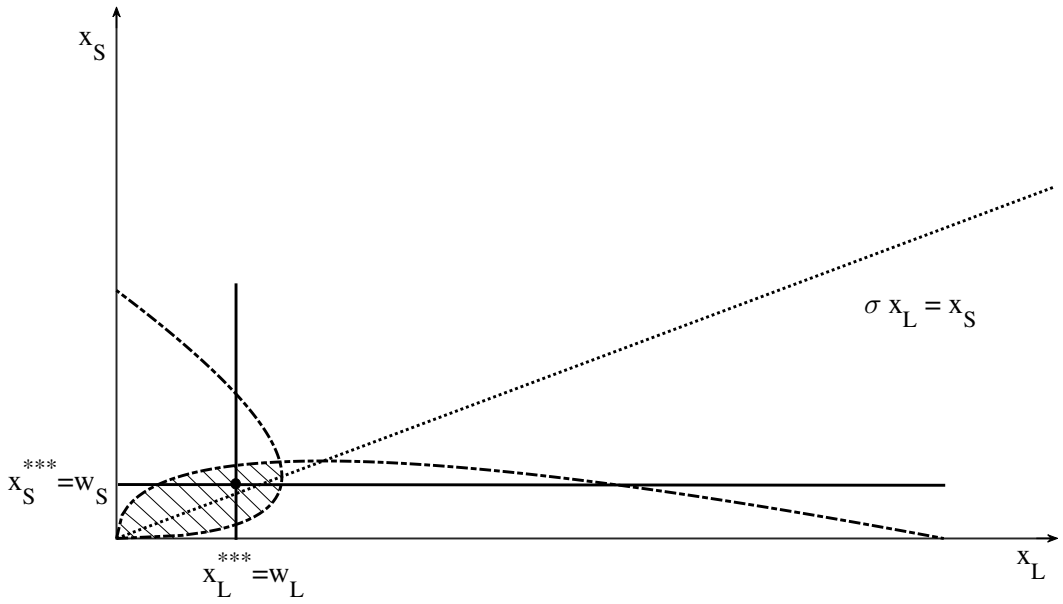

Fig. 4.9: Reaction functions when both firms are financially constrained, and the small firm has an overall advantage ($\alpha\sigma < 1$)

For $\alpha\sigma > 1$ the large firm has larger expected profits if both firms have at least the same financial resources (compare equation 4.29). Alternatively, if $\alpha\sigma < 1$, the small firm has larger expected profits. In case the large (small) firm has less financial resources than its competitor but is overall advantaged, i.e., $\alpha\sigma > 1$ ($\alpha\sigma < 1$), its expected profits are higher or lower dependent on its financial resources and its overall advantage:

$$\Pi_L^{***} \begin{Bmatrix} > \Pi_S^{***} \\ = \Pi_S^{***} \\ < \Pi_S^{***} \end{Bmatrix} if \begin{Bmatrix} \\ \omega_L(\alpha\pi\sigma - \sigma\omega_L) = \omega_S(\pi - \sigma\omega_L) \\ \\ \end{Bmatrix} \begin{matrix} > \\ \\ < \end{matrix}. \tag{4.29}$$

4.4 Conclusion from the model, real world significances and future research

There is a wide debate on whether small or large firms are more capable innovators. The presented model reveals explanations for different outcomes of R&D contests. Table 4.1 summarizes the presented results. In several cases small firms have a higher success probability. Either they value the patent more than large firms and have at least the same innovative efficiency, or they can overcome their relatively lower patent valuation with a higher innovative efficiency ($\alpha\sigma < 1$). Interestingly, this prediction even holds true for small firms that are weakly financially constrained. In this case, if the financial resources of the small firm are sufficiently large, i.e., $\omega_S > \hat{\omega}_S$, innovative efficiency is a lever with which the small firm can overcome its lower

Table 4.1: Summary of results

Relative advantage	x_S^*	$\hat{\omega}_S < \omega_S < x_S^*$	$\omega_S < \hat{\omega}_S < x_S^*$	$\omega_S < \omega_L$
$\alpha\sigma < 1$	$p_S > p_L$	$p_S > p_L$	$p_S < p_L$	$p_S \lessgtr p_L$
$\alpha\sigma = 1$	$p_S = p_L$	$p_S < p_L$	$p_S < p_L$	$p_S < p_L$
$\alpha\sigma > 1$	$p_S < p_L$	$p_S < p_L$	$p_S < p_L$	$p_S < p_L$

