1 Introduction

1.1 Problem definition and objectives of the thesis

Auto loans constitute an important type of debt in contemporary consumer credit markets. In the U.S., for example, outstanding auto loans accounted at the end of 2023 for US-$ 1.61 trillion of household debt, which was the second largest share (i.e., 9.2%) in total U.S. household debt. In this regard, auto loans exceeded student loans (9.1%) or credit card debt (6.5%) and they were outnumbered only by mortgage debt (70.0 %) (Federal Reserve Bank of New York, 2024).

The mechanisms of auto loans are rather simple. When a consumer aims to buy a car, he or she often requests a loan from a financial institution, either directly or brokered by the dealer, to finance the purchase. Possibly after a short grace period, the consumer owes fixed monthly loan installments over a period of typically five or six years. Depending on market conditions, manufacturer subsidies, and individual risk characteristics, the lender charges a fixed interest rate on the outstanding capital, which is transparently incorporated in the monthly payments. If the borrower misses some payments, the lender can terminate the loan and repossess the car. Otherwise, the contract ends regularly. If the loan does not fully amortize over the term, it ends in a so-called balloon rate, which can exceed previous installments by far and might be financed by a follow-up loan.

Despite the large share in total household debt, some reasons suggest that auto loans might be a matter of limited importance in terms of credit risk. First, similar to other consumer debt, auto loan portfolios exhibit a high granularity regarding the borrowers, so that personal misfortune of individuals hardly harms the lender. That is, the idiosyncratic counterparty risk is diversified away. Further, auto loans have a high degree of collateralization. Serving as collateral, financed vehicles typically weigh up a large fraction of the outstanding capital. Moreover, compared to real estate, for example, it is relatively easy for lenders to seize and remarket such collateral. Finally, financed cars are typically insured against sudden loss in value, related to theft or car accidents, for example.

Nevertheless, auto loan portfolios have characteristics that make it interesting and economically relevant to study their credit risk. For example, there is a general trend in auto lending that loans become longer and riskier (An et al., 2020), which indicates a growing importance in the future. In the focus of this thesis, auto loan portfolios can have a non-trivial risk profile, even if the borrower structure is highly diverse, given that the financed vehicles share certain properties like engine types. In particular, the market value of auto collateral can correlate significantly within auto loan portfolios due to spillover effects of brand reputation, which arose in the context of the 2015 diesel emissions scandal (Che et al., 2022). Brand-reputation risk is relevant on portfolio level particularly for lenders who finance primarily cars of one or a few vehicle brands. Such lenders are not uncommon in auto lending, since financial services in the context of new-car purchases are often provided by manufacturer-affiliated institutions called "captives."

From the findings about secondary-market prices in Che et al. (2022), it can be deduced that the diesel emissions scandal had at least two negative externalities for auto lenders. First, loss rates in case of loan defaults can be assumed to have increased, as a direct effect of decreased collateral value. Rather indirectly, the scandal might also have led to an increased frequency of loan default events, as borrowers might have conducted so-called "strategic defaulting" (Bradley et al., 2015; Brown et al., 2024; Cunningham et al., 2021; Guiso et al., 2013; Gupta, 2019; Ratnadiwakara, 2021; Seiler et al., 2012). This behavior is often described in the context of mortgage loans, where house price declines are known to disincentivize borrowers to make due payments. However, the occurrence of strategic defaulting is not yet proven in the context of the diesel emissions scandal. In addition, it is not clear whether decreased collateral value is the only channel through which a corporate scandal in the automobile industry can impair the performance of auto loan portfolios. For example, highly visible violation of social norms might impair default behavior through a deterioration of debt repayment norms (Gupta, 2019). Therefore, this thesis examines the following research questions:

- Do loans on durable goods show increased credit risk when the financed good becomes associated with norm-violating behavior during the time of loan repayment?
- If so, is the increase in credit risk due to a loss in collateral market value or a deterioration of social norms (or both)?

Apart from ongoing loans, it is also interesting to examine loans taken out only after the scandal erupted. By choosing to buy a good of a scandal-embroiled brand, consumers reveal an increased willingness to substitute ESG preferences with other preferences (e.g., related to purchase prices). The disregard of ESG principles might be linked to a lack of moral concerns over defaulting or other characteristics that imply heightened credit risk. Therefore, the thesis also addresses the following research question:

- Do loans on durable goods show increased credit risk if the decision to buy the good is made when the good is associated with norm-violating behavior?

Auto loan portfolios are subject to further risks than those discussed above. For example, increasing unemployment levels can raise the default risk of consumer auto loans on portfolio level. In addition, vehicle market values depend on technical and political developments (e.g., related to promoted or rejected engine types).

