The rate of collateral reuse within the financial system

Implications on bank and non-bank financial institution regulation

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The Rate of Reuse of Collateral within the Financial System

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The main subject of this thesis is the activity of collateral reuse - an activity that connects traditional and non-bank financial institutions (NBFI) across the global financial markets. As this opaque activity remains largely unregulated, this dissertation focuses on the question of whether reuse of collateral should be regulated or left to discretion of reusing financial intermediaries that include both traditional banking institutions as well as NBFIs. The general conclusion is that the activity of collateral reuse could benefit from regulation of the collateral reuse rate or the portion of the collateral assets that is reused in subsequent transactions. Such regulation is especially beneficial in times of low credit quality of the reusing financial institutions.

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The Rate of Reuse of Collateral within the Financial System
Implications on Bank and Non-Bank Financial Institution Regulation

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Acknowledgments

My PhD journey was anything but conventional. All my life, I have known that I wanted to do a PhD; however, my early educational and career choices took me on another path - a path of actuarial consulting, later followed an MBA at a top global school and a successful career in finance. Nevertheless, the idea of the PhD had lingered in my mind until, in my mid-thirties, I started to hear the proverbial "last bell" to embark on the PhD path. Many have told me that I was too old to start a PhD, especially a quantitative one, as apparently one peaks with their mathematical skills at age 27; I heard many times that no PhD program would accept someone of my age, etc. As stubborn as I am, I decided to prove all these nay-sayers wrong and I quit my corporate career to pursue a path in academia.

In hindsight, the nay-sayers were right. My older brain was slower, the math somehow got harder and none of the five or so PhD programs that I originally applied to accepted me. It took two scientific Master programs to convince others that I am still capable of doing a PhD in finance and to learn the skills and tools necessary to do so. What followed were long years of dissertation work - first as a full-time PhD candidate at University of Amsterdam, and later attempting to write this thesis alongside a highly-demanding full-time corporate job (yes, after all, I decided that I belong in the corporate world).

Ten years later, here I am at the end of the PhD journey. It has been the hardest achievement in my life and a lesson in self-discovery, humility and perseverance. What is certain is that I could not have gotten here without the help of countless kind souls and organizations that have supported me along the way.

First and foremost, I would like to thank my supervisor, Enrico Perotti, and my co-supervisor, Jan Wrampelmeyer, for their invaluable guidance and undying patience throughout this process. I will never forget Enrico's willingness to take me under his experienced supervisor wing after my original supervisor resigned - that moment truly was a turnaround for my thesis. The ideas and challenges of Enrico and Jan were essential in shaping my scattered research thoughts into the chapters of this dissertation, and their kind support and trust in me, especially in the moments where I had lacked that trust myself, were crucial to my perseverance with this project. Finally, I greatly appreciate their patience while working with me after I started my corporate job and had very scarce time and limited energy to continue with my dissertation.

In terms of support that I have received from various organizations, I thank the University of Amsterdam and its Faculty of Finance for trusting in me and offering me a full-time PhD position to pursue this dissertation. I am very grateful to my colleagues at the faculty for creating an environment for inspiring discussions and exchange of ideas. In addition, I wrote the third chapter of my thesis while working for the Financial Stability team at the Dutch National Bank. Through the employment at the Bank, I was able to receive access to a brand new and exciting data set managed by the European Central Bank (ECB), which became the basis for Chapter 3 of this dissertation. Working alongside national bank professionals gave me important insights into the world of financial policy and regulation, which is a topic very relevant for this thesis. I am especially grateful to Jeroen Huiting for coordinating and managing my stay at the Dutch National Bank. I also would like to thank the Securities Financing Transactions Data Store team at the ECB for granting me an early access to the database and working with me to support the data extraction process.

I would have not gotten through this PhD process without the emotional support of my fellow PhD friends. They say that hardships bring people together and it is definitely true in our case. Domenico, Benji, Paul and Ioana - a heartfelt thank you for the listening ears and the crying shoulders over the years, especially when the impostor syndrome was making me doubt myself. As importantly, our tears and sighs had been nicely dispersed with fun travels, nights of cooking and wine, intense discussions and getting lost in techno beat. We were there for each other through the good and the bad, and I will always cherish the friendship that grew out of this experience.

I would like to thank my parents, Eugeniusz and Emilia, to whom I will forever remain grateful. They have always allowed me to make my own decisions and supported me no matter how unconventional they seemed. Their ongoing trust that I will succeed, no matter what obstacles life throws at me, shaped me into the independent woman that I am today. In addition, from early on, they instilled in me a belief that education is the only fool-proof way to lift oneself up in this world, and it is thanks to this belief that I embarked on this path to become a Doctor of Philosophy.

I would like to end with a big THANK YOU to my life partner, Wieger. You have been with me through most of my PhD journey, and it was your undying support and faith in me throughout this tough and long process that made it possible. I will never forget your countless sacrifices to help me achieve this goal: starting with the move from your beloved Berlin to Amsterdam so that we could be together during my PhD studies, all the way to being alone on long weekends in Basel and taking care of our household as I was trying to finish my thesis while working full-time. It had not been an easy process for me and you were truly there for better or worse - I simply could not have done it without you. I cannot promise that my restless overachiever mind does not come up with another crazy idea of something to achieve in the future, but I hope that in the meantime we can enjoy the well-deserved peace and relaxation that come with the end of my PhD journey.

Contents

Introduction

The last two decades have seen a few financial crises that rippled across the globe and wreaked havoc on the global financial system, with important negative spillovers to the real economy. Those crises include the global financial crisis of 2008-2009 ("GFC"), the global liquidity shock that ensued at the onset of the global COVID-19 pandemic in the spring of 2020 and, to a smaller extent, the liability-driven investor crises of 2022 in the UK and the Netherlands. These crises exposed various vulnerabilities of the global financial system.

As a response, various banking and liquidity regulation has been rolled out across the globe. For example, the Basel III capital requirements and liquidity regulation (as outlined in Basel Committee on Banking Supervision (2010a), Basel Committee on Banking Supervision (2010b) and Basel Committee on Banking Supervision (2013)) have been instituted following the GFC. The aim of this regulation was to promote general health of the global financial system and to prevent such severe crises and global contagion from happening in the first place.

However, the effectiveness of such regulation has been hampered by a presence of non-bank financial intermediary ("NBFI") institutions, which are sometimes referred to as shadow banks. NBFIs include investment funds, insurance companies, pension funds, hedge funds, finance companies and other financial intermediaries that are not traditional banks. While such institutions often engage in credit intermediation, they are not regulated to the same degree as the traditional banking system.

The less severe regulation of NBFIs means that they are not subject to stringent capital requirements but at the same time they lose the benefit of liquidity support or rescue mechanisms that central banks and regulators provide to the traditional banks. In addition, as NBFIs are not subject to the same disclosure and reporting requirements, their activities are often more opaque than those of traditional banks. The less severe regulatory oversight and the opaqueness of activities within the NBFI system contributed to the important role that NBFIs played in propagation of the various financial crises of the last two decades.

One such activity that remains largely unregulated and opaque is reuse of collateral. Collateral reuse is essential to an efficient functioning of the financial system: as many borrowing transactions require to be backed by collateral, collateral reuse enables one unit of often scarce financial asset to act as collateral in further financial transactions. The activity generates many benefits as well as potential risks to the stability of the financial system. Despite the potentially grave systemic risks, reuse of collateral is to a large extent unregulated, with decisions on whether to reuse collateral and how much of it to reuse left to the reusing institutions themselves.

Both the benefits and risks of collateral reuse are extensively discussed throughout this dissertation. The overarching goal of this work is to answer the question of whether reuse of collateral should be regulated or left to the discretion of reusing financial intermediaries that include both traditional banking institutions as well as NBFIs. The general conclusion is that the activity of collateral reuse could benefit from regulation of the collateral reuse rate or the portion of the collateral assets that is reused in subsequent transactions. Such regulation is especially beneficial in times of low credit quality of the reusing financial institutions. The thesis supports these conclusions as follows.

In a theoretical setup, the first chapter of this dissertation explores a question of whether there is a rate of collateral reuse within the financial system that is optimal from the social welfare perspective. To derive this socially optimal rate of collateral reuse, I build a model of secured lending in an NBFI setting that trades off the benefit of reuse in facilitating more productive investment with its potential to generate fire sales and related negative externalities.

I find that there is scope for regulation of financial intermediaries that engage into reuse. Such regulation should limit the reuse rate in downturns, which are characterized by a deteriorating credit quality of the reusing financial intermediaries. When the credit quality of the reusing intermediaries is low, they chose to reuse too much collateral vs. what is optimal from the social welfare perspective, presenting a case for regulation of the collateral reuse rate.

The second chapter of the thesis is also theoretical in nature. It applies an extension to the benchmark model of collateral reuse that is showcased in Chapter 1. The model extension allows to gather insights into choices regarding the rate of collateral reuse made by reusing financial intermediaries and decisions on liquidity holdings made by secondary asset market participants. Through this model extension, I show that secondary market participants choose to hold a liquidity level that is lower than what is socially optimal. Such financial intermediaries would hold inefficiently too little liquidity when left to their own devices and minimum liquidity requirements can help to restore it to more efficient levels.

This result provides support for liquidity regulation in a form of minimum liquidity requirements applied to secondary asset market participants. In other words, just by regulating liquidity holdings, the social planner could achieve social welfare that is higher than in absence of any liquidity regulation. However, I show that regulation of liquidity alone has potential to restore the first-best level of social welfare only in some cases, while others require additional regulation of the rate of collateral reuse, in line with Chapter 1.

The final chapter of the dissertation provides a novel empirical evidence on the systemically important activity of collateral reuse, which has been to date largely empirically unexplored due to an unavailability of transaction-level data. My empirical analysis focuses on how the credit quality of reusing financial institutions affects collateral reuse, with an aim to test predictions from theoretical literature (including the first chapter of this thesis) that link lower credit quality of the financial institutions with lower reuse of collateral.

Using a new transaction-level dataset on Security Financing Transactions and the associated reuse of collateral in the EU, I find that firms that face a deteriorating credit quality contract less collateral reuse in both absolute and relative terms: they reduce the volume of reuse and lower the intensity of reuse as measured by the reuse rate. The research lays an important foundation for further explorations of the dataset and the topic.

Chapter 1

The Socially Optimal Rate of Collateral Reuse

1.1 Introduction

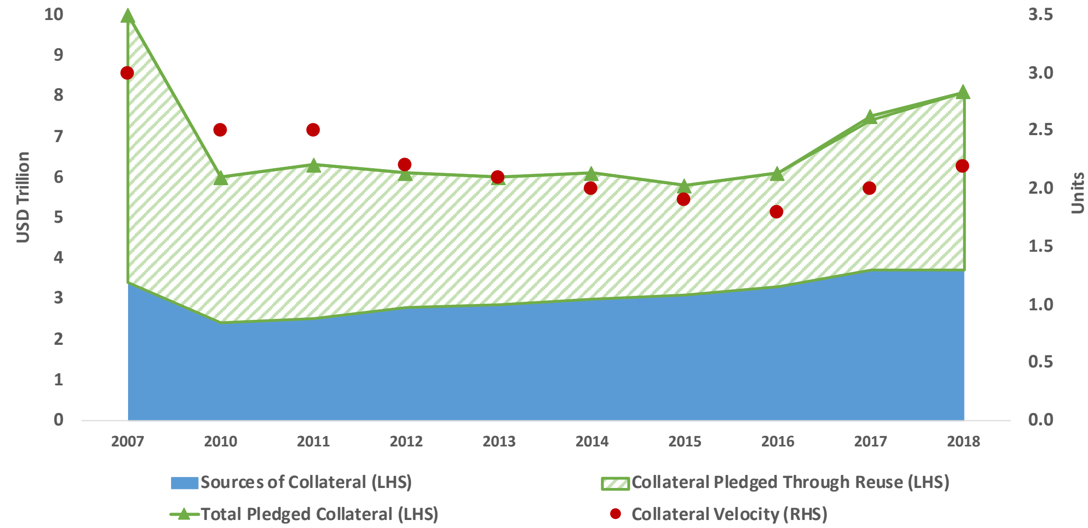
Many borrowing transactions taking place within the global financial system are backed by collateral, which then can be reused to facilitate other financial contracts. Hence, with reuse[1], one unit of a collateral asset can support many borrowing transactions. The collateral reuse market has grown rapidly over the last decades and now represent a substantial source of financial lubrication. Singh (2011) estimates that right before the latest financial crisis collateral reuse represented USD 6.6 trillion worth of collateral globally. While this amount had shrank to USD 3.6 trillion at the end of 2010 and further to USD 2.7 trillion at the end of 2015, it has been growing again, reaching USD 4.4 trillion at the end of 2018 (Singh (2019)). An associated metric that measures the churn of collateral within the financial system, referred to as collateral velocity, has followed a similar pattern as shown in Figure 1.1 below.

The significant scale at which collateral is reused globally underlines its potential to stimulate financial transactions and, with that, the greater economy - a point acknowledged both by finance practitioners and regulators alike. It can increase the borrowing capacity of financial players and decrease the cost of funding for both financial intermediaries and their clients, including non-financial firms (FSB (2017b)). Reuse can also alleviate to some degree the scarcity of high quality collateral that has become a problem for financial institutions over the last decades (BIS Committee on the Global Financial System CGFS (2013), FSB (2017b), Gorton et al. (2018), Jank et al. (2022)). Furthermore, collateral reuse plays an important role in ensuring a smooth functioning of financial markets: it stimulates price discovery and efficiency of the markets by lowering transaction and liquidity costs (CGFS (2013), FSB (2017b)).

However, collateral reuse is also associated with a set of potential downsides for the

[1]The term "reuse of collateral" is used broadly in the paper and encompasses both reuse and rehypothecation of collateral, which have different legal definitions but represent the same type of transactions from the economic perspective. See Appendix 1.A for more details on the legal definitions.

Figure 1.1: Reuse and Velocity of Collateral
Data from Singh (2019)



stability of the financial system and the economy as a whole. Importantly, reuse introduces a new source of a counter-party risk referred to as the double-commitment problem: if one of the intermediaries that make up the reuse chain defaults, the valuable collateral asset might not return to the original borrower. Instead, it might end up in the hands of an agent that will not be able to realize the full potential value of the asset. For example, such situation might transpire when the collateral asset is seized and sold while access to liquidity is limited, generating fire sales (Shleifer and Vishny (1992), Gale and Allen (1994) and FSB (2017b)) - an important risk considered in this paper.

Despite the serious risks that come with reuse of collateral, the practice remains largely unregulated. The amount of collateral that the borrower allows the lender to reuse is determined bilaterally in each contract and the pricing terms reflect the agreed-upon rate of collateral reuse. While the reuse rate is regulated to some extent in the US, there is no regulation concerning it in the EU and other main jurisdictions[2]. Hence, it is important to understand the inner workings of the collateral reuse market, the private and the social trade-offs involved and any potential scope for policy and regulation.

In fact, the lack of regulation and transparency around collateral reuse played an important part the the events that unfolded after the infamous Lehman Brothers bankruptcy, which occurred in 2008 and eventually sparked the global financial crisis (GFC). In the years leading up to the crisis, many global hedge fund clients of Lehman chose to fund themselves through Lehman's UK subsidiary, Lehman Brothers International Europe (LBIE), because it allowed them to leverage up more than would have been permitted in other jurisdictions. Since collateral reuse was not regulated in the UK with regards to a cap or even the client's consent, the clients' pledged collateral was often commingled with LBIE's proprietary collateral and reused by LBIE to facilitate its own financial transactions - often without the client's knowledge.

After LBIE filed for bankruptcy, Lehmans bankruptcy administrators confirmed that

[2]See Appendix 1.A for details on the collateral reuse regulation in the most important jurisdictions.

some of the assets pledged to LBIE were reused and no longer held for the clients in segregated accounts. It was deemed that the affected clients lost their proprietary interests in the reused assets and were considered as unsecured creditors in bankruptcy proceedings. These hedge funds found their assets frozen in the UK in the months that followed and consequently suffered substantial losses (Singh and Aitken (2010)). The Lehman Brothers story serves as a real-life example of the double-commitment problem inherent in reuse of collateral (or the inability of the original borrower to retrieve the pledged collateral that was subsequently reused) and illustrates the potential threats to financial stability that arise from collateral reuse.

Given the scale of the collateral reuse market, the recent trends that show its return to growth and importance and its potential to generate financial instability, reuse of collateral should be better understood. While recent literature starts to explore this area of financial research, more work remains to be done. In particular, since collateral reuse involves risks and externalities that might not be appropriately considered by the contracting agents, it is policy-relevant to analyze if there exists a socially optimal rate of collateral reuse.

With this goal in mind, I develop a tractable benchmark model of secured lending in a shadow banking setting that trades off the benefit of collateral reuse in facilitating more borrowing transactions with its potential to generate fire sales and the resulting negative externality of later underinvestment. The simple 3-period contracting model focuses on frictions on the lender's side of the contract in the bilateral secured lending market.

The novel aspect of the model is that it features secondary market for collateral where prices are determined endogenously taking into account the rate of reuse and available liquidity. As such, it provides important insights into how liquidity holdings of agents active on the secondary asset markets (and the resulting secondary collateral asset market liquidity) affects collateral reuse choices. Another novelty of the model is that collateral featured in the model does not serve to protect the lending intermediary from the counter-party risk of the borrower but to allow the intermediary to reuse it for its own purposes. This role of collateral appears to be more and more prevalent in the secured markets over the last years (FSB (2017b), Grill et al. (2017)).

In the context of the benchmark model, agents form a collateral reuse chain where reuse enables more profitable investment by the reusing party. At the same time, reuse introduces the double-commitment problem: by allowing some of the collateral to be reused, the original borrower now faces the risk that the valuable collateral will never be returned to it by its lender. In essence, the collateral asset might get "stuck" further along the reuse chain and subsequently sold at fire-sale prices. While the contracting agents reflect the direct risks associated with the loss of the collateral and the resulting fire sales when agreeing on the collateral reuse rate, these effects become irrelevant from the social welfare perspective. On the other hand, private agents neglect indirect effects arising from the fire sales of assets: negative externalities associated with later underinvestment that imposes real costs on the economy. Since the contracting parties and the social planner consider different costs in their optimization problems, the private and social choices regarding collateral reuse diverge under some circumstances, creating role for policy and regulation.

In this setting, I characterize the conditions in which there is scope for regulation. The optimal regulation is dynamic: it adjusts with expectations on the health of the financial system and liquidity conditions, with the health approximated in the model by the credit quality of the reusing intermediaries and liquidity conditions referring to liquidity holdings of agents active on the secondary asset markets. Because the private agents tend to reuse inefficiently too much collateral as the strength of the financial system and liquidity conditions deteriorate, social welfare benefits from a regulator that curbs reuse to the socially optimal levels during "bad" times associated with lower credit quality of the reusing agents and limited liquidity holdings of agents that are active on secondary asset markets and the associated limited market liquidity on such markets.

The remainder of the paper is organized as follows. Section II outlines existing literature related to the topic of collateral reuse. Section III details the setup of the benchmark model, the related private and social optimization problems, the results and implications on policy and regulation. A discussion about the results and potential extensions of the benchmark model as well as the concluding remarks are included in Section IV. In addition, Appendix 1.A details existing regulation around reuse of collateral while Appendix 1.B ends with numerical and graphical illustrations of the results for the benchmark model derived by applying a specific functional form to the model solutions. Finally, Appendix 1.C outlines a benchmark model extension by considering risky assets.

1.2 Literature Review

While the role of collateral itself has been widely researched over the last few decades, a reuse of collateral specifically is a relatively newer topic. The first publications on the subject were spurred by the 2007-2009 GFC. The earliest studies (Singh and Aitken (2010) and Singh (2011)) estimate the size of the global collateral reuse market and study its importance as a source of financial lubrication as well as the role that it played in the most recent financial crisis. In another early piece, Monnet et al. (2011) introduces the concept of a double commitment problem involved in reuse, which arises from the fact that the lender might not deliver the collateral back to the borrower at the end of the contract period - the risk that is a crucial element of my model.

In more recent years, theoretical literature on the subject of collateral reuse has emerged. One group of theoretical publications in this area analyze the binary choice of whether it is optimal to reuse collateral or not. Bottazzi et al. (2012) provide a general theoretical model of reuse of collateral involved in repurchase agreement (or repo[3]) funding, but do not consider the important double-commitment problem that emerges when reuse is allowed. Park and Kahn (2018) study the relationship between haircuts and the likelihood of reuse. Similarly to my analysis, Park (2021) studies impact of credit quality of the reusing intermediaries on private reuse choices and resulting aggregate

[3] A repo is essentially a secured loan that is backed by financial collateral. The repo borrower sells a security for cash to the repo lender, who holds the security as collateral. The borrower agrees to repurchase the security at a pre-specified date for a pre-specified price. The pre-specified price determines the so-called repo rate, which reflects the borrowing rate inherent in the contract.

output. However, the model of Park (2021) does not reflect secondary collateral market and hence misses the important aspects of endogenous collateral asset prices and liquidity that are considered in my analysis.

Another strand of related theoretical literature focuses on the role of collateral reuse in facilitating funding liquidity. Infante (2019) and Infante and Vardoulakis (2021) produce models where dealer banks generate additional liquidity through repo collateral reuse by being able to charge different margins to their borrowing and lending clients. They show how reuse of collateral might generate inefficient repo runs by collateral providers on their lenders. Neither of these papers take into account the supply of liquidity available for purchases of collateral assets on secondary markets and hence do not consider its impact on prices and collateral reuse choices.

While all the theoretical studies mentioned above analyze important private and social trade-offs associated with the reuse of collateral, they do not address what rate of reuse is optimal from the social welfare perspective - a subject that begins to be explored in a couple of more recent publications. Andolfatto et al. (2017) develop a theory on how reuse can increase the availability of liquidity within the financial system but they do not consider the important double-commitment risk that is a crucial element of my work. Gottardi et al. (2019) discuss how reuse impacts collateral constraints and haircuts in the repo markets and find a minimum level of reuse that restores the first-best allocation of consumption by increasing the borrowing capacity of some agents. However, they do not reflect private costs or negative externalities associated with collateral reuse, which play an important part of my analysis. In a quantitative study, Brumm et al. (2022) show that collateral reuse produces a trade-off between the benefits of risk-sharing versus suboptimal leverage and asset price volatility and derive a range of the reuse rate that increases welfare. Yet, their quantitative results crucially depend on the strong assumptions of their agent-based model regarding the heterogenous risk aversion and beliefs.

In addition, my study draws on the ample theoretical research about fire sales (Shleifer and Vishny (1992) and Gale and Yorulmazer (2019)) and specifically on the cash-in-the-market pricing literature (Gale and Allen (1994) and Allen and Gale (1998)), where the prices of assets being sold depend on limited market liquidity. Fire sales are problematic because they generate different types of costs to different parties (Gale and Yorulmazer (2019)). Because the private agents and the social planner consider different types of risks that come with collateral reuse and the resulting fire sales, there is potential for reuse to be inefficiently utilized from the social perspective. These cases will become transparent in my results. Furthermore, I base the derivation of the endogenous fire sale discount factor on the methodology of Stein (2012) and Hanson et al. (2015), which they apply to show excessive creation of money-like claims by the shadow banking system.

1.3 Benchmark Model

1.3.1 Model Setup

The contracting model features three periods: $t = 0$, $t = 1$ and $t = 2$. For simplicity, I assume that the agents have no time preferences. I further assume that reputation-related risk is prohibitively high so that all the agents honor all the aspects of their contracts when they have means to do so. In other words, strategic defaults on debt repayment or strategic failures to deliver collateral are not possible.

There are four types of agents, labelled A, B, C and D, that are ultimately owned by households. They represent different types of financial intermediaries. Agent A is the ultimate borrower, agent C is the ultimate lender and agent B is a party that intermediates between the two. Agent A and agent B are risk-neutral and are the contracting agents, while agent C is infinitely risk-averse and plays a passive role. One can think of agent A as a hedge fund and agent B as a broker-dealer bank. The hedge fund hires the broker-dealer to provide it with prime brokerage services that include financing. Agent C can be represented as a money market fund that wants to prevent "breaking the buck"[4] at any cost and hence is willing to engage only into perfectly safe projects. Agent C can provide financing to B via various secured transactions such as tri-party repos[5]. In addition, there is a passive risk-neutral patient investor labelled as agent D that can step in during the intermediate period to purchase financial assets on the secondary market or invest into its own productive projects. It can be represented by a commercial bank or any other patient investor interested in and able to buy financial assets on a secondary market (e.g, a mutual fund, a pension fund, etc.).

I assume that agent A cannot bypass the intermediary agent B to interact directly with the ultimate lender agent C (or, in the context of the example, that the hedge fund cannot raise financing directly from the money market fund). This could be due to a severe asymmetric information problem that the parties face when interacting with opaque-by-nature hedge funds (as reflected in the "lemons" problem of Akerlof (1978)). There is an incentive for a party that has an advantage in acquiring the costly information on the quality of agent A and in monitoring its complex activities to develop a specialized relationship with that agent. The party with this advantage becomes then a financial intermediary between agent A and others, in line with the "delegated monitor" concept coined by Diamond (1984). The assumption implicit in the model is that it is agent B who holds such an advantage over agent C. Hence, agent B (the prime-broker) acts as a specialized intermediary between agent A (the hedge fund) and agent C (the money market fund). As a result, the latter two agents do not interact directly with each other[6].

[4]An event when a money market fund's net asset value (NAV) per share falls below $1.

[5]Repurchase agreement transactions where a custodian bank is involved to intermediate and facilitate the administration of the transaction between the repo buyer and seller. Collateral involved in such transaction is deposited with a custodian for the duration of the transaction and the flow of funds between the buyer and seller is funneled through the custodian. A tri-party repo is the most common vehicle through which US money market funds provide financing to the broker-dealers and other financial institutions.

[6]The assumption that agent A obtains financing only from agent B mimics the real-world arrange-

At $t = 0$, agent A has an opportunity to invest into a long-term infinitely divisible asset, which can then be used as collateral. The long-term asset of agent A requires 1 unit of investment and matures at $t = 2$ producing a certain gross return[7] of $R > 1$. At $t = 0$, agent A does not have any liquid funds to finance the investment on its own and needs to secure the required financing of 1 from agent B.

At $t = 0$, agent B does not have any assets of its own that could be used as collateral to obtain financing. It does, however, have 1 unit of existing liquid funds that were raised at a cost of 1. These funds could be used to finance the long-term assets of agent A via unsecured lending or a secured transaction such as margin lending or a bilateral repo[8]. Aside from providing funding to agent A, agent B has an outside option to invest at $t = 0$ into an NPV-positive short-term project. The project matures at $t = 1$, producing a gross return of R^B for each unit of investment with probability p. With probability $(1-p)$, the project is unsuccessful and returns 0. The long-term investment opportunity of agent A is more profitable than the short-term investment opportunity of agent B with $R > pR^B > 1$. They both, however, produce value as they are both NPV-positive.

Agent C has access to safe storage that generates return of 1 per unit of investment per period. At $t = 0$, agent C has unlimited funds available and is willing to provide funding to agent B for one year at the safe rate of 1 as long as the investment is structured so that it is completely safe.

Agent D does not have any investment opportunity or liquid funds available at $t = 0$. It will have, however, an exogenous endowment of limited liquid funds of $W \leq R$ available at $t = 1$, with the amount W known to all agents at $t = 0$[9]. Agent D can use these funds to buy financial assets available on the secondary market at that time. Agent D also has a late-arriving unlimited productive investment opportunity available at $t = 1$. This late-arriving project matures at $t = 2$ and returns a certain $g(X)$ for an investment of X, where $g(\cdot)$ is an increasing and concave production function so that $g'(\cdot) > 0$ and $g''(\cdot) < 0$. Hence, agent D needs to trade off using its limited liquid funds of W to purchase financial assets available on the secondary market with investing them into the late-arriving productive investment opportunity.

The assumptions on the investment opportunities of agent A, B and D can be summa-

ments of hedge funds and their prime-brokers. In practice, money market funds do not interact directly with hedge funds as they do not operate in the tri-party repo market. Instead, hedge funds establish prime brokerage relationships with broker-dealers, through which virtually all of their transactions are funneled. Broker-dealers then enter into tri-party arrangements with money-market funds to obtain financing from these "ultimate" lenders that cannot reuse collateral pledged to them and hence find themselves positioned at the end of the collateral reuse chain.

[7]A model extension outlined in Appendix 1.C considers a case of a risky long-term asset of agent A, which produces results and policy implications in line with the benchmark model.

[8]A repo transaction where the repo buyer and seller transact directly without an involvement of a third party responsible for the administration process. This typo of repo is commonly used by broker-dealers to transact among themselves or with hedge funds and securities dealers.

[9]Chapter 2 of this thesis considers an extension of the benchmark model that features an endogenously chosen liquidity level W.