This table displays the model's predicted contest outcomes, measured by the winning probabilities p_S and p_L. Column 1 indicates the firms' relative advantage, dependent on the valuation parameter α and the innovative efficiency parameter σ. While for $\alpha\sigma < 1$ the small firm is favored, $\alpha\sigma > 1$ indicates an advantageous situation for the large firm. Column 2 shows the financially unconstrained cases where both firms invest x_S^*. Column 3 depicts the outcomes when the small firm is weakly financially constrained ($\hat{\omega}_S < \omega_S$). Column 4 shows the result when the small firm is extremely financially constrained ($\omega_S < \hat{\omega}_S$). In the last column both firms face financial constraints but the small firm has less financial resources.

incentive to innovate despite limited funds. If the small firm, however, is extremely financially constrained, i.e., $\omega_S < \hat{\omega}_S$, the large firm is more likely to win, even if the small firm is more efficient and values the patent higher. Analogously, on an individual project level innovative efficiency is a lever with which the small firm can overcome its limited funds.

The presented findings are relevant for policy makers. They identify the significant contribution of small firms to innovation. As a result of this finding, the founding of small firms should be encouraged by the government. If small firms have sufficient funding, they can outplay their larger competitors. Public policies designed to promote innovation should therefore facilitate access to finance for small firms. In this context, governments can use regulation to make financial markets more attractive and accessible for small firms. Additionally, small firms should be made more visible for investors. In order to financially help small firms, governments could offer R&D subsidies. Identifying the firms likely to innovate might, however, be challenging (Archibugi et al. 2013). Alternatively, according to Howell (2017), R&D grants given on a one-time basis at an early stage are an effective option.

Although prior empirical literature examined the characteristics of the most innovative firms, they focused on the average success of small versus large firms due to difficulties in observing contestants. These results, however, might be biased since only successful small firm innovators are included in the sample. Making use of U.S. patent data, Thompson and Kuhn (2020) provide a novel strategy to identify direct contestants, i.e., firms that compete for the same patent. Using this approach, the accuracy of the model could be examined using the outcome of real innovation contests. For example, it could be directly explored whether financially unconstrained small firms (e.g., measured by employee size) outperform their larger contestants. Based on the model, this should be the case if they have a higher innovative efficiency and/or value the patent more. In the study by Thompson and Kuhn (2020) which examines R&D contests between publicly traded firm pairs, small firms more often win the patent. Although they claim that the contestants in their sample are similar, the small firms have a slightly higher innovative efficiency (R&D intensity, measured by R&D expenditures per patent). A more thorough analysis of the model parameters is needed to assess their relative importance. Empirically, the role of innovative efficiency could

be potentially disentangled from the valuation parameter by following specific employees as they move to different firms. Similar to Akcigit and Kerr (2018), it could be examined how innovation qualities and types (process vs. product innovation) relate to firm characteristics. Conclusions on the expected profits resulting from the innovations could then be drawn. Alternatively, patent valuations could be measured by using takeover offers for small firms, as suggested by Phillips and Zhdanov (2013).

In the future, the impact of financial resources in direct R&D contests must be examined. Based on the model, weakly financially constrained firms are expected to win if they can overcome their limited resources with a higher patent valuation and/or a higher innovative efficiency. This hypothesis is in line with empirical findings from Almeida et al. (2013). They show that on average weakly financially constrained firms have a higher innovative efficiency, resulting in a higher innovative success rate. On an individual project level, severe financial constraints also delay firm innovation (Kukuk and Stadler 2001). Given that both firms are comparably financially constrained, the firm with the higher innovative efficiency should win.

In summary, the model could be applied to empirically explore many different aspects of the innovative process.

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Chapter 5
Identifying Corporate Venture Capital Investors: A Data-Cleaning Procedure

Abstract The majority of research on corporate venture capital relies on data retrieved from secondary databases. However, various databases define CVC differently. Generally, researchers rely on the definition of the used database. As a result, empirical CVC research is not readily comparable, and replicability across databases is often impossible. This article examines the scope and consistency of the most popular databases in CVC research: Eikon from Thomson Reuters and Dow Jones' VentureSource. The outcome is a replicable data-cleaning procedure based on an appropriate CVC definition. The article provides a necessary basis for the future discourse on CVC.

5.1 Introduction

Corporate venture capital is increasingly becoming a means through which established firms gain an edge in today's business. Investment funds, or in this case CVC units, are established within a parent company (Dushnitsky 2006). The funds target nascent firms with promising technologies that are usually strategically aligned with the mother firm (Ernst et al. 2005). CVC investments provide start-ups with capital and industry knowledge, and in turn, the parent companies acquire access to potentially disruptive technologies and emerging markets (e.g., Dushnitsky and Lenox 2005). The increased CVC activity has stimulated academic interest in the topic, resulting in a rapidly growing body of research (see Röhm 2018 for an overview). However, empirical research into its workings and impact has been hindered by data limitations and the absence of a common definition of CVC. This makes it particularly difficult to gauge the progression of CVC research.

