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MASTER THESIS

MITIGATING BASEL IV IMPACT WITH NEW SECURITISATION METHODOLOGIES SUPPORTED BY A BLOCKCHAIN ENVIRONMENT

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Abstract

Upcoming revisions to Basel III (colloquially known as Basel IV) are set to have a large impact on the amount of capital Dutch banks have to hold and will therefore also impact their profits. This large impact is due to the relatively large mortgage portfolios of Dutch banks with atypically high Loan to Value ratios. Securitisation is a possible technique for the mitigation of these higher capital requirements. In the past year (2018) Deloitte Netherlands has done research on the topic of Blockchain and securitisation. In light of the regulatory developments and the interest of Deloitte Netherlands in this topic we examined the possibilities of new securitisation methodologies made possible by a digital Blockchain environment. Those examined are the splitting of mortgages into multiple parts (as made interesting by Basel IV's Loan-Splitting Approach) as well as the active swapping of mortgages between a security and a bank. In this thesis, the possible effects of these methodologies on the theoretical Return on Equity (ROE) of a bank are described as well as the degree to which they influence the Risk Weight of an imaginary mortgage portfolio. Further qualitative analysis as to the possible workings of these methodologies was also performed. The possible impact of both are seen to be substantial, showing vast benefits over "traditional" securitisation. In terms of ROE, mortgage splitting was shown to increase the absolute ROE by 2,3% as compared to standard securitisation. Mortgage swapping was shown to increase the absolute ROE by 15,2%. However, certain factors were omitted in this thesis such as the possible risk premium required on these novel securities by investors as well as various other financial considerations. For mortgage swapping especially there is the very important caveat that re-financing might eliminate ROE benefits or even reduce them. While further research has to be done on the technical, legal, operational and further financial feasibility on these methods the results are promising and warrant further analysis by the Dutch banking industry.

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List of Abbreviations

A-IRB	Advanced Internal Ratings Based
API	Application Programming Interface
CLTCMV	Current Loan To Current Market Value
DLT	Distributed Ledger Technology
IAA	Internal Assessment Approach
LGD	Loss Given Default
LS	Loan-Splitting
LSA	Loan-Splitting Approach
LTV	Loan To Value
MFP	Matched Funding Principle
NMa	Nederlandse Mededingingsautoriteit
RCA	Regulatory Capital Arbitrage
ROE	Return On Equity
RW	Risk Weight
RWA	Risk Weighted Asset
SA	Standard Approach
SEC-ERBA	Securitisation-External Ratings Based Approach
SEC-IRBA	Securitisation-Internal Ratings Based Approach
SEC-SA	Securitisation-Standardised Approach
SPV	Special Purpose Vehicle

1 Introduction

The banking sector is often seen as a static environment, but it is in fact constantly evolving and at a pace that requires constant adaption. This thesis sits at the intersection of three topics within banking that have seen or caused great upheaval and development: Blockchain, securitisation, and the regulatory environment. The introduction of the new framework Basel IV[1] has Dutch banks worried given the large effects it might have on the capital that they are required to hold and subsequently on their profits as banks will be able to invest less. The effects for Dutch banks are larger compared to those in other countries given the large mortgage portfolios of Dutch banks.

The severity of these effects has sparked a need for the reduction of the capital requirements. Different possibilities exist, but the possible mitigation of these effects might be found in securitisation.

In recent years, multiple parties have performed research on securitisation in a Blockchain environment. One of these is Deloitte Netherlands, whose exploratory research into this topic sparked our interest given the current regulatory developments. While securitisation in a Blockchain environment was primarily investigated by Deloitte Netherlands for various benefits native to the Blockchain, it might also open up new as of yet unexplored securitisation methodologies. These methodologies are presented and explored in this thesis.

Provided in the first section of this chapter is a introduction to the topic of Basel IV in which we showcase the large impact it will have. This will be followed by a brief introduction to Securitisation on the Blockchain. These will give the reader a context in which to place the sections that follow, amongst which are the research relevance, the research questions, and the outline of this thesis.

[1]Substantial upcoming changes to the current Basel framework are colloquially known as Basel IV, though technically still referred to by the Basel committee as revisions to Basel III. We will adhere to the use of Basel IV in this thesis.

1.1. Background

In this section we will provide the reader an introduction to the topic of Basel IV and the effect it will have on Dutch banks. Briefly introduced thereafter is the concept of Securitisation and Blockchain, though this will mainly be explored in Chapter 2.

A more extensive literature research has been performed on the topics of Basel I-III, Securitisation, and the Blockchain. For this, we kindly refer the reader to Appendix A (Basel), Appendix B (Securitisation) and Appendix C (Blockchain). It is a recommended read for anyone completely unfamiliar with any of these topics. However, a basic understanding should be sufficient.

1.1.1. Basel IV

It is in the interest of the economy for all banks to be stable entities. Banks sit in the middle of a financial web and their downfall could be of harm to other financial institutions and the financial system as a whole, possibly triggering a systemic crisis that negatively affects the monetary system as well as the rest of the economy (Moch, 2013). A bank going bankrupt is thus costly and should be avoided. For this, laws and requirements from governments and regulators are in place. The most important framework is that developed by the Basel committee, which is often adopted in to law by institutions and countries around the world.

The framework of Basel is in constant development, the latest iteration of which is Basel IV. One of the important changes that it introduces are those relating to the risk weights of residential mortgages. Risk weights are percentages by which the value of an asset is multiplied in order to determine the capital that a bank is required to hold for that asset. Changing risk weights are especially relevant for Dutch banks as they have atypically large mortgage portfolios with high Loan to Value (LTV) ratios. A total of 60% of Dutch mortgages are currently interest only meaning that these high LTV ratios are often maintained as loans aren't paid off (Mastrogiacomo & van der Molen, 2015).

The mortgage sector has been steadily growing since the 1990s, both in volume and as a percentage of a typical bank's assets. At the end of the 1990s total mortgage portfolios stood at around 70% of GDP. Now, they stand at 120% (De Nederlandsche Bank, 2015). We calculated from their 2017 annual reports that for ING, ABN AMRO and Rabobank consumer mortgages form on average 37% of total assets (ABN AMRO, 2018; Rabobank, 2018; ING, 2018).

In Basel IV, risk weights will depend on various factors. This as opposed to the previously universally applied 35% risk weight for a residential mortgage. Different splits will be made depending both on whether the mortgages are residential or commercial, whether the general requirements are met, whether the repayment is dependent on cash flows generated by the property, and what the Loan to Value ratios are. Most mortgages in the Netherlands are residential mortgages where repayment is not materially dependent on cash flows generated by the property and where general requirements are met. Table 1.1 shows the new risk weights for various LTV ratios for this category.

Table 1.1.: Risk Weights for different Loan to Values

Loan to Value	Risk Weight
LTV $\leq 50\%$	20%
$50\% <$ LTV $\leq 60\%$	25%
$60\% <$ LTV $\leq 80\%$	30%
$80\% <$ LTV $\leq 90\%$	40%
$90\% <$ LTV $\leq 100\%$	50%
LTV $> 100\%$	70%

(Committee on Banking Supervision, 2017)

1.1.2. Advanced Internal Ratings-Based Approach

Table 1.1 of the previous subsection would be used if a bank were to apply the Standardised Approach (SA). It is Basel's pre-described method used to determine the Risk Weights of assets on a banking book.

However, it is also possible for a bank to make use of the Advanced Internal Ratings-Based Approach (A-IRB). This is a different approach to determine the Risk Weights of assets and makes use of a bank's internal models for its expected loss on the asset.

All major Dutch banks make use of the A-IRB which gives them an average RW of 13% compared to a RW of 35% if they were to apply the SA (Koppen et al., 2018). If it was only the Risk Weights that changed in Basel IV the banks would be unaffected as they all make use of the A-IRB.

However, different Risk Weights for the SA is not the only change introduced by Basel IV. Another change which is vital for Dutch banks is the new treatment of the A-IRB approach. In order to prevent any systemic model risks as well as to enhance the comparability between banks, an output floor is now introduced which sets a minimum for the A-IRB capital requirements as compared to the SA. This floor is set as a percentage of the SA, and will be implemented over the span of five years, finally setting the Output Floor at 72,5% in 2027.

1.1.3. Basel IV impact

The impact of Basel IV on the level of capital a Dutch bank is required to hold will be significant. For this reason it has been widely discussed in various Dutch newspapers. The 'Nieuw Rotterdamsche Courant' reports that according to the European Banking Authority the largest European banks will have to hold an additional 39,7 billion euros of capital (NRC, 2017). The 'Financieel Dagblad' reports that Dutch banks specifically might have to expect a 14 billion euro increase (Keuning & de Horde, 2017). The 'Volkskrant' comments on the possible effects of this increase, such as increased costs for consumers, loans with lower LTVs, or new players on the mortgage market such as insurances and pension funds replacing traditional banks (Haegens, 2017). A bank that has to hold more equity might see a drop in their Return on Equity (ROE), an important measure of financial performance.

Deloitte Netherlands has done preliminary calculations on the effect of Basel IV on a typical Dutch bank with 100 billion in assets and 33.62 billion in Residential Real Estate assets specifically. The Risk Weighted Assets (RWA) is the value of a banks assets multiplied by their respective RWs. This was done for both a SA bank and an A-IRB approach bank. The results are briefly summarised in Table 1.2.

Table 1.2.: Effect of Basel IV on mortgage portfolio capital requirements

	Basel III		Basel IV		
	Risk weight	RWAs	Risk weight	RWAs	Effect
SA	35%	11.77	45%	15.29	+30%
	Risk weight	RWAs	Floor	Output Floor	Effect
A-IRB	13%	4.28	72,5%	11.10	+159%

(Koppen et al., 2018)

The effects of Basel IV for both methods can be seen to be significant, with the increase for the A-IRB approach being in the triple digits. It is paramount for Dutch banks to mitigate these costly capital requirements if they wish to remain competitive in the mortgage market as they might otherwise see their market shares drop even further given the competition of parties not bound to such regulations.

1.1.4. Securitisation and the Blockchain

A common method for reducing the portfolio size of a bank (and thus reducing the total capital requirements) is through securitisation. In securitisation financial products called securities are created from the cash flows of assets, which can amongst others include mortgages. These securities are then sold to a third party which removes the underlying assets from the banking book and thereby reduces the amount of capital that the bank has to hold.

In recent years research preliminary albeit limited research has been done on moving securitisation to a Blockchain environment. Amongst these are an article on the possibility of securitisation in a Blockchain environment as published by members of law firm Hogan Lovells (Cohen, Samuelson, & Katz, 2017) and more elaborate conceptual research by Deloitte USA (Deloitte & Touche, 2017). Deloitte Netherlands has also done similar research on the matter though this is confidential.

Benefits quoted are often increased reliability, data transparency, security, automation and decreased costs. However, the digitisation and tokenisation of the securitisation environment might also introduce new possibilities for securitisation. Instead of permanently and fully removing a mortgage from the banking book it might be an option to only temporarily remove it from the banking or to only remove part of it.

Combined with new regulations introduced in Basel IV new methodologies for securitisation could be developed. As of yet these possible methodologies are completely unexplored. It is this that sparked the goal and research questions of this thesis.

1.2. Research Objective and Questions

The goal of this thesis is to investigate the mitigation of Basel IV's effects on the mortgage portfolios of Dutch banks through the use of innovative securitisation methodologies as supported by a Blockchain environment.

The main research question to guide this thesis is the following:

To what degree do innovative securitisation methodologies as supported by a Blockchain environment allow for the mitigation of Basel IV's effects on the mortgage portfolios of Dutch banks?

To properly answer this question in a structured manner the following subquestions were developed:

1. *What are the benefits and possibilities of securitisation in a Blockchain environment?*
2. *What effect do different new securitisation methodologies have on the return on equity of a bank looking to fund additional mortgages?*
3. *What effect do different new securitisation methodologies have on the risk weighted assets of a bank's mortgage portfolio?*

1.3. Research Methodology

We will seek to answer our main research question by first answering our three subquestions. Together, they should give an encompassing answer that reflects all the facets of the main research question.

The first subquestion will be answered through a literature research. At first we will look at the current securitisation environment and any recent regulatory development. This is done based on various reports published by the European Central Bank, the European Commission, and Basel. By doing so, we seek to make clear the need for a new securitisation environment.

We will then outline the benefits of a Blockchain environment and its possible functioning using reports on securitisation in a Blockchain environment (such as that of Deloitte USA) but also general literature on Blockchain and Blockchain in financial systems. These reports will be supplemented by our own ideas on the matter, especially as it pertains to the new securitisation methodologies.

To answer the second subquestion we will first develop a model which we can use to determine the ROE of a bank applying securitisation. This model will in part based on a method previously used by the Nederlandse Mededingingsautoriteit which in turn is based on the Matched Funding Principle. It is a method in which we determine the interest rates of the various elements of a balance sheet by breaking them down into smaller components, such as interest swap rates and Euribor. Using these interest rates we can build an income statement that reflects reality. Using this, "micro-scenarios" are created in which we use only a limited number of mortgages to in a clear manner determine the ROE of a bank in different securitisation scenarios.

With this model we will first analyse standard securitisation. Following this, we will also analyse the mortgage splitting methodology and finally also the mortgage swapping methodology. The ROEs of these methodologies in different scenarios will be determined but we will also explain how these methodologies might function and any risks that they might introduce. We deem the qualitative assessment of these methodologies necessary as to justify whether or not they're attainable and thus whether or not the ROEs might be realistic.

To answer the third subquestion we make use of an existing security of ABN AMRO which reports monthly on the various features of the many mortgages it contains. Using this description, we will model the effects that Basel IV will have on the RWA of a bank owning such a mortgage portfolio. In part, this is done using data from the EU-wide transparency exercises.