Auto lenders can actively manage the size and riskiness of their loan portfolios. For this purpose, an often used mechanism is loan securitization, which allows the so-called "originator" to transform future cash flows of illiquid assets (like consumer loans) into marketable securities. At the end of 2022, asset-backed securities (ABS) backed with claims on U.S. auto loan repayments had an outstanding balance of approximately US-$ 221 billion, making auto loans the most important asset class in U.S. non-mortgage securitization (SIFMA, 2024). In the course of the diesel emissions scandal, however, auto lenders specialized on involved brands could no longer securitize their loans. In particular, Volkswagen's captive VW Credit Inc., which had frequently issued auto loan ABS in the time from 2002 until 2015, issued no more auto ABS until the mid of 2018.[1]

[1]The last U.S. Volkswagen auto ABS before the diesel emissions scandal has been issued by "Volkswagen

Nevertheless, significant fragility of securitization markets has been observed earlier, and to a much greater extent, than with the diesel emissions scandal. Particularly, in the context of the 2007 financial crisis, excessive mortgage securitization activity caused detrimental developments that raised concerns about the securitization mechanism in general, which led to an overall collapse of securitization markets.

There are two issues of asymmetric information that affect securitization markets. First, originators can have private information about the securitized cash flow at the time of security issuance. For example, lenders might have gathered superior knowledge, compared to ABS investors, about credit risk during the loan screening process. As investors cannot reward unobservable qualities, originators might tend to choose especially "bad" assets for securitization, in what is known as lemons problem or "adverse selection."

Second, there might be agency problems resulting from so-called "hidden action." Originators often have opportunities to apply costly technologies to improve the securitized cash flow, but whether they use them cannot be observed by investors. In consumer lending, for example, the originator and loan servicer might be the same party, which has to decide on servicing measures in response to loan repayment defaulting. In this situation, making appropriate decisions can require costly actions like a thorough analysis of the default case or extensive communication with the borrower. Leaving economically beneficial effort undone due to missing individual benefit is called "moral hazard."

Despite the issues of asymmetric information, market participants and regulators consider securitization as an important element of well-functioning financial markets. Its main benefits pertain to risk transfer and refunding, as securitization allows to transform risky cash flows expected in the future into risk-free sale proceeds earned at the present. Thus, securitization can enable ABS originators to use further socially beneficial investment opportunities, like the expansion of lending. The lessons learned from the 2007 financial crisis include that the incentives of originators need to be aligned with those

Auto Lease Trust 2015-A", with the final prospectus stemming from February 27, 2015; and the first U.S. Volkswagen auto ABS after the scandal has been issued by "Volkswagen Auto Loan Enhanced Trust 2018-1", with the final prospectus from June 29, 2018.

of ABS investors. In the center of this alignment, post-crisis securitization deals employ retention of cash flow or similar credit risk retention. That is, originators who sell claims on future loan repayments retain a fraction of the securitized cash flow.

In recent years, a market trend towards transparency regarding asset quality at the time of ABS issuance can be observed, so that adverse selection appears to be a neglectable issue in the future. Nevertheless, moral hazard related to hidden action after ABS issuance remains a major concern. There is a large body of theoretical literature dealing with the optimal security (and retention) design in ABS or ABS-similar settings (e.g. Ahn & Breton, 2014; Botsch, 2022; Chemla & Hennessy, 2014; Daley et al., 2020; DeMarzo & Duffie, 1999; DeMarzo et al., 2021; Dionne & Malekan, 2017; Fender & Mitchell, 2009; Flynn et al., 2020; Gorton & Pennacchi, 1995; Guo & Wu, 2014; Keys et al., 2010, 2012; Kiff & Kisser, 2014; Kuong & Zeng, 2021; Malekan & Dionne, 2014; Pennacchi, 1988; Rajan et al., 2010, 2015; Vanasco, 2017). A part of this work focuses on post-issuance moral hazard. However, there are two important features of contemporary securitization markets that are not captured by the existing studies.

First, many studies oversimplify how the originator's hidden action improves the securitized cash flows. The claims on a securitized cash flow are typically partitioned into so-called ABS "tranches" that are rank-ordered by seniority, resulting in AAA-rated debt securities as well as subordinate equity-like tranches. Thus, to align incentives, ABS originators can retain positions in different rank-ordered securities with varying subordination levels. Most theoretical models rely on the (implicit or explicit) assumption that the most subordinate securities are most sensitive to effort. However, empirical results in Maturana (2017) about monitoring effort towards residential mortgage loans suggest that lowest-ranked ABS claims are not necessarily most sensitive to effort, because the beneficial effect of effort is highest under adverse economic conditions under which equity tranche holders can expect no revenues at all. The empirical results motivate to analyze cash flows that exhibit a relationship between subordination level and effort sensitivity that is non-monotonic (i.e., most subordinate claims are *not* most sensitive to effort). No

existing model provides insights about how this property affects the optimal retention design. Only a few existing models rely on assumptions that do not contradict with this property and in these models, the property is entangled with other relevant cash flow properties so that its impact on the results remains unclear.