There have been some attempts to propose a common theoretically-grounded CVC definition for future empirical work. Chemmanur et al. (2014), for example, define several dimensions that a firm should comply with in order to be considered a CVC. In their view, CVCs are stand-alone subsidiaries of nonfinancial corporations that strategically invest in new ventures on behalf of their corporate parents to enhance competitive advantage. CVCs typically pursue both strategic and financial goals and are characterized by a managerial compensation practice that is tied to the parent company's performance.

In contrast, the majority of empirical studies base their definition of CVC on presets from the corresponding data providers, each of which has its own slightly different CVC definition. VentureSource classifies investors as a CVC if they invest in ventures through a dedicated fund to simultaneously achieve financial and strategic objectives (personal communication, September

2017; VentureSource 2018*a*). Eikon treats corporate subsidiaries as CVCs if they are actively involved in PE related investments (personal communication, September to October 2017). According to Crunchbase, a CVC is an arm of a corporation that invests in innovative start-up companies, whereas Pitchbook considers all forms of equity investment to be CVCs. CB Insights defines CVCs as specialized divisions of larger companies that directly invest in external private companies.[29] Even for the same database, it is hard to replicate empirical results because the understanding of CVC activities varies among researchers (see, e.g., Dushnitsky 2006 for an overview) and most studies give no detailed information on the applied search settings within the commercial databases. Additionally, researchers have reported inconsistencies among databases (e.g., Lerner 1994, 1995; Kaplan et al. 2002; Maats et al. 2011). In fact, we are unaware of any detailed comparison of CVC databases.

Based on the theoretical literature, we define CVC units as wholly-owned subsidiaries of non-financial corporations that invest in start-ups on behalf of their corporate parent (e.g., Souitaris et al. 2012; Chemmanur et al. 2014). Using this definition, we propose a replicable data-cleaning procedure for the two most popular CVC research databases: Eikon from Thomson Reuters and Dow Jones' VentureSource.[30] We thereby help to put future CVC research on a common footing, which would facilitate academic discussion and promote coherence across future research. Additionally, we contribute to the literature on the consistency and reliability of venture capital related databases by shedding light on the scope of CVC data in the two most extensively used databases.

5.2 Relevant databases for CVC research

To identify the most prominent databases for CVC research, we conducted an extensive literature review based on Elsevier's Scopus database. We searched Scopus for occurrences of the search strings venture capital or corporate venture capital in either the title, abstract, or keywords. Additionally, we limited the results to academic papers published in journals before March 2018 and written in English; applying the initial criteria meant we downloaded 2,128 articles. To extract information about the underlying databases used by the articles, we drew on the text analysis program Linguistic Inquiry and Word Count from Pennebaker et al. (2015), and controlled for inconsistencies in spelling. With 551 appearances, Eikon (also known as Thomson One, VentureXpert, or Venture Economics and with a history of data collection going back to 1961) is used most extensively, followed by VentureSource (also known as VentureOne that has been collecting data since 1994) with 95 appearances. Other databases such as Crunchbase (26 appearances), Preqin (31 appearances), Pitchbook (9 appearances) and CB Insights (9

[29] Prequin does not provide any specific definition of CVC but considers it a subgroup of VC.

[30] Note that the VentureSource data is now offered by CB Insights who acquired the database from Dow Jones (CB Insights 2020).

appearances) play only a minor role.[31] The results are similar to those of Da Rin et al. (2013), who reported that the two primary commercial databases used in VC research are Thomson Reuters' Eikon and VentureSource from Dow Jones. Hence, we will focus on these two databases in the remainder of this paper.

VentureSource provides information for 36,000 CVC investors and offers data points for about 101,000 private equity (PE-) and VC-backed companies (VentureSource 2018*b*). In comparison, the "private equity screener" of Eikon comprises information on about 22,000 investors with 51,000 funds and a total number of 133,000 PE- and VC-backed companies (Thomson Reuters 2018). To gather information both databases rely on extensive quarterly surveys of investors in the VC industry; surveys that grant access to sensitive information that is not presented in official deal statements. Additionally, VentureSource uses its Factiva database and a web-crawler to identify information from press releases and investors' homepages (personal communication, September 2017). Likewise, Eikon draws on government filings, public news releases, and on PE newsmakers including the European Venture Capital and Private Equity Journal (personal communication, September to October 2017; Thomson Reuters 2008, 2010).