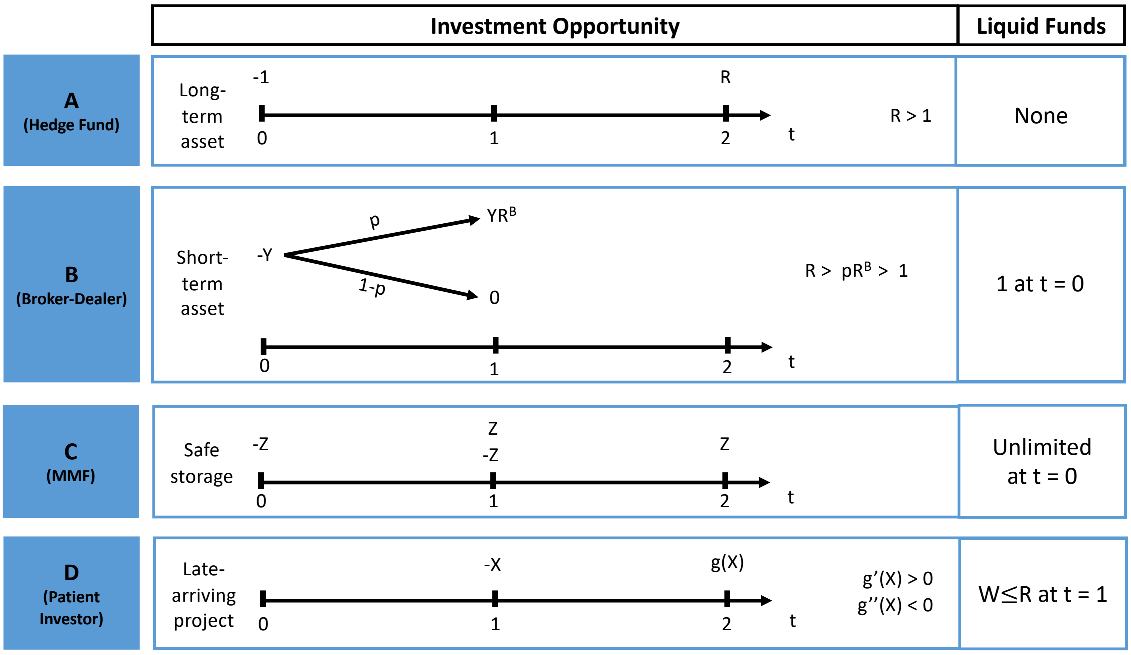
rized as:

Assumption Set 1: The investment opportunities of agent A, B and D satisfy

$$\begin{aligned} R &> pR^B > 1 \\ R &\geq W \\ g'(\cdot) &> 0 \\ g''(\cdot) &< 0 \end{aligned} \tag{1.1}$$

Figure 1.2 illustrates the investment opportunities of all the agents and their endowments of liquid funds:

Figure 1.2: Investment Opportunities and Liquid Fund Endowments of the Intermediaries



Agent B retains the surplus generated through collateral reuse and presents a take-it-or-leave-it contract to agent A at $t = 0$. This arrangement means that agent B reaps the benefits of collateral reuse (if any) but needs to compensate A for the risks that come with it[10]. The contract presented by agent B features two items. The first one is ϕ or the fraction of the long-term asset that agent A is asked to pledge as reusable collateral to obtain the 1 unit of funds from agent B at $t = 0$ (where $0 \leq \phi \leq 1$). ϕ represents the rate of collateral reuse and is the main subject of study in this paper. This ϕ fraction of the long-term asset of Agent A that is pledged as collateral can be then reused by agent B to raise funds for its own purposes. The second item outlined in the contract is the corresponding cost of borrowing rate, $r^A(\phi)$, agent A will pay agent B for the loaned funds at $t = 2$ upon receipt of the pledged collateral. Agent A's borrowing rate depends on ϕ and compensates it for the risks associated with that rate of collateral reuse.

[10]The bargaining power distribution between agents A and B does not affect the results that stem from the model. What is crucial is that the contracting agents reflect all the private risks and benefits of collateral reuse in the same way and not how they share them between each other.

The implicit haircut involved in the transaction is $\left(1 - \frac{1}{\phi R}\right)$. Since the long-term project of agent A produces a certain return and strategic defaults are excluded in the model, theoretically agent B does not require any collateral to ensure agent A's debt repayment. However, the purpose of collateral in this model is to facilitate additional lending by agent B and not to protect it in case of agent A's default. Therefore, agent B might have incentives to require agent A to pledge some of the collateral but, at the same time, it needs to compensate agent A for the associated risks. Hence, the important adjustment mechanism in this analysis is not the haircut[11] but the cost of borrowing rate $r^A(\phi)$ that takes into account the risks to agent A stemming from agent B's choice of ϕ.

Since the possibility of a default by agent A is excluded, agent B is wiling to loan its 1 unit of existing funds to agent A on an unsecured basis or without requiring any pledged collateral ($\phi = 0$). In this case, no reuse of collateral is possible and agent A retains the full return of R on its long-term asset when it matures at $t = 2$. Agent B, however, forfeits the investment into its own project since it does not have any assets that could be used as collateral to obtain additional financing for its own purposes from the infinitely risk-averse agent C. Therefore, with unsecured lending or when $\phi = 0$, the short-term investment opportunity of agent B remains unrealized and it charges agent A a borrowing rate of $r^A(0) = pR^B$ that represents agent B's opportunity cost on its own investment.

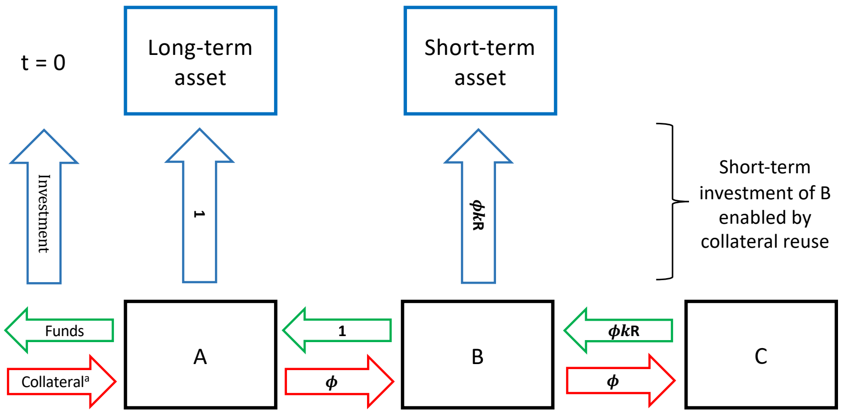
To ensure that the NPV-positive investment opportunity of agent B is not completely forfeited, it is willing to offer agent A a borrowing rate of $r^A(\phi)$ with $r^A(\phi) \leq R^B$ for the 1 unit of its existing funds in exchange for agent A pledging a ϕ fraction of the long-term asset as collateral. Under this contract, agent B can reuse the ϕ part of long-term asset of agent A for its own purposes. Specifically, agent B can pledge this collateral to agent C to secure additional funding for its own short-term NPV-positive investment. Agent A retains rights to the remaining $(1 - \phi)$ fraction of the long-term asset throughout the contract.

Because in this setting collateral reuse allows to finance both the long-term investment of agent A and some short-term investment of agent B, reuse of collateral generates more productive investment in the economy. Please refer to Figure 1.3 for a visual representation of the flows of funds, collateral and investments at $t = 0$ in case that a ϕ fraction of the long-term asset is pledged and reused as collateral.

In the p probability case that agent B's project is successful at $t = 1$, it is able to repay agent C as contractually promised at $t = 1$ and the default is avoided. Agent B receives the ϕ part of the long-term asset back from agent C at $t = 1$, and returns it to agent A at $t = 2$. Hence, agent A realizes a gross return of R on the whole long-term asset and repays to agent B the full contractually agreed-upon $r^A(\phi)$ at $t = 2$. Because there are no sales of financial assets at $t = 1$, Agent D invest all of its liquid assets of W into the

[11] Ozdenoren et al. (2018) provide theoretical evidence that lender's credit quality or liquidity constraints do not affect haircuts involved in secured debt transactions. In addition, Julliard et al. (2019) provide empirical evidence that haircuts involved in repo transactions are not impacted by the default rates or the liquidity position of the lender. Since it is the lender's credit quality that is the focus of the analysis presented in this paper, these studies provide support for not focusing on the haircut as the main adjustment mechanism.

Figure 1.3: Flow of Funds, Collateral[a] and Investments[b] **at t=0** Assuming Collateral Reuse Rate of ϕ



[a]Collateral flows represent the fraction of the long-term asset and not its value.

[b]The derivation of the ϕkR amount of funds obtained and invested by agent B is explained in the following paragraphs.

late-arriving project at $t = 1$, which will reap $g(W)$ at $t = 2$. See Figures 1.4 and 1.5 for details on the flows of funds, collateral, investments and debt repayment at $t = 1$ and at $t = 2$ assuming that agent B's own investment is successful and it does not default on its debt repayment to agent C.

However, the potential of collateral reuse to increase economic growth through higher productive investment comes at a price. By allowing the collateral to be reused, agent A faces a possibility that the ϕ fraction of the long-term asset will be "trapped" along the reuse chain in case that agent B's project is unsuccessful. In this case, agent B is forced to default on its debt repayment to agent C which then seizes the collateral pledged to it by agent B. Hence, agent B ultimately fails to deliver the collateral back to agent A at $t = 2$ and the double-commitment problem inherent in collateral reuse arises - a situation where it is not only the lender that bears the counter-party risk of the borrower not repaying debt but it is also the borrower that faces the counter-party risk of the lender not returning valuable collateral at the end of the contract.

In the context of the model, agent A will not get back its full pledged collateral if agent B defaults on its obligation to repay debt as contractually promised at $t = 1$ to agent C. This will occur with probability $(1 - p)$ in case that agent B's own investment fails. In this event, agent B is forced to default at $t = 1$ as it does not have enough funds to repay agent C. At this point, agent C seizes the ϕ fraction of the long-term asset, meaning that agent A is left with only $(1 - \phi)$ claim to its asset at $t = 2$, which realizes a return of $(1 - \phi)R$ to Agent A. Agent A is, however, exempt in this case from debt repayment to agent B.

In the $(1 - p)$ chance that agent B's project is unsuccessful and it defaults at $t = 1$, agent C seizes and immediately sells the pledged ϕ of collateral to agent D as it is not equipped to hold the asset directly[12]. Since agent D's liquid funds available at

[12]One can think of the collateral asset as not falling under the mandate of the money market fund, in which case, upon the borrower's default, it would immediately sell the seized collateral on the secondary market.

Figure 1.4: Flow of Asset Returns, Debt Repayments and Collateral[a] **at t=1** Assuming Collateral Reuse Rate of ϕ and **No Default by Agent B**

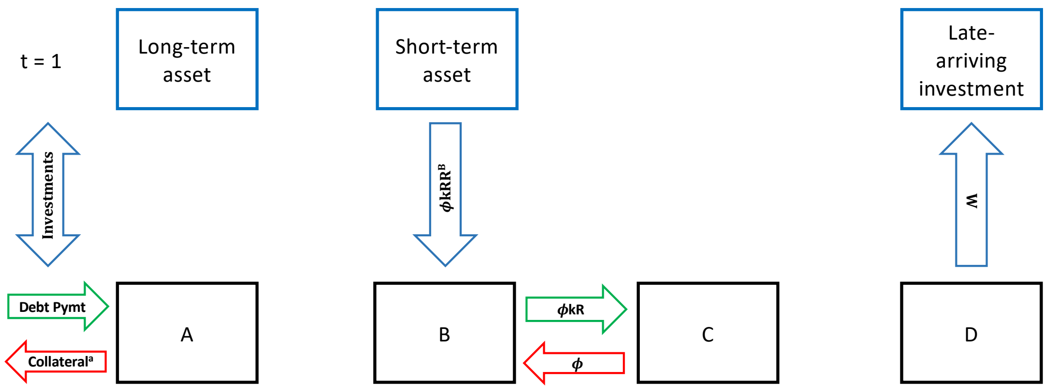
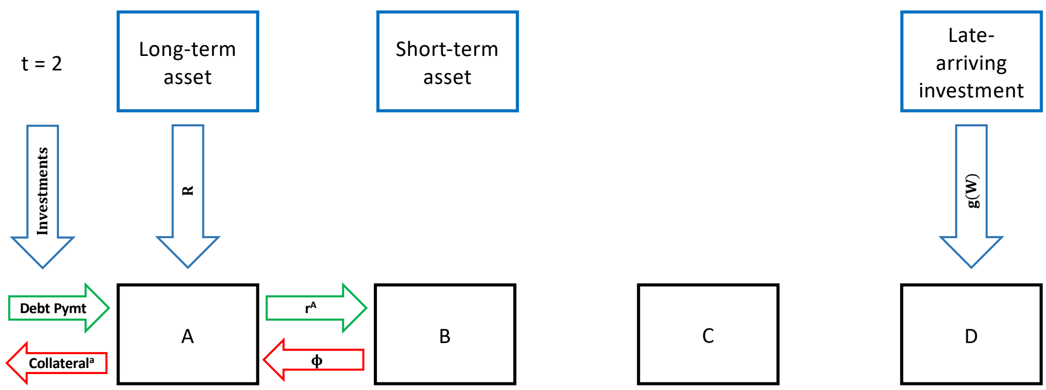


Figure 1.5: Flow of Asset Returns, Debt Repayments and Collateral **at t=2** Assuming Collateral Reuse Rate of ϕ and **No Default by Agent B**



[a]Collateral flows represent the fraction of the long-term asset and not its value.

Figure 1.6: Flow of Collateral[a] and Fire Sales **at t=1** Assuming Collateral Reuse Rate of ϕ and **Default by Agent B**

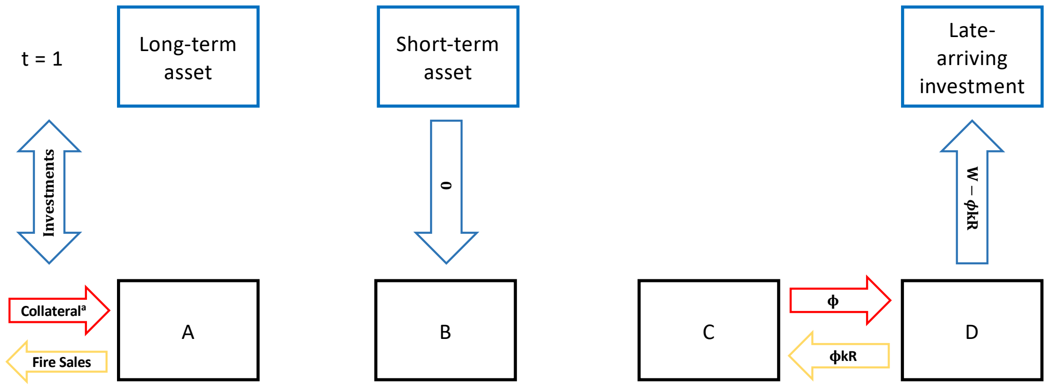
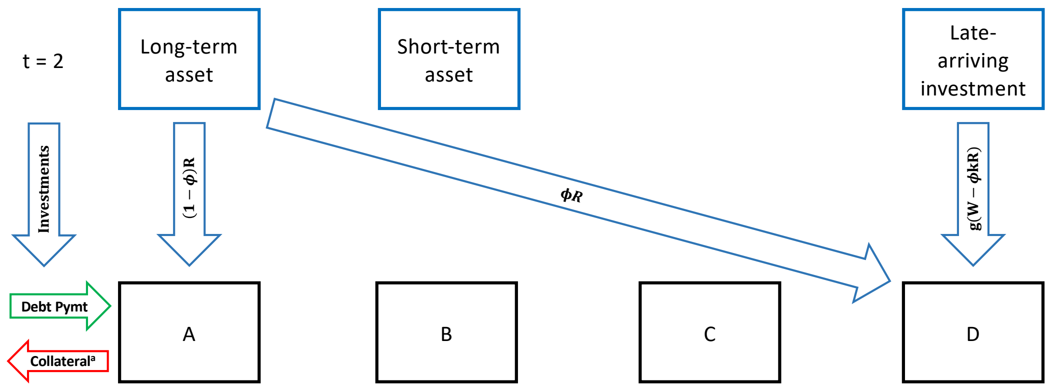


Figure 1.7: Flow of Asset Returns, Debt Repayments and Collateral **at t=2** Assuming Collateral Reuse Rate of ϕ and **Default by Agent B**



[a]Collateral flows represent the fraction of the long-term asset and not its value.

$t = 1$ are limited, the urgent selling generates cash-in-the-market pricing (as in Gale and Allen (1994) and Allen and Gale (1998)), resulting in fire sales of the reused part of the long-term asset. Consequently, D buys the ϕ fraction of the asset for $\phi k(\phi)R$ at a fire sale discount[13] $k(\phi)$ where $0 < k(\phi) \leq 1$. Figure 1.6 illustrates fire sales of the collateral asset at $t = 1$ in case that agent B's own investment is unsuccessful.

Since at $t = 1$ agent D has only limited W of liquid funds available for investment, it faces a trade-off between using the funds to invest into the late-arriving productive project or to buy up the fire-sale discounted collateral asset from agent C. If agent D buys the ϕ fraction of the collateral asset from agent C at $t = 1$ for $\phi k(\phi)R$, the purchase will generate a certain profit of $\phi[1 - k(\phi)]R$ at $t = 2$. But the purchase of the fire sale asset leaves agent D only $W - \phi k(\phi)R$ to invest into the late-arriving project at $t = 1$, which will return $g(W - \phi k(\phi)R) < g(W)$ at $t = 2$. Agent D's investments and returns are shown in Figure 1.6 and Figure 1.7 that illustrate the flows at $t = 1$ and at $t = 2$ assuming that the agent B's own investment is unsuccessful and it defaults on agent C at $t = 1$ and ultimately fails to deliver collateral back to agent A at $t = 2$.

[13]The microfoundations of the fire sale discount factor $k(\phi)$ used in this paper follow Stein (2012).

Given the trade-off, in equilibrium agent D allocates the W of liquid funds between the fire-sale collateral asset and the late-arriving project such that the marginal return on both is the same. As agent D buys the collateral at a fire sale discount of $k(\phi)$, the marginal return on this investment is $\frac{1}{k(\phi)}$. On the other hand, the marginal return on the late-arriving project is $g'(W - \phi k(\phi)R)$. Therefore, the trade-off between the two investments can be expressed as:

$$\frac{1}{k(\phi)} = g'(W - \phi k(\phi)R) \tag{1.2}$$

This equilibrium representation allows for a derivation of the endogenous fire sale discount factor $k(\phi) = \frac{1}{g'(W-\phi k(\phi)R)}$. The discount factor $k(\phi)$ captures the degree of fire sales and is a function of ϕ as it depends on the amount of collateral that is sold at $t = 1$. Given the properties of the $g(\cdot)$ function, $k(\phi)$ is strictly decreasing $(k'(\phi) < 0)$ and convex $(k''(\phi) > 0)$ in ϕ, with the decreasing relationship reflecting the fact that the higher the reuse rate, the more of the asset will be sold at $t = 1$ in case that agent B defaults and the lower the prices will have to be to absorb the purchases in presence of limited liquidity. I further assume that without reuse, the long-term asset's price at $t = 1$ cannot exceed its fundamental value $(k(0) \leq 1)$ and that the long-term asset retains some value at $t = 1$ even when all of it is sold in fire sales $(0 < k(1) < 1)$.

Assumption Set 2: The fire sale discount factor $k(\phi)$ function satisfies

$$\begin{gathered} k(0) \leq 1 \\ 0 < k(1) < 1 \end{gathered} \tag{1.3}$$

$k(\phi)$ is also affected by the liquid funds available at the time of the purchase of the fire-sold asset, namely the W liquidity held by agent D at $t = 1$. Given the properties of the $g(\cdot)$ function, $k(\phi)$ is strictly increasing in W $\left(\frac{\partial k(\phi)}{\partial W} > 0\right)$. This is because the more liquid funds agent D has at $t = 1$ to purchase the asset being sold at a fire sale discount, the less of a "cash-in-the-market" effect it has on the asset price. Hence, the asset is sold at a lower markdown to its fundamental value, which is captured in a higher fire sale discount factor $k(\phi)$.

Given that the fire sale discount factor, $k(\phi)$, determines the collateral asset's price at $t = 1$, it puts a limit on how much funds agent B can raise at $t = 0$ from the infinitely risk-averse agent C. Specifically, agent B can raise up to $\phi k(\phi)R$ of funds from agent C at $t = 0$ in exchange for ϕ fraction of the long-term asset pledged as collateral to agent C to make the investment perfectly safe from agent C's perspective. Agent C's loan of $\phi k(\phi)R$ to agent B at the cost of borrowing at a rate of 1 is perfectly safe as agent C will receive $\phi k(\phi)R$ at $t = 1$ with certainty. The repayment will occur either via debt repayment of $\phi k(\phi)R$ by agent B (in case that its project is successful) or via selling the captured ϕ part of the long-term asset at a fire sale price for $\phi k(\phi)R$ (in case that agent B's project fails). Agent B can then obtain the $\phi k(\phi)R$ of funds at $t = 0$ from agent C at the safe rate of borrowing of 1 per unit of funds to invest into its own project.

1.3.2 The Private Optimization Problem

Agent B maximizes the change in its expected profit due to collateral reuse by choosing a collateral reuse rate, ϕ, while satisfying the participation constraint of agent A by offering it a borrowing rate of $r^A(\phi)$. To ensure that agent A allows reuse of ϕ of the long-term asset, agent B must make agent A indifferent between allowing reuse ($0 < \phi \leq 1$) and not allowing reuse ($\phi = 0$). To do so, agent B offers to loan the funds to agent A at the rate $r^A(\phi)$ that compensates it for the risks associated with reuse. With $r^A(\phi)$ as the adjustment mechanism, agent A faces the same expected profit with reuse of a ϕ fraction of the long-term asset as the expected profit under the "no reuse" scenario:

Participation Constraint of Agent A:

$$\begin{gathered} E(\Pi^A_{Reuse}) = E(\Pi^A_{NoReuse}) \Leftrightarrow \\ [1 - (1-p)\phi]R - pr^A(\phi) = R - pR^B \end{gathered} \tag{1.4}$$

from which the borrowing rate $r^A(\phi)$ paid in expectation by Agent A for $\phi > 0$ can be derived:

$$pr^A(\phi) = pR^B - (1-p)\phi R < pR^B \tag{1.5}$$

Equation 1.5 implies that $r^A(\phi)$ decreases in ϕ. Hence, the lower rate of borrowing $r^A(\phi)$ compensates agent A for the risk of losing a part of its valuable long-term asset - a risk of a loss that increases with the fraction of long-term asset at stake or ϕ. Therefore, the borrowing rate used in this model declines when the demand for the underlying collateral rises: agent B's "price" for being able to reuse the collateral increases with its demand for it. In fact, in some cases[14], the cost of borrowing could be less than 1 for large enough ϕ. With $r^A(\phi) < 1$, agent B essentially pays agent A to be able to use the valuable pledged collateral for its own purposes.

If agent B reuses a $0 \leq \phi \leq 1$ fraction of the collateral, its extra net expected profit from collateral reuse can be expressed as:

$$E(\Pi^B) = p\left[\phi k(\phi)R(R^B - 1) + r^A(\phi) - R^B\right] \tag{1.6}$$

Plugging in $r^A(\phi)$ from Equation 1.5:

$$E(\Pi^B) = \phi k(\phi)Rp(R^B - 1) - (1-p)\phi R \tag{1.7}$$

In other words, agent B benefits from the extra investment enabled through collateral reuse in case its project succeeds with an expected return of $\phi k(\phi)Rp(R^B - 1)$. However, this gain is offset by an expected loss of $(1-p)\phi R$ in case that agent B's project fails and the ϕ part of the long-term asset is seized by agent C. The lost part of the long-term asset is worth its fundamental value of ϕR from agent A's perspective and Agent B needs to compensate agent A for this loss of its valuable asset by offering agent A debt financing at a lower cost of $r^A(\phi)$.

[14]For example, in case of a very profitable long-term asset (very high R) and/or a high probability of default by agent B (high p) and/or low rate of return on agent B's investment (low R^B).

To illustrate direct costs that arise from fire sales, Agent B's extra profit generated through reuse as captured in Equation 1.7 can be rewritten as:

$$E(\Pi^B) = \phi k(\phi)R(pR^B - 1) - (1-p)\phi[1 - k(\phi)]R \tag{1.8}$$

In other words, collateral reuse enables investment with an NPV of $\phi k(\phi)R(pR^B - 1)$ but this gain is offset by an expected loss of $(1-p)\phi[1-k(\phi)]R$ associated with fire sales of the collateral in case that agent B's project fails. In essence, agent B bears full fire sale impact because it needs to compensate agent A for the expected loss of part of the long-term asset worth ϕR while the same asset presents a fire-sale discounted value of only $\phi k(\phi)R$ at $t = 1$ to the other agents. Hence, collateral reuse comes with an expected fire sale loss of $(1-p)\phi[1-k(\phi)]R$ that needs to absorbed by the agent B.

Taking into account these trade-offs, at $t = 0$ agent B maximizes the expected change in its profit by choosing the collateral reuse rate ϕ and its optimization problem is:

$$\begin{gathered}\max_{\phi} E(\Pi^B) = \phi k(\phi)R(pR^B - 1) - (1-p)\phi[1-k(\phi)]R \\ \textit{s.t. 2 constraints:} \\ 0 \leq \phi \leq 1\end{gathered} \tag{1.9}$$

Agent B then offers a contract to agent A that requires pledging a ϕ^* part of the long-term assets that reflects the privately optimal rate of collateral reuse. The contract also outlines the corresponding debt repayment by agent A to be made upon receipt of the pledged collateral from agent B at $t = 2$ at a rate $r^A(\phi^*)$ in exchange for 1 unit of financing provided to agent A at $t = 0$.

The model considers agent B that does not internalize the incremental impact of its choice of collateral reuse rate ϕ on the fire sale discount factor $k(\phi)$. Such situation can arise when many agents provide agent B-type intermediation services and their transactions with the ultimate borrowers (agents of type A) are frequent and relatively small in size considering the whole secondary market for the long-term asset. Under such a structure of an intermediation market, it is reasonable to assume that the private agents do not expect that their choice of a collateral reuse rate for a particular transaction will have an incremental impact on fire sale outcomes.

If we approximate agent A with a hedge fund and agent B with a broker-dealer, such interpretation of agent B's intermediation is appropriate. Singh and Aitken (2010) estimate that there are fourteen financial institutions that engage in bilateral collateral reuse globally on a large scale and there are countless others that operate on a smaller or a local scale. Furthermore, individual transactions are relatively small and occur at a very high frequency. Therefore, it is reasonable to assume that the private contracting agents to not internalize the impact of their choice of collateral reuse rate on the fire sale outcomes. Such treatment of fire sales by private agents is also in line with the methodology of Stein (2012) and Hanson et al. (2015).

Solving the optimization problem captured in Equation 1.9, Agent B chooses a collateral reuse rate that represents maximum reuse or $\phi^* = 1$ for low enough probability of default of agent B (high p) and high enough return on its short-term asset (high R^B) and high enough liquidity available at $t = 1$ (high W). Specifically, agent B opts for a maximum reuse rate of $\phi^* = 1$ when $k(1) \geq \frac{1-p}{p(R^B-1)}$ which is equivalent to $p \geq \frac{1}{k(1)(R^B-1)+1}$. Hence, maximum reuse is privately optimal when the financial system is particularly strong as approximated in the model with a high credit quality of the reusing agent B (high p and high R^B) and the liquidity conditions are very favorable as approximated in the model with high levels of liquidity holdings W and the resulting high market liquidity available on the secondary collateral asset market[15].

When the strength of the financial system and/or the liquidity conditions deteriorate but the system remains relatively resilient or when $\frac{1}{k(1)(R^B-1)+1} > p > \frac{1}{k(0)(R^B-1)+1}$, agent B chooses to reuse at an intermediate rate of reuse and $0 < \phi^* < 1$. The internal solution to the private optimization problem ϕ^* is obtained from the first order condition of the maximization problem expressed in Equation 1.9, assuming that Agent B does not internalize the incremental impact of its choice of ϕ^* on the fire sale prices. The internal solution to this problem is expressed in terms of the fire sale discount factor $k(\phi^*)$:

$$p(R^B - 1) = (1 - p) \times \frac{1}{k(\phi^*)} \tag{1.10}$$

which is equivalent to

$$k(\phi^*) = \frac{1}{g'(W - \phi^* k(\phi^*)R)} = \frac{1 - p}{p(R^B - 1)} \tag{1.11}$$

The internal solution captured in Equation 1.10 can be interpreted the following way: agent B chooses collateral reuse rate ϕ^* so that its marginal benefit of reuse, which is its expected per unit profit from the short-term investment (the left-hand side of Equation 1.10), equals the marginal private cost of reuse, which is the expected marginal loss due to the fire sales(the right-hand side of Equation 1.10). In other words, private agents set the reuse rate so that it represents the trade-off between the loss of return that stems from the risk of Agent A losing a ϕ^* fraction of the long-term asset and the expected return on agent B's short-term investment that has been enabled through reuse of ϕ^* of the long-term asset.

Applying comparative statics analysis to the internal solution expressed in Equation 1.10, it becomes apparent that the privately optimal rate of reuse ϕ^* decreases in agent B's probability of default or $(1 - p)$. Because the impact on fire sale prices is more severe with higher levels of reuse ($k'(\phi) < 0$) and the right-hand side of Condition 1.10 increases in $(1 - p)$, higher default probability of agent B implies lower privately optimal rate of collateral reuse ϕ^*. The intuition behind it is clear: higher $(1-p)$ means that means that a default by agent B is more likely. Because of the increased default risk, agent A requires a higher compensation from agent B for the risk of losing its asset pledged as collateral, causing agent B (ceteris paribus) to opt for a lower rate of collateral reuse.

On the other hand, because the right-hand side of Equation 1.10 decreases in R^B, the privately optimal reuse rate ϕ^* increases in R^B. Again, the intuition is straightforward: higher R^B means that agent B's project is more profitable and provides more expected

[15] High W translates into high market liquidity available on the secondary collateral asset market captured by $\phi^* k(\phi^*)R$.

return to offset the potential fire sale losses. This drives agent B to decide on a higher rate of reuse.

In addition, ϕ^* increases in W or the liquidity available at $t = 1$. Because fire sales are less pronounced when the liquidity is high ($\frac{\partial k(\phi)}{\partial W} > 0$), the privately optimal rate of reuse ϕ^* increases in the liquidity available at $t = 1$. Intuitively, higher available liquidity translates into higher asset prices at $t = 1$, which both increases the amount of funds agent B can raise from agent C at $t = 0$ and decreases private costs of fire sales at $t = 1$. Hence, agent B will choose a higher rate of reuse when the liquidity expected at $t = 1$ is higher.

It is also possible that agent B decides not to reuse any collateral at all, despite its short-term project being NPV-positive. Let's define the default probability of agent B so that the NPV of its short-term project is zero as:

$$p_{min} = \frac{1}{R^B} \tag{1.12}$$

When the strength of the financial system and liquidity conditions deteriorate further to where $\frac{1}{k(0)(R^B-1)+1} \geq p > p_{min}$, agent B's expected profit from reuse is negative and it chooses not to reuse any collateral with $\phi^* = 0$. In this region characterized by high default probability or low project return of agent B and/or low liquidity holdings and secondary market liquidity, the fire sale losses outweigh the profit from the short-term investment that was enabled through reuse.