After having modelled these effects we will turn to their mitigation through securitisation. We model all the different securitisation methodologies and determine the degree to which they reduce the impact of Basel IV.

1.4. Research Relevance

It is within this context of a changing regulatory landscape and ever-increasing capital requirements that this thesis is set, as banks are looking for different options for the mitigation of these requirements. Holding capital is very costly for banks and will put pressure on their profit margins or force them to transfer the costs to consumers. This is not something which banks can always afford to do given the emergence of other players in the mortgage market which are not bound by the same regulatory requirements. Solutions are therefore required.

While securitisation is already employed by Dutch banks, a new securitisation environment might open up new possibilities as current methods have a number of flaws (as was made evident in the 2008 credit crisis). With the continued development in the Blockchain technology new methodologies might be explored as well as the benefits that the Blockchain offers. These three different factors -Basel IV, securitisation, and the maturation of Blockchain- provide an important and relevant contemporary setting for the focus of this thesis. This is re-affirmed by the interest of Deloitte Netherlands in this thesis topic as it looks to expand its knowledge on the topic of securitisation as a tool for the mitigation of regulatory pressure as well as its knowledge of the effects of Basel IV. Along with my personal interest it is a primary driver in my choice for this topic. As of yet, coverage of the specific combination of these topics in academic literature is to my knowledge limited or non-existent.

1.5. Thesis Outline

In Chapter 2 we will answer the first subquestion. We give an overview of the necessity of a new securitisation environment, describe the benefits that Blockchain could provide, and finally introduce the new securitisation methodologies that this technology could introduce.

In Chapters 3 - 5 we will answer the second subquestion. For clarity and ease of reading this subquestion is answered in three different chapters.

In Chapter 3 we look at the ROE benefits of standard securitisation. In this chapter the concepts and methods are introduced that we will also be used in Chapters 4 and 5 to determine the financial attractiveness of the new securitisation methodologies.

In Chapter 4 the concept of mortgage splitting is analysed.

In Chapter 5 the concept of mortgage swapping is analysed.

In Chapter 6 we will answer the third subquestion. We will do so by determining the effect of the different securitisation methodologies on the risk weight of a realistic mortgage portfolio.

In Chapter 7 we provide a conclusion to this thesis by answering our main research question and provide our recommendations for further research as well as to the possible future of Blockchain and these novel securitisation methodologies.

In Chapter 8 we reflect on the work done in this thesis and ponder upon new research possibilities and opportunities.

The chapters that follow are Appendices which shed further light or go more into depth on the topics covered in this thesis.

2 Securitisation in the Blockchain

Blockchain technology could aid in creating a new and better securitisation environment. This concept will be explored in this chapter in an effort to answer research subquestion 1:

What are the benefits and possibilities of securitisation in a Blockchain environment?

In the first section we will introduce the current status of securitisation in Europe and the developing regulatory environment in which the criteria for "Simple, Transparent and Standardised" securitisation are introduced. This will point out the evolving need for a new securitisation environment.

In the second section we will in short translate the current securitisation environment to that supported by Blockchain technology.

In the third section we will further expand upon some of the main topics touched upon in the second section. These are data transparency, tokenisation, and smart contracts.

In the fourth section we will give some descriptions as to how these topics will aid in meeting some of the "Simple, Transparent and Standardised" criteria for securitisation.

In the fifth and final section we will touch upon some of the new securitisation methodologies that these specific topics might introduce to the securitisation environment. It is these methodologies that will be further explained and quantified in the rest of this thesis.

2.1. The Securitisation Environment and Developments

Before the 2008 credit crisis securtisations were becoming increasingly popular. Growth occurred until the start of the financial crisis with total values of securitisation outstanding in Europe and the USA at €2 trillion and US$11 trillion respectively (ECB & BoE, 2014). Often, banks were no longer the holders of loans as in the "old" banking model, but were the originators and distributors. This led to a model dubbed the "originate-to-distribute" (O&D) model.

Unfortunately, the fact that bankers were no longer the primary holders of these assets meant that there was a bigger incentive to take larger risks on loans and less of an incentive to monitor borrowers. This was an important instigator of the financial crisis (Affinito & Tagliaferri, 2010). Since then, issuance rates of securitisations decreased greatly in both regions following the crisis, but have largely recovered in the USA in later years. For Europe this has not been the case for various reasons, amongst which are a "post-crisis stigma", regulatory capital charges, risk aversion, limited infrastructure and historically low trading volumes (ECB & BoE, 2014). This despite the fact that securitisations in Europe weathered the Credit crisis far better with far lower default rates and negligible losses.

Widely recognised however amongst various European institutions is the value that securitisation might provide for the economy. The ECB names various motivations such as its value as an investment instrument for non-banks and banks, as a funding tool to support real economy lending and reduce funding costs, and as a means of risk transferal by originating banks (ECB & BoE, 2014).

For these reasons European institutions have performed research as to what changes could be made to promote securitisation and make it a more attractive option for both banks and investors. In 2014 the Bank of England and the European Central Bank together published a paper examining the benefits of securitisation as well as the possible impediments to the growth of a securitisation market (ECB & BoE, 2014). In the same year the European Banking Authority analysed various factors but also introduced the concept of a 'Simple, Standard, and Transparent' securitisation market (EBA, 2014). This was followed by a task force of the BCBS and the International Organization of Securities Commission who developed criteria for identifying 'simple, transparent, and comparable securitisations'. They identified 14 criteria relating to either asset risk, structural risk, or fiduciary and servicer risk (Board of the International Organization of Securities Commissions, 2015).

Finally, these different papers and publications were combined by the European Commission in two legislative proposals, of which the first one focused on "laying down common rules on securitisation and creating a European framework for simple, transparent and standardised securitisation..." which we will expand upon later (European Commission, 2015b). The other focused on the amendment of the Capital Requirements Regulation for proper capital requirements as relating to securitisation (European Commission, 2015a).

2.2. The New Environment

As shown by the European institutions the current securitisation is lackluster. Amongst others low trading volume, high costs, high operational costs and high risk perception hinder the growth of the securitisation market.

Placing the securitisation environment into a Blockchain system would perhaps alleviate these problems. Similar financial infrastructure solutions in the Blockchain are currently being worked on, such as commodity trading, international remittance, share trading, securities settlement, etc.

In a report on "distributed ledger technology in payments, clearing and settlement" by the USA Federal Reserve Board and in a report on "Distributed Ledger Technology (DLT) and Blockchain" by the World Bank Group lists are given of the possible advantages of the Blockchain. Drawing from these lists the following list of benefits was created as pertaining to securitisation and which we believe would be applicable:

1. Decentralisation and disintermediation leading to reduced complexity and lower costs
2. Greater transparency and easier auditability
3. Automation and programmability
4. Reduced operational and financial risks and costs
5. Lower end-to-end processing speed and higher liquidity
6. Enhanced cybersecurity and improved network resilience

We will further expand on some of these benefits and how exactly they pertain to securitisation in the rest of this chapter. The purpose of securitisation on the Blockchain revolves around three core concepts. One is that the securitisation ecosystem is now one database to which all parties are connected and on which the information is shared.

The second is that assets (in this case mortgages) are represented in the form of asset-backed tokens. The third is that the securitisation ecosystem in now in a programmable environment.

Shown in Figure 2.1 are the broad steps currently undertaken in a Securitisation process. As stated before in Section 1.1.4, this is loosely based on research by Deloitte and Hogan Lovells as well as my own input (Cohen et al., 2017; Deloitte & Touche, 2017)).

Figure 2.1.: The securitisation process and the relevant parties

Where B = Banks, R = Regulators, S = SVP, C = Credit Agency, I = Investor, I2 = Other investors

We assume these steps are known to the reader. We will now re-assess these steps as if they were placed in a Blockchain environment:

1. **Loan origination**
   Upon the creation of a new mortgage the bank information about this mortgage is matched to a token on the Blockchain. Alternatively, different parts of a mortgage are matched to different tokens. Information such as the size of the mortgage, the value of the asset, the interest rate, the owner's salary and the tenor are all registered on the token. As (pre)payments are made or the house is re-appraised these values on the token are automatically updated through the use of smart contracts.

2. **Transferal to SPV**
   If the bank wishes to securitise it pools a large amount of tokens. These can be picked for their characteristics such as their high LTV. Double-pledging (the use of a mortgage twice for two different security products) is made impossible. This collection of tokens are then transferred to the SPV who is also a participant on the Blockchain. The transferal is seen as a legal sale and with the proper SPV structure in place it is seen as placing the tokens at arm's length.

3. **Structuring the security**
   The SPV structures the security as it sees fit, such as setting interest rates and determining tranche sizes. This can include the use of Smart Contracts to provide a clear structure as well to automatise any payments involved. This is further commented upon in Section 2.3.2.

4. **Rating**
   The tokens and the security structure could be rated by a credit agency, just as securities are currently rated. This process is made simple by all data being available on the tokens themselves, thus providing the third party full insight. Smart contracts can be put in place to notify the ratings agency of any substantial changes.

5. **Investment**
   Thanks to the Blockchain system possible investors have complete access to all data involved in the Securitisation. Past default and current default rates can be clearly seen. The structure -as described by smart contracts- adds to the comprehensibility of the product for the investor.

6. **Secondary market**
   The Blockchain allows for easier, faster, and cheaper trading of the securities on a secondary market. Any possible investors will again have full access to all required data and the entire process can be overseen by the regulator.

7. **Loan Servicing**
   During this entire process the loan is serviced by the Bank, though steps might have to be taken that the bank while servicing does not know which mortgage is in a security and which is not to prevent bias. Any changes for mortgages are adjusted in their specific tokens. At all time, the current situation is known to all parties on the Blockchain.

An important caveat of the use of Blockchain for securitisation will be the legality of trades. As of yet the legal rights and ownership pertaining to and of digital assets or tokens may not yet be clearly defined. Any shortcomings would either require regulatory changes or would have to be supplemented somehow through contracts between the participating parties.

2.3. Topics

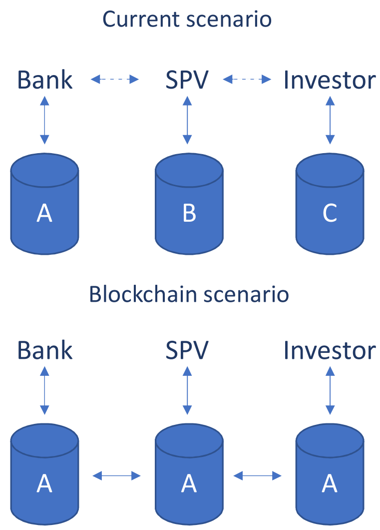
We find three different topics as relating to securitisation most important. These are examined in this section.

2.3.1. Data Sharing, Transparency and Reliability

As stated in the introduction to Blockchain in the previous chapter, Blockchain is a form of distributed ledger technology: a decentralised database (Lai & LEE Kuo Chuen, 2018). In a classical securitisation scenario each entity has its own data. The originator, the servicer, the SVP, the investor: all have their own database or are reliant on the partial and potentially outdated or unreliable data provided to them by other parties.

This would be altered drastically in a Blockchain scenario. There would be one database containing all non-sensitive information to which the different parties would send updates or make alterations. As a consequence of an alteration, the data that each party has is updated and data is current at all times. This idea is illustrated in Figure 2.2.

Figure 2.2.: Data sharing in the current scenario and in the Blockchain scenario



The Blockchain would keep an immutable ledger of ownership and also provide a transaction history which would be available to all participants in real time.

The benefits would be that a party such as a regulator would have access to a complete and reliable audit trail. From token origination to changes in ownership: it would all be recorded and complete. In investment banking, Accenture expects Blockchain to reduce compliance costs by 30-50% (Accenture, 2017). Similar results could be expected here as well.

Its use would lift a veil so to speak: what product you are buying would be clear and precisely defined. This might lead to a higher valuation of securities as there is less uncertainty. The uncertainty associated with and the opaqueness of securities have diminished the popularity of securities in the past and especially now in the wakes of the Credit crisis.

Cryptography is employed for several purposes in the Blockchain, both as a private key to verify the authenticity of a token owner and their intention of making a transaction as well as when encrypting the information on tokens when privacy is required.

2.3.2. Smart Contracts

The use of smart contracts within a Blockchain are a mechanism by which automatic actions can run depending pre-set parameters. Smart contracts created by the bank or SPV are self-executing and would thus not necessarily need human intervention. The securitisation environment could now be deemed "programmable" and act upon information either from the ledger or from other sources. This opens up entirely new possibilities, but will also allow for easier fulfilment of regulatory requirements as well as any other required actions.

Whilst in the past the different actors were reliant on (already outdated) reports, data is now instantaneous and current. The use of this current data can be used to build in triggers to various responses. A delinquency rate above a certain pre-determined rate could set off an alarm for a regulator or an investor.

The use of smart contracts might be of great value in the structure of a security as it relates to tranches and payment fulfillment. The order in which various investors are paid could be made complete automatic depending on pre-defined rules. Not only is the automatisation important, but also the fact that there is once central clearly defined model. It would make impossible any variations between the model of a rating agency, an investor or the SPV.

2.3.3. Tokenisation

In the Blockchain ecosystem the bank registers all mortgages as tokens on the Blockchain. The existence of an individual token with up to date data for each mortgage allows for data analysis on the granular level.

The clarity that a tokenised securitisation environment would provide would be a stark difference compared to the previously available data. Currently, an investor would be reliant on summaries or reports as provided by a SVP or bank. In the Blockchain system, every mortgage is accounted for. This too will prevent an issue previously seen in the USA where a single mortgage was included in multiple securities (double pledging). Given that a mortgage is now a traceable digital asset, this will no longer be possible thus improving the quality as well as the reliability of securitisations.