5.3 Data sample

To develop a common data-cleaning process for the given CVC definition, we rely on the two primary databases: Eikon and VentureSource. For each database we construct two samples, one for U.S.-based CVCs and one for CVC vehicles headquartered in Europe.[32] As described by Gompers and Lerner (2000) CVC activities are recurrent and strongly related to the general economic condition. In order to cover a full boom-bust cycle, we draw on an extensive dataset ranging from January 2000 to December 2015.[33] In addition, we do not restrict the country of origin of the investees, thus allowing for cross-country investments. We are well aware of the fact that particularly the VC market in Europe is highly diverse in terms of institutional attractiveness (Groh et al. 2010). However, using Europe as a subsample makes it possible to demonstrate the data-cleaning procedure in two geographical areas that are commonly used to describe VC-, PE-, and CVC-related phenomena.

In both databases, the search criteria were set to an appropriate minimum, reducing the risk of omitting a CVC unit owing to incorrect classification in the databases. Accordingly, in addition to using geographical settings, we predefine "Corporate Venture Capital" as an investor type in VentureSource and "Corporate PE/Venture" as a firm type in Eikon. For the predefined period of

[31] Because some articles discuss several databases simultaneously, the counts cannot be interpreted as mutually exclusive. Some empirical studies also rely on unique, mostly hand-collected data alongside the use of databases.

[32] Note that Europe also includes the non-EU countries Iceland, Norway, Russia, Switzerland, and Turkey.

[33] According to CB Insights (2017) corporate venture capital amounted to $16.8 bn. in 2000 before it substantially fell off after the dot-com bubble burst. It then began to increase again (before dipping during the financial crisis) and reached its current maximum of $28.4 bn. in 2015.

sixteen years we found 629 investors, 9,602 investees and a total of 19,077 investment rounds for the U.S.-based Eikon sample (Europe: 282 investors, 2,737 investees, 4,540 investment rounds). For VentureSource our initial data set for the U.S. comprised 235 investors, 4,532 investees and a total number of 7,719 investment rounds (Europe: 171 investors, 2,026 investees, 3,283 investment rounds). The previously specified samples serve as a starting point for the subsequent data-cleaning process.

5.4 Data-cleaning process

The proposed data-cleaning procedure comprises seven steps and results in a generic definition for a CVC unit. The underlying methodology of the data-cleaning procedure is shown in Figure 5.1.