The private solution for the collateral reuse rate ϕ^* in case that Agent B does not internalize its impact on fire sale prices can be summarized in the following proposition:
Proposition 1: *Denote the privately optimal rate of collateral reuse as* ϕ^*. *Let*

$$\begin{aligned} p_1^B &= \frac{1}{k(1)(R^B-1)+1} \\ p_0^B &= \frac{1}{k(0)(R^B-1)+1} \end{aligned} \tag{1.13}$$

Then for $p \geq p_1^B$, *it is privately optimal to maximize the reuse of collateral with* $\phi^* = 1$. *For* $p_1^B > p > p_0^B$, *the private solution is internal with* $0 < \phi^* < 1$ *that satisfies* $k(\phi^*) = \frac{(1-p)}{p(R^B-1)}$. *For* $p_0^B \geq p > p_{min}$, no reuse is privately optimal and $\phi^* = 0$.

1.3.3 The Social Welfare Optimization Problem

Before solving for the socially optimal rate of collateral reuse, it is important to note that the private fire sale losses born by agent B become neutralized from the social welfare perspective. In case of agent B's default at $t = 1$, the ϕ fraction of the collateral is captured by agent C and agent B sustains an overall fire sale loss of $\phi[1 - k(\phi)]R$. These private losses are, however, offset by the later social welfare gains to agent D: as it buys the ϕ fraction of the collateral asset from agent C at $t = 1$ at a discounted price of $\phi k(\phi)R$, this purchase will generate a certain profit to agent D of $\phi[1 - k(\phi)]R$ at $t = 2$ when the long-term asset matures. Hence, the private losses of agent B are cancelled out by the gains of agent D, with an overall null effect on social welfare.

On the other hand, the fire sales resulting from collateral reuse also produce negative social externalities - real economic costs associated with fire sales which are disregarded when the private agents contract but which have real consequences on the economy. This negative externality arises because fire sales divert limited liquidity of agent D from the late-arriving productive investment to purchases of discounted fire sale assets. While agent D has no influence on the private choice of ϕ, collateral reuse does have an effect on the agent through the potential purchases of the fire-sale-discounted assets at $t = 1$, which in turn generate underinvestment into the late-arriving project and the related negative social externalities on the households.

This difference between the private and social costs that come with collateral reuse means that the contracting agents, when left to their own devices, might set the collateral reuse rate suboptimally versus the social optimum. While agents A and B anticipate in their optimization problem the direct fire sale losses, these direct effects are irrelevant from the social perspective as the private fire sale losses to agent B become eventual gains to agent D. On the other hand, negative externalities detrimental to social welfare also arise from collateral reuse but these social costs are not considered by the private contracting parties when deciding on the rate of collateral reuse. Hence, a case for policy and regulation of the collateral reuse rate emerges, as will be illustrated in the Policy Implications section that follows.

The socially optimal rate of collateral reuse or ϕ^{**} is solved for by a constrained utilitarian social planner. The social planner is constrained in the sense that it can only influence the rate of collateral reuse[16] or ϕ. It optimizes the total welfare of the households, which takes into account the negative externality introduced by the collateral reuse. Hence, the social welfare is the sum of the expected profits of all the agents, reflecting the additional social costs of reuse that are not considered in the private choice.

The impact of collateral reuse on social welfare is reduced to the sum of the effects of reuse on agent B and agent D. Reuse has no effect on agent A as it is made indifferent between reuse and no reuse with the help of the borrowing costs that depend on ϕ or $r^A(\phi)$. Agent C's loan to agent B is perfectly safe in this context and its expected net profit is zero under any scenario. Hence, reuse of collateral impacts social welfare only through profits of agent B and agent D.

If agent B's project is successful, there are no fire sales of the collateral asset and at $t = 1$ agent D invest the full W into its late-arriving project, which will generate gross return of $g(W)$ at $t = 2$. However, in the event that agent B defaults at $t = 1$ and agent C urgently sells the seized ϕ part of the long-term asset, agent D buys the collateral asset at a fire sale discount for $\phi k(\phi)R$. This means that it only has the remainder of liquid funds or $W - \phi k(\phi)R$ to invest into the late-arriving project. In this case, the overall investment of agent D results in a return on the purchases of fire-sale assets of $\phi[1 - k(\phi)]R$ (effect which is neutral from the social welfare perspective) and a return of $g(W - \phi k(\phi)R) < g(W)$ on the late-arriving investment.

Because agent D funnels some of the limited W of liquid funds away from the late-

[16] Chapter 2 of this thesis considers a case of a social planner that can affect the liquidity available at $t = 1$ or W.

arriving productive investment into purchases of fire-sale assets, fire sales associated with collateral reuse result in later underinvestment and real economic costs from the social welfare perspective. Specifically, the social cost that captures this negative externality, $g(W) - g(W - \phi k(\phi)R)$, is a part of the extra net expected profit from reuse to agent D that can be expressed as:

$$\begin{aligned} E(\Pi^D) &= pg(W) + (1-p)[\phi[1-k(\phi)]R + g(W - \phi k(\phi)R)] - g(W) = \\ &= (1-p)\phi[1-k(\phi)]R - (1-p)\,[g(W) - g(W - \phi k(\phi)R)] \end{aligned} \tag{1.14}$$

The expected change in social welfare when $0 \le \phi \le 1$ of reuse is allowed is then:

$$\begin{aligned} E(\Pi^{SW}) &= E(\Pi^B) + E(\Pi^D) = \\ &= \phi k(\phi)R(pR^B - 1) - (1-p)[g(W) - g(W - \phi k(\phi)R)] \end{aligned} \tag{1.15}$$

Equation 1.15 makes it apparent that the direct impacts of the lost collateral and fire sales,
$(1-p)\phi[1-k(\phi)]R$, are irrelevant from the social perspective as those private losses to agent B become gains to agent D, with an overall null effect on social welfare. What matters is the return from the NPV of the extra investment into agent B's short-term asset that becomes possible because of the reuse, $\phi k(\phi)RR^B(pR^B - 1)$, and the expected real economic losses stemming from the limited funds being funneled away from the productive late-arriving project captured by $-(1-p)[g(W) - g(W - \phi k(\phi)R)]$.

The constrained social planner maximizes the change in social welfare that arises from collateral reuse by choosing the socially optimal collateral reuse rate ϕ^{**}, which represent ϕ that solves the following optimization problem:

$$\begin{gathered} \max_{\phi} E(\Pi^{SW}) = \phi k(\phi)R(pR^B - 1) - (1-p)[g(W) - g(W - \phi k(\phi)R)] \\ \text{s.t. 2 constraints:} \\ 0 \le \phi \le 1 \end{gathered} \tag{1.16}$$

When financial system and liquidity conditions exhibit a particular level of strength, it is socially optimal to maximize collateral reuse with $\phi^{**} = 1$. This required strength transpires when $p \ge \frac{k(1)+1}{k(1)R^B+1}$ or when the reusing agent B's credit quality is sufficiently high (its default probability $(1-p)$ is low enough and the return on its short-term asset R^B is high enough) and when the liquidity W available at $t = 1$ is ample enough. Under such favorable conditions, the investment into the short-term asset that was enabled through reuse is highly profitable and the negative externalities associated with reuse occur with such a low probability that social welfare benefits from maximum reuse.

When the credit quality of the agent B decreases and/or the liquidity conditions deteriorate to a region where $\frac{k(1)+1}{k(1)R^B+1} > p > \frac{k(0)+1}{k(0)R^B+1}$, social planner opts for an intermediate rate of reuse with $0 < \phi^{**} < 1$. The first order condition of the social welfare problem and the resulting internal socially optimal solution ϕ^{**} are captured in Equation 1.17. Unlike the privately optimal choice, ϕ^{**} also reflects the incremental impact of the choice on the fire sale prices, $\phi^{**}k'(\phi^{**})$, evaluated at this optimal rate of reuse. That is, the social planner's choice reflects the dependence of the fire sale discount factor on the average choice of the reuse rate of all agents of type B.

$$(pR^B - 1)[k(\phi^{**}) + \phi^{**}k'(\phi^{**})] = (1-p)g'(W - \phi^{**}k(\phi^{**})R)[k(\phi^{**}) + \phi^{**}k'(\phi^{**})] \quad (1.17)$$

Note that $(pR^B - 1)[k(\phi^{**}) + \phi^{**}k'(\phi^{**})]$ is the incremental benefit of the collateral reuse rate ϕ^{**} on the NPV of agent B's short-term investment and $g'(W - \phi^{**}k(\phi^{**})R)[k(\phi^{**}) + \phi^{**}k'(\phi^{**})]$ is the forgone incremental return on the late-arriving productive investment of agent D. In other words, social planner chooses the socially optimal ϕ^{**} so that the marginal social benefit of reuse from higher short-term investment equals the marginal social cost of reuse due to the underinvestment into the late-arriving project.

Because $g'(W - \phi^{**}k(\phi^{**})R) = \frac{1}{k(\phi^{**})}$, the internal social welfare solution in Equation 1.17 can be further reduced to:

$$k(\phi^{**}) = \frac{(1-p)}{pR^B - 1} \quad (1.18)$$

Applying comparative statics to the internal solution expressed in Equation 1.18, the right-hand side of Equation 1.18 increases in $(1-p)$. Since $k'(\phi) < 0$, it becomes apparent then that the socially optimal rate of reuse ϕ^{**}, like the private optimum, decreases in agent B's probability of default $(1-p)$. Since higher default probability of agent B implies both that its asset is less productive and that the social costs stemming from reuse occur with a higher probability, the social planner chooses lower ϕ^{**} when agent B's default probability $(1-p)$ is higher. On the other hand, because the right-hand side of Equation 1.18 decreases in R^B , the socially optimal reuse rate ϕ^{**} increases in R^B. Again, the intuition is straightforward: higher R^B means that agent B's project is more profitable and provides more expected return to offset fire sale losses and the resulting later underinvestment. Hence, the social planner opts for a higher rate of reuse when R^B is high.

Finally, ϕ^{**} increases in W or the liquidity available at $t = 1$. Higher available liquidity translates into higher fire sale prices at $t = 1$, which increases the amount of funds agent B can raise from agent C at $t = 0$ and hence increases the short-term investment at that time. At the same time, higher fire sale prices mean that more of limited funds will be funneled away from the late-arriving productive project, generating costly underinvestment. Given the properties of the $g(\cdot)$ function and the resulting endogenous fire sale factor $k(\phi)$, the incremental effect of higher $t = 1$ liquidity on the social cost of reuse will be smaller than on the benefit from short-term investment. Hence, the social planner will choose a higher rate of reuse knowing that the liquidity expected at $t = 1$ is higher.

Like the private solution, when the financial system exhibits a certain level of weakness and liquidity conditions deteriorate further, it might also be optimal from the social perspective to avoid collateral reuse altogether with $\phi^{**} = 0$. Specifically, when $\frac{k(0)+1}{k(0)R^B+1} \geq p > p_{min}$, the real economic losses from underinvestment outweigh the potential extra profit from the additional investment by agent B. In other words, when the short-term investment opportunity of agent B is NPV-positive but generates low profits in expectation (when the probability of agent B's short-term project failing is too high in relation to the rate of return on this investment) or when the liquidity is low, the NPV of the short-term project is not sufficient to absorb the social costs arising from the negative externality that comes with fire sales.

The socially optimal solution for the collateral reuse rate ϕ^{**} can be summarized in the following proposition:
Proposition 2: *Denote the socially optimal rate of collateral reuse as ϕ^{**}. Let:*

$$\begin{aligned} p_1^{SW} &= \frac{k(1)+1}{k(1)R^B+1} \\ p_0^{SW} &= \frac{k(0)+1}{k(0)R^B+1} \end{aligned} \tag{1.19}$$

Then for $p \geq p_1^{SW}$, it is socially optimal to maximize reuse of collateral and $\phi^{**} = 1$. For $p_1^{SW} > p > p_0^{SW}$, the social welfare optimum is internal with $0 < \phi^{**} < 1$ that satisfies $k(\phi^{**}) = \frac{1-p}{pR^B-1}$. For $p_0^{SW} \geq p > p_{min}$, it is socially optimal not to reuse collateral at all and $\phi^{**} = 0$.

1.3.4 Policy Implications

Based on the solutions to the optimization problems discussed in Subsections B and C, divergence between the privately and socially optimal choices of collateral reuse rate can occur in some cases, presenting scope for its regulation. Furthermore, such regulation should not be static. Rather, it should adjust with economic expectations that reflect the health of the financial system and liquidity conditions as will be described in more detail below. In Appendix 1.B, I provide a numerical example that illustrates the solutions and the implications for policy and regulation for a specific functional form of the production function $g(\cdot)$ that satisfies all the required assumptions.

In general, the social planner's choice of the rate of collateral reuse might be different from the private choice of agent B because agent B aims to maximize the profit from the additional investment into its own short-term project that is enabled through collateral reuse while compensating agent A for the potential loss of the pledged collateral, which is sold at a fire-sale discount to its fundamental value. The social planner, on the other hand, disregards the direct impact of fire sales on the contracting agents as these effects net out from the social welfare perspective (the private fire sale losses to the contracting agents A and B become fire sale profits to agent D). The social planner does, however, consider the additional effect that collateral reuse has on the economy through the negative externality of underinvestment - an effect that is not taken into account by agents A and B. Hence, it is likely that the social and private optima diverge in some cases.

Comparing the privately and socially optimal solutions for the collateral reuse rate captured in Proposition 1 and Proposition 2 respectively, it becomes apparent that the private and socially optimal choices converge at the maximum reuse rate of 1 in times characterized by a strong financial system and favorable liquidity conditions. A strong financial system in the context of the model is approximated by high credit quality of the financial intermediaries that engage into collateral reuse (a low default probability

$(1-p)$ and high project return R^B of agent B) and favorable liquidity conditions are represented by high liquidity holdings of agents that are active on secondary collateral asset markets (a high W of agent D), which translate into high market liquidity on the secondary markets (high $\phi k(\phi)R$).

Such favorable conditions mean that the severity and the probability of fire sales occurring are low enough so that the benefit of reuse in enabling more short-term investment outweighs both the private and social costs that can arise due to fire sales. This congruence between the private and socially optimal choices can be summarized in the following expression:

$$p \geq \frac{k(1)+1}{k(1)R^B+1} = p_1^{SW} \Rightarrow \phi^* = \phi^{**} = 1 \tag{1.20}$$

With a weaker financial system and less favorable liquidity conditions, agent B will choose a collateral reuse rate that is higher than what is optimal from the social welfare perspective. Comparing the privately and socially optimal internal solutions reflected in Equation 1.10 and Equation 1.18 respectively, it is clear that $k(\phi^*) < k(\phi^{**})$ in the internal solution regions. Given the properties of the $k(\phi)$ function, it implies that $\phi^* > \phi^{**}$ when comparing the internal solutions. In addition, $p_0^{SW} > p_0^B$ so, as the strength of the financial system and the liquidity conditions deteriorate, the socially optimal rate of reuse reaches zero faster than the private optimum.

Hence, the divergence between the two solutions can be characterized as:

$$p_1^{SW} > p > \frac{1}{k(0)(R^B-1)+1} = p_0^B \Rightarrow 0 \leq \phi^{**} < \phi^* \leq 1 \tag{1.21}$$

In other words, when the financial system and the liquidity conditions weaken, private agents will overuse collateral vs. what is optimal from the social welfare standpoint. A weaker financial system and liquidity conditions in the context of the model are characterized by lower credit quality (higher default probabilities $(1-p)$ and/or low project returns R^B) of the financial intermediaries that utilize collateral reuse and/or limited liquidity holdings (lower W), which translate into less ample liquidity on the secondary collateral asset market (lower $\phi k(\phi)R$). These conditions are captured by the range of p in relation to the other parameters as reflected in Condition 1.21.

Finally, a congruence of the social and private choices of collateral reuse rate at the minimum of zero reuse is also possible. When the financial system is weak and liquidity conditions are poor, the private and the social costs of reuse more than outweigh the benefit of the now lowly-profitable short-term investment that is enabled through reuse. Under such conditions, it is optimal both from the private and the social welfare perspective not to reuse any collateral at all (even if the NPV of short-term investment of the reusing intermediary remains positive). This congruence of no reuse is captured by:

$$p_0^B > p > p_{min} \Rightarrow \phi^* = \phi^{**} = 0 \tag{1.22}$$

Hence, the privately optimal rate of reuse can be higher than what is optimal from the social perspective and regulators should limit the private levels of reuse when the financial system and liquidity conditions are weakening. This calls for a regulation of the reuse rate that adjusts with expectations on the health of the financial system and liquidity and limits it in bad times.

Namely, the imposed limit on the reuse should reduce the private reuse rate to the socially optimal level when the credit quality of the reusing intermediaries (as approximated by their default probability and project returns) is deteriorating and/or when the liquidity holdings of agents active on secondary asset markets are becoming less ample. Therefore, when the intermediaries engage into riskier and less profitable projects ($(1-p)$ is rising and/or R^B is falling) and/or the liquidity levels are deteriorating (W is decreasing), the regulator should step in and curb reuse to the level that is optimal from the social welfare perspective. What constitutes high or low enough for any parameter is defined in relation to the remaining parameters, with the relationships captured in Condition 1.21.

The convergence and divergence of the privately and socially optimal solutions for the collateral reuse rate are formally captured in the following proposition[17]:
Proposition 3: *Denote the privately and the socially optimal rates of collateral reuse as ϕ^* and ϕ^{**} respectively. Then for $p \geq p_1^{SW} = \frac{k(1)+1}{k(1)R^B+1}$, it is both privately and socially optimal to maximize reuse of collateral and $\phi^{**} = \phi^* = 1$. For $p_1^{SW} > p > p_0^B = \frac{1}{k(0)(R^B-1)+1}$, private agents will reuse more collateral than the social optimum and $0 \leq \phi^{**} < \phi^* \leq 1$. For $p_0^B \geq p > p_{min}$, the private and the social optima converge at no reuse and $\phi^{**} = \phi^* = 0$.*

1.4 Discussion & Conclusions

The benchmark model presented in this paper is an attempt to understand the complex process of collateral reuse and its repercussions on the financial stability and the greater economy. The model trades off the benefit of collateral reuse in facilitating more productive investment with its potential to generate fire sales and the associated private costs and negative externalities. While fire sale collateral prices are endogenous to reuse, this benchmark model features exogenous liquidity holdings, which nevertheless impact the prices and hence the choices of the reuse rate of the private agents and the social planner. Chapter 2 of this thesis extends the benchmark model to consider endogenous choices of liquidity holdings of agents active on secondary asset markets to show important insights on the interaction of decisions around collateral reuse and liquidity buffers.

The results of the benchmark model point to a possible divergence between the privately and socially optimal choices of the collateral reuse rate, presenting scope for its regulation. The optimal regulation of the reuse rate that stems from the benchmark model is dynamic in nature - it adjusts with expectations on the health of the financial system and liquidity conditions - and it calls for limiting the reuse rate in bad times.

[17]The different cases of convergence and divergence of the solutions for the benchmark model that utilizes a specific functional form of the late-arriving investment production function $g(\cdot)$ are illustrated in Appendix 1.B.

This is because private agents tend to reuse inefficiently too much collateral as the strength of the financial system and liquidity conditions deteriorate, with the financial system strength approximated in the model with the credit quality of the reusing intermediaries and liquidity conditions reflecting liquidity holdings of agents active on the secondary collateral asset markets and the resulting market liquidity. Hence, under this benchmark setting, social welfare benefits from a regulator that curbs reuse to the socially optimal levels as overall credit quality and liquidity conditions deteriorate, which are very interesting theoretical findings.

However, further work to expand the understanding of optimal collateral reuse rates is needed. For example, the benchmark model considers the collateral reuse activity in isolation and does not reflect its impact on the provision of credit and the resulting health of the financial system and the overall economy. Therefore, the proposed regulation (i.e., tightening of reuse in bad times) does not reflect potential destabilizing features of limiting collateral reuse that might arise due to restricted credit availability. These considerations are out of the scope of this study, however. In addition, the model featured in this paper is based upon a trade-off between only one positive and one negative aspect of collateral reuse, namely the potential for increasing profitable investment vs. the costs arising from associated fire sales. However, the risks to financial stability associated with reuse of collateral are not limited to fire sales.

For example, reusing collateral might raise interconnectedness among financial institutions leading to a greater risk of contagion in case that a financial intermediary included in the reuse chain is subject to financial distress (CGFS (2013), FSB (2017a)). To better understand interconnectedness and contagion in the context of collateral reuse activities, the benchmark model could be extended to consider a possibility of a longer collateral reuse chain with many lenders using a part of the collateral pledged to them to obtain additional financing. With more reusing agents, even more profitable investment could be produced through collateral reuse than in the benchmark model but at a cost of a higher probability of a default along the chain and potential contagion. Therefore, both the positive and negative impacts of collateral reuse should become amplified versus the benchmark model featured in this analysis. Extending the model to more agents would allow to derive a socially optimal length of collateral reuse chains, which could be a measure of optimal interconnectedness associated with collateral reuse (FSB (2017a)).

Finally, the benchmark model produces interesting testable predictions. They include the impact of the credit quality of the reusing agents on the prevalence and rate of collateral reuse as well as on the cost of borrowing in transactions that facilitate reuse of collateral (such as repos). In addition, the model presents predictions on the effect of liquidity holdings and market liquidity on collateral reuse. It would be interesting to put these predictions to an empirical test by applying them to real collateral reuse transaction data and Chapter 3 of this thesis empirically explores the relationship between the credit quality of intermediaries that reuse collateral and their intensity of reuse.

Overall, a lot of further research remains to be done to expand and fine-tune the findings presented in this paper. Nevertheless, it does provide interesting insights into the dynamics of collateral reuse, the trade-offs generated by it and its implications for policy and regulation.

Appendices

Appendix 1.A Current Regulation around Collateral Reuse & Rehypothecation

To better understand the existing regulation around collateral reuse as applied in the context of the model presented in this paper, it is important to distinguish between the legal definitions of rehypothecation and reuse of collateral. Rehypothecation has a narrower definition and refers to a use of a client's assets by a financial intermediary to which the client's assets are pledged to. Rehypothecation most frequently occurs in the context of secured margin loan transactions, where the lender (usually a broker-dealer or a bank) uses securities that were pledged by the borrower (usually a hedge fund or a security lender) to finance the client's margin loan or its other transactions as well as (where permitted) to fund the lender's own activities. On the other hand, collateral reuse represents any use by an intermediary (or other party taking collateral) of any assets (not just a client's) that were delivered as collateral in a transaction. This includes securities delivered as collateral in repo transactions that are then reused by the collateral taker as collateral in another transaction with a third party.

Keeping this legal distinction in mind, the rate of collateral reuse remains largely unregulated around the globe. The rate of rehypothecation specifically is regulated to some extent in the US under Federal Reserve Board's Regulation T and the SEC Rule 15c3-3, with both of these rulings applying only to US broker-dealer banks registered with SEC. Rehypothecation and reuse of collateral are regulated to a much lesser extent in the EU and other major jurisdictions, where these practices are subject to prior consent obligations[18] and to transparency and reporting requirements only.

In the US, US-domiciled broker-dealers need to obtain permission of their borrowing clients to rehypothecate collateral pledged to them as part of a borrowing transaction. The Federal Reserve Boards Regulation T limits the amount of credit that broker-dealers can provide to their clients for the purchase of securities up to 50% of their value. The SEC Rule 15c3-3 further specifies that US broker-dealers can rehypothecate pledged collateral that is a worth up to 140% of a given borrower's margin debit with that particular dealer (with the margin debit being the amount the borrower owes the broker-dealer for the purchase of the securities that are pledged as collateral).

For example, let's say that a hedge fund buys $100,000 worth of securities on a 50% margin with a given broker-dealer. This means that the broker-dealer loans the hedge fund $50,000, which represents the hedge fund's debit balance with that particular broker-dealer. The amount of the hedge fund's pledged securities that can be rehypothecated by the broker-dealer as collateral is $70,000 (140% x $50,000 debit = $70,000 available as reusable collateral). Because only $70,000 of the $100,000 of customer securities can be reused by the broker-dealer, the remaining $30,000 of securities

[18] Note that because in the EU repo transactions feature a legal transfer of ownership of the securities used as collateral from the collateral seller (the borrower) to the collateral buyer (the lender), the collateral buyer can reuse the collateral for its own purposes as it sees fit for the duration of the repo contract. Hence, such transactions feature an implicit consent of the borrower for the lender's reuse.

have to be segregated and held in safekeeping by the broker-dealer.

Note that the SEC Rule 15c3-3 generally applies only to margin lending or securities lending transactions and that financial transactions such as repos and derivatives are excluded from the 140% reuse limit. Hence, reuse of collateral that underlies such transactions remains uncapped in the US (Singh and Aitken (2010)). However, the rule does decrease the primary source of collateral from the securities lenders and hedge funds that the broker-dealers can use for their own purposes. This, in turn, limits the total amount of collateral available throughout the financial system.

Other jurisdictions in the developed markets do not feature regulation of the collateral rehypothecation or the reuse rate but do require some degree of transparency and consent around the practices. FSB ascertains that all of its member have some reporting requirements that track rehypothecation of client assets, but the requirements vary widely across jurisdictions in terms of means, scope and frequency. Some rules only stipulate that financial intermediaries need to provide their clients with information on rehypothecation of their pledged assets while others may require regulatory filings with relevant authorities (which are not necessarily publicly disclosed). In addition, FSB claims that most of its members require a client's prior consent to allow rehypothecation of their assets (FSB (2015)).

Specifically in the EU, no cap on rehypothecation of pledged assets is imposed and only some transparency and consent obligations are in place through the EU Securities Financing Transactions Regulation (SFTR) or the EU Regulation 2015/2365. SFTR aims to increase clarity around the extent of rehypothecation and reuse of financial instruments provided as collateral. The idea is to provide more transparency about the risks and consequences of reuse that arise especially in case of default and bankruptcy. Under the regulation, collateral rehypothecation requires a disclosure of the risks and consequences of rehypothecation and a prior consent of the counter-party that pledges the collateral or the express agreement to provide collateral by way of a title transfer. Furthermore, the regulation requires that the counter-parties involved in securities financing transactions must report the details of the concluded transactions in a timely manner to a central database registered with the European Securities and Markets Authority (ESMA).

In the EU, there are additional restriction on collateral reuse concerning investment funds that fall under Undertakings for Collective Investment in Transferable Securities Directive (UCITS), which prohibits fund depositories and custodian from rehypothecating the fund's assets for their own account. In addition, ESMA has issued guidelines for UCITS that prohibit them from reusing non-cash collateral. Similarly, the EU Regulatory Technical Standards on margin requirements involved in non-centrally cleared OTC derivatives prohibits reusing non-cash collateral that was pledged as an initial margin.

The disclosure and consent requirements stipulated under the SFTR as it relates to collateral rehypothecation and reuse continue to apply in the UK after its exit from the EU (with an amendment that shifts responsibilities that currently sit with EU institutions to the equivalent UK bodies). In addition, collateral rehypothecation and reuse transactions by Swiss financial institutions that involve collateral that was pledged by a company domiciled in the EU also fall under the SFTR rules.

Appendix 1.B Numerical and Graphical Example of Benchmark Model Results

Given the requirements imposed on the $k(\phi)$ function as set out in the model, there are restrictions that the $g(X)$ production function that represents the late-arriving investment needs to satisfy. Specifically, in addition to being increasing and concave in X, the $g(X)$ function must be such that the resulting $k(\phi) = \frac{1}{g'(W-\phi k(\phi)R)}$ satisfies $k(0) \leq 1$, $0 < k(1) < 1$, $k'(\phi) < 0$, $k''(\phi) > 0$ and $\frac{\partial k(\phi)}{\partial W} > 0$.

One of functional forms that satisfies all of the conditions for $k(\phi)$, with a further assumption required on the liquidity available at $t = 1$ that $W \geq 1$, is $g(X) = W_{max} \ln(X)$, where W_{max} are the maximum liquidity holdings allowed in the model[19]. The corresponding fire sale discount factor and its properties are:

$$k(\phi) = \frac{1}{g'(W - \phi k(\phi)R)} = \frac{W}{W_{max} + \phi R} \tag{1.23}$$

$$k(0) = \frac{W}{W_{max}} \leq 1 \tag{1.24}$$

$$0 < k(1) = \frac{W}{W_{max} + R} < 1 \tag{1.25}$$

$$k'(\phi) = \frac{-WR}{(W_{max} + \phi R)^2} < 0 \tag{1.26}$$

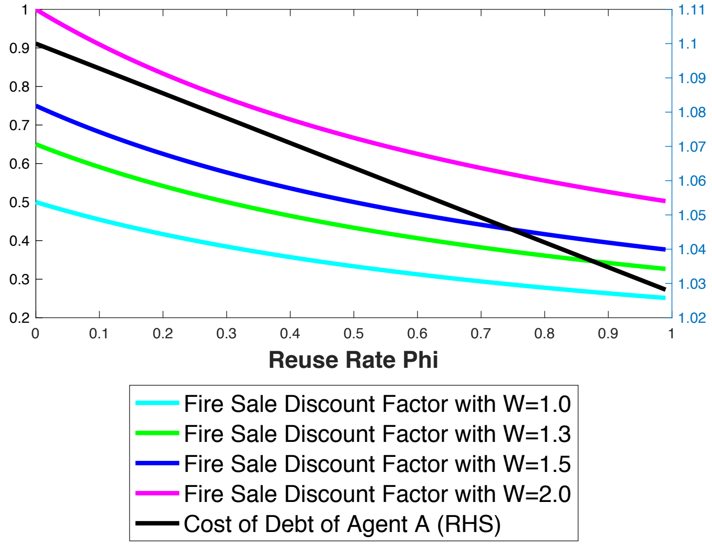
$$k''(\phi) = \frac{2WR^2}{(W_{max} + \phi R)^3} > 0 \tag{1.27}$$

$$\frac{\partial k(\phi)}{\partial W} = \frac{1}{W_{max} + \phi R} > 0 \tag{1.28}$$

Figure A1 illustrates the fact that the fire sale discount factor is a decreasing and convex function of the collateral reuse rate ϕ and that it is higher for higher liquidity holdings W available at $t = 1$. In addition, the figure documents the decreasing nature of agent A's cost of borrowing in relation to the reuse rate. The results assume that the long-term asset that is used as collateral returns a certain rate of $R = 2$ at $t = 2$ and that the short-term asset of agent B returns an uncertain rate of $R^B = 1.1$ at $t = 1$ with probability $p = 96.5\%$.