Similarly, the use of tokens will remove a layer from the securitisation ecosystem through which information must flow. The mortgages become actual digital assets that are uniquely examinable and are no longer represented as summaries on reports.

The existence of mortgages as tokens makes them more easily and readily trade-able. It will increase liquidity in what is normally a slow market in which trading is expensive. By increasing the liquidity of this market the balance sheet of a bank is also made more liquid. Tokens are also easily divisible, which will allow for wholly different possibilities which will be commented on upon later.

2.4. Criteria

In this section a selection of the criteria from the European Commission's Proposal for a European framework for Simple, Transparent and Standardised securitisations are listed and the benefits that Blockchain might provide in the easier or clearer attainment of these criteria are discussed. These benefits are the result of the three topics we have discussed in the previous section.

<u>Criterium 7 of Article 8</u>: *"The underlying exposures, at the time of transfer to the SSPE, shall not include exposures in default".*

<u>Criterium 8 of Article 8</u>: *"The debtors or the guarantors shall have, at the time of transfer of the exposures, made at least one payment".*

The use of a token system where information for each individual mortgage is maintained and current will allow for easy checks as to the current status of the exposure. This will allow for easy verification of these criteria. Built in security checks through the use of smart contracts can automatically prevent the selection of the wrong tokens (or mortgages) for use in a securitisation.

<u>Criterium 5 of Article 9</u>: *"The transaction documentation shall include appropriate early amortisation events or triggers [..] including at least the following: [..] the value of the underlying exposures held by the SSPE falls below a pre-determined threshold".*

The determination of the total value of all underlying exposures and the comparison to a pre-determined threshold could (very simply put) boil down to a simple SUM and IF statement given the openness of data within the Blockchain and the Smart Contract capabilities.

The use of smart contracts can also be applied to other criteria as was touched upon briefly in the previous section. Any requirements such as loans not being in default upon securitisation can be automatically checked by smart contracts. This will reduce the need for reporting and ensure real-time compliance.

Criterium 3 of Article 10: *"The originator or sponsor shall provide a liability cash flow model to investors, both before the pricing of the securitisation and on an ongoing basis".*

This cash flow model can be programmed completely through the use of smart contracts, providing clarity to all parties as well as possibly automating the payment system. The existing code could even be used for investors or regulators as a ready-made simulation for different situations.

Criterium 4 of Article 8: *"The securitisation shall be backed by a pool of underlying exposures that are homogeneous in terms of asset type".*

Criterium 1 of Article 9: *"The originator, sponsor, or the original lender shall satisfy the risk retention requirement".*

Given that the securitisation will consist of tokens with easy verifiable properties and clear ownership status these criteria are easily verified.

2.5. New Methodologies

The efficiencies provided by securitisation in the Blockchain are meant to greatly reduce the costs and the time needed for a securitisation. We believe that this -combined with the digital possibilities of a Blockchain environment- might open up a few new methods of securitisation. A few of these are described below and mortgage splitting and mortgage swapping will be further discussed in subsequent chapters.

2.5.1. Securitisation Dashboard and API

The digitisation of the securitisation environment and the availability of information of the tokens might allow for a much greater degree of customisation for investors. As the process of creating a security is cheaper and simpler, this would open up new options. We might envision a dashboard or Application Programming Interface (API) where certain criteria could be selected by an investor. Mortgages from certain regions, with certain LTVs and tranches of a certain size. Whilst we will not explore this concept within this thesis it is clear that this might make securitisations more attractive to a wider range of investors. This same API would allow an investor to oversee their investment and any developments, such as current delinquency information, LTV ratios, geographic distribution or any other information that might be found in a normal monthly report by a security originator.

2.5.2. Mortgage Splitting

In normal securitisation mortgages are securitised as a whole. However, if allowed by the regulators, it can be envisioned that mortgages are not securitised as a whole but in parts. For example, a mortgage represented by a token could be split right down the middle and 50% of the mortgage could be sold. Each half could then be attributed to their own individual token. Half the cash flow would remain in the possession of the bank, and half could be sold to a SPV. The proper rights and cash flows can be incorporated into the tokens through the use of smart contracts.

Whilst this is financially not very interesting, it might become interesting if splits can be made in a different fashion. What if the risky top half of a loan could be sold? As we will see in Chapter 4 this might provide large benefits to a bank.

2.5.3. Mortgage Swapping

The existence of tokens greatly improves the traceability of the individual mortgages as well as the determination of their individual properties. In the old system mortgages would in a way be “stuck” in the contracts that govern the securitisation process whilst we might envision that in a Blockchain environment the movement of individual mortgages might be much more fluid.

In this regard we expect the securitisation market to become much more dynamic in a Blockchain environment and that liquidity will greatly increase.

However, it is not just the movement of tokens through true sales that might be interesting but also their movement as to allow banks to profit from their individual properties. The extraction of a certain amount of tokens from a securitisation and their replacement by a certain amount of “new” tokens might benefit the bank due to the different properties of the mortgages. We will further analyse the benefits and possibilities of this in Chapter 5.

Standard Securitisation and its Financial Benefits 3

In chapters 3 to 5 we will answer the second research subquestion:

What effect do different new securitisation methodologies have on the return on equity of a bank looking to fund additional mortgages?

In order to properly understand and visualise different novel securitisation methodologies and their effect on the theoretical ROE of a bank we must first consider the standard securitisation method as to provide a performance baseline. This will be done in this chapter.

To allow for this we will in the first sections of this chapter will introduce the various components and considerations necessary to properly model a securitisation. These different components will be a typical Dutch bank balance sheet, securitisation retainment, the funding costs of a mortgage as well as some other considerations.

In the sections that follow we will model scenarios in which a second mortgage is funded with different types of funding. The effects of this are shown through the use of a balance sheet and an income statement from which we determine the ROE.

3.1. Balance Sheet and Income Statement

In order to provide a proper financial overview of a bank a simplified balance sheet is used. A balance sheet is a summary of the assets and liabilities of a bank: a snapshot of the various factors that will either make or cost the bank money. Assets are *owned* by the bank. This consists of for example cash, securities, loans, as well as any physical assets of the bank. Liabilities are *owed* by the bank. These include debt (money loaned from others) as well as the savings deposits made by a bank's customers.

Presented below is as an example of a simplified balance sheet for a Dutch bank roughly based on the financial position of ABN AMRO[1] (ABN AMRO, 2018). A lot of elements, including for example investments and derivatives, have been omitted so results might seem skewed.

Table 3.1.: Typical balance sheet

Assets		Liabilities & Equity	
Reserves	€10,000	Deposits	€70,000
Securities	€5,000	Debt	€25,000
Loans	€85,000	Equity	€5,000
TOTAL	**€100,000**	**TOTAL**	**€100,000**

Reserves are held by a bank for its day to day operations and to maintain liquidity in the case of deposits being withdrawn. Loans are for example mortgages, while securities are securitised loans held by the bank.

Deposits are moneys stored by customers at the bank, debt is funds borrowed by the bank from other institutions, and equity is a bank's own funds.

In the rest of this thesis we will make use of an income statement as well. An income statement is very comparable to a balance sheet, though instead of it showing the size of the various components it shows their costs or revenues.

From an income statement the return on equity can be determined:

$$\text{ROE} = \frac{\text{Net Income}}{\text{Equity}} \tag{3.1}$$

We use ROE as a measure of determining the comparative viability of securitisation or a securitisation method as it is a measure of how effective the bank's assets are being used and is often used by banks themselves. It reflects simultaneously the importance of a bank's profitability as well as the high theoretical cost of equity. Using the profitability of the bank or its equity requirements as a measure would result in misleading figures, as either efficiency could be sacrificed for higher profitability or profitability could be sacrificed for lower capital requirements. Though has been given to using the Return on Risk-Adjusted Capital (RORAC) or Risk-Adjusted Return on Capital (RAROC) but given that the risk is already properly reflected in the denominator of ROE by the regulator this was deemed unnecessary.

[1]ABN AMRO was chosen here as we will be working with an ABN AMRO security as a reference point in this thesis.

3.2. Securitisation Retainment

In order to retain an alignment of interest when a bank securitises its mortgage portfolio, a bank is required to “retain a material net economic exposure and demonstrate a financial incentive in the performance of these assets following their securitisation” as stated in Basel’s ’Revisions to the Securitisation Framework’. Otherwise said: a bank must retain a share of the securitisation. It is common to retain 5% (Committee on Banking Supervision, 2016). This will be reflected in our balance sheet in our models.

As this securitisation is an asset on a bank’s banking book, this too must adhere to the regulator’s capital requirements and this too is described in Basel’s ’Revisions to the Securitisation Framework’. As a reference securitisation the Class A securities issued by major Dutch bank ABN AMRO which have a S&P rating of AAA will be used [2] (ABN AMRO, 2017).

Different approaches exist for weighing a security which in order of hierarchy as given by Basel are the Internal Ratings Based Approach (SEC-IRBA), the External Ratings Based Approach (SEC-ERBA), the Internal Assessment Approach (IAA), and the Standardised Approach (SEC-SA) (Committee on Banking Supervision, 2016). We will make use of the SEC-ERBA as it is the method highest on the hierarchy for which we can easily determine the weights using publicly available data such as its S&P rating. Given the parameters the Risk Weight of the ABN AMRO securitisation is 20% (Committee on Banking Supervision, 2016). Given that Basel IV will set a capital floor for the use of SEC-IRBA, the SEC-ERBA will also be a good reflection of the likely effects that this will have on a bank’s balance sheet.

Normally a security is divided up into various tranches with different levels of risk as described in Section B.2. These levels of risk would be reflected in the interest rate levels of the various tranches. In our securitisation scenarios we will not take tranches into account. The securitisation will consist of one single tranche and no further distinction is made. The interest levels are thus constant for every part of the securitisation.

[2] The ABN AMRO security was chosen as ABN AMRO is in the Netherlands the bank with the most securitisations. For the sake of this thesis there is no particular reason as to why the security of a different bank could not be used.

3.3. Present Value of a Mortgage and Securitisation Costs

There are two one-off costs or profits involved with securitisation which we must give some thought.

One is the possible profit occurred from the selling of the mortgages to the SPV. Mortgages are a profitable asset and their valuation might also differ for an investor as compared to a bank. For this reason, we deem it possible that there might be a difference in the “sales value” and the balance sheet value when mortgage is sold. Unfortunately, we found no proper sources for this within literature. The difference will depend on the valuation of the mortgage, which will depend on a large number of factors of which some will be unknown to us. For this reason, we can not easily determine this with a Net Present Value formula. We must also recognise that the present value-balance sheet difference might be exaggerated by new securitisation methodologies. We will reflect upon the omission of this in Chapter 8 when we discuss the shortcomings of this thesis.

Similarly, securitisation costs are also incurred by a bank. A SPV has to be set up, accountants and notaries have to be paid, and operational costs are incurred. Literature on this matter was rather limited. The costs will also differ greatly depending on the experience of the bank in regards to securitisation and whether or not a structure already exists. A Blockchain environment will also alter these costs. Operational costs are expected to drop, leaving us guessing at eventual figures.

Importantly, both of these matters are “one-off”: they will be incurred by the bank once in the case of securitisation and will not be reflected yearly in the income statements. Also, we might imagine that -to some degree- they might cancel each other out.

For this reason, we have chosen to omit both the present value of a mortgage and the securitisation costs in our framework. We realise this is a limitation on the reliability of our models, but we deem that the comparative nature of our models will still allow us to draw proper conclusions. Overall, given the great uncertainties, the large amount of guesswork, and the lack of proper industry know-how involved, we deem that their inclusion would muddle the result more than their exclusion. We will comment on this further in Chapter 8, 'Discussion and Future Research'.

3.4. Interest Rates

Each element of a balance sheet has its own interest rate which determines either the revenue obtained from it or its cost. These must be determined if we are to analyse the profitability and thus the ROE of a mortgage. This will be done through a method similar to that used by the 'Nederlandse Mededingingsautoriteit' (NMa), the Dutch Competition Authority . In a report on Dutch mortgage margins that they published in 2010 they analysed the profit rate of a Dutch mortgage by breaking down the interest rates of each element into smaller components (NMA, 2010).

The method of the NMa is based on the Matched Funding Principle (MFP) which is commonly used in determining mortgage rates by Dutch banks. The MFP equates the costs of the mortgage to the costs of its funding. These costs are tailored to both the opportunities that banks have on the financial markets as well as to the lifetime of their mortgages (and thus the lifetime of their funding).

The interest rate of for example a mortgage or a deposit is computed based on different components. These different components will first be introduced below. After this the formulas for the rates of the balance sheet elements are given.

3.4.1. Relevant Components

The components relevant for the calculation of the various balance sheet element rates are:

- Mortgage rate, r_m
  The mortgage rate is what the customer pays for the mortgage.

- 7 year interest rate swap rate, r_s
  A swap rate is the rate paid for the fixed leg of a swap. In a swap, the buyer pays a fixed interest rate in exchange for a benchmark rate such as Euribor or LIBOR plus or minus a spread. A swap is bought in order to protect oneself from interest rate risk and is often seen as the benchmark for the risk-free rate of funding. It can thus be seen as the "base" rate of funding and we will use it as such. The 7 year swap is chosen as this is the time period which fits the payoff profile of a standard 10-year fixed interest rate mortgage. A mortgage with a fixed interest rate of 5-10 years is the most common type of mortgage (NMA, 2010).