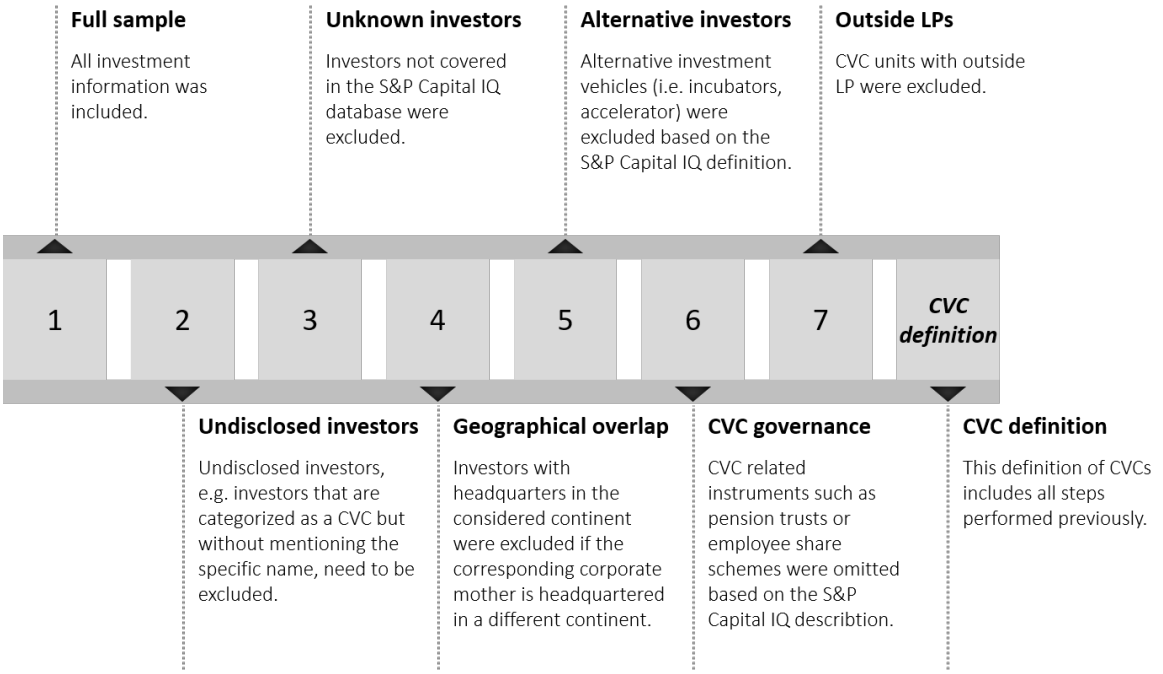

Fig. 5.1: Underlying methodology of the proposed data-cleaning procedure

In the following section, we introduce each step of the procedure and discuss how the underlying samples from both databases are affected. Table 5.1 offers an overview in numbers of the excluded investors, investees, and investment rounds for both data providers and for each continent separately based on the applied criteria.

Table 5.1: Results from the database queries for U.S. and European-based CVCs

		Thomson Reuters Eikon				DowJones VentureSource			
		U.S.		Europe		U.S.		Europe	
		N	in %	in %	in %	N	in %	N	in %
Step 1: Full sample	Initial investors	629		282		235		171	
	Initial investees	9602		2737		4532		2026	
	Initial rounds	19077		4540		7719		3283	
Step 2: Undisclosed investors	Excluded investors	1	0 %	2	1 %	0	0 %	0	0 %
	Excluded investees	3101	32 %	5	0 %	0	0 %	0	0 %
	Excluded rounds	6332	33 %	8	0 %	0	0 %	0	0 %
Step 3: Unknown investors	Excluded investors	44	7 %	25	9 %	11	5 %	7	4 %
	Excluded investees	92	1 %	157	6 %	24	1 %	14	1 %
	Excluded rounds	199	2 %	213	5 %	43	1 %	16	0 %
Step 4: Geographical overlap	Excluded investors	80	14 %	7	3 %	50	22 %	4	2 %
	Excluded investees	731	11 %	55	2 %	571	13 %	12	1 %
	Excluded rounds	1885	15 %	69	2 %	1161	15 %	19	1 %
Step 5: Alternative investors	Excluded investors	63	13 %	61	25 %	15	9 %	13	8 %
	Excluded investees	507	9 %	636	25 %	86	2 %	250	13 %
	Excluded rounds	901	8 %	1089	26 %	207	3 %	510	16 %
Step 6: CVC governance	Excluded investors	240	54 %	31	17 %	33	21 %	21	14 %
	Excluded investees	843	16 %	123	7 %	276	7 %	69	4 %
	Excluded rounds	1828	19 %	155	5 %	419	7 %	91	3 %
Step 7: Outside LPs	Excluded investors	22	11 %	17	11 %	10	8 %	11	9 %
	Excluded investees	1313	30 %	434	25 %	1231	34 %	362	22 %
	Excluded rounds	2604	33 %	732	24 %	2168	37 %	660	25 %
CVC definition	**Remaining investors**	**179**		**139**		**116**		**115**	
	Remaining investees	**3015**		**1327**		**2344**		**1319**	
	Remaining rounds	**5328**		**2274**		**3721**		**1987**	

This table reports the initial investors, investees and rounds for Thomson Reuters Eikon and DowJones VentureSource that were available for the United States and Europe. In addition, the number of excluded investors, investees and rounds is displayed for each proposed data-cleaning step.

5.4.1 Undisclosed investors

Building on the initial step of retrieving the raw data from the databases, we drop all CVC units where only information on the investee but not on the investors was available. This only affected the Eikon samples, in which unknown investors are categorized as "Undisclosed Investors" in the U.S. data and as "Undisclosed Firm" or "Other UK Investor(s)" in the European data. The omission of such investors led to the exclusion of 3,101 (5) investees in the U.S. (Europe) sample. This step eliminates one third of the hits from the U.S. sample. Eikon indicates the investors are inactive or unknown. Eikon either does not have the full information for these cases or promised the CVC investors to keep the information confidential for the next six months or until the next financing round has passed. The fact that this is largely observed in the United States and not in Europe potentially can be traced back to differences in the CVC markets. U.S. American start-ups have a broader set of funding options than their European counterparts. As a result, they can operate with more secrecy and timing defense strategies (Colombo and Shafi 2016).

Using a manual double-check with other sources for each investment might be appropriate for some research questions. This, however, exceeds the scope of this paper.