[19] For example, in the benchmark model $W^{max} = R$ because $W \leq R$.

Figure A1: Fire Sale Discount Factor and Agent A's Cost of Debt as Functions of Collateral Reuse Rate: Benchmark Model Results for $g(X) = W_{max} \ln(X)$, $R = 2$, $R^B = 1.1$ and $p = 96.5\%$



Furthermore, for $g(X) = W_{max} \ln(X)$, the social cost function that represents the negative externality of underinvestment that is associated with collateral reuse and its properties are:

$$c(\phi) = g(W) - g(W - \phi k(\phi)R) = W_{max}[\ln(W) - \ln(W - \phi k(\phi)R)] = \\ = W_{max}\left[\ln\left(W_{max} + \phi R\right) - \ln(W_{max})\right] \tag{1.29}$$

$$c(0) = 0 \tag{1.30}$$

$$c'(\phi) = \frac{RW_{max}}{W_{max} + \phi R} > 0 \tag{1.31}$$

Based on the above, the following benchmark model results are derived for $g(X) = W_{max} \ln(X)$:

$$\phi^* = \frac{1}{R}\left[\frac{Wp(R^B - 1)}{1 - p} - W_{max}\right] \tag{1.32}$$

$$\phi^{**} = \frac{1}{R}\left[\frac{W(pR^B - 1)}{1 - p} - W_{max}\right] \tag{1.33}$$

Table A1 and Figures A2 and A3 illustrate the benchmark model results for various levels of W (the $t = 1$ liquidity holdings of agent D) and $(1 - p)$ (probability of default of agent B) for $g(X) = W_{max} \ln(X)$. The results again assume that $R = 2$ and $R^B = 1.1$. As shown in the table and the figures and in line with the pro-cyclical benchmark model results, both the privately and the socially optimal reuse rates decrease when the credit quality of agent B deteriorates (when $(1 - p)$ increases for a given value of W) or when the liquidity holdings become less ample (when W decreases for a given value of $(1 - p)$).

Table A1: Privately and Socially Optimal Collateral Reuse Rates: Example of the Benchmark Model Results for $g(X) = W_{max} \ln(X)$, $R = 2$ and $R^B = 1.1$

W	1.0		1.0		1.3		1.3		1.5		1.5		2.0		2.0	
1-p_1^{SW}	1.96%		1.96%		2.39%		2.39%		2.66%		2.66%		3.23%		3.23%	
1-p_1^{B}	2.44%		2.44%		3.15%		3.15%		3.61%		3.61%		4.76%		4.76%	
1-p_0^{SW}	3.23%		3.23%		3.79%		3.79%		4.11%		4.11%		4.76%		4.76%	
1-p_0^{B}	4.76%		4.76%		6.10%		6.10%		6.98%		6.98%		9.09%		9.09%	
1-p	2%	2.5%	3.5%	5%	2%	2.5%	3.5%	5%	2%	2.5%	3.5%	5%	2%	2.5%	3.5%	5%
ϕ^*	1	0.95	0.38	0.00	1.00	1.00	0.79	0.24	1.00	1.00	1.00	0.43	1.00	1.00	1.00	0.90
ϕ^{**}	0.95	0.45	0.00	0.00	1.00	0.89	0.14	0.00	1.00	1.00	0.32	0.00	1.00	1.00	0.76	0.00

In terms of the divergence between the social and private optimum regarding the collateral reuse rate, Table A1 as well as Figures A2 and A3 show that the privately and the socially optimal choices converge at full reuse when the credit quality of the reusing agent B is high ($(1-p)$ is low) and/or there is ample liquidity available (W is high). Taking the case of $W = 1.3$ as an example, such favorable conditions are captured by $1-p \leq 1-p_1^{SW} = 2.39\%$, for which $\phi^{**} = \phi^{*} = 1$. For higher levels of $(1-p)$ such that $1-p_1^{SW} = 2.39\% < 1-p < 1-p_0^{B} = 6.10\%$, the private agents always choose to reuse more than what is optimal from the social perspective and $0 \leq \phi^{**} < \phi^{*} \leq 1$. Specifically, when $(1-p)$ reaches a level such that $1-p_0^{SW} = 3.79\% \leq 1-p < 1-p_0^{B} = 6.10\%$, it would be optimal from the social welfare point of view not to reuse any collateral at all but private agents still opt for some level of reuse. Finally, for $1-p_0^{B} = 6.10\% \leq 1-p < 1-p_{min} = 9.09\%$, a convergence of the private and social-welfare solution occurs at the zero level of collateral reuse and $\phi^{**} = \phi^{*} = 0$.

Figure A2: Privately and Socially Optimal Collateral Reuse Rates as a Function Default Probability $(1-p)$ of the Reusing Agent B for Different Levels of Agent D's Liquidity Holdings W: Illustration for the Benchmark Model with $g(X) = W_{max}\ln(X)$, $R = 2$ and $R^B = 1.1$

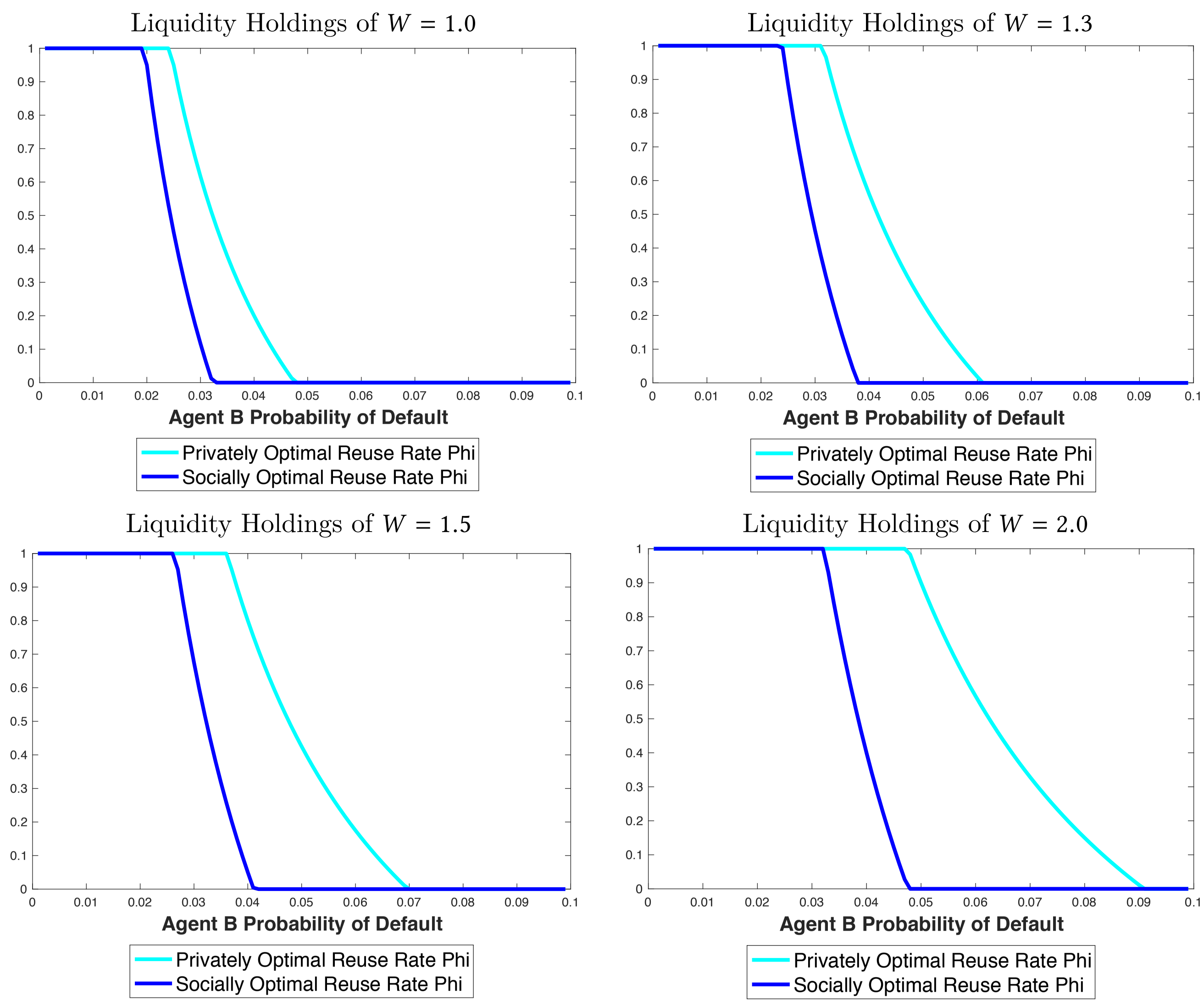
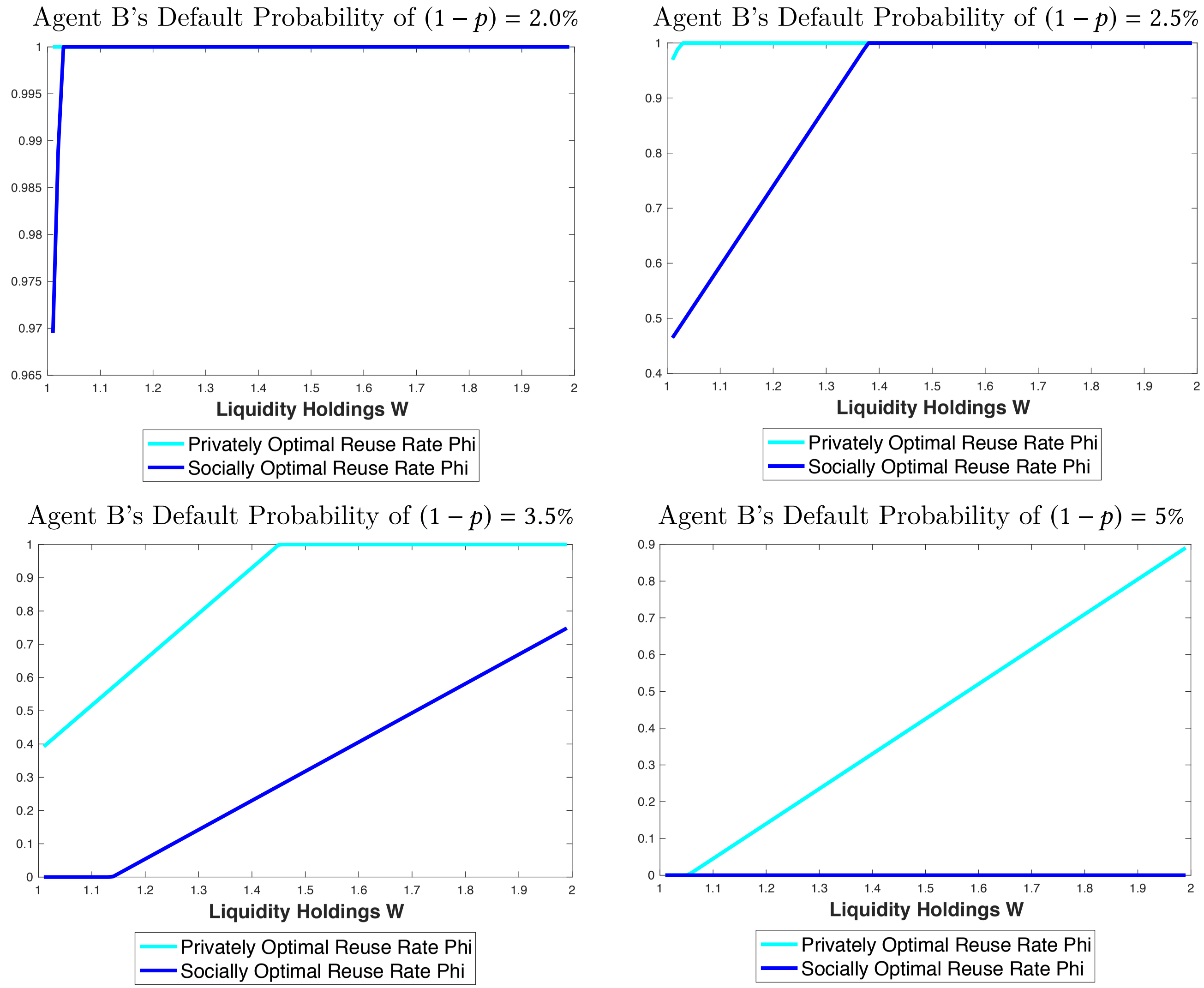


Figure A3: Privately and Socially Optimal Collateral Reuse Rates as a Function of the $t = 1$ Liquidity Holdings W for Different Levels of Default Probability $(1 - p)$ of the Reusing Agent B: Illustration for the Benchmark Model with $g(X) = W_{max}\ln(X)$, $R = 2$ and $R^B = 1.1$



Appendix 1.C Model Extension: Risky Asset of Agent A

This small extension of the benchmark model explores the collateral reuse rate choices in case that the long-term asset of agent A is risky. As we will see, as long as the asset is relatively safe and produces a large enough return as the worst-case outcome, the results and implications for policy hold vs. the benchmark model, which is simpler in its setup.

Let's assume now that for an investment of 1 at $t = 0$, the long-term asset returns a gross rate of R with a probability p^A and a gross rate of ΔR with a probability $(1 - p^A)$, where $0 < \Delta < 1$ and $R[p^A + (1 - p^A)\Delta] - 1 > pR^B - 1 > 0$ (the long-term asset is still NPV-positive and more productive than the short-term asset of agent B).

The participation constraint of agent A in case of its asset being risky is as follow:

Participation Constraint of Agent A:

$$E(\Pi^A_{Reuse,\Delta<1}) = E(\Pi^A_{NoReuse,\Delta<1}) \Leftrightarrow \tag{1.34}$$
$$[1 - (1 - p)\phi]R[p^A + (1 - p^A)\Delta] - pr^A(\phi) = R[p^A + (1 - p^A)\Delta] - pR^B$$

from which the cost of borrowing rate $r^A_{\Delta<1}(\phi)$ paid in expectation by Agent A for $\phi > 0$ can be derived:

$$pr^A_{\Delta<1}(\phi) = pR^B - (1 - p)\phi R[p^A + (1 - p^A)\Delta] < pR^B \tag{1.35}$$

Since the worst case scenario return for the asset of agent A is ΔR, the infinitely risk-averse agent C is willing to lend only $\phi k(\phi)\Delta R$ to agent B at $t = 0$ to make the loan perfectly safe from its perspective. Agent B invests these funds into its short-term asset but needs to compensate agent A for the $(1-p)$ probability risk of agent C seizing the ϕ part of the long-term asset that has a fundamental value of $R[p^A + (1 - p^A)\Delta]$. This trade-off is captured in the private extra profit from reuse to agent B:

$$E(\Pi^B_{\Delta<1}) = \phi k(\phi)\Delta Rp(R^B - 1) - (1 - p)\phi R[p^A + (1 - p^A)\Delta] \tag{1.36}$$

Maximizing this profit function with respect to the collateral reuse rate ϕ, the following solution is obtained:

$$\begin{aligned}
\phi^*_{\Delta<1} = 1 \text{ for } p > p^B_{1,\Delta<1} &= \frac{\left[1 + (\frac{1}{\Delta} - 1)\right]}{k(1)(R^B - 1) + \left[1 + (\frac{1}{\Delta} - 1)\right]} \\
0 < \phi^*_{\Delta<1} < 1 \text{ for } p^B_{1,\Delta<1} \geq p > p^B_{0,\Delta<1} &= \frac{\left[1 + (\frac{1}{\Delta} - 1)\right]}{k(0)(R^B - 1) + \left[1 + (\frac{1}{\Delta} - 1)\right]} \\
\text{with } k(\phi^*_{\Delta<1}) &= \frac{[p^A(1 - \Delta) + \Delta]}{\Delta} \times \frac{(1 - p)}{p(R^B - 1)} \\
\phi^*_{\Delta<1} = 0 \text{ for } p^B_{0,\Delta<1} &\geq p > p_{min}
\end{aligned} \tag{1.37}$$

Comparing these solutions to the results from the benchmark model captured in Proposition 1, one can see that the privately optimal reuse rates are different in the two models. However, the discrepancy between solutions narrows as Δ increases. In fact, the benchmark model is a special simpler case of this extension for $\Delta = 1$, in which case ϕ^* and the divergence region between the privately and the socially optimal solutions overlap with the extended model. Because the long-term asset of agent A used in this setting represents financial collateral that is usually a relatively safe asset (a government bond, a safe corporate bond, a senior tranche of a securitized product, etc.), it is expected to retain high value even in times of distress. Hence, high levels of Δ are justified in this context and the benchmark model results are a close approximation of the risky collateral asset setting considered in this extension while being derived in a simpler setup.

Specifically, comparing the benchmark and the extended model solutions, $(1-p^B_{1,\Delta<1}) < (1-p^B_1)$ and $(1-p^B_{0,\Delta<1}) < (1-p^B_0)$, which means that the region of divergence between the privately and the socially optimal reuse rates is shifted to lower levels of default probabilities of agent B. The first of the conditions holds for $p^A > \frac{\Delta}{1+\Delta}$. Since the financial long-term asset of agent A that can then be used as collateral is a relatively safe asset as discussed above, it is reasonable to assume that p^A satisfies the $p^A > \frac{\Delta}{1+\Delta}$ threshold, which is henceforth assumed. In addition, the internal private solution of this extension implies that $\phi^*_{\Delta<1}$ is lower than the privately optimal reuse rate from the benchmark model ϕ^*. This is because $k(\phi^*_{\Delta<1}) > k(\phi^*)$, which holds for $\Delta > \frac{p^A(pR^B-1)}{(1-p)+p^A(pR^B-1)}$, which is justified with the safe nature of the financial asset of agent A. However, as mentioned above, the discrepancy between the benchmark and the extended model solutions shrinks as Δ increases.

The social welfare solution of this model extension remains the same as the benchmark model. It features the following social welfare function:

$$E(\Pi^{SW}_{\Delta<1}) = \phi k(\phi)\Delta R(pR^B - 1) - (1-p)[g(W) - g(W - \phi k(\phi)\Delta R)] \tag{1.38}$$

and optimizing it with respect to ϕ produces the same optimal reuse rate as the benchmark model:

$$k(\phi^{**}_{\Delta<1}) = \frac{(1-p)}{pR^B - 1} = k(\phi^{**}) \tag{1.39}$$

This is because the marginal social benefit of reuse in facilitating more investment today is affected by Δ in the same way as the marginal social cost of the later underinvestment (the fact that less funds can be raised by agent B at $t = 0$ when $\Delta < 1$ means that at a margin there will be proportionally less underinvestment at $t = 1$).

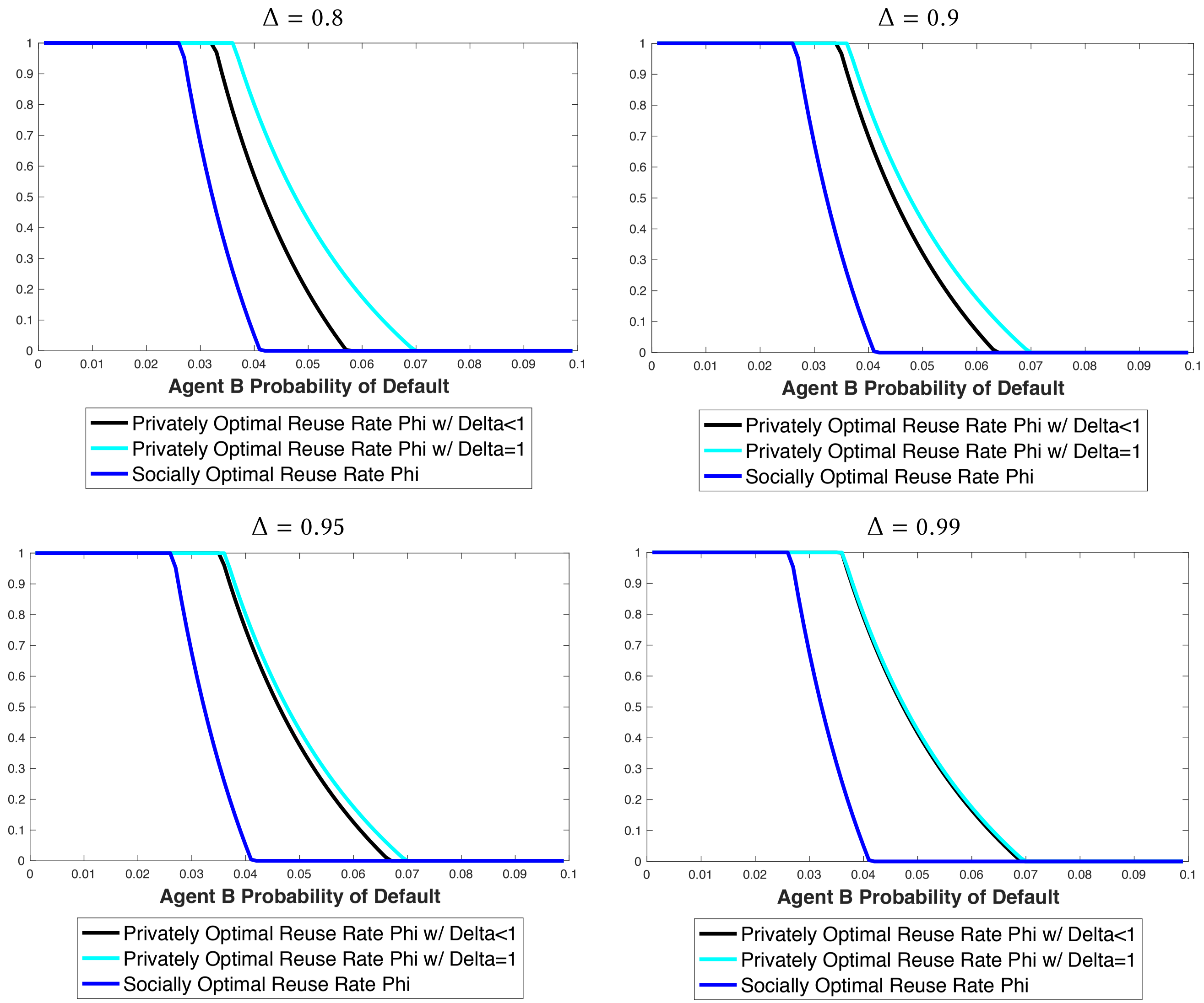
The comparative statics analysis of the effects of p, R^B and W on the benchmark model privately and socially optimal solutions holds also for this extended version of the model. This means that all the policy implications discussed for the benchmark model also apply to this extension. Namely, the private and socially optimal reuse is procyclical and there is scope for regulation of the reuse rate as the health of the reusing intermediaries and the liquidity conditions deteriorate - only the region of divergence changes but again, this difference is minimal when the safe nature of the collateral asset is considered.

The above-discussed results of this model extension are illustrated in Figure A1. Continuing with the numerical example used in Section III.E, I apply $g(X) = W_{max}\ln(X)$.

However, in this case the long-term asset of agent A is risky and at $t = 2$ it returns R with probability $p^A = 95\%$ and only ΔR with probability $(1 - p^A) = 5\%$. In addition, I set $R^B = 1.1$ and $W = 1.5$. Using these parameters, I obtain the privately optimal reuse rate $\phi^*_{\Delta<1}$ from the extended model (reflecting $\Delta < 1$) and plot it versus the privately optimal reuse rate ϕ^* from the benchmark model (reflecting $\Delta = 1$) as well as the socially optimal reuse rate ϕ^{**} that is the same in both versions of the model.

In line with the discussion above, Figure A1 shows that the divergence region of the extended model shifts to the left with respect to the default probability of Agent B vs. the benchmark model divergence region. In the extended model results, the divergence between the privately and the socially optimal reuse rate first occurs for lower levels of default probability $(1 - p)$ but the convergence at no reuse also occurs at lower probabilities of default, resulting in the shift of the divergence region. In addition, the private solution from the extended model is lower than the private solution from the benchmark model. However, as the worst-case scenario return of the long-term asset increases (Δ rises), the discrepancy between the benchmark and the extended model solutions shrinks.

Figure A1: Privately and Socially Optimal Collateral Reuse Rates as a Function of Default Probability $(1-p)$ of the Reusing Agent B for Different Levels of Δ: Illustration for the Benchmark Model with $g(X) = W_{max}\ln(X)$, $R = 2$, $R^B = 1.1$, $W = 1.5$ and $p^A = 95\%$



Chapter 2

Collateral Reuse, Liquidity Holdings and Liquidity Regulation

2.1 Introduction & Related Literature

The events that unfolded in financial markets around the onset of the COVID-19 pandemic in March and April of 2020 spiraled into a global liquidity shock, which froze up primary funding markets and wreaked havoc in various secondary asset markets. Unlike the Global Financial Crisis of 2007-2009 ("GFC"), which was essentially a solvency crisis whereby banks and financial intermediaries found themselves holding low-quality opaque assets, the COVID-19 financial crisis occurred when the financial system was relatively healthy, in large part due to the banking and liquidity regulation that has been rolled out globally since the GFC to ensure resilience of the financial system in such crises (e.g., the Basel III capital requirement and liquidity regulations as per Basel Committee on Banking Supervision (2010a), Basel Committee on Banking Supervision (2010b) and Basel Committee on Banking Supervision (2013)).

The onset of the global COVID-19 pandemic generated substantial uncertainty across financial markets globally - uncertainty over the speed and reach of the spread of the virus, the infection and death rates, the severity of responses to the pandemic by governments across the globe and the resulting impact on the local and global economy. The uncertainty caused market participants to withdraw their liquidity, prompting unprecedented outflows from various secondary asset markets, including money markets and bond markets. Primary funding markets froze and yields on government and corporate bonds on the secondary markets spiked drastically, driving values of fund portfolios down and prompting redemptions by fund investors. Prime money market funds[1] as well as funds that invested in bonds suffered particularly extreme redemptions, and those funds that did not have sufficient liquidity holdings to cover these outflows had to sell some of their assets to facilitate the redemptions.

[1] A prime money market fund is a mutual fund that invests into short-term securities of high credit quality that are not US Treasuries. These might include high-quality commercial paper of corporates and short-term debt issued by US government agencies. The overall purpose of such funds is to create a highly liquid, low-risk investment while generating a higher return than holding cash.

The forced sales of the assets in an environment of limited liquidity generated fire sales, which further depressed the value of the assets held by the funds, prompting yet more redemptions and forced assets sales to cover them. Hence, a negative liquidity spiral was created (in line with Brunnermeier and Pedersen (2009) who show that market liquidity of an asset depends on the funding liquidity of the traders that trade it), which caused the liquidity shock to quickly spread across the world. Because the COVID-19 financial crisis was driven by liquidity and not solvency concerns, central banks were able to successfully intervene by providing extra liquidity in the secondary asset markets, which ensured that the crisis was relatively short-lived. The paragraphs below detail the impact of the COVID-19 liquidity shock on various important global asset markets and the central bank interventions that finally stemmed it.

Money Markets

Eren et al. (2020) document severe dislocations in the US money markets due to the COVID-19 shocks in March 2020. The associated distress in short-term dollar funding markets (especially the commercial paper and certificate of deposit segments) led to a diversion of funding from unsecured to secured funding markets and government money market funds ("MMFs"), resulting in a general liquidity squeeze in the bank funding markets. Specifically, substantial redemptions from prime MMFs in the US market affected the ability of banks to fund themselves, leading to substantially shortened funding maturities and drastic increase in funding costs, despite the fact that the banks were not at the core of the crisis to begin with.

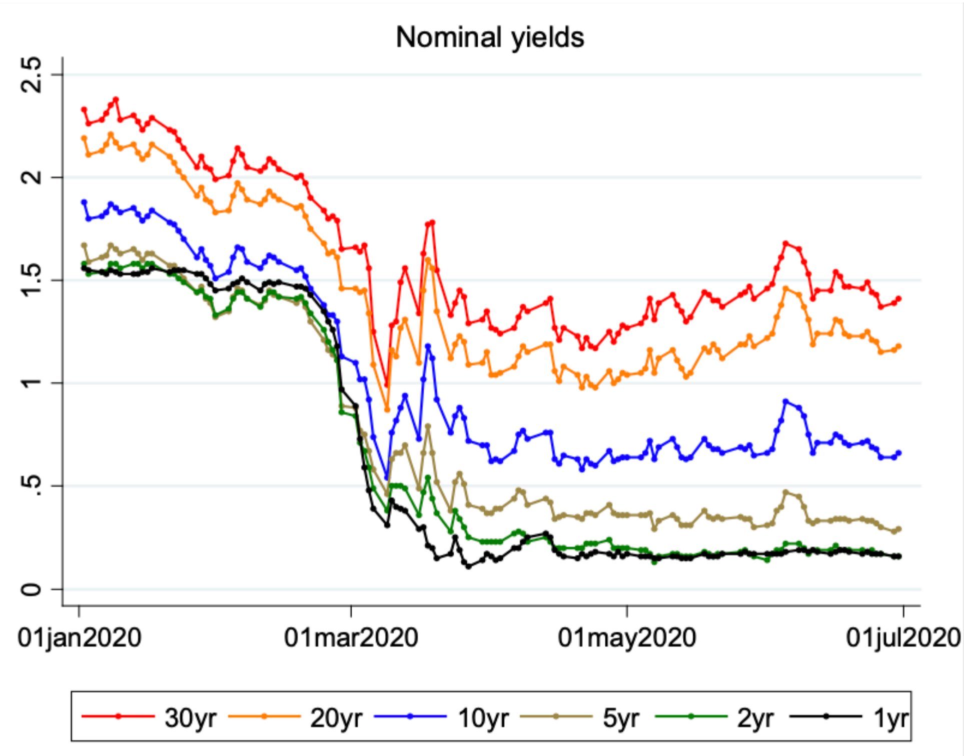
In addition, the sudden large-scale rebalancing from prime to government MMFs further exacerbated the dislocations in the money markets. US prime MMFs had to liquidate large parts of their portfolios to meet the increased redemptions. At the same time, government MMFs needed to purchase large amounts of assets to meet the suddenly increased inflows. The size and speed of the rebalancing left dealers unable or unwilling to accommodate their balance sheets to intermediate the required shifts and only the intervention of the Federal Reserve ("the Fed") restored the functioning of the money markets in the US. The quick intervention of the Fed in providing a back-stop for MMFs restored correct functioning of the funding markets and helped to prevent an even larger run on the MMF sector.