- Credit swap spread, r_c
  In order to borrow money a bank will pay a premium which is dependent on the credit risk of a bank. This credit risk can be estimated through the rate of a credit default swap for that particular bank.

- 3 month Euribor, r_E
  Euribor is a commonly used reference rate for various financial products. It is this rate at which Eurozone banks are willing to make unsecured loans to other banks in the Eurozone.

- Deposit rate, r_d
  The rate which a bank pays to a customer for depositing money with the bank.

- Mortgage specific costs, c
  The costs that a bank incurs when creating a mortgage, which include both various risk premiums such as credit risk, pipeline risk, and the pre-payment risk of a mortgage as well as the operational costs of the bank for creating the mortgage. Unfortunately, it is rather impossible to find the objective rate for these costs as they are mostly classified by banks or hard to determine. Experts from the NMa have set these costs at 0,8%. They are deemed to be stable over time. Whilst not included in the method of the report, we add to these costs an additional 0,2% as to reflect the costs incurred by a bank when dealing with the liquidity requirements for the various components on a balance sheet. Whilst normally this would be reflected on the balance sheet in the 'Reserves' a bank must hold, we believe that the calculation procedure required for the determination of the height of these reserves is too complex and does not add value to this paper. This simpler approach has thus been chosen.

The rates of the components are shown in table 3.2. The rates (where applicable) were determined based on ABN AMRO as a reference bank. Rates were based on the values on January 10, 2019.

Table 3.2.: Interest rate components

Variable	Rate	
Mortgage rate, r_m	2,26%	(ABN AMRO, 2019a)
7 years swap rate, r_s	0,43%	(SEB, 2019)
Credit swap spread, r_c	0,45%	(DDV, 2019)
3 month Euribor, r_E	-0,31%	(GlobalRates, 2019)
Deposit rate, r_d	0,03%	(ABN AMRO, 2019b)
Mortgage specific costs, c	1,00%	(NMA, 2010)

3.4.2. Interest Rate Formulas

These components can now be used to determine the costs of the various elements of a balance sheet. This is first explained below and subsequently given in formulaic form.

- Deposits
  For depositing their money at a bank consumers are paid an interest rate. This interest rate is a premium over Euribor as to incentivise consumers to deposit their money. Consumers are thus paid Euribor plus this premium.

  The costs for this are calculated as follows. If a bank has to pay a consumer Euribor they will hedge this interest rate. This is done through buying a 7 year swap, the "base rate of funding". Added to this swap rate is the height of the deposit premium paid to depositors. This is the deposit rate minus the 3 month Euribor rate.

- Debt
  As with a deposit the base rate of funding is the 7 year swap rate. Added to this is the credit swap spread, which quantifies the risk that an institution runs by borrowing to the bank.

- Securities & Loans
  These are treated as equal as the rates obtained will be the same whether the bank holds the original mortgages or the subsequent securitisations. The rate is dependent on the height of the mortgage rate paid by customers minus the operational costs of a bank.

- Equity & Reserves
  The costs of equity are set to 0%. While a bank such as ABN AMRO has a target ROE of 10-13%, we omit this as we will be calculating the ROE ourselves (ABN AMRO, 2018). A cost of equity that is not set to 0% would not fit into this method. As explained in Section 3.5.1, we will have no reserves, though these would also have a rate of 0%.

This results in the component rates as shown in Table 3.3.[3]

[3]We acknowledge that the deposit rate seems rather high compared to the debt. This is a correct reflection of the current market situation. We would like to refer the reader to (Brown, Davies, Fabbro, & Hanrick, 2010) and (Mckinnon, 2018) for insights and further reading on developments.

Table 3.3.: Interest rates for the elements of a balance sheet

Elements	Formula	Rate
Deposits	$r_s + r_d$ - r_E	0,77%
Debt	$r_s + r_c$	0,88%
Securities	r_m - c	1,26%
Loans	r_m - c	1,26%
Equity	-	0,00%
Reserves	-	0,00%

3.5. Securitisation Scenarios

Using what we have shown in the previous sections we can model a bank in different securitisation scenarios, portraying the effects though a balance sheet as well as an income statement.

This will be done through a "micro-scenario": a bank will first be modelled with only one mortgage on its books. The bank will then seek to add a second mortgage through different funding methods. By scaling down to just one or two mortgages we seek to give the reader a clearer insight into the effects of securitisation.

In the followings sections these three scenarios will be modelled in detail using both a balance sheet and an income statement:

1. Single mortgage bank
   - Standard approach

2. Second debt-financed mortgage
   - Standard approach

3. Second full-security financed mortgage
   - Standard approach

The mortgage used is given a Loan to Value of 100%. We deem this a reasonable starting point for a Dutch mortgage and we will use this as our base LTV. The actual average initial LTV of Dutch mortgages is a bit lower, but we think any shifts in equity will be more pronounced for a 100% LTV and that a 100% LTV will most intuitively illustrate the Loan-Splitting Approach which will be discussed later on in this thesis. Other LTV ratios will also be modelled but will be summarised in a graph in Section 3.7.

Weights for the standard approach are used as given in Table 1.1. Before finally modelling these scenarios we will first discuss some restrictions on the model in the next section.

3.5.1. Scenario Restrictions

Some general restrictions apply to all scenarios:

- The asset "Reserves" is set to €0. Normally, there would be a reserve for day to day liquidity as well as expected shortfalls. For our purpose the costs of holding a reserve which provides the proper liquidity has been reflected through the increase mortgage specific costs as explained before.

- The deposits are constant and set to a starting figure of 64,3% of the total of deposits + debt in the single mortgage bank scenario namely €61,728. This figure was determined by finding the average ratio of deposits to total liabilities[4] from the annual reports of the three major Dutch banks: ABN AMRO, ING and Rabobank (ABN AMRO, 2018; ING, 2018; Rabobank, 2018). This figure of €61,728 is maintained for the other scenarios. Whilst funding new mortgages with deposits might be a possibility on the long-term, this is not a short-term option and thus left out of the scope of this paper. This leads us to:

- Any funds required for new mortgages that is not provided through securities will be provided through borrowing. Solely debt-financing will be used.

  As a result, we will see that for the micro-scenarios the ratio of deposits to debt will vary greatly. While this will look rather odd, this is intentional. One of the effects we will see is that the ROE of a bank slightly decreases if it uses relatively more debt funding. An intended consequence, as research shows that securitisation is often used if a bank faces liquidity constrains or costlier alternatives of funding (Almazan, Martín-Oliver, & Saurina Salas, 2015). Some exploratory calculations have shown that the overall effect is rather minor and won't affect the overall conclusions we will draw of the different securitisation methodologies. However, it will be noticeable and thus show the effects of a bank having limited funding options. If the rate gap between debt and deposits were much larger the effect might have been more pronounced and we would have to keep the ratio of debt to deposits the same.

[4]Instead of using the average ratio of deposits to total liabilities, consideration was made to use the Loan-to-deposit ratio instead. This is 125,50% for the Netherlands (ECB, n.d.). However, it was deemed that this would produce too high a value for deposits as the asset side of our balance sheet consists solely of Loans.

- Equity is set equal to the bare minimum required by regulations, even though normally a bank will hold more than the bare minimum. This is done in order to simplify the balance sheet and to show the changing effect on the required equity with as much sensitivity as possible.

3.5.2. Single Mortgage Bank

Shown in this section is the starting situation of the bank where the bank has just one mortgage on its books. The balance sheet and income statement are given in Tables 3.4 and 3.5.

Table 3.4.: Balance sheet - single mortgage bank - SA

Assets		Liabilities & Equity	
Reserves	€0	Deposits	€61,728
Securities	€0	Debt	€34,272
Loans	€100,000	Equity	€4,000
TOTAL	**€100,000**	**TOTAL**	**€100,000**

Table 3.5.: Income statement - single mortgage bank - SA

Assets	Rate	Income	Liabilities & Equity	Rate	Cost
Reserves	0,00%	€0	Deposits	0,77%	€475
Securities	1,26%	€0	Debt	0,88%	€302
Loans	1,26%	€1,260	Equity	0,00%	€0
TOTAL		€1,260	**TOTAL**		€777
			ROE		12,1%

3.5.3. Second Debt-financed Mortgage

The second option we will look into is where the bank finances a second €100,000 mortgage using debt financing.

This is shown in Tables 3.6 and 3.7.

Table 3.6.: Balance sheet - second debt-financed mortgage - SA

Assets		Liabilities & Equity	
Reserves	€0	Deposits	€61,728
Securities	€0	Debt	€130,272
Loans	€200,000	Equity	€8,000
TOTAL	**€200,000**	**TOTAL**	**€200,000**

Table 3.7.: Income statement - second debt-financed mortgage - SA

Assets	Rate	Income	Liabilities & Equity	Rate	Cost
Reserves	0,00%	€0	Deposits	0,77%	€475
Securities	1,26%	€0	Debt	0,88%	€1,146
Loans	1,26%	€2,520	Equity	0,00%	€0
TOTAL		€2,520	**TOTAL**		€1,622
			ROE		11,2%

3.5.4. Second Full-security Financed Mortgage

We will now look to finance the second mortgage not solely through borrowing but through standard securitisation. The first mortgage here is securitised and 5% of the security is retained on the balance sheet.

This is shown in Tables 3.8 and 3.9.

Table 3.8.: Balance sheet - second full-security financed mortgage - SA

Assets		Liabilities & Equity	
Reserves	€0	Deposits	€61,728
Securities	€5,000	Debt	€39,192
Loans	€100,000	Equity	€4,080
TOTAL	**€105,000**	**TOTAL**	**€105,000**

Table 3.9.: Income statement - second full-security financed mortgage - SA

Assets	Rate	Income	Liabilities & Equity	Rate	Cost
Reserves	0,00%	€0	Deposits	0,77%	€475
Securities	1,26%	€63	Debt	0,88%	€345
Loans	1,26%	€1,260	Equity	0,00%	€0
TOTAL		€1,323	**TOTAL**		€820
			ROE		12,3%

3.6. ROE Comparison

Summarised in Table 3.10 are the ROEs for the different scenarios.

Table 3.10.: ROE summary - SA

Scenario	ROE
Single mortgage	12,1%
Second debt-financed mortgage	11,2%
Second full-security financed mortgage	12,3%

The table shows a decrease in the ROE when adding a second debt-financed mortgage, which is due to the higher cost of funding as the bank turns to debt.

We see that financing it with a second full-security financed mortgage marginally increases the ROE as compared to a single mortgage, benefiting from the slightly lower RW of a security on the balance sheet as opposed to a mortgage.

These figures will act as a reference point for when we model new methodologies in the next chapters. As a matter of verification of our method, we see that these ROEs fit into the target ROE set by ABN AMRO, which is 10-13% (ABN AMRO, 2018). Though this is bank-wide and thus not a concrete reference point, it does point to an increased reliability of our results.

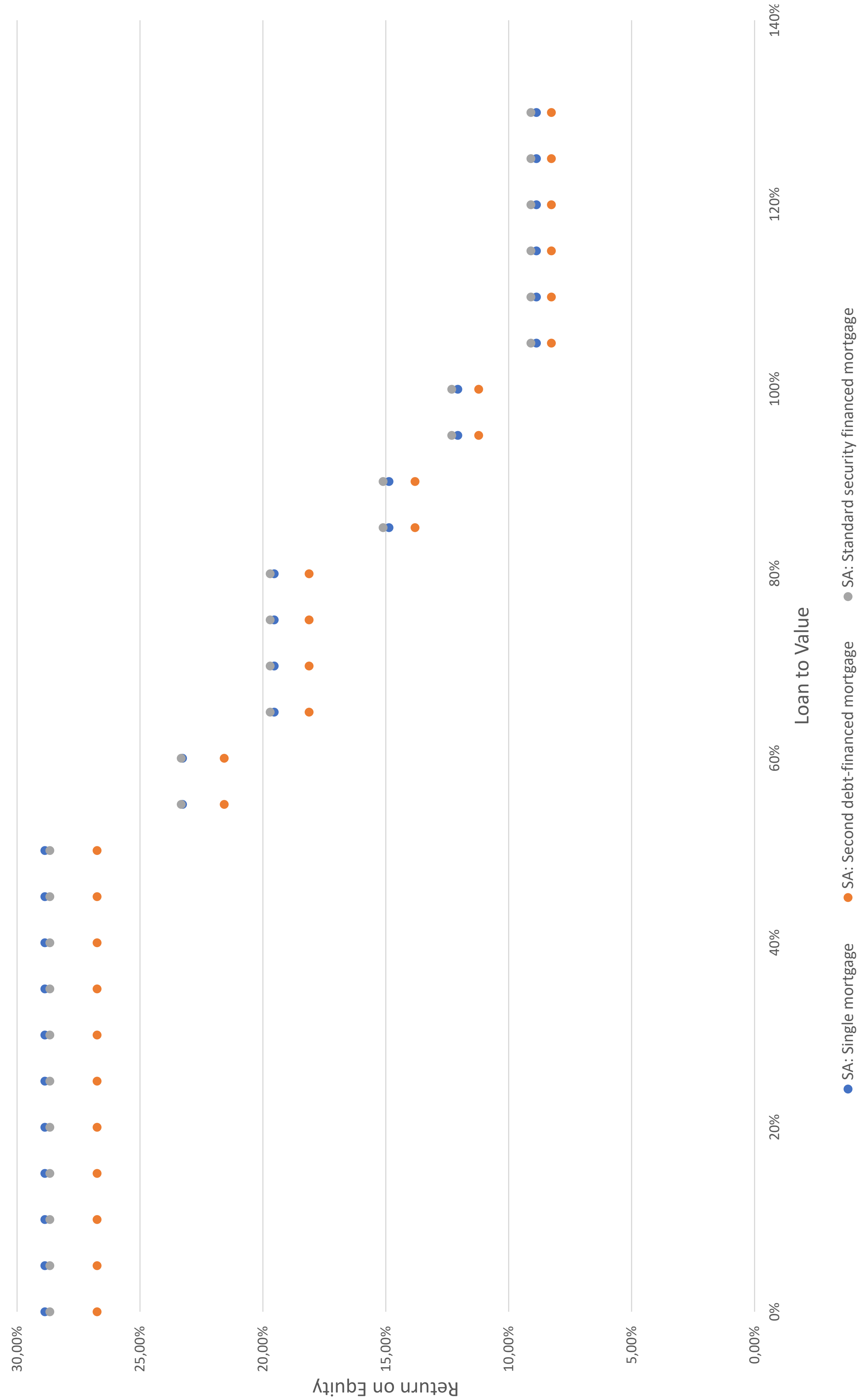
3.7. LTV Variation

A mortgage with a LTV of 100% is of course not the only mortgage that a bank has. For clarity we have used this when we looked at the three scenarios in depth, but we must also have a look at the effect of using different LTVs in these scenarios.