5.4.2 Unknown investors

Third, we merge all investor specific information with data from the Capital IQ platform of Standard & Poor's. This made it possible to triangulate our data by drawing on an extensive pool of more than 4 million companies (S&P Global 2018). Compared to other databases, Capital IQ offers a broad coverage of both private and public companies. The database provides information on the investors' business descriptions and information related to the company affiliation. We exclude all investors where we could not find a fitting investor profile in the Capital IQ database. Doing so ensured data consistency and simultaneously provided a solid and reliable foundation for the subsequent steps. This step led to the exclusion of 44 U.S.-based investors appearing in the Eikon sample (25 in Europe) and 11 appearing in the VentureSource sample (7 in Europe).

5.4.3 Geographical overlap

The fourth step includes the analysis of the investors' position within an existing corporate network. This is important because knowledge typically flows from the investor to the corresponding corporate mother (e.g., Gupta and Govindarajan 2000). Hence, the corporate mother determines the geographical affiliation. However, previous articles in the field of CVC limit their empirical analysis to one geographical area (Röhm 2018), thus making them vulnerable to excluding external factors such as cultural aspects or institutional settings. Therefore, authors need to clarify if their selected CVC units are still suitable to their research question. In order to elucidate the ownership status and thus determine the geographic affiliation, we draw on the Capital IQ database to identify potential corporate mothers for each investor. Accordingly, we use the business descriptions in conjunction with the corporate tree function of Capital IQ to clearly match the investor to a corporate mother. Although we excluded non-U.S. and non-European investors from our sample construction, we could still identify a large number of investors with a corporate mother from an excluded geographical region. For instance, German-based companies such as BMW and Bertelsmann operate investment vehicles in the USA. Both databases classify these CVC units as U.S.-based, although the corporate mother is from Europe. Accordingly, we omit all CVC units with a corporate mother from a different region. This procedure resulted in the exclusion of 80 investors from the U.S. sample of Eikon (7 in Europe) and 50 from VentureSource (4 in Europe).

5.4.4 Alternative investors

Based on the business description, we omit business associations, NGOs, universities, regional development vehicles, advisory firms, independent VCs, and several other non-CVC investment vehicles such as hedge funds, PE investors, and business angels. These investor types were initially recorded as CVC units in the databases but do not meet the definition due to missing corporate parents or because of their own descriptions of the unit in the Capital IQ database. Including them would therefore risk skewing the empirical analysis. Accordingly, between eight and twenty-five percent of the remaining investors were removed.

5.4.5 CVC governance

The sixth step includes the deep analysis of the remaining corporate investment vehicles. Following Dushnitsky (2006), corporations can structure their venturing activities in three ways: first, they can act as a limited partner (LP) in already existing funds of independent venture capitalists (IVCs). Second, the investments can be organized through an operating business unit responsible for the venturing strategy (also called direct investments). In practice, it is mainly R&D or business development units that are responsible for such transactions (Bertoni et al. 2013). Third, CVC units can also be organized as wholly-owned subsidiaries within corporate boundaries. The problem, however, is that investments made through IVCs cannot be assigned to a specific corporate LP and are therefore not observable in the databases. There are also challenges involved in clearly matching direct CVC investments, because commercial databases only provide information about the existing corporate entities but not on the business unit level. Consequently, only wholly-owned subsidiaries were considered in the further analysis using the corporate trees in Capital IQ. In line with Dushnitsky and Lenox (2005), we also exclude corporate pension trusts and comparable investment schemes. This step led to the exclusion of 54 percent of the remaining investment vehicles in the U.S.-based sample of Eikon (17 percent in Europe) and 21 percent of the remaining VentureSource investors (14 percent in Europe).

5.4.6 Outside LPs

In contrast to the proper sense of CVC, some corporate venture units act as a general partner (GP) for external investors. In this case, LPs such as insurance firms, can invest in a fund organized and run by a CVC and benefit from the knowledge and experience of the GP. However, this investment practice is accompanied by a risk of sharing knowledge with actual or potential competitors through a knowledge outflow. Therefore, we excluded CVC vehicles with external LPs. This results in the exclusion of 22 investors appearing in the Eikon U.S. sample (Europe

17), including prestigious CVCs such as Intel Capital. Looking at the VentureSource samples we excluded investors of similar magnitude resulting in a drop of 8 (9) percent of the remaining investors in the U.S. (European) sample.

5.4.7 CVC definition

The process deployed above yields the specified CVC vehicles. Of 629 (282), we consider 179 as CVCs in the Eikon sample (Europe 139). In VentureSource, we identify out of 235 (171) listed CVCs, 116 (115) for the USA (Europe). All other firms cannot be considered a CVC because they are funded by financial companies, partnerships, or multiple corporate parents, or have a foreign or unknown parent (Chemmanur et al., 2014).