Treasury Bond Markets

Vissing-Jorgensen (2021) analyzes dislocations in the US Treasury market related to the COVID-19 shock in March and April of 2020 (see Figure 2.11). The author proposes that the price distortions were not a result of a loss of confidence in Treasuries but rather were driven by liquidity needs. Specifically, the dislocations were not associated with an increased expected inflation or higher CDS rates on US government debt (see Figure 2.12). Instead, the price distortions were mainly caused by bond mutual funds disproportionally selling Treasuries to meet large scale fund redemptions experienced during the period. Large-scale selling by foreign central banks and hedge funds further contributed to the price pressure.

The author relates the poor performance of Treasuries around the COVID-19 shock to a disappearance of the so-called "safety-effect". The "safety-effect" was documented by Krishnamurthy and Vissing-Jorgensen (2011) and Krishnamurthy and Vissing-Jorgensen (2012), and it refers to the willingness of investors to pay premium for ultra-safe and/or ultra-liquid assets such as Treasuries. In addition, because Treasury yields started to fall within days of the first large daily Fed purchases of Treasuries after March 18, 2020, the author proposes that providing liquidity in the Treasury markets requires actual large-scale buying of the Treasuries (see Figure 2.13). This is unlike the corporate bond market where the announcement of the purchases alone was able to successfully stabilize the market (see subsection 2.13 below).

Figure 2.11: Treasury yield dislocation
Reuse of Panel B of Figure 1 from Vissing-Jorgensen (2021)



Corporate Bond Markets

The COVID-19 pandemic shock also triggered major disruptions in the corporate bond market. Liquidity of the US corporate bond market as measured by trading costs fell drastically at the onset the COVID-19 shock (Kargar et al. (2020)). In addition, Haddad et al. (2021) document major price dislocations in the US corporate debt market during the COVID-19 shock. Interestingly, they find that bonds with higher credit quality and liquidity traded at a higher discount to their CDS-implied spread than high-yield bonds.

The price dislocations in the US corporate bond market are captured in Figure 2.14, which tracks the CDS-bond basis, or the difference in the CDS spread and the spread implied in the bond prices, for a basket of investment-grade and high-yield US companies around the COVID-19 shock. The figure shows that as corporate bond yields

Figure 2.12: Reuse of Panel C of Figure 1 from Vissing-Jorgensen (2021)

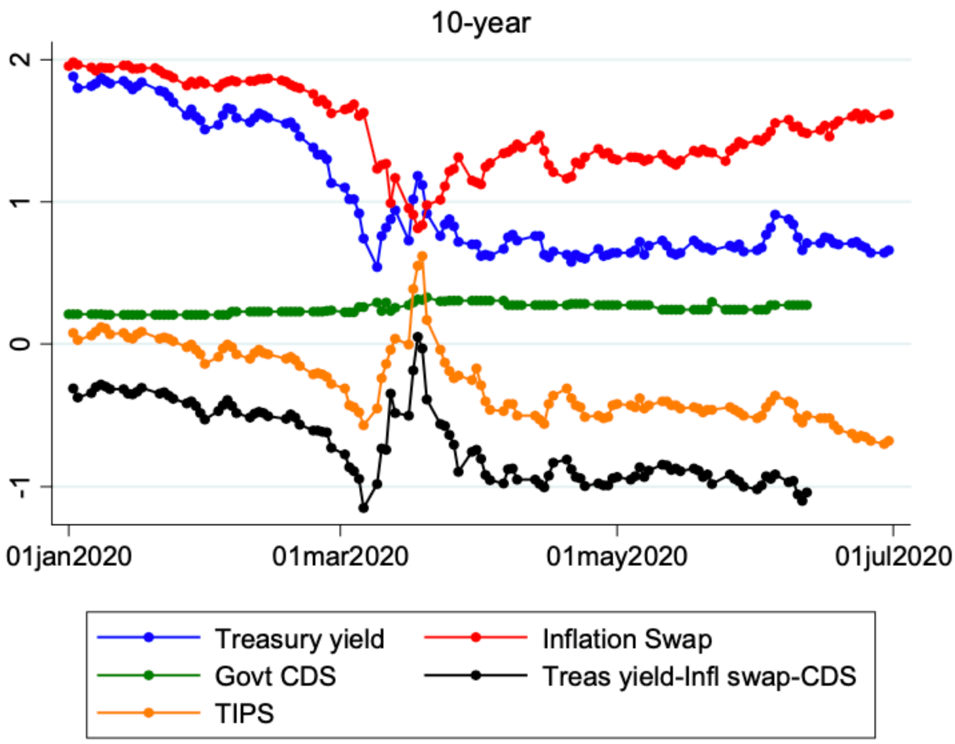
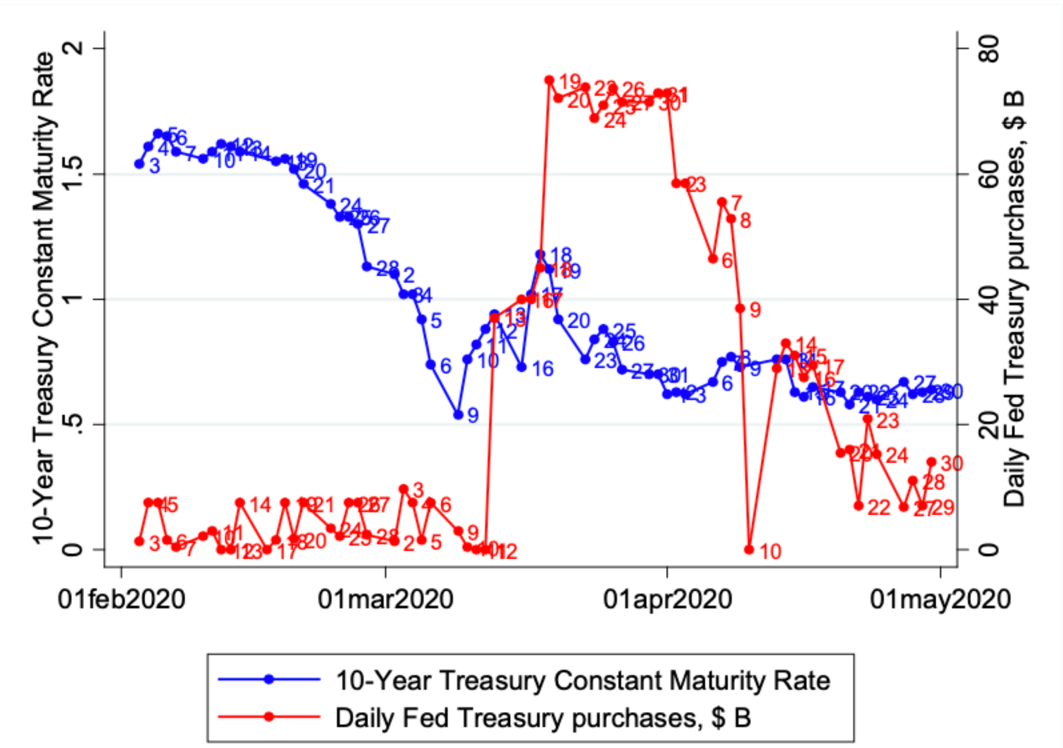
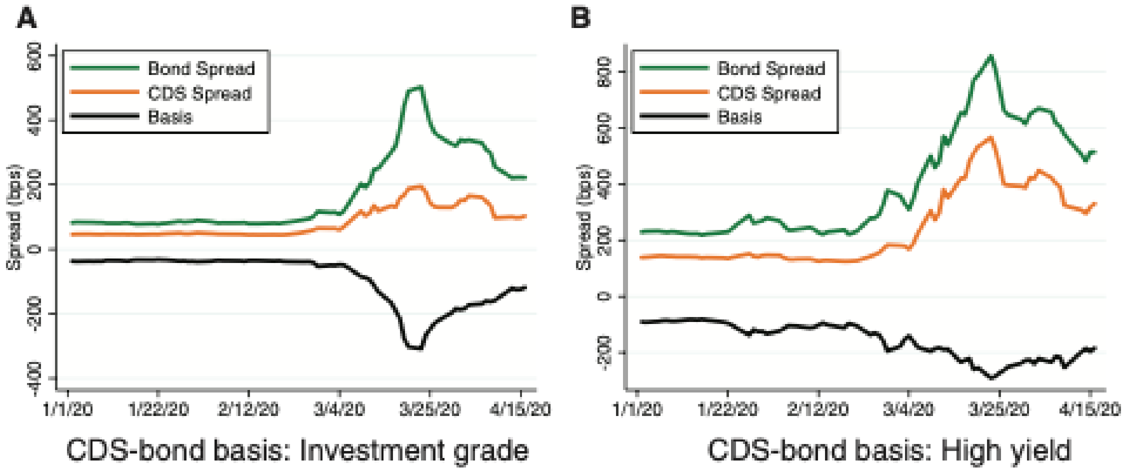


Figure 2.13: Reuse of Panel B of Figure 4 from Vissing-Jorgensen (2021)



spiked, the CDS spreads did not increase by as much; in fact, they remained relatively stable for the investment grade bonds. As a result, the CDS bond basis widened significantly by around 300 bps and more sharply for the investment-grade than the high-yield bonds.

Figure 2.14: CDS-bond basis (the difference between the CDS spread and the bond yield spread) of the US corporate bonds from Jan 1 to April 30, 2020. Reuse of Figure 4 from Haddad et al. (2021)

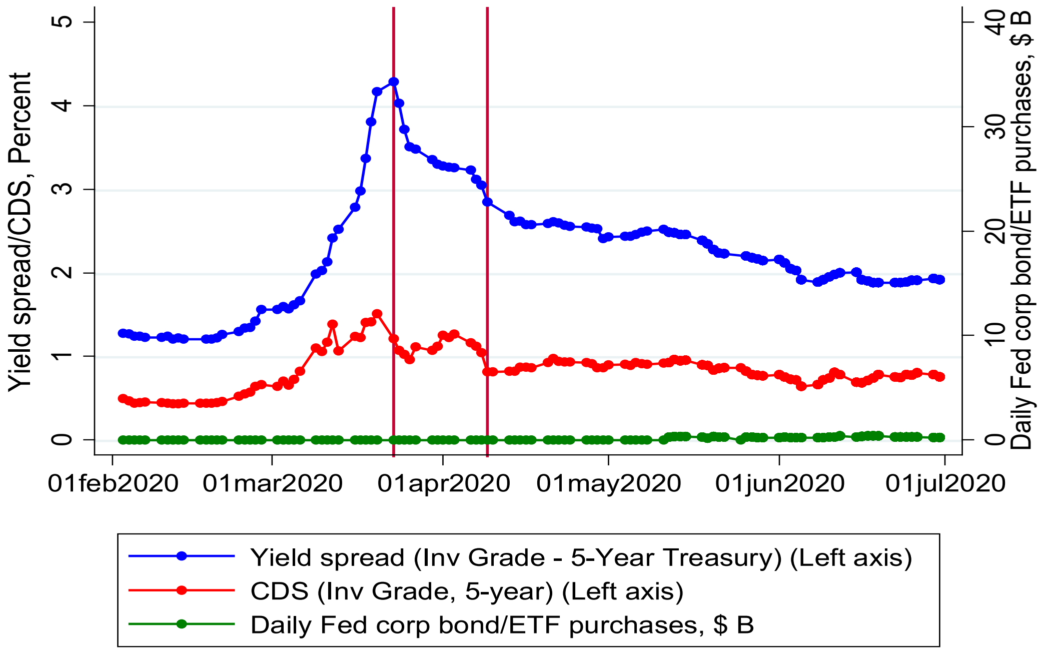


Haddad et al. (2021) attribute this development to cash-seeking investors deciding to sell the more liquid investment-grade bonds to meet redemptions, rather than selling illiquid, difficult-to-value high-yield bonds at fire sale prices: the so-called "dash for cash" phenomenon. Ma et al. (2020) identify a similar "reverse flight to liquidity" effect in the US investment grade corporate bond market. The effect was a result of bond funds meeting increased redemptions by first selling more liquid assets from their portfolios to avoid taking large losses. The effect was a divergence between bond spreads and CDS rates of investment-grade corporate bonds.

Only the unprecedented Fed interventions on two dates in the US bond market ensured that the US corporate bond market price dislocations were relatively short lived. Specifically, on March 23, 2020, the Fed announced two asset-purchase programs (the Primary Market Corporate Credit Facility and the Secondary Market Corporate Credit Facility) to buy up to USD 300 billion of investment-grade corporate bonds with maturities of up to five years. On April 9, 2020, these programs were subsequently expanded to USD 850 billion and allowed the Fed to buy high-yield bonds as long as they were investment-grade before the program announcement in March. As a result of the announcements themselves, spreads both of the US investment-grade and the US high yield bonds dropped substantially (see Figure 2.14).

Vissing-Jorgensen (2021) documents that the US corporate bond market stabilized without immediate large purchases by the Fed (in stark contrast to the quickly implemented and large-scale Fed purchases of Treasuries). In fact, the Fed purchases of corporate bonds were both delayed and small (see Figure 2.15). Hence, the author postulates that the corporate bond market can be effectively stabilized with even small purchases as long as the announcement itself is able to affect the perceived credit risk enough to tamper the selling.

Figure 2.15: Fed purchases of corporate bonds were very limited. Reuse of figure from Vissing-Jorgensen (2020)



The European response to the COVID-19 shock was similar. On March 18, 2020, the ECB announced its EUR 750 billion Pandemic Emergency Purchase Program (PEPP). The program was later extended on June 4, 2020, by EUR 600 billion to a total of EUR 1.35 trillion. While the main purpose of this ECB program is to intervene in sovereign bond markets of the Eurozone member states, some PEPP funds were funneled into a Corporate Sector Purchase Program (CSPP). The announcement of the PEPP resulted in a drastic decrease in non-financial corporate bond spreads (see Figure 2.16).

According to Wigglesworth (2020), as a consequence of the COVID-19-related disruptions in the corporate bond markets, mutual funds that invested into such bonds suffered substantial losses and faced unprecedented outflows as documented by the IMF for the global bond fund market (see Figure 2.17). The COVID-19 shock had a long-lasting effect on the global bond fund market in terms of redemptions, with the funds experiencing a net outflow of USD 9 billion during the first seven months of 2020.

Falato et al. (2021) confirm record redemptions from US corporate bond funds during the COVID-19 shock time (see Figure 2.18). They find that high outflows were associated with fund asset illiquidity and the likely susceptibility to fire sales (for example, when a fund has an exposure to holdings similar to other funds). Funds exposed to industries that were highly affected by the COVID-19 pandemic suffered the largest redemptions. Finally, they also confirm that the March and April 2020 announcements of the Fed was effective in calming down the market, propping up prices and stemming bond fund redemptions. The second Fed announcement on April 9, 2020, went further, finally reversing daily outflows into inflows for high-yield funds.

Figure 2.16: Euro Area Corporate Bond Spreads Around the COVID-19 Shock. Source: Reuse of ECB Chart from Lane (2020)

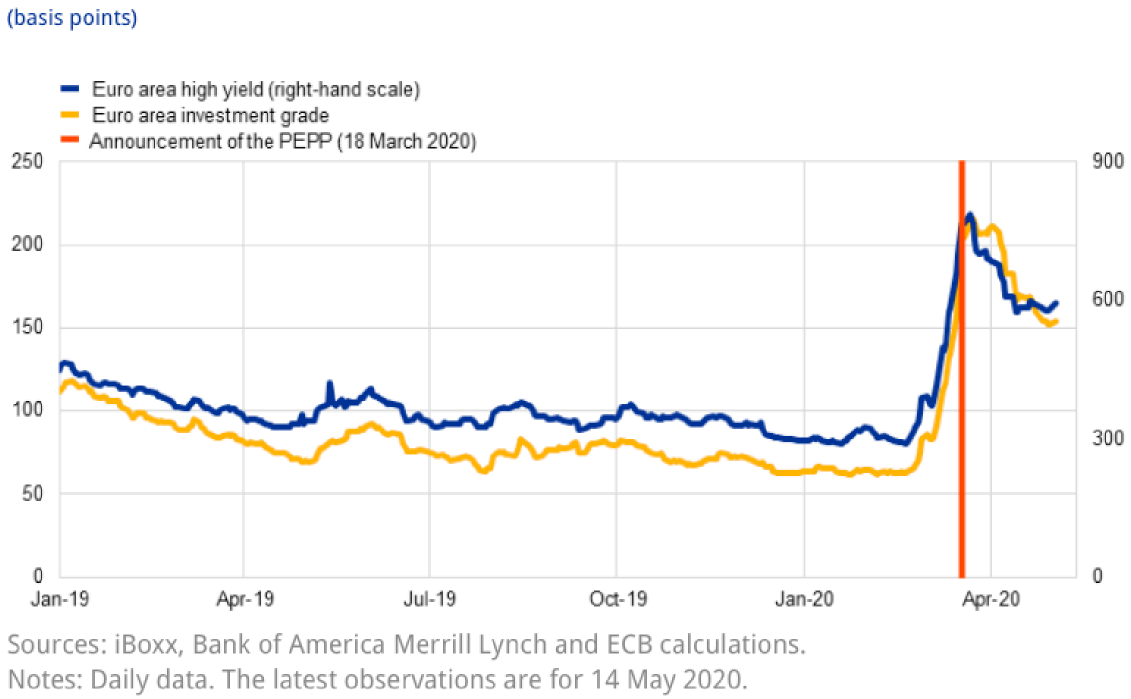


Figure 2.17: Losses and Redemptions of Investment Funds (Global Fund Data). Reuse of Figure 1.11 from IMF (2020)

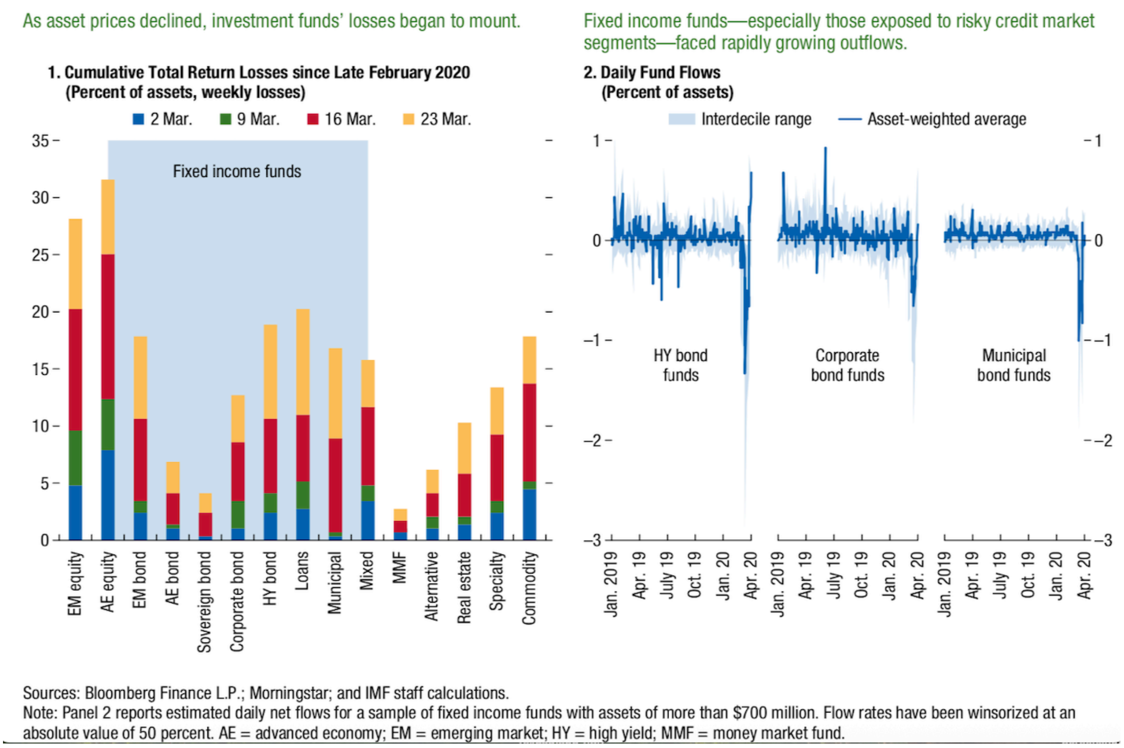
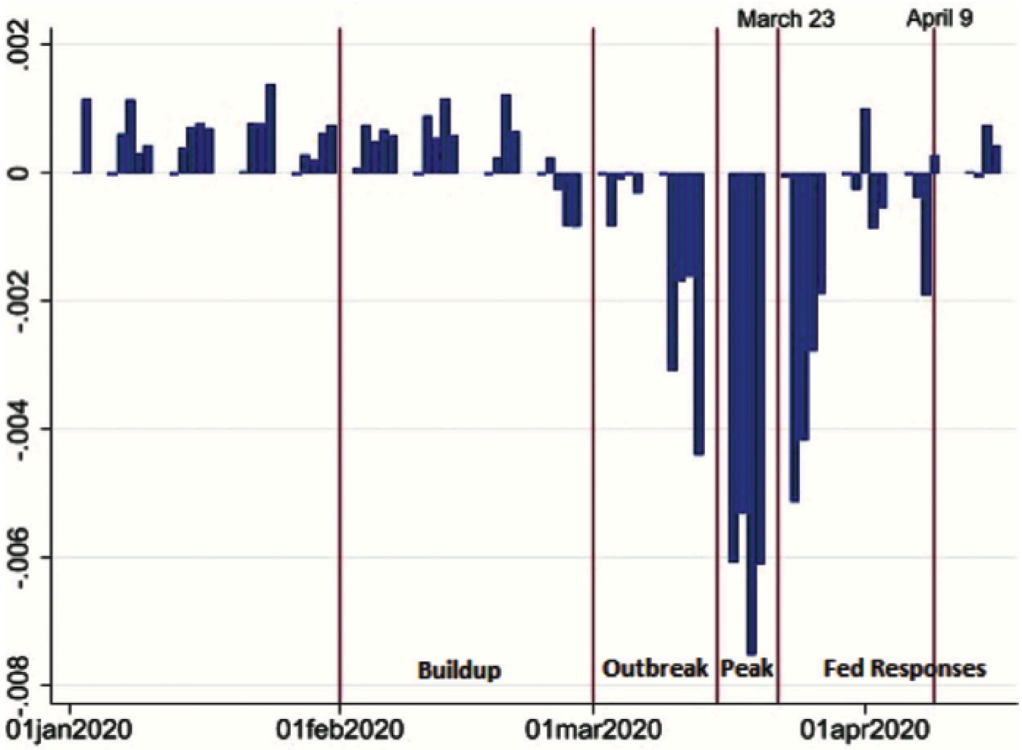


Figure 2.18: Daily Aggregate Net Fund Flows for Corporate Bond Funds (US markets). Reuse of Figure 2 from Falato et al. (2021)



Bond ETF Markets

Despite warnings about the fragility of bond Electronically Traded Fund ("ETF") market that have been raised in the years leading up to the COVID-19 crisis, bond ETFs showed a surprising resiliency during the COVID-19 pandemic shock, especially when compared to the long-lasting effect of the shock on the bond mutual fund net outflows. While the bond ETF market did experience a severe dislocation at the onset of the shock in March, it was very short lived. The prices rebounded quickly and the market experienced net inflows of USD 150 billion overall in the first seven months of 2020, while bond funds experienced a net outflow of USD 9 billion during the same period (Wigglesworth (2020)).

Haddad et al. (2021) postulate that because ETFs themselves were much more liquid than the underlying bonds, cash-seeking fund managers sold them instead of the underlying assets. This caused a brief period of ETF prices being well below their net asset values. In line with the trend for the corporate bond market, the discount of price to net asset value was more pronounced for liquid bond ETFs than for less liquid ETFs that track high-yield bonds.

The paragraphs above outline the effect that the COVID-19 liquidity shock had on various asset markets and the unprecedented central bank interventions that were used to stem it, highlighting the important role that sufficient liquidity holdings play in preventing liquidity spirals and the related shocks to the global financial system. Given this importance of liquidity holdings, Chapter 2 of this thesis examines endogenous choices of secondary asset market participants regarding their liquidity buffers. The secondary asset market participants include traditional banks as well as non-bank financial institutions ("NBFI") such as pension funds and institutional investment funds and mutual funds and that provide access to secondary asset markets to retail investors. The novel aspect of Chapter 2 is that it examines an interaction of choices of liquidity holdings held by banks and NBFI institutions with the activity of collateral reuse across the financial system.

Collateral reuse is an activity that has become crucial to an efficient functioning of the global financial system. It allows one piece of a pledged financial asset to be reused in further financial contracts. As such, it has been likened to a "lubrication" of the financial system (Singh and Aitken (2010)). On the other hand, collateral reuse might also generate fragility within a financial system as it could drive collective leverage beyond safe levels and it could increase interconnectedness of financial intermediaries. While collateral reuse has been frequently researched in isolation, like in Chapter 1 of this thesis, this chapter brings insights into the connection of decisions around collateral reuse and liquidity holdings.

Applying an extension to the benchmark model from Chapter 1, I show that secondary market participants choose to hold a liquidity level that is lower than what is optimal from the social welfare perspective. Essentially, this is because they do not internalize the effect of their choice of the liquidity holdings on the investment decisions of other financial intermediaries, through the impact of their liquidity holdings on expected fire sale prices and the corresponding rate of collateral reuse.

Based on the model results, secondary asset market participants would hold inefficiently too little liquidity when left to their own devices, and minimum liquidity requirements can help to restore it to more efficient levels. In other words, just by regulating liquidity holdings, the social planner could achieve higher social welfare than in absence of any liquidity regulation. The findings from this chapter also provide some support for direct interventions of central banks in the asset markets in some cases, especially as a response to liquidity shocks that are exogenous to the health of the financial system, such as the COVID-19 shock.

These results provides support for liquidity regulation in the form of minimum liquidity requirements applied to secondary asset market participants and echo the existing literature on private underinvestment of liquidity that calls for liquidity regulation of financial intermediaries. For example, Allen and Gale (2004) find that complete markets for aggregate liquidity risk is required for efficient private provision of liquidity. If such market is incomplete, liquidity regulation can bring about more efficient outcomes. Stein (2012) argues that because banks do not internalize social benefits of higher liquidity holdings (e.g, its effect on stability of the financial system and hence reduced taxpayer cost), regulation of liquidity holdings is advisable and it is more efficient than interventions of central banks as lenders of last resort. Finally in a setting of asymmetric information on banks' susceptibility to a bank run, Diamond and Kashyap (2016) also find that banks do not have adequate incentives to hold efficient levels of liquidity and liquidity regulation reduces a probability of runs on banks.

However, I show that regulation of liquidity alone has potential to restore the first-best level of social welfare only in some cases, while others require additional regulation of the rate of collateral reuse, in line with Chapter 1. When the credit quality of financial intermediaries that reuse collateral is adequately high, the first-best social welfare can be achieved with liquidity regulation alone. In this case, as long as the investors that are active on secondary asset markets adhere to the minimum liquidity requirements, it will be privately optimal for high-credit-quality reusing intermediaries to choose maximum rate of reuse, which would also be the social optimum. On the other hand, when the credit quality of reusing financial intermediaries is lower, it can be that they opt for a reuse rate that is sub-optimally too high, even when the investors that are active on secondary asset markets hold a socially optimal level of liquidity.

Hence, only by combining minimum liquidity requirements with regulation of the rate of collateral reuse, the regulators can achieve the first-best social outcome in all cases. This result is in line with research that advocates limiting the liquidity mismatch within financial intermediary markets with "quantity constraints" on other activities. For example, Perotti and Suarez (2018) find that when banks are undercapitalized, it is optimal to combine Pigovian taxes on short-term funding of banks with liquidity regulation in a form of net funding ratios. In another study, Calomiris et al. (2015) find that optimal regulation combines liquidity requirements with capital requirements. Similarly, Chapter 2 postulates that when the credit quality of the reusing intermediaries is low, first-best social welfare is achieved when minimum liquidity requirements are supplemented with a "quantity-based" regulation that constrains transformation of risk through the reuse rate.

Chapter 2 adds to academic literature on the importance of adequate liquidity holdings and their effect on limiting fire sales of assets. These topics have been studied in an academic setting for some time. For example, Rochet and Vives (2004) analyzed the impact of various balance sheet variables, including liquidity holdings, of financial institutions on thresholds for asset runs. Later on, Ahnert (2016) shows in a theoretical setting that when financial intermediaries have higher liquidity holdings, the liquidation value of assets in case of "bad times" is higher and the resulting threshold for a run on assets by other intermediaries is higher, generating a more resilient financial system. He finds that because private players do not internalize this externality, they choose to hold less liquidity than would be socially optimal, leaving scope for macroprudential liquidity buffers to restore constrained efficiency.

More recently, in a paper that combines theoretical and empirical research, Chernenko and Sunderam (2020) find that equity mutual funds hold less liquidity than socially optimal. These suboptimal liquidity holdings lead to fire sales of assets in case of a liquidity shock. Furthermore, those funds that care more about a negative impact of potential fire sales (e.g., through their connection with other funds), hold more liquidity than the funds that are not. In addition, Falato et al. (2021) show that fund investor redemptions can induce fire sales of assets, which in turn can generate strong spillovers across funds with portfolios that include the same assets. Such spillovers negatively affect the performance and flows of the impacted funds and create further fire sales of asset, which eventually significantly raise yields of the sold bonds.