The ROEs of the different securitisation scenarios for different LTVs are modeled in Graph 3.1. The results for other LTVs are similar to that of a 100% LTV though there are a few noteworthy effects.

- The ROE decreases as the LTV increases. This is of course a reflection of the increased risk weight and thus the larger equity.
- The differences between a single mortgage and a second debt-funded mortgage become more pronounced at lower LTVs. This is due to the lower RW which makes any income differences more pronounced in the ROE.
- While at 100% LTV securitisation is beneficial, this reverses at a LTV of 50% and lower. This is because at this point the risk weight of the security and the mortgage becomes equal. The full-securitisation scenario has a marginally lower ROE due to the extra debt needed to finance the securitisation.

Figure 3.1.: The ROE of different standard approach securitisation scenarios for various LTV ratios



3.8. Sensitivity Analysis

In order to increase the reliability of our results we have performed a sensitivity analysis on the interest rate of the mortgage and the interest rate of the funding. Risk weights and LTV were kept constant and as used in Section 3.5. The same scenarios modelled in that section were modelled here. The graphs (D.1 and D.2) can be found in the appendix.

Mortgage rate

When we vary the mortgage rate there are no interesting changes in the ROE. The differences between the ROEs of the different scenarios becomes fractionally more pronounced as the interest rate increases. At low interest rates (below the funding rate) the ROE turns negative.

Funding rate

We changed the deposit rate and debt rate equally in 0,05% increments in order to simulate a changing funding rate. The results were unremarkable. The ROE turns negative as the mortgage interest rate is surpassed and the difference between the scenarios are a tad more pronounced at very low funding rates.

4 Mortgage Splitting and its Financial Benefits

In this chapter we will continue answering the second research subquestion:

What effect do different new securitisation methodologies have on the return on equity of a bank looking to fund additional mortgages?

In the last chapter we laid out the foundations for answering this question. We introduced the various elements of a balance sheet and their interest rates and analysed the ROE of a bank employing the standard securitisation methodology. Now, using this model and the ROEs we obtained, we will analyse the benefits of a novel securitisation methodology called 'mortgage splitting'.

We will do so by in the first section introducing the Loan-Splitting Approach, a new method for calculating risk weights as introduced by Basel IV. This is then directly followed by the introduction of the mortgage splitting methodology.

In the second section we will discuss collateral in the case of mortgage splitting, an important concept for mortgage backed securities.

In the sections that follow different mortgage scenarios relating to mortgage splitting and the LSA will be modelled.

4.1. The Loan-Splitting Approach

In the previous chapter we have made use of the "classic" Standardised Approach (SA) for the calculation of the Risk Weights of a mortgage. In Basel IV a second method of determining the risk weight of a mortgage will be made possible which is called the Loan-Splitting Approach (LSA). Technically this too falls under the SA, but since it's another method we will henceforth refer to it separately.

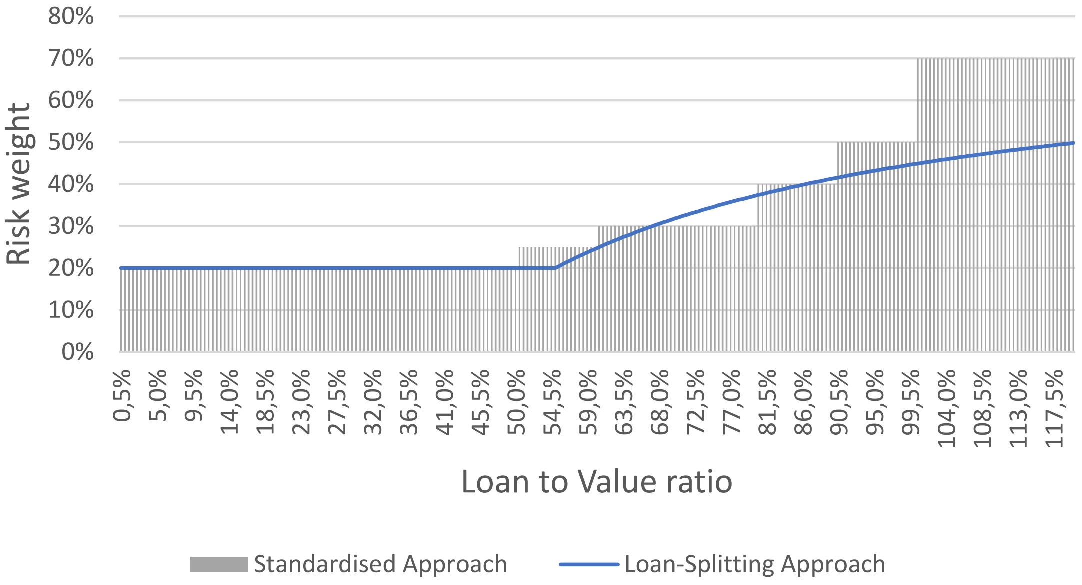
In the LSA a risk weight of 20% is applied to the part of the exposure up to 55% of the property value, while to the rest of the exposure a risk weight of 75% is applied (Committee on Banking Supervision, 2017).

It is unclear as to what Basel's intentions are with this approach and why it was introduced. However, for most LTVs we find that the overall risk weight is decreased using this approach. This is for example the case for a mortgage with a 100% LTV, whose Risk weight is now 44,75% as shown by Formula 4.1. This as opposed to 50% under the SA. We will further analyse these effects on a larger scale in subsequent chapters.

$$\text{RW 100\% LTV asset} = 55\% \cdot 20\% + 45\% \cdot 75\% = 44,75\% \tag{4.1}$$

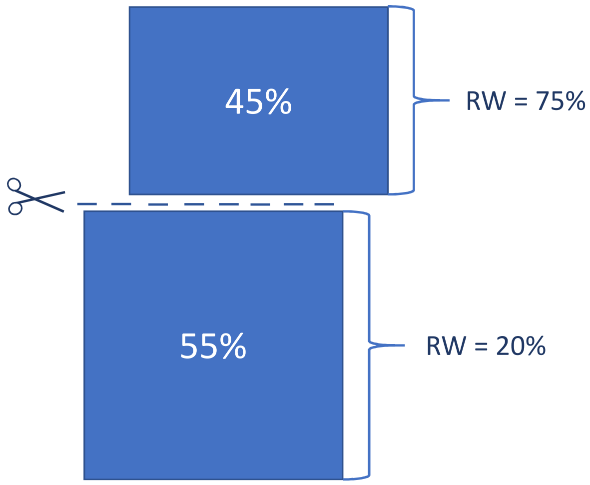
In Figure 4.1 a range of different LTVs ranging from 0,5% to 117,5% have been displayed accompanied by their risk weight as given by the SA and the LSA. We see that for most values the LSA has a lower weighted Risk Weight, except for a LTV between 67% and 80% and a small blip at around 90%. Overall, the LSA would thus be preferred by banks. It makes its introduction a rather odd one.

Figure 4.1.: RW for different LTVs using the Standardised and Loan-Splitting Approach



A possible theory we would like to offer as to the introduction of the LSA is that perhaps the intention of Basel is to provide an incentive to banks to securitise only the top part of the mortgage. Depending on how the collateral would be divided up this could greatly reduce the risk for the bank now holding solely the "bottom part" of the exposure. The removal of the section weighed at 75% would greatly reduce a bank's capital requirements and possibly improve a bank's return on equity. We dub the splitting of a mortgage into multiple parts "mortgage splitting". This is illustrated in Figure 4.2 for a 100% LTV mortgage.

Figure 4.2.: Mortgage Splitting



For clarity, we give two definitions:

Loan-Splitting Approach: The approach described by the Basel Committee which pertains to the method in which the bottom part and top part of a loan are weighed 20% and 75% respectively.

Mortgage Splitting: A new securitisation methodology which splits a mortgage into multiple parts.

An important consideration to be made is as to whether mortgage splitting is possible according to the new regulations. In our analysis in this section and especially the next we think that mortgage splitting would be very logical and might even be the intention of Basel with the introduction of the LSA, but we do not have any concrete data to go on. As such, the regulatory possibility of this method is rather speculative, though it is a method certainly worth exploring.

In the current securitisation environment the sale of the top part of a loan is technically also possible. However, as we have addressed before the current securitisation environment is slow, opaque, and high in operation costs.

It is this where Blockchain would make the concept of mortgage splitting more interesting. The digital environment would add substantial transparency to the products through individual tokens and inherently link these tokens to their assets. The automation provided by smart contracts would greatly reduce operation costs and at the same time provide clarity as to the functioning of the security structure. As such, the Blockchain environment doesn't necessarily make it possible, but it might make it feasible.

4.2. Collateral in Mortgage Splitting

Part of the value of a security lies in the fact that there is a clearly defined asset that acts as a collateral and thus greatly reduces the risk of the product. In the case of mortgage splitting we might see some changes to this clear-cut idea. In this section we will explain two different possible methods of dealing with collateral in mortgage splitting. One method uses a 'proportionally split asset' as collateral and the other a 'tranched asset' as a collateral.[1] We will in this section explain as to why we think the latter is more realistic. It will give the reader a better understanding of mortgage splitting and why it is attainable.

4.2.1. Proportionally Split Asset

When a security is split we can imagine that the rights to the collateral are proportionally split along with it. We illustrate this in Figure 4.3. Three scenarios are illustrated for a 100% LTV mortgage where the owner has defaulted without paying off any part of the loan. These scenarios are:

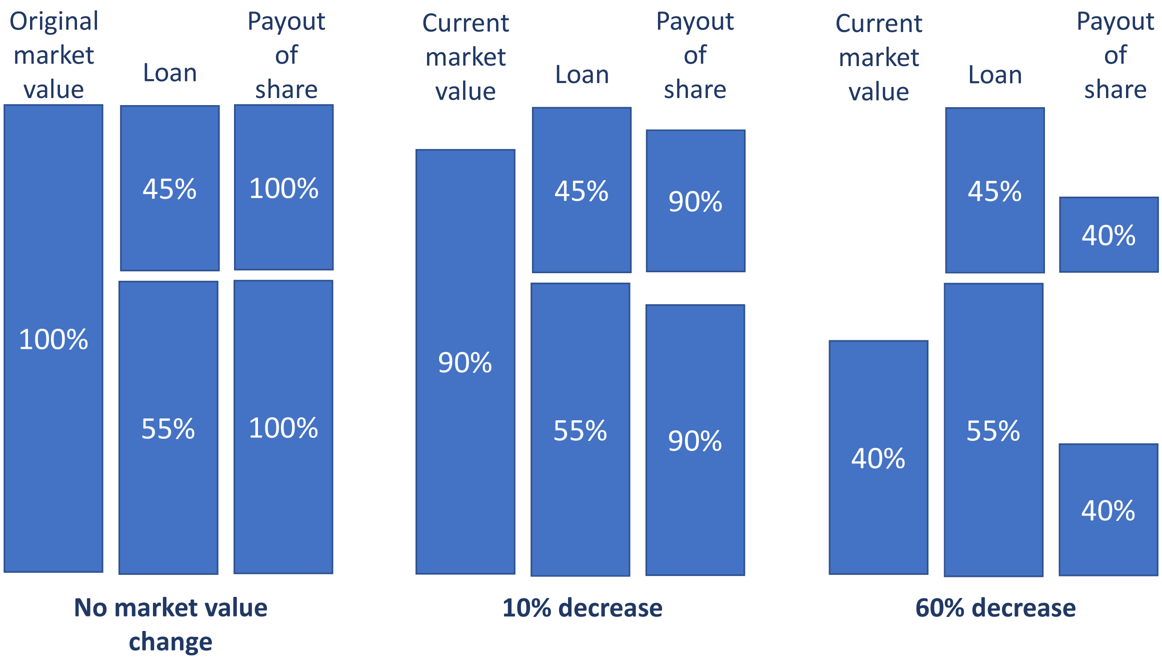
- A scenario in which the market value of the home is still the same as at the time in purchase
- A scenario in which the value has decreased by 10%
- A scenario in which the value has decreased by 60%[2]

[1] The idea that only the top half of the loan was sold but without any collateral at all was also entertained, but given the fact that we would then be leaving the idea of an "Asset-Backed Security" we will not delve into this further. From the results obtained here we can state that it is an interesting possibility.

[2] This is a very unrealistic scenario but will be entertained here for explanatory purposes.

In this instance, the investor in a security that is 45% of the mortgage has the right to 45% of the possible sales value of a house, whilst the bank that still owns 55% has the right to 55% of the sales value. The split is thus proportional.