Second, the existing models oversimplify the benefits of securitization, as they either do not differentiate at all between refunding and risk transfer or assume a risk transfer benefit that fails to reflect the riskiness of different rank-ordered securities adequately.

For these reasons, in this thesis a theoretical model of retention design in securitization markets is developed to answer the following research question:

- What is the optimal design of cash flow retention in securitization markets under the following conditions: (i) an agency problem of post-issuance moral hazard is present, (ii) the functional relationship between the subordination level of ABS claims and their sensitivity to originator effort is non-monotonic, and (iii) both major welfare benefits of securitization, refunding and risk transfer, adequately reflect the riskiness of different rank-ordered securities.

1.2 Course of Investigation

Using the example of the 2015 diesel emissions scandal, Chapter 2 analyzes whether corporate fraud in the manufacturing sector can have negative externalities for consumer lending through the channels of decreased collateral value and deteriorated social norms. Section 2.1 elaborates on the starting point and aims of the analysis. Section 2.2 illuminates the scandal, which rocked the global automobile industry in late 2015. Section 2.3 explains the economics of default behavior in consumer lending. Subsequently, it derives hypotheses about how decreased collateral value and deteriorated social norms might affect loans taken out at the height of the scandal as well as loans that were already running before the scandal unfolded. Section 2.4 describes how monthly regulatory loan data of several U.S. auto lenders is collected and harmonized to verify the hypotheses. Section 2.5 presents logistic regressions that estimate the scandal's impact on default rates regarding

both new and existing loans. Section 2.6 deals with the implications of the regression analyses, including the strategic nature of default behavior and the importance of the two channels, decreased collateral value and deteriorated social norms. It also discusses the necessity to perform active risk management when loan pools on durable goods accumulate goods of single manufacturers or brands. Section 2.7 presents concluding remarks about the chapter. Finally, Section 2.8.1 illuminates technical details on the data preparation.

Chapter 3 illuminates the mechanism of securitization to transform otherwise illiquid assets, like auto loans, into marketable securities. Section 3.1 characterizes the different parties involved in securitization deals and how they interact. Besides, the beginnings of securitization markets are briefly described. Afterwards, Section 3.2 explains the benefits that lenders can gain from securitization. Thereafter, Section 3.3 illuminates disadvantages of excessive securitization activity, particularly dealing with the example of the 2007 financial crisis. Finally, Section 3.4 introduces different mechanisms of credit risk retention as a measure to align incentives between ABS originators and investors.

Next, Chapter 4 addresses informational frictions in securitization markets, and how they can be mitigated, in greater detail. Section 4.1 summarizes empirical evidence of the issue of adverse selection in real securitization markets. Subsequently, Section 4.2 discusses theoretical models about how the market can deal with this imperfection, especially by employing cash flow retention as a measure of signaling the private information. Thereafter, Section 4.3 illuminates the special case in which some sophisticated investors (or "speculators") can use a costly technique to learn the lender's private information independently of the cash flow retention. Turning to the second type of information frictions, Section 4.4 presents empirical evidence of moral hazard related to hidden action occurring either before or after ABS issuance. Section 4.5 gives an overview about theoretical models on moral-hazard problems in securitization markets or similar settings. It is also discussed how cash flow retention can be used to align the incentives of originators and investors. Afterwards, Section 4.6 analyzes how the mitigation of moral-hazard problems in the secondary loan market affects lending behavior in the primary market.

Next, Section 4.7 presents theoretical models that combine the two types of informational frictions, by considering hidden action at a time before ABS issuance followed by hidden information at the time of issuance. Section 4.8 summarizes the empirical evidence on determinants of retention design and whether cash flow retention indeed mitigates the negative effects of informational frictions in securitization markets. Afterwards, Section 4.9 compares the conditions in real securitization markets with the existing theoretical literature and derives open research questions. Section 4.10 concludes the chapter.