This chapter also sheds more light on the important activity of collateral reuse, which is extensively studied in Chapter 1 of this thesis. I extend the benchmark model of collateral reuse from Chapter 1 by allowing the private agents that are active on secondary asset markets to make endogenous choices regarding their liquidity choices that depend on the level of collateral reuse within the financial system. This extension adds to the literature that studies the impact of reuse of collateral in generating liquidity. For example, Andolfatto et al. (2017) show that collateral reuse can generate extra liquidity that can be utilized by the financial system; their work, however, does not reflect the important double-commitment problem that is considered in Chapters 1 and 2 of this thesis. In related research, Infante (2019) and Infante and Vardoulakis (2021) show that when financial intermediaries reuse collateral, they can increase their liquidity by charging different margins to their lenders and creditors. However, they do not consider how the available secondary-market liquidity affects fire sale prices and collateral reuse choices, which is an important addition of this chapter.

Furthermore, this paper is connected to the well-established theoretical literature on the topic of fire sales of assets (Shleifer and Vishny (1992) and Gale and Yorulmazer (2019)), which are a result of limited available liquidity or the so-called "the cash-in-the-market pricing" (Gale and Allen (1994) and Allen and Gale (1998)) and can generate various externalities (Gale and Yorulmazer (2019)). In my model, the private agents do not internalize all of the impacts that arise from their choices of a level of liquidity holdings and a rate of collateral reuse and the potential of these decisions to generate socially undesirable fire sales. Hence, the private agents might choose suboptimal levels of liquidity buffers and collateral reuse, creating scope for regulation of both of these decisions.

Finally, the microfoundations and methodology to derive the endogenous fire sale discount factor and choices of liquidity holdings are based on the work of Stein (2012) and Hanson et al. (2015).

The remainder of the paper is organized as follows. Section II details the model and solutions to its private and social optimization problems. Section III outlines a numerical example as an illustration of the results of the model. Section IV finishes with implications of the analysis on policy and regulation, discussion of potential model extensions and concluding remarks.

2.2 The Model of Collateral Reuse, Endogenous Liquidity Holdings & Liquidity Regulation

While the benchmark model in Chapter 1 analyzes scope for regulation of the collateral reuse rate, the extended model considered in Chapter 2 explores the question of whether the first-best social welfare outcome could be achieved instead by regulating liquidity holdings of agents that are active on secondary asset markets. I find that this is possible in some case, specifically when the credit quality of financial intermediaries that reuse collateral is high. However, when their credit quality deteriorates, it is advantageous to also regulate the collateral reuse rate.

In line with the benchmark model presented in Chapter 1, this extension features three periods: $t = 0$, $t = 1$ and $t = 2$ and there are four types of agents, labelled A, B, C and D, that are ultimately owned by households and have no time preferences. They represent different types of financial intermediaries. Agent A is the ultimate borrower, agent C is the ultimate lender and agent B is a party that intermediates between the two. Agent A and agent B are risk-neutral and are the contracting agents, while agent C is infinitely risk-averse and plays a passive role. Because Agent C is willing to engage only into perfectly safe projects, it can provide financing to B only via a secured transaction that requires a pledge of collateral.

In addition, there is a passive risk-neutral patient investor labelled as agent D that can step in during the intermediate period to purchase financial assets on the secondary market or to invest into a productive project that generates $g(x)$ for an investment of x, with the $g(x)$ function being a concave function with the same attributes as in Chapter 1. We can think of agent D as representing NBFI intermediaries such as investment funds, pension funds, etc. As such investors are active both on primary and on secondary asset markets, in the context of this model extension we can think of the trade-off that such investors face as a choice between using their limited funds to either buy up discounted assets on the secondary market or investing the limited funds into new productive projects through the primary markets.

For liquid fund endowments and investment opportunities of each of the agents, please see Figure 2 of Chapter 1 of this thesis. In addition, Figures 3-6 of Chapter 1 outlines the flows of asset returns, debt repayments and collateral in all possible cases. Furthermore, Assumptions Set 1 and 2 from Chapter 1 hold. While private and social optimization problems in Chapter 1 consider an **extra** private profit and social welfare that collateral reuse generates, what follows in Chapter 2 focuses on **total** profit and welfare to allow for easier derivation without affecting the results.

The benchmark model of Chapter 1 assumed that the liquidity W that is available at $t = 1$ to agent D is exogenous, namely that agent D does not optimize its liquidity holdings and takes them as a given. At $t = 1$, agent D then decides between using its limited liquidity W to invest into its productive project that would generate $g(x)$ for an investment of x or to buy a discounted collateral asset available (if any) on the secondary market at a discount of $k(\phi)$, where $0 \leq \phi \leq 1$ represent the collateral reuse rate. However, is it reasonable to assume that the liquidity holdings of agent D are determined endogenously, which is considered in this chapter of the thesis.

The liquidity holdings W become endogenous if agent D is allowed to choose at $t = 0$ the level of liquid funds it will hold at $t = 1$. We first examine what W agent D opts for at $t = 0$ when it optimizes its liquidity holdings and discusses any scope for improving social welfare through liquidity regulation of agent D's liquidity holdings. The results show that regulation of liquidity alone can increase social welfare. However, liquidity regulation alone will not always lead to the most efficient outcome. Overall, what appears to be the best regulatory approach is to regulate the collateral reuse rate while also imposing minimum liquidity requirements on agents that participate in the secondary collateral asset markets.

Let's assume now that agent D chooses at $t = 0$ a level of $t = 1$ liquidity W^* that maximizes its profit and that the W^* of liquidity at $t = 0$ is raised at an interest rate of 1[2]. However, agent D does not internalize the impact of its choice of W on the

[2] While this assumption does not reflect the reality faced by most financial institutions and even

short-term investment of agent B through the expected fire sale prices.

In line with Chapter 1, the private profit of agent D can be summarized as follows. With probability p, the short-term asset of agent B is successful and hence agent B's default and the resulting fire sales are avoided, in which case agent D reaps a profit of $g(W)$ from the late-arriving project. With probability $(1-p)$, the short-term asset of agent B returns zero and fire sales occur, producing a return on the purchases of fire-sold assets and the now smaller investment in the late-arriving producing $g(W - \phi k(\phi)R)$.

Hence, agent D chooses W^* so that its marginal product equals the marginal cost of liquidity[3]:

$$pg'(W^*) + (1-p)g'(W^* - \phi k(\phi)R) = 1 \tag{2.1}$$

On the other hand, the social planner maximizes the welfare of households, which own all of the agents. Hence, the social welfare comprises not only of the profit of agent D but also the private profit from the short-term investment of agent B that was enabled through collateral reuse[4]. The expected social welfare assuming collateral reuse rate ϕ and liquidity holdings of W can be expressed as:

$$E(\Pi^{SW}) = \phi k(\phi)R(p^B - 1) + pg(W) + (1-p)g(W - \phi k(\phi)R) - W - 1 \tag{2.2}$$

The social planner then chooses W^{**} that maximizes social welfare, and the social welfare trade-off is captured as:

$$pg'(W^{**}) + (1-p)g'(W^{**} - \phi k(\phi)R) = 1 - p\phi RR^B \frac{\partial k(\phi)}{\partial W}|_{W=W^{**}} \tag{2.3}$$

Remembering from Chapter 1 that $g'(W - \phi k(\phi)R) = \frac{1}{k(\phi)}$, we can express Equation 2.3 as

$$k(\phi^{**}|_{W=W^{**}}) = \frac{(1-p)[1 - \phi R \frac{\partial k(\phi)}{\partial W}|_{W=W^{**}}]}{1 - \phi R \frac{\partial k(\phi)}{\partial W}|_{W=W^{**}} - pg'(W^{**})} \tag{2.4}$$

As we can see by comparing Equation 2.1 to Equation 2.3, the privately and socially optimal solutions diverge for $\phi > 0$, in which case the marginal product of W^{**} is lower than the marginal product of W^* because $\frac{\partial k(\phi)}{\partial W} > 0$ (in line with Chapter 1). Given the properties of the $g(\cdot)$ function, it means that agent D prefers to hold a lower level of liquidity than what is optimal from the social welfare perspective and $W^* \leq W^{**}$. Essentially, this is because agent D does not internalize the impact of its choice of W on the short-term investment of agent B through the expected fire sale discount.

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central banks, it does not impact the derivation of the optimal liquidity level as long as the amount being raised does not impact the marginal liquidity cost, which is assumed in this model.

[3]The microfoundations and methodology for the $t = 0$ choice of the $t = 1$ liquidity used in this paper are in line with Stein (2012).

[4]In line with Chapter 1, social welfare reduces to the expected profits of agent B and D. This is because agent A is made indifferent between collateral reuse and no reuse with the help of the borrowing costs that depend on rate of reuse, ϕ, and agent C's loan to agent B is perfectly safe, with an expected net profit of zero.

The $W^* \leq W^{**}$ result provides support for liquidity regulation in the form of minimum liquidity requirements $W = W^{**}$ imposed on agents of type D, which represent financial institutions that are active on the secondary asset markets, including NBFI institutions such as mutual funds, pension funds, etc. Based on the results, such institutions would hold inefficiently too little liquidity when left to their own devices and minimum liquidity requirements can help to restore it to more efficient levels. In other words, by regulating liquidity holdings (while not regulating collateral reuse rate ϕ), the social planner could achieve higher social welfare than in absence of any regulation, with $E(\Pi^{SW})|_{\phi=\phi^*,W=W^{**}} \geq E(\Pi^{SW})|_{\phi=\phi^*,W=W^*}$.

The private and social-welfare optimizing choices of the liquidity holdings of agent D (when the collateral reuse rate is left unregulated) and the resulting implications for liquidity regulation are summarized in the proposition below.

Proposition 4: *Denote the privately and the socially optimal liquidity holdings of agent D (when optimizing only liquidity holdings) as W^* and W^{**} respectively. Assume that $W_{min} \leq W \leq W_{max}$ (liquidity is restricted). Then the social planner will always choose at least as much liquidity as the private agent D that operates on secondary asset markets, with $W_{max} \geq W^{**} \geq W^* \geq W_{min}$.*

Regulation of liquidity alone has potential to restore social welfare, $E(\Pi^{SW})|_{\phi=\phi^{**},W=W^{**}}$ in some cases, resulting in $E(\Pi^{SW})|_{\phi=\phi^{**},W=W^{**}} = E(\Pi^{SW})|_{\phi=\phi^*,W=W^{**}}$. Specifically, if the minimum liquidity requirements W^{**} are imposed when the credit quality of agent B is high (its probability of success, p, is high and its short-term asset return, R^B, is high), both agent B and the social planner opt for the maximum reuse and $\phi^*|_{W=W^{**}} = \phi^{**}|_{W=W^{**}} = 1$. Hence, in this case, the optimal social welfare of $E(\Pi^{SW})|_{\phi=1,W=W^{**}}$ can be achieved with liquidity regulation alone.

However, if the reuse rate remains unregulated, it can be that agent B chooses a suboptimally too high reuse rate, even at the socially optimal level of liquidity W^{**}. Such divergence between the private and socially optimal choices of collateral reuse occurs at lower credit quality of agent B because $\phi^* \geq \phi^{**}$ for lower success rate p and/or lower R^B. At very low levels of agent B's credit quality, it might be that even at the highest possible liquidity levels, W_{max}, it is optimal from the social welfare perspective to reuse $\phi^{**} < 1$ or even not to reuse at all with $\phi^{**} = 0$, while agent B chooses a higher level of reuse, resulting in $E(\Pi^{SW})|_{\phi=\phi^*,W=W^{**}} < E(\Pi^{SW})|_{\phi=\phi^{**},W=W^{**}}$. In such situation, social welfare would benefit from regulation of the collateral reuse rate, in addition to regulating the liquidity holdings.

To derive the threshold for what constitutes a low enough credit quality of the reusing intermediaries so that liquidity regulation should be supplemented with collateral reuse regulation to restore the first-best social welfare, I maximize social welfare with respect to both the liquidity holdings, W, and the collateral reuse rate, ϕ. From Equation 18 of Chapter 1, we know that the optimal rate of reuse is captured by the expression:

$$k(\phi^{**}) = \frac{1}{g'(W - \phi^{**}k(\phi^{**})R)} = \frac{1-p}{pR^B - 1} \tag{2.5}$$

Plugging $g'(W - \phi^{**}k(\phi^{**})R) = \frac{pR^B-1}{1-p}$ into the first order condition of the social function captured as Equation 2.3, I obtain an expression for the first-best socially optimal level of liquidity holdings, W^{**}_{FB}, which can be stated as:

$$g'(W^{**}_{FB}) = \frac{1 - (pR^B - 1) - p\phi^{**}_{FB}RR^B \frac{\partial k(\phi,W)}{\partial W}|_{\phi=\phi^{**}_{FB},W=W^{**}_{FB}}}{p} \tag{2.6}$$

By plugging in $g'(W^{**}_{FB})$ from Equation 2.6 into Equation 2.4, the internal solution for the first-best socially optimal welfare can be summarized as a system of equations that can be solved for W^{**}_{FB} and ϕ^{**}_{FB}:

$$\begin{aligned} g'(W^{**}_{FB}) &= \frac{1 - (pR^B - 1) - p\phi^{**}_{FB}RR^B \frac{\partial k(\phi,W)}{\partial W}|_{\phi=\phi^{**}_{FB},W=W^{**}_{FB}}}{p} \\ k(\phi^{**}_{FB}) &= \frac{(1-p)[1 - \phi^{**}_{FB}R\frac{\partial k(\phi,W)}{\partial W}|_{\phi=\phi^{**}_{FB},W=W^{**}_{FB}}]}{(pR^B - 1)(1 + \phi^{**}_{FB}R\frac{\partial k(\phi,W)}{\partial W}|_{\phi=\phi^{**}_{FB},W=W^{**}_{FB}}))} \end{aligned} \tag{2.7}$$

While the socially optimal rate of collateral reuse that is captured in the set of the equations above depends on the liquidity holdings, W, the reusing agents of type B disregard the impact that their choice of the privately optimal reuse rate, ϕ^*, has on the choices of liquidity holdings W by the agents of type D that are active on secondary asset markets. Equation 11 from Chapter 1 that outlines the privately optimal choice of the collateral reuse rate is captured in the equation below.

$$k(\phi^*) = k(\phi^*|_{W=W^*}) = k(\phi^*|_{W=W^{**}_{FB}}) = \frac{1-p}{p(R^B - 1)} \tag{2.8}$$

The expression of $k(\phi^*|_{W=W^*})$ allows us derive an expression of the agent D's private choice of liquidity holdings after Agent B made its private choice of the collateral reuse rate, ϕ^*, which are captured as $W^*|_{\phi=\phi^*}$. The expression is derived by plugging in the expression of $k(\phi^*|_{W=W^*})$ into Equation 2.1:

$$g'(W^*) = \frac{1 - p(R^B - 1)}{p} \tag{2.9}$$

When you compare $k(\phi^{**}_{FB})$ from Equation 2.7 with $k(\phi^*|_{W=W^{**}_{FB}})$ from Equation 2.8, we can solve for the threshold of credit quality where the social welfare benefits from combining liquidity regulation with regulation of the collateral reuse rate. Specifically, applying both regulations is beneficial when $k(\phi^{**}_{FB}) > k(\phi^*|_{W=W^{**}_{FB}})$ as a higher fire sale discount factor means a lower negative impact of the fire sales, ceteris paribus.

The condition $k(\phi^{**}_{FB}) > k(\phi^*|_{W=W^{**}_{FB}})$ can be solved in terms of the probability of success of the project of agent B, or $\tilde{p}$, where $\tilde{p}$ solves:

$$\frac{(1-\tilde{p})[1 - \phi^{**}_{FB}R\frac{\partial k(\phi,W)}{\partial W}|_{\phi=\phi^{**}_{FB},W=W^{**}_{FB}}]}{(\tilde{p}R^B - 1)(1 + \phi^{**}_{FB}R\frac{\partial k(\phi,W)}{\partial W}|_{\phi=\phi^{**}_{FB},W=W^{**}_{FB}}))} > \frac{1-\tilde{p}}{\tilde{p}(R^B - 1)} \tag{2.10}$$

This condition can be further simplified to:

$$\tilde{p} < \frac{1 + \phi_{FB}^{**} R \frac{\partial k(\phi)}{\partial W}|_{\phi=\phi_{FB}^{**}, W=W_{FB}^{**}}}{1 + (2R^B - 1)\phi_{FB}^{**} \frac{\partial k(\phi)}{\partial W}|_{\phi=\phi_{FB}^{**}, W=W_{FB}^{**}}} \tag{2.11}$$

Condition 2.10 can be interpreted as follows. The left-hand side of the condition represents a trade off of the social planner, which balances the marginal loss in the social welfare in case the project of agent B is not successful and fire sales occur with the marginal gain in the social welfare in case the project is successful. The right-hand side of the condition represents the equivalent trade-off of agent B, which balances the marginal private loss and gain from its private project.

When we take a look at the specification of $\tilde{p}$ in Condition 2.11, it is apparent that the right-hand side of the condition is lower than 1 when $R^B > 1$, which is always true by assumption. Hence, below a certain level of the probability of success of the private project of the reusing agents, $\tilde{p} < 1$, it is beneficial to regulate reuse. Overall, this means that regulation of the collateral reuse rate is necessary only when the credit quality of the reusing agents is low enough (equivalent to the success probability of their private projects, p, being low enough). These results are in line with Chapter 1, which also found that when the credit quality of the reusing agents is low (p is low), they will choose to reuse more collateral than the social planner.

The private and the first-best social-welfare optimizing choices of the liquidity holdings of agent D when both the liquidity holdings and the reuse rate is optimized by the social planner, and the resulting implications for regulation are summarized in the proposition below:

Proposition 5: *Let W^* be the privately optimal level of liquidity holdings of agent D (the agent active on secondary asset markets) and let W_{FB}^{**} be the first-best socially optimal level of liquidity holdings of agent D when the social planner optimizes both the liquidity holdings and the collateral reuse rate. Let $\phi^*|_{W=W_{FB}^{**}}$ be the privately optimal choice of the collateral reuse rate by the reusing agents when faced with socially optimal liquidity holdings, W_{FB}^{**}. Let ϕ_{FB}^{**} be the first-best socially optimal choice of the collateral reuse rate by the social planner that optimizes both the liquidity holdings and the collateral reuse rate. Then the internal solutions for the optimal choices can be summarized as:*

$$g'(W^*) = \frac{1 - p(R^B - 1)}{p} \tag{2.12}$$

$$g'(W_{FB}^{**}) = \frac{1 - (pR^B - 1) - p\phi_{FB}^{**} R R^B \frac{\partial k(\phi, W)}{\partial W}|_{\phi=\phi_{FB}^{**}, W=W_{FB}^{**}}}{p} \tag{2.13}$$

$$k(\phi^*|_{W=W_{FB}^{**}}) = \frac{1 - p}{p(R^B - 1)} \tag{2.14}$$

$$k(\phi_{FB}^{**}) = \frac{(1 - p)[1 - \phi_{FB}^{**} R \frac{\partial k(\phi, W)}{\partial W}|_{\phi=\phi_{FB}^{**}, W=W_{FB}^{**}}]}{(pR^B - 1)(1 + \phi_{FB}^{**} R \frac{\partial k(\phi, W)}{\partial W}|_{\phi=\phi_{FB}^{**}, W=W_{FB}^{**}}))} \tag{2.15}$$

Furthermore, let $\tilde{p} = \frac{1+\phi^{**}_{FB}R\frac{\partial k(\phi)}{\partial W}|_{\phi=\phi^{**}_{FB},W=W^{**}_{FB}}}{1+(2R^B-1)\phi^{**}_{FB}\frac{\partial k(\phi)}{\partial W}|_{\phi=\phi^{**}_{FB},W=W^{**}_{FB}}}$. *Then for* $p < \tilde{p}$, $\phi^{**}_{FB} < \phi^*|_{W=W^{**}_{FB}}$ *and the first-best level of social welfare* $E(\Pi^{SW})|_{\phi=\phi^{**}_{FB},W=W^{**}_{FB}}$ *cannot be achieved only by imposing the minimum first-best socially optimal liquidity requirement of* $W = W^{**}_{FB}$ *on agent D, and limiting of the collateral reuse rate to* $\phi = \phi^{**}_{FB}$ *is also necessary to achieve it.*

2.3 A Numerical Example of Model Results

To illustrate the results of Proposition 4 and Proposition 5 and their implications for regulation, let's apply a specific functional form to function $g(x)$. Specifically, in line with Chapter 1, let's define $g(x) = W_{max}\ln(x)$ and $1 \leq W \leq R$. For this example, $W_{min} = 1$ and $W_{max} = R$.

As a reminder from Chapter 1, with this functional form of the $g(x)$ function:

$$k(\phi) = \frac{1}{g'(W - \phi k(\phi)R)} = \frac{W}{W_{max} + \phi R} \tag{2.16}$$

$$\frac{\partial k(\phi)}{\partial W} = \frac{1}{W_{max} + \phi R} > 0 \tag{2.17}$$

$$\phi^* = \frac{1}{R}\left[\frac{Wp(R^B-1)}{1-p} - R\right] \tag{2.18}$$

Utilizing the privately and socially optimal solutions from Equation 2.1 and 2.3, we obtain the privately optimal liquidity holdings, W^*, and the socially optimal liquidity holdings when only the liquidity holdings are optimized, W^{**}:

$$W^* = min\left\{W_{max}, max\left\{1, \frac{pW_{max}}{W_{max} + p - pR^B}\right\}\right\} \tag{2.19}$$

$$W^{**} = W_{max} \geq W^* \tag{2.20}$$

As we can see, in line with Proposition 4, when the social planner optimizes only the liquidity holdings, W, its socially optimal choice, W^{**}, is always greater than or equal to the privately optimal choice of the liquidity holdings, W^*.

Applying the expressions for privately optimal reuse rate captured in Equation 2.18 and for the socially optimal liquidity holdings from Equation 2.20, we can also solve for the privately optimal choice of the collateral reuse rate when only the liquidity holdings are regulated, $\phi^*|_{W=W^{**}}$:

$$\phi^*|_{W=W^{**}} = \frac{1}{R}\left(\frac{2p^2(R^B-1)}{(1-p)(2-pR^B)} - Wmax\right) \tag{2.21}$$

Based on Proposition 5 and using $\frac{\partial k(\phi)}{\partial W} = \frac{1}{W_{max}+\phi R}$, we can solve a system of equations below for the first-best socially optimal liquidity holdings, W_{FB}^{**}, and for the first-best socially optimal collateral reuse rate, ϕ_{FB}^{**}:

$$\begin{aligned} g'(W_{FB}^{**}) &= \frac{1-(pR^B-1)-p\phi_{FB}^{**}RR^B\frac{\partial k(\phi,W)}{\partial W}|_{\phi=\phi_{FB}^{**},W=W_{FB}^{**}}}{p} = \frac{W_{max}}{W_{FB}^{**}} \\ k(\phi_{FB}^{**}) &= \frac{(1-p)(1-\phi_{FB}^{**}R\frac{\partial k(\phi,W)}{\partial W}|_{\phi=\phi_{FB}^{**},W=W_{FB}^{**}})}{(pR^B-1)(1+\phi_{FB}^{**}R\frac{\partial k(\phi,W)}{\partial W}|_{\phi=\phi_{FB}^{**},W=W_{FB}^{**}})} = \frac{W_{FB}^{**}}{W_{max}+\phi_{FB}^{**}R} \end{aligned} \tag{2.22}$$

From the system of equations above, we derive:

$$\phi_{FB}^{**} = \frac{p(pR^B-1)-(1-p)(2-pR^B)}{2(pR^B-1)} \tag{2.23}$$

$$W_{FB}^{**} = min\left\{W_{max}, max\left\{1, \frac{pW_{max}(4-p-3pR^B)}{2(4-p+2p^2(R^B)^2+p^2R^B-6pR^B)}\right\}\right\} \leq W^{**} \tag{2.24}$$

Tables I, II and III summarize results for the privately and socially optimal collateral reuse rates and liquidity holdings for three different scenarios when applying the functional form $g(X) = W_{max}\ln(X)$ for the late arriving investment of the agent D, which represents agents active on secondary asset markets. The three scenarios differ in the profitability of the private investment of agents B, which is captured by the return on its private project, R^B, and show results for a range of its probability of success, p. The two dimensions, R^B and p, capture the credit quality of the reusing agents, with the credit quality increasing in both dimensions.

All tables assume that $W_{max} = R = 2$. Table I shows results assuming a low profitability of the private project of agent B as reflected by $R^B = 1.1$. Table II represents a scenario with an intermediate profitability of the private project of agent B with $R^B = 1.5$. Finally, Table III outlines results assuming a high profitability of the private project of agent B with $R^B = 1.9$. We see that the socially optimal reuse rate for all three scenarios is lower than the privately optimal reuse rate for some $p < \tilde{p}$. Hence, to achieve the first-best social welfare, the social planner should regulate the reuse rate in addition to regulating the liquidity holdings when the probability of success of the private project of agent B, p, is low enough (representing a low credit quality of the agents that reuse collateral).

In line with Chapter 1, we see that the regulation of the reuse rate is less restrictive for more profitable projects of the reusing agents. In Table I, we see that when $R^B = 1.1$, it is socially beneficial to regulate rate of collateral reuse for $p < \tilde{p} \approx 0.97$ and it is socially optimal to prohibit reuse already for probability of success $p \lessapprox 0.95$. When $R^B = 1.5$, it is socially beneficial to regulate rate of collateral reuse for $p < \tilde{p} \approx 0.85$ and it is socially optimal to prohibit reuse for probability of success $p \lessapprox 0.81$ as the private agent would like to reuse some collateral until $p \approx 0.71$, as shown in Table II.

Table III captures results for a scenario where the private project of the reusing intermediaries is very profitable, with $R^B = 1.9$. Here the project is so profitable that regulation of the reuse rate to reach the first-best social welfare only is required only when the probability of success of the private project $p < \tilde{p}$ where $\tilde{p} \approx 0.73$. Hence, in this scenario, no regulation of the reuse rate is needed for $p \geq 0.73$ as in this case it is optimal both from the private and social perspective to maximize the reuse. In this case, it is socially optimal to prohibit reuse only for $p \lessapprox 0.65$.

Table 2.31: Table for $W_{max} = R = 2$, $R^B = 1.1$

p	$\phi^*\|_{W=W^{**}}$	ϕ^{**}_{FB}	W^*	W^{**}	W^{**}_{FB}
0.9100	0.0000	0.0000	1.0000	2.0000	1.0000
0.9200	0.0709	0.0000	1.0000	2.0000	1.0000
0.9300	0.2647	0.0000	1.0000	2.0000	1.0000
0.9400	0.5245	0.0000	1.0000	2.0000	1.1705
0.9500	0.8901	0.0000	1.0000	2.0000	1.8692
0.9600	1.0000	0.4000	1.0084	2.0000	2.0000
0.9700	1.0000	1.0000	1.0194	2.0000	2.0000
0.9800	1.0000	1.0000	1.0305	2.0000	2.0000
0.9900	1.0000	1.0000	1.0416	2.0000	2.0000

Table 2.32: Table for $W_{max} = R = 2$, $R^B = 1.5$

p	$\phi*$	ϕ^{**}_{FB}	W*	W**	W^{**}_{FB}
0.7000	0.0000	0.0000	1.0000	2.0000	1.4737
0.7200	0.0062	0.0000	1.0000	2.0000	1.5652
0.7400	0.1832	0.0000	1.0000	2.0000	1.6629
0.7600	0.3992	0.0000	1.0000	2.0000	1.7674
0.7800	0.6659	0.0000	1.0000	2.0000	1.8795
0.8000	1.0000	0.0000	1.0000	2.0000	2.0000
0.8200	1.0000	0.2778	1.0314	2.0000	2.0000
0.8400	1.0000	0.6250	1.0633	2.0000	2.0000
0.8600	1.0000	1.0000	1.0955	2.0000	2.0000
0.8800	1.0000	1.0000	1.1282	2.0000	2.0000
0.9000	1.0000	1.0000	1.1613	2.0000	2.0000
0.9200	1.0000	1.0000	1.1948	2.0000	2.0000
0.9400	1.0000	1.0000	1.2288	2.0000	2.0000
0.9600	1.0000	1.0000	1.2632	2.0000	2.0000
0.9800	1.0000	1.0000	1.2980	2.0000	2.0000

Table 2.33: Table for $W_{max} = R = 2$, $R^B = 1.9$

p	$\phi^*\vert_{W=W^{**}}$	ϕ^{**}_{FB}	W^*	W^{**}	W^{**}_{FB}
0.6000	0.0000	0.0000	1.0000	3.0000	1.4948
0.6200	0.0628	0.0000	1.0000	3.0000	2.0874
0.6400	0.2719	0.0000	1.0000	3.0000	2.7907
0.6600	0.5302	0.1353	1.0000	3.0000	3.0000
0.6800	0.8526	0.3375	1.0000	3.0000	3.0000
0.7000	1.0000	0.5667	1.0000	3.0000	3.0000
0.7200	1.0000	0.8286	1.0000	3.0000	3.0000
0.7400	1.0000	1.0000	1.0156	3.0000	3.0000
0.7600	1.0000	1.0000	1.0536	3.0000	3.0000
0.7800	1.0000	1.0000	1.0924	3.0000	1.0000
0.8000	1.0000	1.0000	1.1321	3.0000	1.0000
0.8200	1.0000	1.0000	1.1725	3.0000	1.0000
0.8400	1.0000	1.0000	1.2139	3.0000	1.0000
0.8600	1.0000	1.0000	1.2561	3.0000	1.0000
0.8800	1.0000	1.0000	1.2992	3.0000	1.0000
0.9000	1.0000	1.0000	1.3433	3.0000	1.0000
0.9200	1.0000	1.0000	1.3883	3.0000	1.0000
0.9400	1.0000	1.0000	1.4344	3.0000	1.0000
0.9600	1.0000	1.0000	1.4815	3.0000	1.0000
0.9800	1.0000	1.0000	1.5297	3.0000	1.0000

2.4 Discussion & Conclusions

Proposition 4 from Section III and the results from the numerical solution from Section IV show that there is scope for regulation of the liquidity holdings of agents acting on secondary asset markets, especially when the credit quality of intermediaries that reuse collateral is low. However, an important caveat needs to be made for implications on regulation that stem from Proposition 4 as the theoretical minimum liquidity requirements as envisioned in this chapter would be difficult to be efficiently implemented and enforced. In addition, the results captured in Proposition 4 feature an implicit assumption that liquidity is costless and that the cost of raising liquidity does not depend on the amount being raised. This assumption might not reflect the reality faced by most financial institutions and even central banks, especially in periods of financial stress.