Figure 4.3.: Proportionally split asset collateral scenario



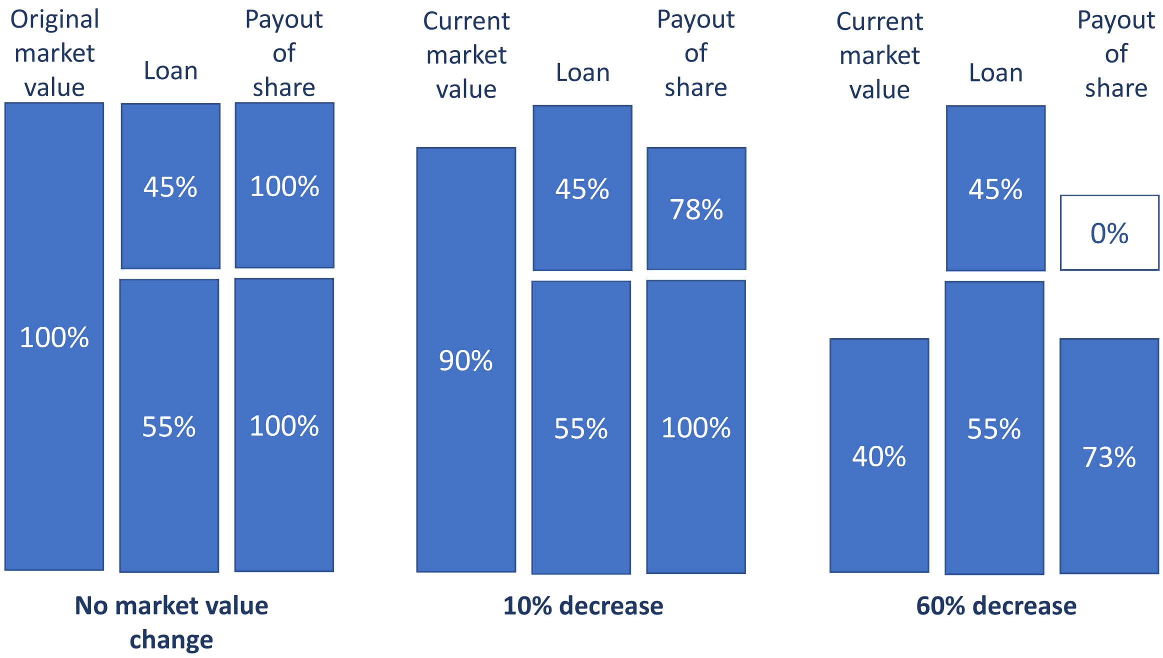
We see that owners of both shares are impacted when the market value of the asset drops, proportionally with the share they own. Whether they own the "top part" or "bottom part" of the loan does not matter.

4.2.2. Tranched Asset

A different possibility is that the owner of a security that is the top 45% of a mortgage has the right to only that which is left after the owner of the bottom 55% has received its share. In some way, this functions as a 'tranche system'[3]. This is illustrated in Figure 4.4.

[3]A tranche system is also called a senior-subordinated structure and pays some parties before it pays others, thus decreasing the risk of the first mentioned parties. This is further explained in Appendix B.2.

Figure 4.4.: Tranched asset collateral scenario



We see that in the case of a slight market value decrease, the owner of 45% of the loan already loses quite a chunk of their payout. In the case of a severe drop, they lose all of their payout while the owner of the bottom 55% only loses a part.

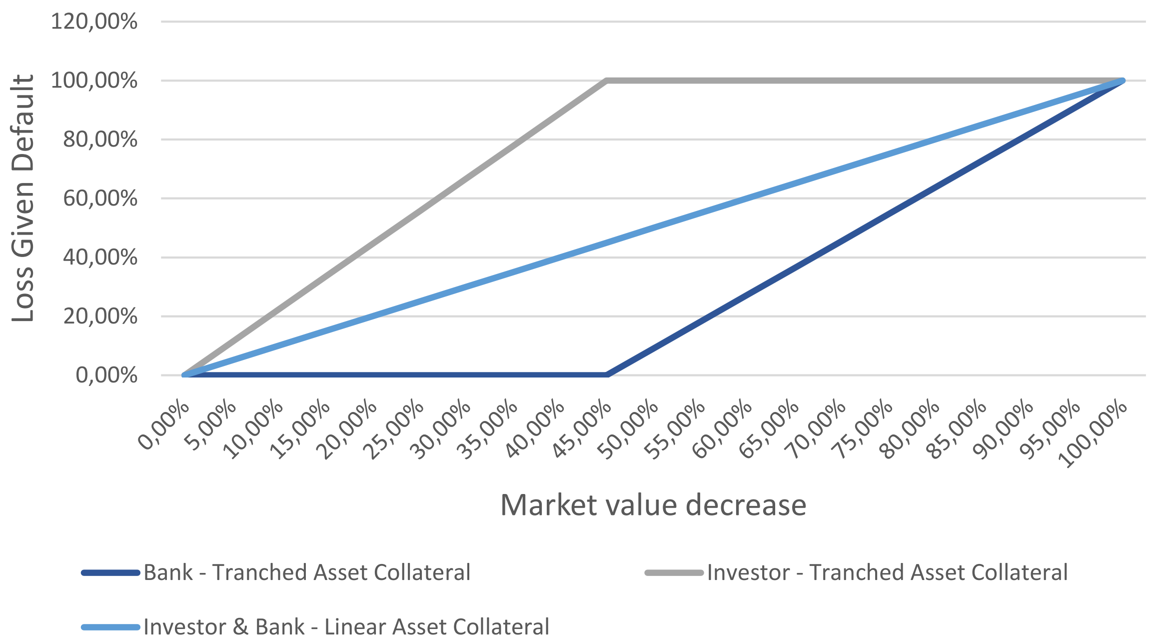
4.2.3. Loss Given Default

To better illustrate the losses incurred by the investor and the bank in the case of a default, we determine their Loss Given Default (LGD) for various market scenarios, where:

$$\text{LGD} = \text{Value Loan} - \text{Market Value Asset} \tag{4.2}$$

This is shown in Graph 4.5.

Figure 4.5.: Share payouts for different collateral scenarios at different market value decreases



We clearly notice the greatly different behaviour of the Tranched Asset Collateral. The bank share is only affected if the asset value drops by 45%.

4.2.4. The LTV Equivalent

The splitting of collateral leads to new behaviour for the LGDs of the different shares. Given this behaviour, we find it necessary to re-examine the concept of the LTV of a split mortgage. We do so to illustrate the risk differences in mortgage splitting, but also to perhaps shed some further light on as to why Basel might have introduced the LSA.

What we saw is that the bank share of a tranched asset collateral doesn't lose any value until the asset has dropped by 45%. In this regard, the bank share functions as if it were a normal mortgage with a LTV of 55%: there too the asset has to drop by 45% before losses are incurred by the bank. For this reason, we will re-define the concept of the LTV ratio and make it suitable for mortgage splitting.

So far we have defined LTV implicitly as Current Loan to Original Market Value (CLTOMV), where:

$$\text{CLTOMV} = \frac{\text{Current Loan}}{\text{Original market value}} \tag{4.3}$$

We have used this version of LTV as it is the standard used for the calculation of risk weights by Basel and by banks. It does not reflect the current market value of the asset.

To do so, we should use the industry defined Current Loan to Current Market Value (CLTCMV), where:

$$\text{CLTCMV} = \frac{\text{Current loan}}{\text{Current market value}} \tag{4.4}$$

However, given that we are making use of mortgage splitting, we must reflect that an investor or bank owns only a share of the mortgage and thus only a share of the collateral.

We redefine CLTCMV for our purpose:

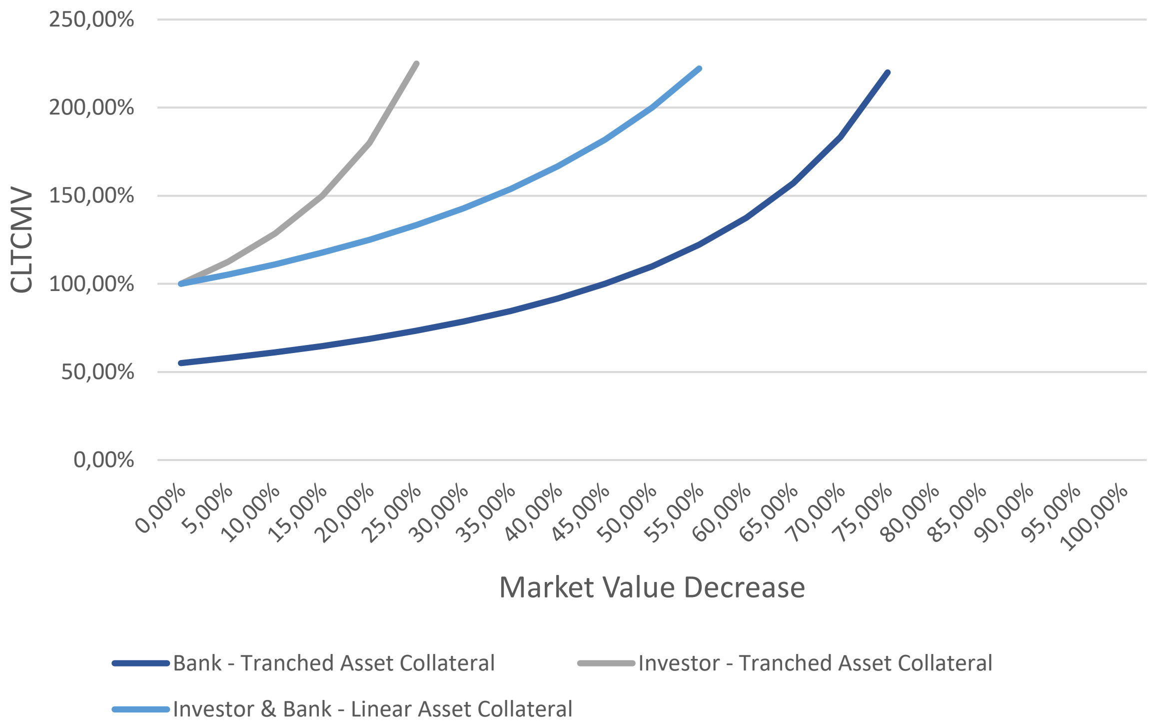
$$\text{CLTCMV} = \frac{\text{Current loan share}}{\text{Current market value share}} \tag{4.5}$$

We still find that this equation falls short for the bank's share. It is not the current market value of the share that is important, as this would not reflect the fact that a tranched system exists and the bank share will not lose value until a 45% decrease. We find that we should make use of a 'Virtual current market value share', which for the bank includes both it's own market value share and that of the investor.

$$\text{CLTCMV} = \frac{\text{Current loan share}}{\text{(Virtual) current market value share}} \tag{4.6}$$

We calculate these new LTVs and plot the results for the bank share and investor share in the case of a tranched asset collateral as well as the bank and investor share for the linear asset collateral (plotted together as it gives the same results). The results were capped at a LTV of 225% as to keep the graph legible.

Figure 4.6.: CLTCMVs for different collateral scenarios at different market value decreases



The linear asset collateral functions as a normal mortgage. The moment the market value start decreasing the CLTCMV rises above a 100%. For the tranched asset collateral we see two very different risk profiles. The investors's LTVCMV is amplified and rises quickly. That of the bank only changes slowly and requires a 45% market value decrease before the LTV rises above a 100%.

Again, we point out the equivalence between a normal mortgage with a LTV of 55% and that of a bank with a tranched asset collateral. This behaviour will be similar for lower LTVs. It gives us an idea as to why the LSA was introduced and the validity of mortgage splitting. If the top part of the mortgage is sold, what remains is a mortgage with a de facto LTV of 55% or lower. The LSA gives this mortgage a RW of 20%. The SA gives a mortgage with a LTV of 55% or lower a RW of 25%, and a mortgage with a LTV of 50% or lower a RW of 20%.

4.2.5. The Correct Collateral Method

It is clear to see that the scenarios in the two different possibilities are vastly different. In the proportionally split asset collateral scenario, even under terrible market conditions (a drop in house value by 60%), the owner of the top part of the loan will still recover a part of their investment.

This is not the case in the tranched asset collateral scenario of Basel. We see that in the most grim scenario the complete investment of the owner of the top part is lost.

The most interesting aspect of these scenarios is what happens to the share of the bank, the bottom part of the loan. In a small market value decrease the recovery is completely unaffected, and even in a very grim scenario the payout is still substantial.

It is our understanding that it is the tranched asset collateral scenario that is the possible intention of the LSA as described by Basel. By selling the risky part of the loan the risk to the bank is decreased substantially, and given the unlikeliness of more than a 45% decrease in house value their risk is removed almost completely. This is clearly not the case in the proportionally split asset collateral scenario where only the size of the loan is decreased but not the relative impact of market effects.

4.2.6. Increased Risk Investor

In our discussion in the previous sections we have focused on the decreased risk to the bank as to warrant the use of mortgage splitting and the possible approval by the regulator. However, we have payed no real attention to the increased risk of the investor, even though it is clear that the decrease in risk of the bank means that the risk is now shouldered by the investor.

This was first shown in Figure 4.4, where we see that a 60% decrease in current market value leaves an investor with nothing. We further illustrated this in Figure 4.5, where the LGD of the investor is shown. We have seen there that while for the bank the loss is delayed, the loss started immediately for the investor.

This is also reflected in Figure 4.6 where any form of market value decrease will immediately push the CLTCMV of the investor over 100% and increase rapidly. This as opposed to the “classic” system, where the increase is much slower.