A large number of the identified CVCs are present in both databases. In particular, we identify 75 (65) shared CVC investors in the U.S. (European) sample. Overall, it appears that Eikon offers a greater availability of CVC investors. However, a closer look reveals that this is mainly driven by past data points. More recently, VentureSource has caught up, offering similar numbers of CVC investors (see Table 5.2). Examining the industry groups of the unique investors reveals that

Table 5.2: Comparison of unique CVCs and investment rounds (follow-on rounds excluded) covering the period 2000 to 2015

		2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Unique CVCs U.S. sample	VentureSource	31	29	24	28	26	29	25	26
	Eikon	63	58	36	44	37	43	38	38
Investment rounds U.S. sample	VentureSource	288	180	117	109	107	136	147	147
	Eikon	716	321	166	134	150	161	214	227
Unique CVCs European sample	VentureSource	23	24	26	25	21	21	22	23
	Eikon	26	25	23	19	20	21	14	21
Investment rounds European sample	VentureSource	78	103	79	94	80	81	78	103
	Eikon	113	98	64	81	94	83	77	98

		2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Unique CVCs U.S. sample	VentureSource	35	33	33	34	30	31	36	43
	Eikon	45	34	35	42	36	38	43	45
Investment rounds U.S. sample	VentureSource	147	136	176	203	217	252	313	381
	Eikon	234	159	210	244	246	263	284	354
Unique CVCs European sample	VentureSource	27	24	27	23	24	31	36	38
	Eikon	29	19	23	22	29	27	31	38
Investment rounds European sample	VentureSource	104	77	78	110	173	85	110	122
	Eikon	112	82	85	82	102	107	129	138

This table reports the number of uniquely identified CVC and investment rounds for the United States and Europe for both, VentureSource and Eikon, over time.

Eikon is especially suited for U.S.-based CVCs from the transportation and utilities industries (Standard Industrial Classification (SIC) codes starting with 4). In comparison, VentureSource has a greater availability of European CVCs from the manufacturing industry (SIC codes starting

with 2 or 3) and U.S.-based CVCs from the service industry (SIC codes starting with 7 or 8). Regarding the covered investment rounds, Eikon systematically offers greater data coverage with one exception: VentureSource covers more investment rounds in the European sample between the years 2011 and 2012.

5.5 Conclusion

This article seeks to address how CVC activity is measured and in which ways the commonly used databases, namely Eikon and VentureSource can be used to reach a theoretically defined dataset of CVCs. Most published studies provide researchers with insufficient information about the technical definition of CVC or base their empirical work on the definition of the commercial data providers. We propose a data-cleaning procedure to promote future coherence in research. Future research could also apply our data-cleaning procedure to repeat previous studies. It would be interesting to see whether differences in the results can be traced back to the data-cleaning procedure. The presented results significantly contribute to the ongoing discussion of CVC. We provide a data-cleaning process allowing researchers to more generically define CVC. This would increase comparability and replicability of the research results. Moreover, we provide a comprehensive analysis of the data coverage in the commonly used databases of Eikon and VentureSource. This can help researchers decide which data provider is better suited for their research question.

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Chapter 6
Conclusion and Outlook

The goal of the presented work was to gain a more thorough understanding of the modern financial system's function and its utilized infrastructure in developed countries.

The first part of this dissertation specifically looked at the role of banks in developed countries. Chapter 2 explored the importance of lending and payment and transaction services from banks for SMEs, utilizing the unique situation of the U.S. marijuana industry. The presented paper used a mixed-method approach, consisting of event studies and a self-administered survey, to identify the perceived value of different banking services. As expected, the study finds bank financing relevant for SMEs. Rather surprisingly, the banks safekeeping depository and efficient payment services were found to be perceived significantly more important. Contrarily, in developing countries, where only a small percentage of the population uses banking services, research has found that payments could be adequately covered by alternative service providers (FinTechs). One prominent example in literature is Kenya's M-Pesa (Jack and Suri 2014; Beck et al. 2018). Based on the findings in this dissertation, however, in developed countries, it appears that banks today play a too integral part in transaction processing and safekeeping deposits, preventing widespread use of alternatives. Thakor and Merton (2018) and Stulz (2019) trace this back to the demand for safe assets and the existing deposit insurance, that make banks innately more trustworthy than FinTechs. Thakor and Merton (2018) also point out that this distinction provides banks with a competitive funding-cost advantage over non-depository lenders. The findings here indicate that access to banking services in developed countries remains vital for SMEs. Today, specialized FinTechs have not yet taken away significant market shares from banks, and there is even evidence that banks encourage experimentation in this space and often take over successful FinTechs (Hornuf et al. 2018). The results should be considered in future policies. Future attempts to boost the growth of SMEs should not only focus on providing adequate financing but also guarantee access to bank transaction and savings services.