Nevertheless, the implications on regulation based on this study might serve as an indirect support for the liquidity regulation of banks and non-bank financial intermediaries that has been introduced in the last decade. This includes Basel III Liquidity Coverage Ratio requirement imposed on banks globally and the EU liquidity regulation for certain EU investment funds (Undertakings for Collective Investment in Transferable Securities (UCITS) and Alternative Investment Funds). While this regulation was introduced to increase resilience of such institutions in periods of high outflows and not to specifically address collateral reuse and fire sales of assets, it generally increases liquidity held by agents that are active on secondary asset markets. In the context of the model, increasing liquidity holdings of such institutions leads to less severe fire sales in case of a downturn, with an overall positive effect on social welfare.

The results captured in Proposition 4 might also justify direct interventions of central banks in secondary asset markets in some cases, especially as a response to shocks exogenous to the health of the financial system such as the COVID-19 shock in the first half of 2020. When such shocks induce stress in the funding and asset markets while the reusing intermediaries exhibit a relatively high credit quality, it might be beneficial for central banks to inject extra liquidity into the collateral asset markets by buying up such assets directly on secondary markets. Such interventions prop up asset prices, making fire sales less severe, which restores activity in the collateral reuse market that is essential to the correct functioning of the financial system. As outlined in the Introduction of this chapter, we have seen that the direct interventions of the FED and ECB in the secondary asset markets as a response to the COVID-19 shock were very successful in stemming the shock. As a result, the financial crisis that resulted from this liquidity shock was very short-lived.

On the other hand, the results point to the fact that such direct liquidity interventions might be welfare-decreasing when the shocks occur as a result of poor credit quality of the reusing agents such as the GFC of 2007-2009. This is because when the credit quality of financial institutions that engage in collateral reuse is low, injecting extra liquidity might generate inefficiently too high reuse in the context of the model.

In addition, Chapter 2 provides theoretical evidence that regulation of liquidity holdings alone might not be sufficient to achieve socially optimal outcomes. Similarly to Chapter 1, the results outlined in Chapter 2 show that regulation of collateral reuse rate is beneficial depending on the credit quality of the reusing intermediaries. Specifically, in times when the credit quality of the reusing agents is not very high (with high credit quality characterized by both a high probability of success of the private project of the reusing agents and a high profitability of the project), it is welfare increasing to combine the liquidity holdings regulation with a regulation of the collateral reuse rate.

In the case of not very high credit quality, the reusing agents might choose to reuse too much collateral vs. the social optimum. This is because, in line with Chapter 1, they do not internalize the impact of their choices on the later-arriving investment (through fire sales of assets that divert liquid funds from such investment). The novelty of Chapter 2 is that it shows that the reusing agents do not internalize the endogenous effect on the choices of liquidity holdings of agents active on the secondary asset markets, either. Hence, Chapter 2 offers further support for regulation of collateral reuse, even if liquidity holdings are already regulated.

In terms of model extensions, there is scope for further refinement of the model presented in this chapter of the thesis. For example, the model assumes that that liquidity is raised at no cost, which is not a realistic assumption. However, this assumption does not impact the derivation of optimal holdings of liquidity as long as the amount of raised liquidity does not impact the overall marginal cost of liquidity, which is further assumed in the model. Extending the model so that the marginal cost of liquidity varies with the amount that needs to raised might provide additional insights on the private choices and the advisable regulation of liquidity holdings and collateral reuse.

Chapter 3

Empirical Study of Collateral Reuse & Credit Quality of Reusing Financial Intermediaries[1]

3.1 Introduction & Related Literature

Chapter 3 provides novel empirical evidence of the effect of the credit quality of financial institutions on their choices regarding the systemically important activity of collateral reuse. The research presented in this chapter builds on the theoretical literature on the subject that has emerged over the last few years and fills in an important gap in the empirical literature on collateral reuse, which has been scarce so far due to unavailability of granular transaction-level data.

The activity of collateral reuse, which is widely utilized across the global financial system, allows the same collateral asset to enable multiple financial transactions. There are indications that financial intermediaries reuse collateral globally on a large scale, facilitating USD trillions of transactions (Singh (2011), Singh (2017)), as reuse appears to provide many benefits to the reusing firms and the economy in general. However, collateral reuse also generates important risks to the stability of the financial system - risks that have a potential to negatively impact the general economy. These risks, which are detailed below, highlight the relevance of the subject of this empirical study, which analyzes the important role that the credit quality of reusing institutions plays in the activity of collateral reuse and the associated aspects of financial stability.

When the credit quality of the reusing intermediaries is high, collateral reuse lubricates the financial system (Singh (2011)) and hence facilitates profitable investment. For ex-

[1] I would like to thank De Nederlandsche Bank for organizing my access to the Securities Financing Transactions Data Store ("SFTDS") managed by the European Central Bank ("ECB"), which ultimately allowed me to gather the data for the research contained in Chapter 3 of this thesis. I am especially thankful to Jeroen Huiting for coordinating and managing my stay at the De Nederlandsche Bank. I also would like to thank the SFTDS team at the ECB for granting me an early access to the database and working with me to support the data extraction process. The views contained in this chapter are solely those of the author and do not necessarily represent those of De Nederlandsche Bank, the ECB or their staff.

ample, reuse of collateral can generate extra borrowing capacity and lower funding and liquidity costs for financial institutions as well as their financial and non-financial clients, leading to more investment (FSB (2017b)). Collateral reuse also appears to rectify (at least to some degree) the scarcity of safe assets and high quality collateral. The safe asset scarcity is an important problem that financial institutions have been increasingly facing over the last decades (Infante and Saravay (2020), Jank et al. (2022))). Furthermore, since reuse of collateral helps to achieve lower transaction and liquidity costs, it stimulates price discovery and hence the efficiency and smooth functioning of financial markets (CGFS (2013), FSB (2017b)).

However, when the credit quality of the reusing institutions is low, there is potential for disruptive risks that can spark periods of financial instability with spill-over effects to the real economy. For example, reuse of collateral might result in a build-up of excessive leverage by individual firms with low credit quality and across the financial system (FSB (2017b)). In addition, collateral reuse might result in a higher interconnectedness among financial institutions, increasing the risk of contagion within the financial system in case some of the reusing agents default along the reuse chain.

In fact, reuse of collateral played an important role in propagation of effects of the infamous bankruptcy of Lehman Brothers, which became the ultimate catalyst of the Global Financial Crisis of 2008-2009 ("GFC"). The Lehman Brothers example illustrates one of the main risks that come with collateral reuse - the so-called double-commitment problem, which is related to the credit quality of financial intermediaries that reuse collateral. This problem is inherent in the activity of collateral reuse and represents a new source of counterparty risk to the original borrower: a risk of being unable to retrieve the collateral that the borrower pledged to the lender and which was subsequently reused by the lender.

The essence of the double-commitment problem is as follows: if one of the agents that participate in the reuse chain defaults, the original borrower might not receive its valuable collateral at the end of the contract. Aside from the losses that this might generate to the borrower, a host of additional financial stability risks arises. For example, if the collateral is ultimately seized by an agent that cannot realize its full value, a default along the reuse chain might result in costly asset misallocation, triggering fire sales, which might destabilize the financial system if they occur on a large scale.

The Lehman Brothers story is a real-life example of how the credit quality of reusing intermediaries can impact collateral reuse and of the detrimental impacts on financial stability that the activity of collateral reuse can ultimately generate. Many prime brokerage clients of Lehman Brothers funded themselves through its UK subsidiary, where the local regulation allowed for unlimited reuse of collateral without an explicit consent of the clients. After the subsidiary declared its bankruptcy, the hedge funds whose pledged collateral has been reused by Lehman Brothers lost their secured creditor status with respect to those assets in bankruptcy proceedings. As a result, their assets were frozen in the UK for a few months and consequently generated substantial losses (Singh and Aitken (2010)).

To provide empirical evidence on the link between collateral reuse and the credit quality of reusing institutions, I use data from a brand new granular transaction-level dataset on Security Financing Transactions ("SFT") in Europe. SFT are financial borrowing and lending transactions that are backed by financial collateral. They include repurchase agreements ("repos"), securities or commodities lending and borrowing, buy-sell and sell-buy backs and margin lending transactions. I extract data on SFT and the related reuse of collateral in Europe from the Securities Financing Transactions Data Store ("SFTDS"), which is compiled by the European Central Bank ("ECB") to aggregate SFT data reported under the requirements of the EU Securities Financing Transaction Regulation ("SFTR").

SFTR was enacted as a response to financial risks associated with SFT. SFT have been linked to various aspects of financial instability such as pro-cyclicality, excessive leverage and higher interconnectedness in the financial system. Following the GFC, major financial regulators around the world recognized SFT as a potential source of risks in the financial system. These risks are especially pronounced due to the size and importance of such transactions as well as the lack of transparency around them and the linkages that they create between regulated traditional banks and non-bank financial intermediaries ("NBFI"), which are regulated to a much less extent.

Both the Financial Stability Board ("FSB") and European Systemic Risk Board ("ESRB") recommended to enhance transparency of the SFT markets (including collateral chains that form within them), with the main goals being a greater understanding of financial markets in general and a mitigation of risks in the NBFI sector in particular. As a response, in early 2016, the European Commission adopted the SFTR, which requires EU-incorporated or located firms (both financial and non-financial) as well as non-EU entities that enter into an SFT with an EU entity to report SFT on a daily basis to the European Securities Markets Authority ("ESMA"). The SFT data is then aggregated on an on-going basis in the Securities Financing Transactions Data Store (SFTDS), which is discussed in more detail in Section III of this chapter.

Using data from SFTDS, I measure collateral reuse in two ways. Specifically, I derive an absolute and a relative measure of the reuse of collateral by the European financial institutions. The absolute measure of collateral reuse tracks per-entity volume of reuse as captured by the USD value of reused collateral. The relative measure of collateral reuse represents the intensity of reuse as reflected by the reuse rate or the ratio of collateral reused to collateral received.

To analyze the important link between the credit quality of reusing intermediaries and their activity of collateral reuse, I study the effect of proxies of the credit quality of the reusing intermediaries on the two metrics of the reuse of collateral outlined above. My main proxy for the credit quality are credit default swap (CDS) spreads. As a robustness check, I utilize credit ratings of the reusing entities as another measure of their credit quality. Finally, I apply an alternative metric of the reuse intensity that controls for the size of the reusing agents: instead of the reuse rate, I utilize a ratio of their reuse volume to their reported assets.

The study finds evidence in support of theoretical literature that links lower credit quality of reusing financial institutions with lower collateral reuse. Based on the empirical results, when faced with a deteriorating credit quality, the institutions tend to reuse less collateral in both absolute and relative terms: they contract the volume of reuse and lower the intensity of reuse as measured by the reuse rate. These conclusions are not only congruent with the theoretical research on the matter, but are also in line with the development of aggregate collateral reuse documented by Singh (2011) around the GFC, with the absolute and relative reuse plummeting during the GFC and its aftermath that was associated with a drastically reduced credit quality of financial institutions.

Recent academic literature has began to explore the theoretical underpinnings of the systemically important activity of collateral reuse, including how the credit quality of reusing financial institutions affects choices of agents that form collateral reuse chains, which will be the main focus of this study. For example, Infante (2019), Park and Kahn (2018) and Park (2021) find that borrowers prohibit reuse of collateral when the lender's credit quality is low because of the double-commitment problem that is inherent in reuse: the risk that the lender will not return the valuable collateral back to the borrower at the end of the contract. Hence, the amount of reused collateral increases with the credit quality of the reusing agents as the double-commitment problem diminishes and the originators of collateral have less incentives to withhold collateral from reuse.

In addition, Chapter 1 of this thesis shows that the collateral reuse rate (or the proportion of a financial asset that the lender receives as collateral through a financial transaction that is then reused by the lender in further transactions) is an increasing function of the credit quality of the reusing agents. Lenders with higher credit quality reuse more of the received collateral asset because the associated lower probability of default means that the compensation to the borrower for the risk of not being able to return its collateral is lower. In addition, Luu et al. (2021) find that the reuse rate decreases in the probability of an idiosyncratic liquidity-driven default of a reusing institution, with such probability being at least partially proxied by the credit quality of the reusing agents.

Finally, Chapter 3 expands the rather scarce body of empirical research on collateral reuse. The empirical studies produced to date have either relied on aggregate reuse measures (Singh and Aitken (2010), Singh (2011)) or have focused on the scarcity of safe collateral and its effect on reuse (Infante and Saravay (2020), Jank et al. (2022), Inhoffen and van Lelyveld (2024)). In addition, existing research has been very limited in geographical scope, with (Cheung et al. (2014) analyzing the Australian reuse market, Fuhrer et al. (2016) studying the Swiss market, and Jank et al. (2022) considering the German market.

Importantly, this chapter provides an opportunity to empirically test unexplored theoretical predictions around the impact of credit quality on reuse of collateral, including some predictions from Chapter 1. Additionally, it adds important insights into the activity of collateral reuse in an important and largely unexplored from this perspective market of the EU, aside from the research conducted by Inhoffen and van Lelyveld (2024), which derives a measure of collateral reuse rate from a dataset on the 53 largest banks within the EU based on the Money Market Statistical Reporting ("MMSR"). Further exploration of the activity of collateral reuse in the EU is particularly interesting given the 27 different jurisdictions that fall under this market and the fact that collateral reuse is not regulated in this jurisdictions.[2]

[2]See Appendix 1.A of Chapter 1 for more details on collateral reuse regulation across main global

The rest of this paper is organized as follows. Section II outlines the hypotheses which are tested in this chapter while Section III discusses the used data samples and their extraction and processing. Section IV outlines empirical results of testing the hypotheses and finally Section V concludes and discusses the limitations of this study as well as ideas for future research. Appendices 3.A and 3.B contain tables with additional information.

3.2 Testable Hypotheses

Chapter 3 examines two main testable hypotheses, with an aim to understand how the credit quality of reusing institutions impacts their choices around the systemically important activity of collateral reuse.

Hypothesis 1: The amount of reused collateral increases in the credit quality of the reusing agents.

The first testable hypothesis is based on work of Infante (2019), Park and Kahn (2018) and Park (2020). Their theoretical models propose that when the lender's credit quality is low, the borrower will tend to prohibit the lender from reusing the collateral pledged to it by the borrower. Faced with a poor credit quality of the lender, the borrower faces a higher risk that the collateral reused by the lender never returns to the borrower.

This risk materializes when the lender defaults and the collateral is seized by the next agent in the collateral reuse chain. This risk is referred to as the double-commitment problem that was explained in the first section of the chapter: the usual issue of the borrower's commitment and its ability to repay borrowed funds to the lender is supplemented with the risk around the lender's commitment and its ability to return the valuable collateral back to the borrower at the termination of the contract. Therefore, the lender will be able to reuse more collateral when its credit quality is high - with higher credit quality, the lender's commitment becomes less of a problem and the borrower has less of an incentive to prohibit the lender from reusing the collateral.

Hypothesis 2: The collateral reuse rate increases in the credit quality of the reusing agents.

The second testable hypothesis is derived from the theoretical works outlined in Chapter 1 of this thesis and Luu et al. (2021). Chapter 1 analyzes how the collateral reuse rate is impacted by the characteristics of the reusing agents and finds that the reuse rate increases in the credit quality of the reusing institutions. With higher credit quality, the lender has incentives to reuse a higher proportion of collateral that it has received through other transactions. When the lender's credit quality is high, two things occur: (1) its own project, which requires collateral reuse to get funded, is more profitable and (2) the compensation that the borrower requires for the risk it bears regarding the lender's inability to return the valuable collateral back to the borrower is lower. The two elements combined incentivize the lender to reuse collateral at a higher rate.

In addition, Luu et al. (2021) find that the reuse rate is a decreasing function of the probability of an idiosyncratic liquidity-driven default by a reusing institution. This probability is high when expected losses from a large liquidity shock are significant for

jurisdictions.

a given institution, in which case it is optimal for it to reuse less collateral and to hold it instead as a liquidity buffer. If we allow the credit quality of the reusing agents to be a proxy of this probability of default due to illiquidity (with a higher credit quality representing a lower probability of the liquidity-driven default), their work suggests that a higher credit quality of the reusing agents implies higher reuse rates.

3.3 Data

I derive the data used in this study from multiple sources. The collateral reuse amounts and corresponding reuse rates are obtained from SFTDS and serve as the main dependent variables in the regression analysis that is detailed in Section IV. SFTDS was created to aggregate SFT data that is collected as a requirement of the SFTR regulation. Under SFTR, any firm (financial and non-financial) that is incorporated or located in the EU needs to send daily reports on its SFT to one of the official trade repositories registered with ESMA. Non-EU entities that enter into an SFT with an EU entity are also required to report. Transactions with the members of the EUCB (i.e., with the ECB and Eurozone national central banks) are exempt from the reporting requirements.

SFTR obligates counterparties that engage into an SFT to report counterparty data, detailed loan and collateral information and, where applicable, margin and collateral reuse or cash reinvestment data. Regarding the non-cash reuse data, SFTR requires entities to report details of any reuse of financial instruments that have been received as collateral in a prior SFT. Those details include information on the reporting counterparty (including a legal entity identifier, the Global Legal Entity Identifier Foundation or the GLEIF code), the event date, a unique identifier of the reused asset (ISIN) and the monetary value of reused collateral per each financial asset. It is the first time that such granular transaction-level data on collateral reuse has been collected in the EU.

The SFTR reporting requirements were supposed to commence as from April 2020 for regulated credit institutions (traditional banks) as well as investment firms, with a cascaded schedule of the reporting obligation for other types of entities. However, actual reporting started in mid-July 2020. The delay was caused by the COVID-19 pandemic, with all the required entities reporting only as from January 2021. The reported SFT data has been aggregated on an on-going basis in the SFTDS. SFTDS is a large IT infrastructure, which is jointly managed by the ECB and seven Eurozone national central banks (Belgium, Germany, France, Italy, Luxemburg, Netherlands and Spain). It provides an end-to-end service to collect and process the SFT data that is reported to trade repositories, with an overarching goal to prepare it for analysis and policy-related objectives. The SFTDS Release 1.0 went live on 21-05-2021 and is the basis of data for this analysis.

SFTDS allows ECB and the participating national banks to better monitor market finance activities and perform a better-informed analysis of financial stability of the EU financial system. In general, it supports the fulfillment of various regulatory mandates and reporting requirements of ECB, national banks and ESRB (e.g., five of the participating national central banks have an obligation to report to FSB regarding SFT data). In particular, SFTDS data allows to monitor how SFT impact a build-up of leverage, and to track interconnectedness within the EU financial system. It can also help to better understand the quality of collateral that underlies SFT, the role and importance of central clearing counterparties, the impact of margins on leverage and many other systemically important aspects of the EU financial system that can help derive and implement better prudential policy measures.

The most relevant aspect of SFTDS for this study is that it provides data that allows to take a more transparent look at collateral reuse within the European financial system. The transaction-level self-reported data on reused and received collateral allows to compute collateral reuse rates and link them to reusing institutions, which can provide empirical evidence on how different characteristics of the reusing entities impact this systemically important activity - the main goal of this particular chapter.

Although some entities have already been reporting the required reuse data to the trade repositories as from mid-July 2020, I choose to discard the period before January 2021 for this study. This is because the earlier period was characterized by a poor reporting data quality. In addition, not all entities that are required to report under SFTR had done so before 2021. As I had only had access to SFTDS until June 2021, the final sample comprises of a period spanning over the first six months of 2021, which still provides a large sample of data given the transaction-level reporting of the data. Overall, the chapter provides an interesting early glimpse into this brand new data set and valuable insights into the activity of collateral reuse in the EU.

3.3.1 Dependent and Independent Variables

Regarding data on the non-cash collateral received, SFTDS contains tables with a "stock" view of collateral received through reverse repo, securities lending and margin lending transactions that originated through a SFT with an EU counterparty, and that is indicated as eligible for collateral reuse. From this data, I construct variable Collateral Received, Eligible for $\text{Reuse}_{i,j,t}$, which represents the amount of a reusable non-cash collateral asset j (with j assigned at the asset ISIN level) held at the end of a particular day t by reporting entity i.

In terms of collateral reused data, SFTDS provides a table with a "stock" view of the amount of reused collateral outstanding, or Collateral $\text{Reused}_{i,j,t}$, at the end of a particular day t per reporting entity i and collateral asset j. Reporting entities can report the amount of the reused collateral using two methods. If the amount of reused collateral is known and can be directly determined at an SFT level, they can provide this actual amount of collateral reused. If the amount is unknown or cannot be determined directly, reporting entities can estimate it based on a methodology outlined by FSB (FSB (2017a)). In this case, the amount of reused collateral per entity i and per collateral asset j that is outstanding at the end of day t is estimated and reported as:

$$\text{Collateral Reused}_{i,j,t} = \frac{\text{Collateral Received, Eligible for Reuse}_{i,j,t}}{\text{Collateral Received, Eligible for Reuse}_{i,j,t} + \text{Own Assets}_{i,j,t}} \times \text{Collateral Posted}_{i,j,t} \tag{3.1}$$

where Own Assets$_{i,j,t}$ represents assets of type j owned by entity i at time t while Collateral Posted$_{i,j,t}$ captures the amount of collateral of type j posted by entity i at time t.

Collateral received amounts are matched with collateral reuse amounts using the reporting entity ID (the GLEIF code), the reporting day and the asset identifier, ISIN. If no amount of reused collateral is matched to a particular amount of received collateral, it is assumed that the entity has not reused any of the particular collateral asset on that day. The matched data is then aggregated by day and reporting entity to provide a daily overview of the total received collateral outstanding, Collateral Received, Eligible for Reuse$_{i,t}$, and the total daily reused collateral, Collateral Reused$_{i,t}$, per reusing agent i.

The aggregation results in 175,317 day-entity records of collateral received that represent 1,925 entities, 24 countries and seven sectors. However, only those entities that reported reuse at least once during the sample period from January 2021 to end of June 2021 are kept in the sample. This selection is applied to address the fact that some entities appear not to have started yet reporting their reuse of collateral and hence should be removed not to distort the results. The remaining sample contains 57,698 day-entity records attributable to 405 entities that still represent the same 24 countries and seven sectors.

The aggregated reuse and collateral received amounts are winsorized at the 95th percentile to address the most pronounced outliers, which reflect unreasonably high amounts of reused collateral. Collateral reuse rates are then calculated at the day-entity level in line with the FSB methodology (FSB (2017a)):

$$\text{Reuse Rate}_{i,t} = \frac{\text{Collateral Reused}_{i,t}}{\text{Collateral Received, Eligible for Reuse}_{i,t}} \tag{3.2}$$

Data for Credit Default Swap ("CDS") spreads and credit ratings, which act as independent variables to proxy for the credit quality of the reusing agents, are derived from Refinitiv Eikon, which is also the main source for control variables utilized in this analysis. To address potential issues with endogeneity between the reuse metrics and the credit quality of the reusing institutions, 5-business-day lags of credit ratings and CDS spreads are used. Finally, as a robustness check, I construct an additional measure of reuse intensity to serve as a dependent variable, which is derived by combining reuse amount data from SFTDS with a control variable from Refinitiv Eikon that serves as a proxy for firm size.

Two subsamples are then created to reflect the two proxies of the credit quality of the reusing institutions utilized in this study: a 5-year CDS spread and a credit rating. The two subsamples are smaller as they contain only those entities that could be matched with a 5-year CDS spread (CDS Spread Data Sample) or a credit rating (Credit Rating Data Sample). Given the amount of the reused collateral and the breadth of entities and countries that are represented in the samples, they provide interesting insights into the EU collateral reuse landscape.

CDS Spread Data Sample

Historical 5-year CDS spreads are derived from Refinitiv Eikon. For the purposes of this study, a higher CDS spread reflects a lower quality of credit. Out of the 57,698 day-entity observations of the collateral received and reused, 2,354 are matched with 5-year CDS spreads, where if a CDS spread is not available for the reporting entity, the spread of its direct parent or the ultimate parent (if the direct parent data is not available) is used. These 2,354 observations represent 21 entities from nine countries and three sectors. The reduction of the sample size after matching with the CDS spread is in line with expectations, as only the larger institutions that engage into SFT have CDS outstanding.

Further 377 observations are discarded due to poor data quality, which is discussed in the Data Quality sub-section below. The resulting 1,970 day-entity records are attributable to eighteen entities from eight countries and two sectors (traditional banks and investment banks/brokers) with a total USD 188 billion worth of reused collateral outstanding at the end of each day in the studied period on average. The firms in this sample tend to be on average larger and more conservative with their capital structure choices than the firms in the credit rating sample.

Hence, the entities from the CDS sample also have a higher average credit rating (the average credit rating score is 15.6 representing a rating of between A2 and A1 on Moody's scale; see next subsection for the mapping of credit rating scores). The average daily 5-year CDS spread of 56 bps is in line with the credit rating sample. Furthermore, they reuse more collateral than an average firm from the credit rating sample in both absolute and relative terms: the average reused collateral outstanding per entity at the end of each day is USD 7.4 billion and the average collateral reuse rate is 26%. See Table 3.31 for the summary of statistic for the CDS Data Sample.

The reuse rate of 26% found in the CDS sample is smaller than the 53% rate observed by Inhoffen and van Lelyveld (2024) in a data sample derived from MMSR (which tracks only the largest 53 banks within the EU) over a period of July 2016 to December 2021. The difference between the reuse rates might be attributable to the different nature of the intermediaries within the SFTDS data sample used in this chapter and the MMSR data sample used by Inhoffen and van Lelyveld (2024). For example, this the MMSR data captures reuse of collateral by largest EU-domiciled banks, the SFTDS data captures reuse of collateral "within" the EU, with a possibility that the reusing intermediary is not from the EU (as only one counterparty to a SFT transaction needs to be from the EU to necessitate SFTR reporting that would be captured in SFTDS). The difference in the reuse rate might also be due to the different time periods covered by the two data samples.

Credit Rating Data Sample

The final sample for the credit rating analysis is larger than the CDS Data Sample as not all entities that have a credit rating also have a traded 5-year CDS. Credit ratings are also obtained from the Refinitiv Eikon database and are based on a rating that has been the most recently updated by one of the main rating agencies (Moody's, S&P or Fitch). The most recent rating was chosen instead of an average of the three ratings to reflect the latest available credit assessment. Long-term credit ratings are converted into numerical scores in increments of 1 per rating notch, ranging from 20 for a AAA rating to 0 for a C rating (see Appendix 3.A for the exact mapping). If only a short-term credit rating is available, the rating is converted into a numerical score using a mapping reflected in Appendix 3.B. For the purposes of this study, a higher credit rating score represents a higher quality of credit.

Historical credit ratings are available for 12,168 out of the 57,698 day-entity records of collateral received and reused (using the same matching methodology that was applied to the CDS spread). The match with credit ratings reduces the coverage of the sample to 96 entities from 20 countries and 5 sectors. From the 12,168 day-entity records, 3,241 records are discarded due to questionable data quality (see the subsection Data Quality below for more details).

The final sample contains 83 different reporting entities from two sectors (traditional banks and investment banks/brokers) and sixteen countries of domicile. In total, the entities in the sample have USD 460 billion of reused collateral outstanding per day on average in the 01-01-2021 to 30-06-2021 period. The average daily reuse rate for this sample is 16% and the average reused collateral outstanding per entity at the end of each day is USD 6.4 billion. Again, the reuse rate is smaller than the one found by Inhoffen and van Lelyveld (2024) and smaller than the CDS spread sample. The latter observation is in line with Inhoffen and van Lelyveld (2024), who find that larger intermediaries (as in the CDS spread sample) reuse more collateral than smaller ones (as in the credit rating sample).

Over the sample period, the average numerical credit rating score of the entities in the sample is 13.8 (representing a rating of between A3 and Baa1 on Moody's scale) while the daily average 5-year CDS spread is 56 basis points (bps). Only three out of the 83 entities represented in this sample experienced a credit rating change during this time. Table 3.32 summarizes data statistics for the Credit Rating Data Sample.

3.3.2 Control Variables

The analysis performed in this chapter attempts to control for variables that are correlated with the utilized measures of credit quality, the CDS spread and the credit rating score, and which might also impact collateral reuse activity. One such variable is the size of the reusing firm as size is an important determinant of credit quality that is reflected both in the CDS spreads and the credit rating and it is foreseeable that the size of a reusing institution might also impact the amount and the intensity of collateral reuse.

For example, larger banks tend to have higher credit ratings and lower CDS spreads due to their competitive positioning, easier access to funding and liquidity and the "too big to fail" effect. Because they are bigger, it is reasonable to assume that they reuse more collateral to fund their operations, but they might do so at a different intensity than smaller banks (e.g., bigger banks might reuse assets at a higher rate given that they are perceived as safer by their collateral providers or because they prefer to fund themselves in a different way than smaller banks). In addition, controls are added for the profitability and the strength of the capital structure of the reusing entities as those are directly related to the credit quality and might also affect collateral reuse choices.

Refinitiv Eikon is again the main source of the control variables. To minimize attrition of observations, the data missing from Refinitiv Eikon is then supplemented by extracting it directly from quarterly financial reports of the relevant firms. The size of reusing institutions is proxied with the USD value of reported assets (shown as Assets in Tables 3.31 and 3.32). Natural logs of Assets are used in the regression analysis to address issues with non-linearity of this data element.

The profitability measure is derived by dividing quarterly reported revenue in USD of the reusing entity by the end-of-quarter reported assets (RoA in Tables 3.31 and 3.32). The capital structure measure is calculated as the reported equity in USD divided by the asset value (Equity Ratio iin Tables 3.31 and 3.32). Since the measures rely on reported numbers, only two time points are available over the study period: 31-03-2021 and 30-06-2021. Hence, only two values of each control variable are available per each reusing entity.