Overall, it is rather clear that the risk to the investor is increased greatly. For this, an investor will demand a premium from the bank as to warrant the increased risk as compared to standard securitisation. While we leave pricing outside of the scope of this thesis, it is clear that this will affect the ROE of a securitisation. In the section that follows we will determine the ROEs of the LSA. Here, we do not take into account any premiums. The ROEs should thus be considered an ideal scenario.

4.3. Securitisation Scenarios

From what we have learned in the previous chapter and in the previous sections we can model a bank in different securitisation scenarios using the LSA and mortgage splitting, portraying the effects though a balance sheet as well as an income statement as we have done in the last chapter.

The following scenarios will be modelled in detail as pertaining to mortgage splitting:

1. Single mortgage bank
   - Loan-splitting approach

2. Second debt-financed mortgage
   - Loan-splitting approach

3. Second standard security financed mortgage
   - Loan-splitting approach

4. Second mortgage-splitting security financed mortgage
   - Standard approach
   - Loan-splitting approach

The mortgage used will again have a Loan to Value of 100%. Weights for the LSA are applied as stated in Section 4.1 and weights for the SA are used as given in Table 1.1. This means that in the LSA the share maintained by the bank when the top half is sold is given a Risk Weight of only 20%.

Again, other LTV ratios will also be modelled but will be summarised in a graph in Section 4.5.

4.3.1. Securitisation Retainment

In the previous chapter we have already discussed the concept of securitisation retainment requirements for a bank.

One could argue that through the use of mortgage splitting a bank inherently retains a vested interest in the securitisation through keeping the bottom 55% of the mortgage on its books. It would thus not be necessary to retain a 5% share in the securitisation. However, as we explain in Section 4.2 the risk level between the bank and the investor in the security might differ substantially and a bank might be unaffected by any defaults. For this reason, even for mortgage splitting, the 5% retainment of the securitisation is maintained.

4.3.2. Single Mortgage Bank

Shown in this section in Tables 4.1 and 4.2 is the starting situation of the bank, though now making use of the LSA which results in lower capital requirements than the SA.

Table 4.1.: Balance sheet - single mortgage bank - LSA

Assets		Liabilities & Equity	
Reserves	€0	Deposits	€61,728
Securities	€0	Debt	€34,692
Loans	€100,000	Equity	€3,580
TOTAL	**€100,000**	**TOTAL**	**€100,000**

Table 4.2.: Income statement - single mortgage bank - LSA

Assets	Rate	Income	Liabilities & Equity	Rate	Cost
Reserves	0,0%	€0	Deposits	0,77%	€475
Securities	1,26%	€0	Debt	0,88%	€305
Loans	1,26%	€1,260	Equity	0,00%	€0
TOTAL		€1260	**TOTAL**		€781
			ROE		13,4%

The most valuable result that we obtain from this section is the fact that the Return on Equity for the LSA is higher than for the SA. This is as was to be expected: the total weight for the LSA is simply lower than the total weight for the SA for a mortgage with a LTV of 100%, leading to a lower required level on equity.

4.3.3. Second Debt-financed Mortgage

The second option we will look into is where the bank finances a second €100,000 mortgage using debt financing. This is given in Tables 4.3, and 4.4.

Table 4.3.: Balance sheet - second debt-financed mortgage - LSA

Assets		Liabilities & Equity	
Reserves	€0	Deposits	€61,728
Securities	€0	Debt	€131,112
Loans	€200,000	Equity	€7,160
TOTAL	**€200,000**	**TOTAL**	**€200,000**

Table 4.4.: Income statement - second debt-financed mortgage - LSA

Assets	Rate	Income	Liabilities & Equity	Rate	Cost
Reserves	0,0%	€0	Deposits	0,77%	€475
Securities	1,26%	€0	Debt	0,88%	€1,154
Loans	1,26%	€2,520	Equity	0,00%	€0
TOTAL		€2,520	**TOTAL**		€1,629
			ROE		12,4%

4.3.4. Second Standard Security Financed Mortgage

We will now look to finance the second mortgage not through solely borrowing but through standard securitisation: the securitisation of the entire first mortgage. This is shown in Tables 4.5 and 4.6.

Table 4.5.: Balance sheet - second standard security financed mortgage - LSA

Assets		Liabilities & Equity	
Reserves	€0	Deposits	€61,728
Securities	€5,000	Debt	€39,612
Loans	€100,000	Equity	€3,660
TOTAL	**€105,000**	**TOTAL**	**€105,000**

Table 4.6.: Income statement - second standard security financed mortgage - LSA

Assets	Rate	Income	Liabilities & Equity	Rate	Cost
Reserves	0,0%	€0	Deposits	0,77%	€475
Securities	1,26%	€63	Debt	0,88%	€349
Loans	1,26%	€1,260	Equity	0,00%	€0
TOTAL		€1,323	**TOTAL**		€824
			ROE		13,6%

4.3.5. Second Split-security Financed Mortgage

In this section the second mortgage is financed through means of partial securitisation: only the top 45% of the mortgage is sold as a security. The bottom 55% is not sold. We will determine the effects of this form of financing using not only the LSA but also the SA. This as to be able to compare the difference of split-security financing between the two approaches.

This is shown in Tables 4.7, 4.8, 4.9, and 4.10.

Standard approach

Table 4.7.: Balance sheet - second mortgage-splitting security financed mortgage - SA

Assets		Liabilities & Equity	
Reserves	€0	Deposits	€61,728
Securities	€2250	Debt	€89,286
Loans	€155,000	Equity	€6,236
TOTAL	**€157,250**	**TOTAL**	**€157,250**

Table 4.8.: Income statement - second mortgage-splitting security financed mortgage - SA

Assets	Rate	Income	Liabilities & Equity	Rate	Cost
Reserves	0,00%	€0	Deposits	0,77%	€475
Securities	1,26%	€28	Debt	0,88%	€786
Loans	1,26%	€1953	Equity	0,00%	€0
TOTAL		€1,981	**TOTAL**		€1,261
			ROE		11,6%

Loan-Splitting Approach

Table 4.9.: Balance sheet - second mortgage-splitting security financed mortgage - LSA

Assets		Liabilities & Equity	
Reserves	€0	Deposits	€61,728
Securities	€2,250	Debt	€91,026
Loans	€155,000	Equity	€4,496
TOTAL	**€157,250**	**TOTAL**	**€157,250**

Table 4.10.: Income statement - second mortgage-splitting security financed mortgage - LSA

Assets	Rate	Income	Liabilities & Equity	Rate	Cost
Reserves	0,0%	€0	Deposits	0,77%	€475
Securities	1,26%	€28	Debt	0,88%	€801
Loans	1,26%	€1,953	Equity	0,00%	€0
TOTAL		€1,981	**TOTAL**		€1,276
			ROE		15,7%

4.4. ROE Comparison

Summarised in Table 4.11 are the ROEs for the different scenarios.

Table 4.11.: ROE summary - SA and LSA

Scenario	ROE SA	ROE LSA
Single mortgage	12,1%	13,4%
Second debt-financed mortgage	11,2%	12,4%
Second standard security financed mortgage	12,3%	13,6%
Second mortgage-splitting security financed mortgage	11,6%	15,7%

We see that the ROE's for the LSA are higher in all scenarios as the Risk Weights applied are lower.

We also see that a second debt-financed mortgage lowers the ROE for the LSA. The reason for this is that the funding source used shifts towards the more expensive Debt instead of Deposits, just as it does for the SA. If the same ratio of funding could have been maintained the ROE would have remained constant.

For both methods the ROE improves when funding the second mortgage through the full securitisation of the first one. The addition of 5% of this security on the balance sheet brings extra profits whilst the equity levels are hardly affected. This is due to the lower RWA of a security as compared to a 100% LTV mortgage.

As for the mortgage-splitting security financed mortgage, we see that the ROE for the SA is low. This is because funding through debt is still increased without a significant drop in the required equity. This is not the case for the LSA, where the significant drop in equity is present while income is greatly increased.

Overall, we see the benefits of securitisation and especially the benefits of mortgage splitting for improving the ROE of a bank.

4.5. LTV Variation

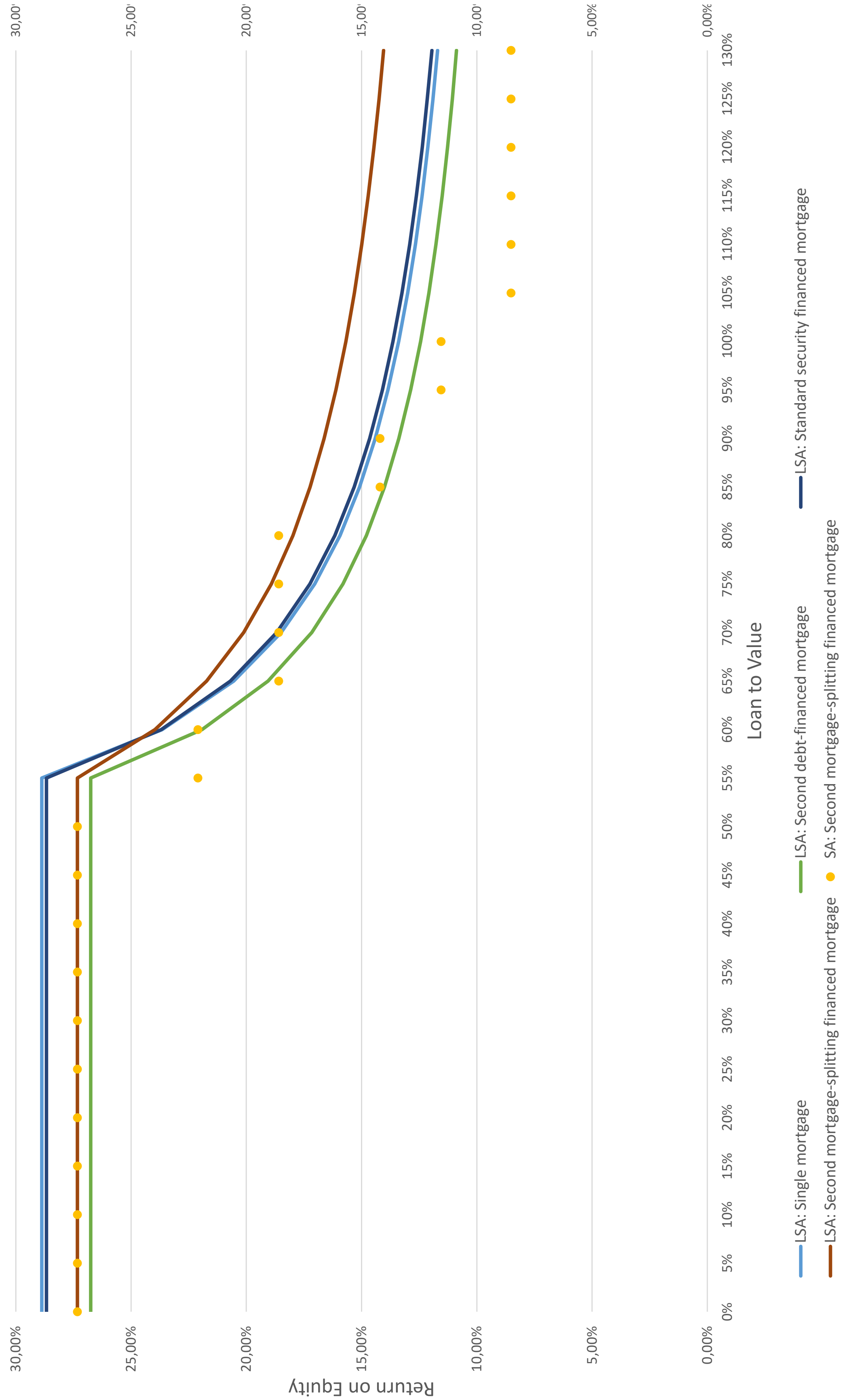
In this section we will first take a look at the effect of different LTVs in the case of the LSA, as we have done in the last chapter, though we add mortgage splitting. Subsequently we will make some comparisons between the SA and the LSA.

4.5.1. Loan-Splitting Approach

Shown in Graph 4.7 is the ROE of the different mortgage splitting scenarios for different LTVs. We see that:

- ROE remains constant until an LTV of 55% is reached. This is as to be expected as there are no Risk Weight changes.
- For the higher LTVs we see that the order of ROEs is maintained just as we saw for a LTV of 100%, though the difference becomes more pronounced for high LTVs.
- We see that at lower LTVs the standard single mortgage scenario and the full security scenario have the higher ROEs. This is a reflection of having a lower level of debt.