Currently, banks are not only an integral part of payments and transactions on a national level but also are necessary for cross-border payments. Although national (or currency-zone-wide) payment systems have undergone continuous digitization and innovation over the last decades (Rysman and Schuh 2017), the cross-border payment system has barely changed (Committee on Payments and Market Infrastructures 2018). DLT has the potential to revolutionize cross-border payments, which currently are still carried out via correspondent banks. In a world where BigTech firms, like Amazon and Alibaba, enable online real-time payment and tracking, customers struggle to accept opaque, costly and long-lasting cross-border payments processed by banks. The study presented in Chapter 3 showed theoretically that the use of a permissioned DLT system (e.g., RippleNet) could significantly reduce economy-wide transaction costs. A widespread use

of DLT would make traditional correspondent banks needless because the technology allows the direct interaction between the sender and the beneficiary bank. This increases the efficiency of the financial system and eases the trade of goods and services, stimulating economic growth. So far European and U.S. BigTech firms (in contrast to Alibaba in China) have not been very active in financial services. In case BigTechs start to branch out more from the provision of digital (platform) services into financial services, the banking landscape could profoundly change, also in developed countries. The digitization and potential entrance of BigTechs poses new research questions on risk sources, such as cyber risk, and might require a stronger focus of regulators on consumer protection. Overall, however, based on the findings here, correspondent banks are likely to disappear in the future.

The second part of this dissertation examined the effect of financial constraints and R&D investment on innovation. Chapter 4 used an asymmetric contest model to theoretically answer under what conditions small firms have an innovative advantage. The presented model reveals explanations for different outcomes of R&D contests based on variation in the firms' innovative efficiency, patent valuation and financial resources. It is shown that small firms can be the patent winner if their innovative efficiency is high enough to overcome their financial constraints, even in cases of lower patent valuation. Although the findings here indicate that innovative efficiency can be a lever to overcome financial constraints, small firms always require a certain level of financial resources. Public policies designed to foster innovation should therefore facilitate access to finance for small firms. This is especially important because small firms are better at generating major breakthroughs whereas larger firms focus more on incremental refinements of products (Akcigit and Kerr 2018; Knott and Vieregger 2020). According to Howell (2017), R&D grants given on a one-time basis at an early stage are an effective medium. Alternatively, governments can use regulation to make financial markets more attractive and accessible for small firms (Kerr and Nanda 2009; Brown et al. 2013). More information on the interdependency of financial constraints and innovative efficiency is still needed. In this context, the role of access to non-financial resources is also a promising research area.

In addition to R&D grants by governments, recent empirical evidence shows that the unique combination of corporate expertise and research laboratories in the context of venture-backed start-ups spurs innovation. CVCs not only promote innovation at the start-up level (Chemmanur et al. 2014; Colombo and Murtinu 2017) but also at the investor level (Dushnitsky and Lenox 2005; Maula et al. 2013; Ma 2020). Empirical research on the impact and workings of CVC is difficult due to limited data. The majority of studies rely on data obtained from commercial vendors such as Thomson Reuters, Dow Jones, etc., that all have varying CVC definitions (Röhm et al. 2020). Chapter 5 provided a proposal for ways to standardize CVC research. A widespread use of the presented data-cleaning procedure would increase comparability and replicability of empirical studies and thus promote future coherence in CVC research.

In conclusion, in the future digitization is projected to drastically change the financial landscape. The evolution of the bank-customer relationship in the last decades as a result of internet-enabled services (e.g., online banking) forebodes the potential future advancement. Already in the near future, interbank intermediaries could become superfluous as a result of DLT. At this point, however, banks in general are still too integrated into the financial system of developed countries. Predicting what role banks will play for SMEs in the future is difficult and offers further opportunities for research. Innovation continues to be an important driver for economic growth. Using a theoretical model it was possible to explain why SMEs more often discover innovations despite being financially constrained. Large firms also utilize the higher innovative efficiency in small firms by engaging in CVC. As CVCs are becoming ever more popular, research interest will continue to increase. A broad application of the presented data-cleaning procedure would facilitate to gauge progression of CVC research. Specifically, a deeper knowledge of CVCs and other financial intermediaries and markets on the amount and nature of firm-level innovation is needed. As the financial system develops, with new regulations and financial innovation changing the landscape, new questions and challenges for researchers will arise.

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