Consequently, Chapter 5 develops a theoretical model of retention design that reflects important properties of securitization markets derived in Chapter 4. Section 5.1 elaborates on the starting point and aims of the chapter. Section 5.2 defines the theoretical model, which reflects the usual forms of cash flow retention introduced in Section 3.4. Thereafter, Section 5.3 uses the concept of Perfect Bayesian Equilibrium to characterize the model's equilibria. Subsequently, an equilibrium selection procedure is applied to characterize the unique equilibrium. Section 5.4 discusses the application of the model's results to securitization markets. Besides, the section provides guidance to regulators who pursue different goals like ensuring high levels of unobservable effort. Section 5.5 contains concluding remarks about the chapter. As an appendix, Section 5.6 contains proofs of mathematical results stated before in the chapter. Besides, empirical results of a former study are used to motivate the chapter's approach of cash flow modeling. Furthermore, it is discussed what design of retention would be optimal in the chapter's model if the cash flow retention was not limited to the usual forms of horizontal and vertical retention.

Finally, Chapter 6 concludes the thesis.

2 Brand-reputation risk in auto loan portfolios[2]

2.1 Starting point and aims of the analysis

When a family of durable consumer goods, such as cars of a certain brand, is implicated in a corporate scandal, the credit risk of loans taken to finance such goods may be affected in two ways. First, regarding new loans, consumers whose buying decisions suggest a casual attitude towards norm-violating behavior might reveal a lack of moral standards (Gross & Souleles, 2002; Guiso et al., 2013) or other characteristics negatively related to creditworthiness. We call it the "demand-during-scandal" effect if loans granted for the purchase of scandal-implicated goods have heightened credit risk. Second, regarding existing loans, borrowers who encounter norm-violating behavior (Gupta, 2019) or a loss in collateral market value (Che et al., 2022) might exhibit an increased propensity to default. We call this phenomenon "scandal-induced" defaulting, which in part is a variety of the well-known "strategic" defaulting. From a social perspective, defaulting is undesirable due to liquidation costs and lost interest earnings, for example. Besides, it can limit the borrowers' and co-borrowers' future access to credit (Brown et al., 2024).

The main contribution of this chapter is to demonstrate that both the demand-during-scandal effect and scandal-induced defaulting occurred in the context of the diesel emissions scandal, which rocked the automobile industry in late 2015. The results confirm that the act of borrowing on scandal-implicated collateral predicts an increased probability of default, even when controlling for a variety of common risk factors. Besides, we show that the credit risk of existing loans increases when borrowers witness norm-violating behavior related to the collateral. Such scandal-induced defaulting partially relates to decreased collateral value, but the main channel appears to be deteriorated repayment moral.

For our empirical analysis, we use granular regulatory reporting data on securitized U.S. auto loans, including monthly information about loan performance and modifications. The regulations under which the data was collected came into effect in late 2016, allowing

[2]This chapter is mainly based on the working paper "The role of ESG in consumer lending: Evidence from the Diesel Emissions Scandal," which is joint work with Marc Gürtler (Gürtler & Koch, 2024).

us to observe a large number of loans originated between 2015 and 2017. In addition, we use information on the diesel emissions scandal, which is hand-collected from *Notices of Violation* issued by the U.S. Environmental Protection Agency (EPA), to exclude from our sample all loans of borrowers who might have been eligible to participate in class action settlements programs. Furthermore, we use data from *Google Trends* to identify influential scandal-related events and data from Kelley Blue Book (2023) to identify high price discounts of "ordinary" origin, unrelated to norm-violating behavior.

We analyze loan performance from November 2017 to December 2019. Similar to Agarwal et al. (2008), we conduct logistic regressions and use the criterion of 60 days past due to create a default indicator as main dependent variable. For robustness checks, we resort to other repayment delinquency thresholds and vehicle repossession. Our key dependent variable is a dummy that flags loans on vehicles of VW brand. Similar to Che et al. (2022), we focus on Volkswagen's core brand and exclude other involved brands such as Audi from the sample. We also control for a variety of characteristics concerning the borrower, lending process, vehicle, and loan terms.

To test for the demand-during-scandal effect, we separate our loan sample into monthly cohorts, based on the origination date. The results suggest that lending on cars of a scandal-embroiled brand entails significant abnormal credit risk. VW loans granted shortly after the scandal erupted show a substantial (absolute) increase of 5.9 % in the annual 60+ days default rate, compared to otherwise equal loans on uninvolved brands. Besides, we are able to show that ordinary price discounts unrelated to norm-violating behavior (but of similar height) also relate to increased default frequencies, but the increase is about five times weaker than with the demand-during-scandal effect.

To prove scandal-induced defaulting, we analyze loan repayment in different calendar months. After the most influential scandal-related event in the analyzed repayment period, VW loan repayment worsens in different delinquency buckets. Over a single month, we measure an additional probability of 0.38 % to firstly miss a payment and 0.33 % to enter 60+ days delinquency, respectively. Moreover, we detect decreased liquidation