3.3.3 Additional Measure of Collateral Reuse Intensity

For purposes of a robustness check, I construct an additional measure of the collateral reuse intensity, *Reuse/Assets*, which is the ratio of the collateral reused amount from SFTDS to the reported value of the entity's assets from the Refinitive Eikon database. The goal of using *Reuse/Assets* instead of the reuse rate obtained purely from the SFTDS data is to at least partially control for the quality of data reported in the SFTDS and the resulting issues with matching of collateral received with collateral reused and the corresponding calculation of the reuse rates.

Data Quality

It appears that some reporting entities consistently misreport the amount of collateral received and/or reused. International Capital Market Association (ICMA), which compiles weekly repo-related SFT data that it obtains directly from trade repositories, also notes the poor reporting quality when it comes to the collateral aspects of the SFT reporting (ICMA (2021)). It is expected that the reporting quality will improve over time although it will most likely be a very slow process. In the meantime, diligent efforts are applied to clean the collateral received and reused data that is utilized in this study, as per below.

Table 3.31: Summary of Data Statistics for the CDS Data Sample

VARIABLES	(1) N	(2) Mean	(3) St. Deviation	(4) p25	(5) p50	(6) p75
Reuse Rate	1,970	0.258	0.313	0.00996	0.125	0.434
Reuse Amount (USD mln)	1,970	7,447	13,778	67.57	2,029	8,640
Reuse/Assets	1,848	0.0116	0.0171	0.00078	0.00401	0.0113
Rating	1,876	15.57	3.101	14	16	17
CDS (bps)	1,970	55.69	42.69	30.33	44.35	54.55
Assets (USD mln)	1,848	1.230e+06	1.058e+06	372,648	642,495	2.314e+06
Ln Assets (USD mln)	1,848	13.65	0.864	12.83	13.37	14.65
Revenue (USD mln)	1,848	8,966	6,407	2,845	7,009	12,986
RoA (%)	1,848	0.847%	0.339%	0.629%	0.751%	0.959%
Equity Ratio (%)	1,848	8.174%	4.054%	5.409%	6.329%	9.199%
Max. # of Firms	18					
Min. # of Firms	17					

Table 3.32: Summary of Data Statistics for the Credit Rating Data Sample

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	N	Mean	St. Deviation	p25	p50	p75
Reuse Rate	8,812	0.158	0.256	0	0.0292	0.217
Reuse Amount (USD mln)	8,812	6,415	14,816	0	207.7	2,976
Reuse/Assets	5,834	0.00826	0.01630	0.00000	0.00054	0.00783
Rating	8,808	13.78	3.317	12	14	16
CDS (bps)	1,880	56.33	44.43	30.26	43.48	54.60
Assets (USD mln)	5,834	1.113e+06	1.046e+06	287,186	768,401	1.722e+06
Ln Assets (USD mln)	5,834	13.25	1.426	12.57	13.55	14.36
Revenue (USD mln)	3,968	7,468	7,713	1,854	3,755	12,913
RoA (%)	3,968	0.833%	0.374%	0.514%	0.814%	0.970%
Equity Ratio (%)	5,771	7.093%	3.213%	5.009%	5.980%	7.782%
Max. # of Firms	83					
Min. # of Firms	44					

To arrive at the final CDS Spread Data Sample, I remove two entities with persistent reporting quality issues representing 207 observations. I also discard 170 observations (eliminating an additional entity) where the computed reuse rate is higher than 1.05. The reuse rates that are between 1.00 and 1.05 are set to 1. One sector (investment funds) is eliminated from the final sample due to a very minor representation (representing one entity with only 22 day-entity records). The resulting final CDS sample contains 1,970 day-entity observations.

For the Credit Rating Data Sample, entities with persistent reporting quality issues are eliminated from the sample (representing 738 day-entity records and eliminating seven entities and four countries). In addition, 2,503 day-entity records where the computed reuse rate is higher than 1.05 are also discarded (while the reuse rates that are between 1.00 and 1.05 are set to 1). This eliminates further four entities and one sector. Finally, the non-financial company and government agency sectors are eliminated from the final sample due to a very minor representation (115 day-entity records total between two entities). The resulting final credit rating sample contains 8,808 day-entity records.

3.4 Empirical Results

I analyze Hypotheses 1 and 2 by using unbalanced panel data regressions of the amount of reused collateral and the reuse rate on the CDS spread, which acts as the main independent variable that proxies for the credit quality of reusing institutions. Because CDS spreads are available daily, they provide enough variability to utilize fixed effects regression analysis that controls for unobserved heterogeneity across firms and time - a very important aspect to consider in the analysis given that only a few and rather static controls are available for this study.

I perform two sets of robustness checks. Firstly, I evaluate Hypotheses 1 and 2 by also regressing the amount of reused collateral and the reuse rate on another measure of credit quality, the credit rating score. Since the credit rating score had changed only for three out of the eighty-four firms from the credit rating sample over the first six months of 2021, a fixed effects analysis is not appropriate as there is not enough variation in the independent variable to warrant it. Hence, the credit rating score robustness check consists of only a pooled OLS regression analysis.

As a second robustness check, I evaluate Hypothesis 2 by utilizing a ratio of the reuse amount to the reporting entity's assets as another proxy of the intensity of collateral reuse. I regress this additional measure on the CDS spreads and on the credit rating scores. This second robustness check aims to partially control for the data quality of the SFTDS data that might result in a poor match of the collateral received with the collateral reused as reported by the entities. Using a ratio of the reuse amount that comes from SFTDS to the publicly reported assets is one way to partially address any potential problems with matching of the SFTDS data. In addition, the ratio also controls for the effect of the size of the reusing institution.

Overall, I find evidence in support of Hypothesis 1 and Hypothesis 2. In accordance with Hypothesis 1, a higher credit quality of the reusing agents is associated with higher amounts of reused collateral. This conclusion holds for both proxies of a higher credit quality: a lower CDS spread and a higher credit rating score (see Tables 3.41 and 3.44). The study also appears to substantiate the claims made under Hypothesis 2, which stipulates that higher credit quality is linked to higher reuse rates.

Indeed, as the results of the analysis captured in Table 3.42 show, collateral reuse rates tend to be higher for firms with lower CDS spreads. While higher credit rating scores appear to be associated with lower reuse rates (Table 3.45) in apparent contradiction to Hypothesis 2, those results are insignificant. When applying another method of estimating the intensity of reuse instead of the reuse rate, namely the ratio of the amount of reused collateral to the reported assets, the obtained effect of the credit quality on the reuse intensity is in line with Hypothesis 2. Specifically, lower CDS spreads and higher credit rating scores are linked to higher ratios of reuse to assets (see Table 3.43 and Table VII respectively). Details of the results and their interpretations for each of the two data samples follow in the subsection below>

3.4.1 Results of the CDS Spread Data Sample

Table 3.41 shows results of regressions of the USD reuse amount on the CDS spread, the main proxy for the credit quality of reusing intermediaries that is used in this study. In line with the expectations stipulated under Hypothesis 1 that link higher credit quality with more reuse, a lower CDS spread is associated with higher amounts of collateral reuse.

A negative and statistically significant effect is obtained when controlling for the unobserved firm heterogeneity that remains stable across time and the unobserved time heterogeneity that applies across all firms and controls for general market developments (regression (4) of Table 3.41). While the significance of the effect of the CDS spread on the reuse amount dissipates when further controlling for the observable but rather static measures of the company size, profitability and capital structure strength (regression (5) of Table 3.41), it remains negative in accordance with Hypothesis 1.

The disappearance of a statistical significance in regression (5) might be caused by the particular and slightly smaller sample that results when the company-specific controls are applied. Based on this regression, a one basis-point increase in a firm's CDS spread is linked with a decrease in its daily reuse amount of nearly USD 44 million on average. This effect is economically significant considering that a 1 standard deviation increase in the CDS spread would be equivalent to an approximate decrease in the reuse amount that represents 14% of its standard deviation.

The results of regressions of the reuse rate on the CDS spread can be found in Table 3.42. Although the impact of the CDS spread appears to be positive when applying a pooled OLS methodology (see regressions (1) and (2) in Table 3.42), it turns negative when the firm and time fixed effects are utilized (regressions (3), (4) and (5) in Table 3.42). The negative results are in line with Hypothesis 2, which states that a higher credit quality of the reusing agents (a lower CDS spread) is associated with higher rates of collateral reuse.

The effect is statistically significant when controlling for the important unobserved

Table 3.41: Regression Results: Reuse Amount Regressed on CDS Spread

VARIABLES	(1) OLS	(2) OLS	(3) Fixed Effects	(4) Fixed Effects	(5) Fixed Effects
Reuse Amount (USD mln)					
CDS (bps)	-39.23*	-25.12	2.734	-8.971**	-43.59
	(0.0654)	(0.748)	(0.492)	(0.0478)	(0.257)
Inv. Bank		-6,365			
		(0.515)			
Ln Assets (USD mln)		1,542			17,917
		(0.762)			
RoA (%)		7,923			-8,117
		(0.426)			(0.578)
Equity Ratio (%)		-642.9			-673.1
		(0.510)			(0.882)
Constant	9,632**	-11,833	7,294***	6,336***	-223,601
	(0.0258)	(0.863)	(0)	(1.93e-08)	(0.696)
Observations	1,970	1,848	1,970	1,970	1,848
Number of Firm	18	17	18	18	17
R-squared	0.015	0.056	0.000	0.098	0.125
Adj. R-squared	0.0143	0.0531	-0.000371	0.0387	0.0610
Firm Clustered Errors	YES	YES			
Firm FE			YES	YES	YES
Day FE				YES	YES

firm heterogeneity but loses its significance when controlling for time fixed effects (regression (4)), indicating that there might be other potential determinants of the reuse rate that vary over time but apply to all the reusing firms (e.g., market developments, general liquidity conditions, etc.).

The impact of the CDS spread on the reuse rate remains insignificant when further controlling for company-specific characteristics (regression (5)). It appears that the proxies of the company size (Ln Assets) and the strength of the capital structure (Equity Ratio) are important determinants of the reuse rate, with larger and more capital-conservative companies reusing collateral more intensively. Based on regression (5), a one bps increase in the CDS spread is linked with a decrease of 0.000615 in the reuse rate. This effect is economically significant as a 1 standard-deviation increase in the CDS spread represents a decrease of around 8% of the standard deviation of the reuse rate.

As a further robustness check that serves as an alternative approach to test Hypothesis 2, I use a different measure of the collateral reuse intensity in place of the reuse rate. Specifically, I utilize a ratio of the reuse amount to the reported value of assets as the dependent variable *Reuse/Assets* and regress it on the CDS spread (Table 3.43). Based on the results, a higher credit quality of a reusing agent is associated with a higher ratio of reuse to assets in support of Hypothesis 2.

The conclusion is based on the statistically significant and negative relationship between the CDS spread and the ratio of reuse to assets when controlling for the unobservable firm and time fixed effects and company-specific characteristics. Specifically, a one bps increase in the CDS spread is linked to a decrease of 0.000131 in the reuse-to-assets ratio (see regression (6) in Table 3.43). This effect is also economically significant: an increase of 1 standard deviation in the CDS spread is expected to generate a decrease in the ratio that represents 33% of its standard deviation.

Table 3.42: Regression Results: Reuse Rate Regressed on CDS Spread

VARIABLES	(1) OLS	(2) OLS	(3) Fixed Effects	(4) Fixed Effects	(5) Fixed Effects
Reuse Rate					
CDS (bps)	2.71e-05	8.71e-05	-5.06e-05*	-2.64e-05	-0.000615
	(0.776)	(0.769)	(0.0909)	(0.531)	(0.188)
Inv. Bank[3]		0.130			
		(0.300)			
Ln Assets (USD mln)		-0.0985			5.700***
		(0.414)			(0.00570)
RoA (%)		0.143			0.749
		(0.618)			(0.238)
Equity Ratio (%)		-0.00946			0.839**
		(0.622)			(0.0480)
Constant	0.243**	1.488	0.286***	0.310***	-84.66***
	(0.0287)	(0.456)	(0)	(3.06e-06)	(0.00668)
Observations	1,970	1,848	1,970	1,970	1,848
Number of Firm	18	17	18	18	17
R-squared	0.001	0.096	0.001	0.048	0.190
Adj. R-squared	0.000861	0.0938	0.000790	-0.0144	0.132
Firm Clustered Errors	YES	YES			
Firm FE			YES	YES	YES
Day FE				YES	YES

Table 3.43: Regression Results: Reuse/Assets Ratio Regressed on CDS Spread

VARIABLES	(1) OLS	(3) OLS	(4) Fixed Effects	(5) Fixed Effects	(6) Fixed Effects
Reuse/Assets					
CDS (bps)	-8.89e-05	-0.000163	3.68e-05	-5.10e-05	-0.000131*
	(0.411)	(0.144)	(0.613)	(0.414)	(0.0540)
Inv. Bank		-0.00799			
		(0.362)			
Ln Assets (USD mln)		-0.00473			0.0690
		(0.399)			(0.309)
RoA (%)		0.00499			-0.00370
		(0.698)			(0.799)
Equity Ratio (%)		-0.000457			0.00249
		(0.764)			(0.739)
Constant	0.0157*	0.0852	0.00985***	0.0108***	-0.944
	(0.0553)	(0.297)	(0.00945)	(0.00184)	(0.331)
Observations	1,848	1,848	1,848	1,848	1,848
Number of Firm	17	17	17	17	17
R-squared	0.016	0.168	0.001	0.102	0.139
Adj. R-squared	0.0156	0.165	0.000441	0.0384	0.0765
Firm Clustered Errors	YES	YES			
Firm FE			YES	YES	YES
Day FE			YES	YES	YES

3.4.2 Results of the Credit Rating Data Sample

As another set of robustness checks, I also perform the analysis utilizing credit rating score as a proxy for the credit quality of the reusing firms represented in the Credit Rating Data Sample. Because of the very low variability of the credit rating score over time (only three changes observed over the relevant period), a fixed effects approach is not possible and only a pooled OLS analysis is applied. Hence, the interpretation of results stemming from the Credit Rating Data Sample is limited.

Starting with the reuse amount, I find that a higher credit rating score is linked to a higher amount of reused collateral, in line with Hypothesis 1 (see Table 3.44). Based on regression (1), a one-notch increase in a firm's credit rating is associated with an additional USD 634 million of its reused collateral outstanding on average. The impact of the credit rating score on the reuse amount is economically significant as a

1 standard-deviation increase in the rating score is linked to an increase in the reuse amount of around 14% of its standard deviation.

After controlling for company-specific characteristics, the statistical significance of the estimate of the impact of the credit rating score on the reuse amount disappears (regression (2)). The loss of significance of effect of the rating score on the collateral reuse amount in regression (2) might be due to the particular and significantly smaller sample that results from an application of company controls.

When regressing collateral reuse rates on credit rating scores, I find some weak evidence against Hypothesis 2. The estimates of the effect of the credit rating score on the reuse rate are negative before and after controlling for company-specific characteristics (see regressions (1) and (2) of Table 3.45). This is in contrast to the expectations set under Hypothesis 2, which stipulates that a higher credit quality should result in a higher collateral reuse rate. However, given the statistical insignificance of the results, this evidence is very limited.

Applying a robustness check for the Credit Rating Data Sample by replacing the collateral reuse rate with a ratio of the reuse amount to the reported assets as the proxy for the credit quality of reusing institutions, it appears that a higher credit rating score is associated with a higher reuse-to-assets ratio, with a one notch increase in the credit rating linked with an increase of 0.00117 in the ratio. This impact is not only statistically significant but also relevant from the economic perspective, with an increase of 1 standard deviation in the credit rating score representing an increase in the reuse-to-assets ratio of approximately 24% of its standard deviation.

However, the robustness check results performed on the Credit Rating Data Sample (as presented in Tables 3.44, 3.45 and 3.46) need to be evaluated in light of the fact that the unobserved firm and time heterogeneity are not considered in this analysis. As more data is collected on credit rating developments over time, the resulting variation of credit rating score over time should allow for an application of the more sophisticated fixed effects methodology, which would strengthen conclusions stemming from the robustness checks utilizing credit rating scores.

Table 3.44: Regression Results: Reuse Amount Regressed on Credit Rating Score

VARIABLES	(1) OLS	(3) OLS
Reuse Amount (USD mln)		
Rating	634.2**	541.0
	(0.0211)	(0.361)
Inv. Bank		-10,141
		(0.139)
Ln Assets (USD mln)		3,360
		(0.117)
RoA (%)		-2,419
		(0.671)
Equity Ratio (%)		-611
		(0.416)
Constant	-2,322	-35,474
	(0.464)	(0.163)
Observations	8,808	3,968
Number Firms	83	44
R-squared	0.020	0.134
Adj. R-squared	0.0200	0.133
Firm Clustered Errors	YES	YES

Table 3.45: Regression Results: Reuse Rate Regressed on Credit Rating Score

VARIABLES	(1) OLS	(2) OLS
Reuse Rate		
Rating	-0.000236	-0.00331
	(0.965)	(0.786)
Inv. Bank		0.0876
		(0.488)
Ln Assets (USD mln)		0.0135
		(0.711)
RoA (%)		0.00883
		(0.946)
Equity Ratio (%)		-0.00484
		(0.640)
Constant	0.162*	0.0794
	(0.0584)	(0.856)
Observations	8,808	3,968
Number Firms	83	44
R-squared	0.000	0.020
Adj. R-squared	-0.000104	0.0183
Firm Clustered Errors	YES	YES

Table 3.46: Regression Results: Reuse/Assets Ratio Regressed on Credit Rating Score

VARIABLES	(1) OLS	(3) OLS
Reuse/Assets		
Rating	0.000668*	0.00117**
	(0.0866)	(0.0494)
Inv. Bank		-0.0118**
		(0.0441)
Ln Assets (USD mln)		0.000334
		(0.831)
RoA (%)		-0.00727
		(0.409)
Equity Ratio (%)		-0.000315
		(0.806)
Constant	-0.000947	-0.00106
	(0.851)	(0.959)
Observations	5,834	3,968
Number Firms	59	44
R-squared	0.021	0.078
Firm Clustered Errors	YES	YES
Adj. R-squared	0.0210	0.0767

3.5 Discussion & Conclusions

The results of the empirical analysis discussed in Section IV provide an early empirical evidence that the credit quality of financial institutions is linked to their collateral reuse choices. In line with the prior theoretical research discussed in Section II (which serves as the basis for Hypotheses 1 and 2 tested in this chapter), the study finds that reusing entities tend to reuse less collateral when their credit quality is low. Specifically, when faced with a decreasing credit quality, they appear to reuse less collateral in both absolute (the volume of reuse) and relative (the reuse rate) terms.

Despite some limitations that are outlined below, the study adds important new insights to the current body of literature on the reuse of collateral - an activity that financial institutions engage in on a large scale and across the globe, but which so far has been largely unexplored from the empirical perspective. To the author's knowledge, it is the first empirical study that attempts to understand the impact of the credit quality and related firm characteristics on the systemically-important activity of collateral reuse. It also provides a glimpse into a new, transaction-level dataset on SFT and collateral reuse - a dataset of an unprecedented granularity and detail. Finally, because it covers a wide-range of SFT transactions and associated reuse of collateral in the EU, it offers interesting and important insights into collateral reuse in a market which has not been explored yet sufficiently from this perspective.

At a first glance, the conclusions that financial entities tend to contract reuse as their credit quality deteriorates without an intervention of a regulator[4] might appear encouraging from the financial stability perspective. Because collateral reuse is associated with a range of potential systemic risks such as asset fire sales, increased interconnectedness and a build-up of excessive leverage within the financial systems, the fact that financial institutions reuse less collateral when they are experiencing "bad times" appears to support the idea of self-regulation when it comes to this aspect of financial stability. It might be tempting then to view the activity of collateral reuse as self-regulated and after all not warranting worries of financial regulators.

However, the conclusions of this study as they pertain to financial stability and regulation of collateral reuse need to be carefully evaluated: while the study finds some evidence that reusing institutions with lower credit quality reuse less collateral, the study does not test if they contract reuse **enough** to minimize the negative impact of reuse on financial stability that could eventually spill over to the wider economy.

In fact, Chapter 1 of this thesis provides theoretical evidence that while reusing agents decrease their reuse activities as their credit quality deteriorates, they do not do so sufficiently from the social-welfare perspective. This insufficient contraction stems from the fact that the reusing institutions do not internalize some of the negative externalities that come with reuse. Hence, regulation over collateral reuse might be still advisable.

An interesting idea for further empirical research would be to use the collateral reuse data from SFTDS that is utilized in this study to calibrate the theoretical model from Chapter 1 to see if financial institutions indeed overuse collateral in bad times vs. what is socially optimal. Another idea for further exploration is to use the SFTDA data to analyze the degree of interconnectedness of financial institution through collateral reuse. For example, the data allows to derive length of collateral reuse chains, which can offer a new understanding on how collateral reuse impacts interconnectedness within the financial system - a very interesting topic for future research.

Regarding limitations of the study, it is important to point out potential challenges to the research outcomes discussed in this chapter as it comes to the quality of the data. The issues with the SFTDS data quality that has been reported by the financial entities are discussed in Section III. While the author exerts diligent effort to clean the data, it is possible that the resulting data samples still suffer from reporting mistakes and omissions when it comes to the reported collateral reused and the reported collateral received as well as the collateral reuse rates that are derived from these two data elements.

[4]The activity of collateral reuse remains largely unregulated across jurisdictions. See Appendix 1.A of Chapter 1 of this thesis for an overview of current regulation of collateral reuse in the major financial jurisdictions around the world.

In addition, because a lot of problematic observations ware discarded, the final data samples might suffer from a sample selection bias. It could be that the institutions that are included in the final sample (i.e., firms that appear to report collateral aspects of their SFT with a higher quality and consistency) represent a specific subset of financial institutions. For example, the firms that report reuse with a higher quality might reuse more collateral than average and hence allocate more importance and resources to this activity, resulting in a better reporting quality than other institutions. If the final "clean" data samples used in this study indeed suffer from a sample selection bias, the results and conclusions outlined in this paper might be internally invalid.

The empirical identification strategy applied in this analysis also presents potential challenges to the internal validity of the study. While the fixed effects methodology controls for unobserved heterogeneity across firms and time, the analysis could benefit from a higher number of explicit control variables to control for various company-related characteristics and market-wide developments. Additionally, the utilized control variables rely on reported quarterly measures with only two observations available over the study period. As the SFTDS database grows, the analysis could be extended by considering a longer time period so that more quarterly observations are available for the relevant control variables.

Finally, the robustness checks that utilize credit rating scores as a proxy for the credit quality of the reusing institutions are based on a pooled OLS regression methodology as there is not enough variability in the credit rating scores to justify an application of fixed effects. Hence, the robustness checks do not control for any unobserved firm or time heterogeneity, limiting the validity of results and interpretations that stem from this part of the analysis.

Appendices

Appendix 3.A Mapping of Credit Rating Scores to Long-Term Credit Ratings

Credit Rating Score	Moodys	S&P	Fitch
20	Aaa	AAA	AAA
19	Aa1	AA+	AA+
18	Aa2	AA	AA
17	Aa3	AA-	AA-
16	A1	A+	A+
15	A2	A	A
14	A3	A-	A-
13	Baa1	BBB+	BBB+
12	Baa2	BBB	BBB
11	Baa3	BBB-	BBB-
10	Ba1	BB+	BB+
9	Ba2	BB	BB
8	Ba3	BB-	BB-
7	B1	B+	B+
6	B2	B	B
5	B3	B-	B-
4	Caa1	CCC+	CCC+
3	Caa2	CCC	CCC
2	Caa3	CCC-	CCC-
1	Ca	CC	CC
0	C	D	D

Appendix 3.B Mapping of Credit Rating Scores to Short-Term Credit Ratings

Credit Rating Score	Moodys	S&P	Fitch
18		A-1+	F-1+
17	P-1	A-1	F-1
13	P-2	A-2	F-2
11.5	P-3	A-3	F-3

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Summary

The main subject of this thesis is the activity of collateral reuse - an activity that connects traditional and non-bank financial institutions (NBFI) across the global financial markets. As this opaque activity remains largely unregulated, this dissertation focuses on the question of whether reuse of collateral should be regulated or left to discretion of reusing financial intermediaries that include both traditional banking institutions as well as NBFIs. The general conclusion is that the activity of collateral reuse could benefit from regulation of the collateral reuse rate or the portion of the collateral assets that is reused in subsequent transactions. Such regulation is especially beneficial in times of low credit quality of the reusing financial institutions. The thesis supports these conclusions as follows.

In a theoretical setup, Chapter 1 of this dissertation explores a question of whether there is a rate of collateral reuse within the financial system that is optimal from the social welfare perspective. To derive this socially optimal rate of collateral reuse, I build a model of secured lending in an NBFI setting that trades off the benefit of reuse in facilitating more productive investment with its potential to generate fire sales and related negative externalities. I find that there is scope for regulation of financial intermediaries that engage into reuse. Such regulation should limit the reuse rate in downturns, which are characterized by a deteriorating credit quality of the reusing financial intermediaries

Chapter 2 of the dissertation is also theoretical and it applies an extension to the benchmark model of collateral reuse that is outlined in Chapter 1. The extension allows to gather insights into choices regarding collateral reuse rate by reusing financial intermediaries and decisions on liquidity holdings by secondary asset market participants. Through this model extension, I show that secondary market participants choose to hold a liquidity level that is lower than what is socially optimal. Hence, regulation in a form of minimum liquidity requirements can help to restore social welfare to more efficient levels. However, I show that to restore the first-best social welfare, regulation of liquidity should be supplemented with additional regulation of the rate of collateral reuse in some cases, in line with Chapter 1.

The final chapter of the dissertation provides a novel empirical evidence on collateral reuse, which has been to date largely empirically unexplored due to an unavailability of transaction-level data. The empirical analysis focuses on how the credit quality of financial intermediaries that reuse collateral affects collateral reuse, with an aim to test predictions from theoretical literature (including Chapter 1 of this thesis) that link lower credit quality of the financial institutions with lower reuse of collateral. Using

a new transaction-level dataset on Security Financing Transactions and the associated reuse of collateral in the EU, I find that firms that face a deteriorating credit quality contract less collateral reuse in both absolute and relative terms: they reduce the volume of reuse and lower the intensity of reuse as measured by the reuse rate.

Samenvatting (summary in dutch)

Het centrale onderwerp van dit proefschrift is het hergebruik van onderpand - een praktijk die traditionele en niet-bancaire financiële instellingen (NBFIs) met elkaar verbindt binnen de wereldwijde financiële markten. Het hergebruik van onderpand is een niet-transparante en grotendeels ongereguleerde activiteit. Dit proefschrift zich op de vraag of het hergebruik van onderpand gereguleerd zou moeten worden, of aan de discretie van financiële tussenpersonen, zoals traditionele banken als NBFIs, kan worden overgelaten. De algemene conclusie is dat deze activiteit gebaat zou zijn bij regulering van het hergebruikpercentage, oftewel het deel van het onderpand dat in opeenvolgende transacties opnieuw wordt ingezet. Dergelijke regulering is met name wenselijk in tijden waarin de kredietwaardigheid van de hergebruikende instellingen onder druk staat. Dit proefschrift onderbouwt deze conclusies als volgt.

In een theoretische benadering onderzoekt hoofdstuk 1 de vraag of er binnen het financiële systeem een hergebruikpercentage bestaat dat maatschappelijk optimaal is. Om dit sociaal optimale niveau te bepalen, ontwikkel ik een model voor onderpandgedekte kredietverlening door NBFIs. Dit model weegt de voordelen van hergebruik voor productieve investeringen tegen het risico op gedwongen verkopen en andere negatieve externe effecten. Hieruit blijkt dat er ruimte is voor regulering van financiële tussenpersonen die zich bezighouden met hergebruik. Dergelijke regulering zou het hergebruikpercentage moeten beperken tijdens de laagconjunctuur, waarin de kredietkwaliteit van hergebruikende instellingen afneemt.

Hoofdstuk 2 is eveneens theoretisch van aard en bouwt voort op het model uit hoofdstuk 1. Deze uitbreiding biedt inzicht in het gedrag van hergebruikende financiële instellingen ten aanzien van het hergebruikpercentage, evenals de liquiditeitskeuzes op de secundaire markt. Uit deze analyse blijkt dat marktdeelnemers geneigd zijn minder liquiditeit aan te houden dan maatschappelijk wenselijk is. Hierdoor zouden minimale liquiditeitseisen kunnen bijdragen aan een efficiënter evenwicht. Echter, om het sociaal optimale evenwicht te bereiken, moet in sommige gevallen ook het hergebruikpercentage gereguleerd worden, in lijn met de bevindingen uit hoofdstuk 1.

Het laatste hoofdstuk van het proefschrift biedt nieuwe empirische inzichten in het hergebruik van onderpand, een onderwerp dat tot op heden grotendeels onderbelicht is gebleven vanwege het gebrek aan transactieniveau-data. De empirische analyse richt zich op de vraag hoe de kredietkwaliteit van hergebruikende financiële instellingen het hergebruik van onderpand beïnvloedt, met als doel de voorspellingen uit de theoretische literatuur (waaronder hoofdstuk 1) te toetsen die een verband leggen tussen lagere kredietwaardigheid en een lager niveau van hergebruik. Aan de hand van een nieuwe

Security Financing Transactions dataset met daarin gerelateerde transactie data en het bijbehorende hergebruik van onderpand in de EU, laat ik zien dat instellingen met een verslechterende kredietkwaliteit het hergebruik van onderpand verminderen. Dit gebeurt in zowel absolute als in relatieve termen. Zij verkleinen het volume van hergebruik én verlagen de intensiteit ervan, gemeten aan de hand van het hergebruikpercentage.

The Tinbergen Institute is the Institute for Economic Research, which was founded in 1987 by the Faculties of Economics and Econometrics of the Erasmus University Rotterdam, University of Amsterdam and Vrije Universiteit Amsterdam. The Institute is named after the late Professor Jan Tinbergen, Dutch Nobel Prize laureate in economics in 1969. The Tinbergen Institute is located in Amsterdam and Rotterdam. For a full list of PhD theses that appeared in the series we refer to List of PhD Theses Tinbergen.nl. The following books recently appeared in the Tinbergen Institute Research Series:

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