Figure 4.7.: The ROE of different mortgage splitting securitisation scenarios for various LTV ratios



4.5.2. Standard Approach versus Loan splitting Approach

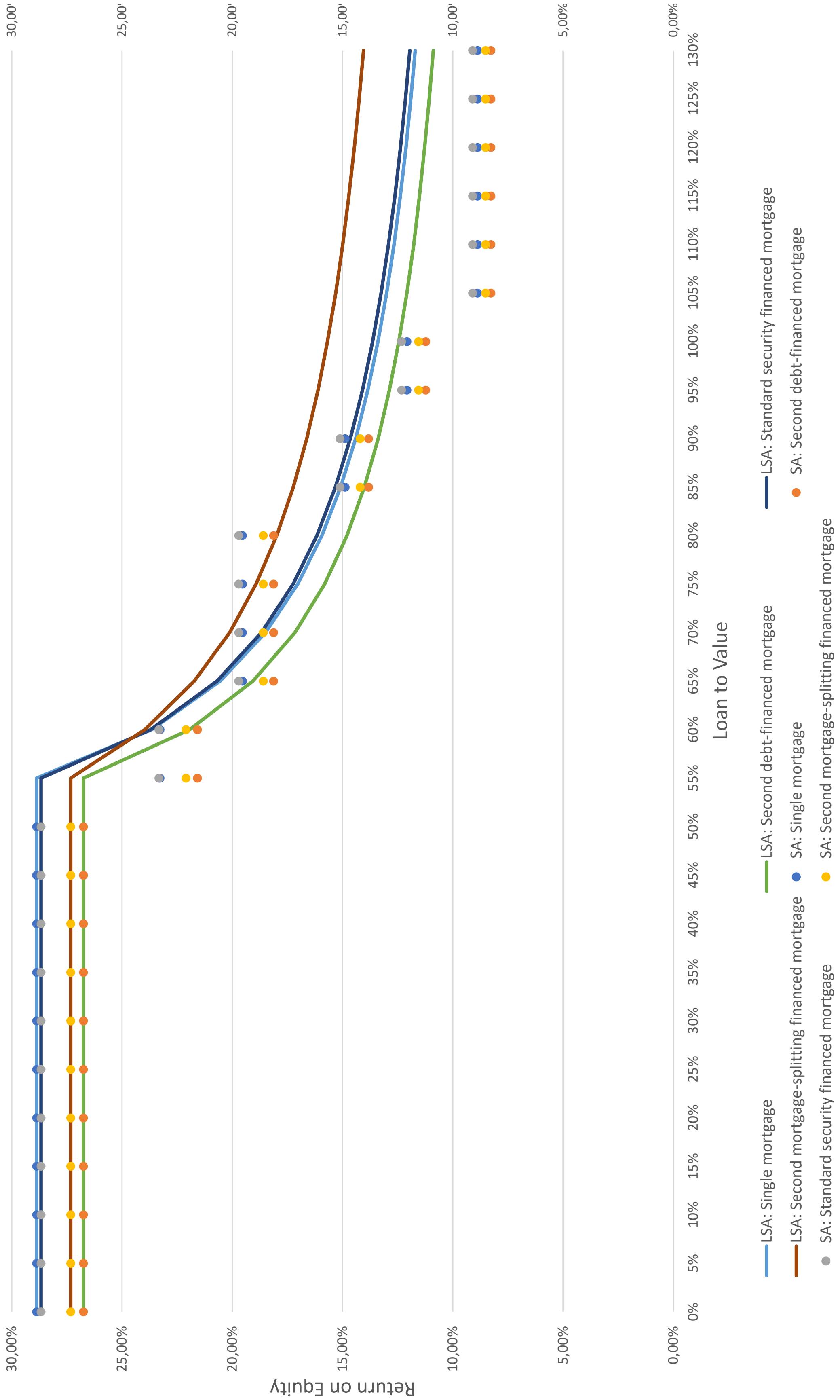
The different scenarios we modelled that made use of a 100% LTV have all shown better ROEs for the LSA than the SA, as we saw in the ROE summary table. It begs to question if the use of a different LTV might alter the results, especially because in Section 4.1 we have seen that for a small range of LTVs (67% to 80%) the overall risk weight given by the SA is lower than that given by the LSA.

Shown in Graph 4.8 are the ROEs for all scenarios, using both the SA and the LSA. We will comment briefly on some trends:

- We know that at some LTVs (mainly between 67% and 80%) the overall risk weight for the SA is lower than that of the LSA. To some degree we see this effect in the graph as the ROEs for the SA are relatively higher in this area.

- Unlike what we saw previously for a LTV of 100%, the LSA is not always preferential at all LTVs.

Figure 4.8.: The ROE of different standard approach and mortgage splitting securitisation scenarios for various LTV ratios



4.6. Sensitivity Analysis

As done in the last chapter we will vary the interest rate of the mortgage and the interest rate of the funding. We will perform the sensitivity analysis on the Loan-Splitting Approach scenarios. The graphs (D.3 and D.4) can be found in the appendix.

Mortgage rate

The differences for a changing mortgage rate are similar to the differences we saw in our previous sensitivity analysis, though more pronounced. The order of which method has the highest ROE remains constant if the mortgage rate does not drop below the funding rate and at high mortgage rates the differences become much larger.

Funding rate

Again, both the deposit rate and the debt rate were varied. As with the mortgage rate the order of which method has the highest ROE remains constant, though for low funding rates the differences become much larger.

Mortgage swapping and its financial benefits 5

In this fifth chapter we will finish answering the second research-subquestion:

What effect do different new securitisation methodologies have on the return on equity of a bank looking to fund additional mortgages?

The methodology that has been researched in this chapter is that of 'mortgage swapping'.

In the first section we will further explain this concept and how it might function.

In the sections that follow we determine the effects that it might have on the ROE of a bank through the use of balance sheets and income statements, as well as perform sensitivity analyses and analyse some limitations.

In the last sections attention is given to the increased risk of mortgage swapping for the investor by looking at the effects of house price changes.

5.1. The Concept

In previous chapters we have shown that the ROE of a mortgage will differ as the LTV (and hence the RW) of the mortgage differs: a higher LTV will increase the equity that is required to be held and will decrease the ROE of the bank. The higher equity is of course through regulation a reflection of the fact that a mortgage with a higher LTV carries more risk.

The situation of a potential investor in a security will differ. While they too are risk-averse and would rather own low LTV mortgages than high LTV mortgages, they are not bound to the same regulations as a bank. They do not have to hold capital in reserve as a result of the assets they own. They might thus be less averse to high LTV mortgages.

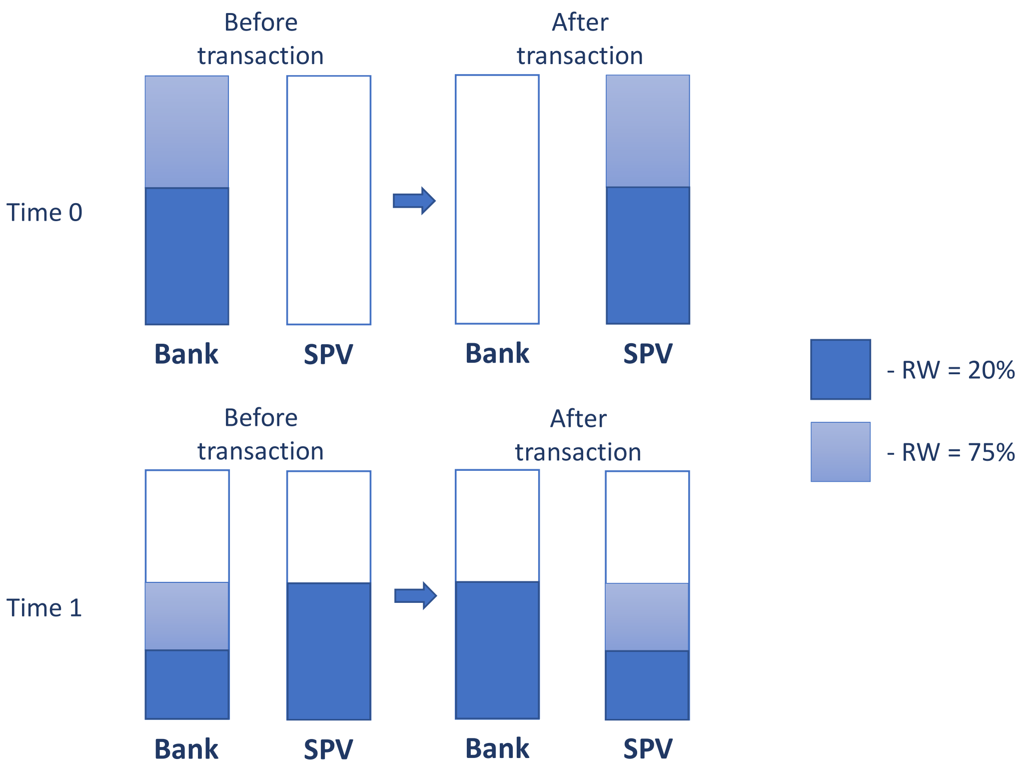
As a result, it might be in the banks interest to sell of mortgages with a high LTV while maintaining those with a lower LTV. In normal securitisation, after the high LTV mortgages are sold off to a SPV their LTV ratio will slowly decrease as payments are made. mortgage swapping takes advantage of this.

The concept of "mortgage swapping" is that at Time 0 the bank will securitise its mortgages with a high LTV by transferring them to a SPV. Years later at Time 1 these mortgages will have dropped below a certain LTV threshold as the loans are partially paid off. These mortgages will then be brought back on the bank's banking book and will be exchanged for the bank's newly underwritten mortgages with high LTVs.

The benefit for the bank is the difference in equity required between holding the high LTV mortgages and the low LTV mortgages. In return for the increased risk an investor would require an increased return. Though we do not take this into account in our calculations, we comment on this in Section 5.7.1.

We visualise this concept in Figure 5.1. In the left column the pre-transaction situation is shown and in the right column the post-transaction situation. The top and bottom row each represent a different moment in time. The LSA is used.

Figure 5.1.: Mortgage swapping



At Time 0 (before transaction) the bank holds all mortgages, all with a LTV of 100%. The SPV holds none. All mortgages are then securitised and fully transferred to the SPV. By Time 1 (before transaction) two things have occurred: the mortgages of the SPV have been partially payed off and only 55% of the original value is left. These are solely mortgages with a LTV of 55%, which only have a Risk Weight of 20%. In this time, the bank has also underwritten a number of new mortgages. These all have a LTV of 100%. At time 1 these two mortgage portfolios are swappped between the Bank and the SPV. After the transaction, the bank owns the mortgages with a low LTV while the SPV owns the mortgages with a high LTV.

The two sets of mortgages are equal in banking book value and are exchanged for one another. The bank now owns the same total value of mortgages but their LTV is lower. Through this system, the average LTV of a bank's mortage portfolio will be lowered. This provides an alternative and likely more profitable solution to banks than other means of achieving this. Other forms of active LTV management such as the active stimulation on the repayment of interest-only loans would thus be less vital.

In Figure 5.1 we have shown the mortgage swapping of the bank's entire portfolio. While as an example this works well to illustrate the concept, we imagine reality to be different. Changes could be continuous or possibly occur every month, constantly optimising the mortgage holdings of the bank and providing the largest possible benefit.

The concept of mortgage swapping could be attainable without the Blockchain as the concept could simply be expressed in contracts. We see the benefit of the Blockchain in the various elements that we have expressed in Chapter 2. The use of tokens in a Blockchain would put the mortgages at "arm's length" and solidify the sale, the use of smart contracts might automate this entire process, and the perpetually up to date database would ensure that the data of all parties is current.

Great consideration would have to be taken as to the legality of such a construction. Whilst at the moment selling a security as a bank and subsequently buying it back is permitted, this construction would be more intricate. The greater fluidity of the owner of a securitisation would bring to consideration as to whether the consideration is actually placed at "arm's length" of the bank and true sale is actually achieved.

Of importance is also the increased risk of a security with only high LTVs. We will analyse this in Section 5.6.

5.2. Numerical example

In this section we will illustrate the possible benefits of the swap as taken to an extreme.

We imagine that 15 years ago (2004), a bank securitised mortgage Portfolio 1 as described in Table 5.1. This entire portfolio was since then in possession of the SPV. Through the annuity the book value has decreased over the past 15 years as the loan is paid off. In year 15 (2019) the SPV owns Portfolio 2 as described in Table 5.1.

Since the last security issuance the bank has rebuilt its mortgage portfolio. For our own ease, we assume that the mortgage portfolio it has rebuilt is equal in value and type to the current portfolio of the SPV with the only difference being the loan value (and subsequently the LTV). It owns Portfolio 3 as described in Table 5.1.

Table 5.1.: Mortgage swapping portfolios

Variables	Portfolio 1	Portfolio 2	Portfolio 3
Number of mortgages	10,000	10,000	5,333
Tenor (years)	30	15	15
Loan value	€100,000	€53,333	€100,000
Asset value	€100,000	€100,000	€100,000
LTV	100%	53,3%	100%
Annuity	€3,333	€3,333	€3,333
Total value	€1,000 million	€533 million	€533 million

In this scenario, we will replace the mortgages currently in the securitisation (Portfolio 2) by new mortgages which have a higher risk weight (Portfolio 3). On the Asset side of the balance sheet we will see no effect. Direct replacement with equal value means that the Loans and Securities stay the same in balance sheet value. However, as the risk differs the equity required will change and more value is captured for the bank.

The lower equity and substantially higher ROE are shown in the tables that follow. We assume that funding rate and mortgage rate are kept constant throughout the years. We will comment on the effects of this in Section 5.4.

Balance sheet and income statement pre-swap

Table 5.2.: Balance sheet - pre-swap

Assets		Liabilities & Equity	
Reserves	€0	Deposits	€348m
Securities	€27m	Debt	€193m
Loans	€533m	Equity	€20m
TOTAL	**€560m**	**TOTAL**	**€560m**

Table 5.3.: Income statement - pre-swap

Assets	Rate	Income	Liabilities & Equity	Rate	Cost
Reserves	0,00%	€0	Deposits	0,77%	€2,7m
Securities	1,26%	€0,3m	Debt	0,88%	€1,7m
Loans	1,26%	€6,7m	Equity	0,00%	€0
TOTAL		€7,1m	**TOTAL**		€4,4m
			ROE		13,7%

Balance sheet and income statement post-swap

Table 5.4.: Balance sheet - post-swap

Assets		Liabilities & Equity	
Reserves	€0	Deposits	€348m
Securities	€27m	Debt	€204m
Loans	€533m	Equity	€9m
TOTAL	**€560m**	**TOTAL**	**€560m**

Table 5.5.: Income statement - post-swap

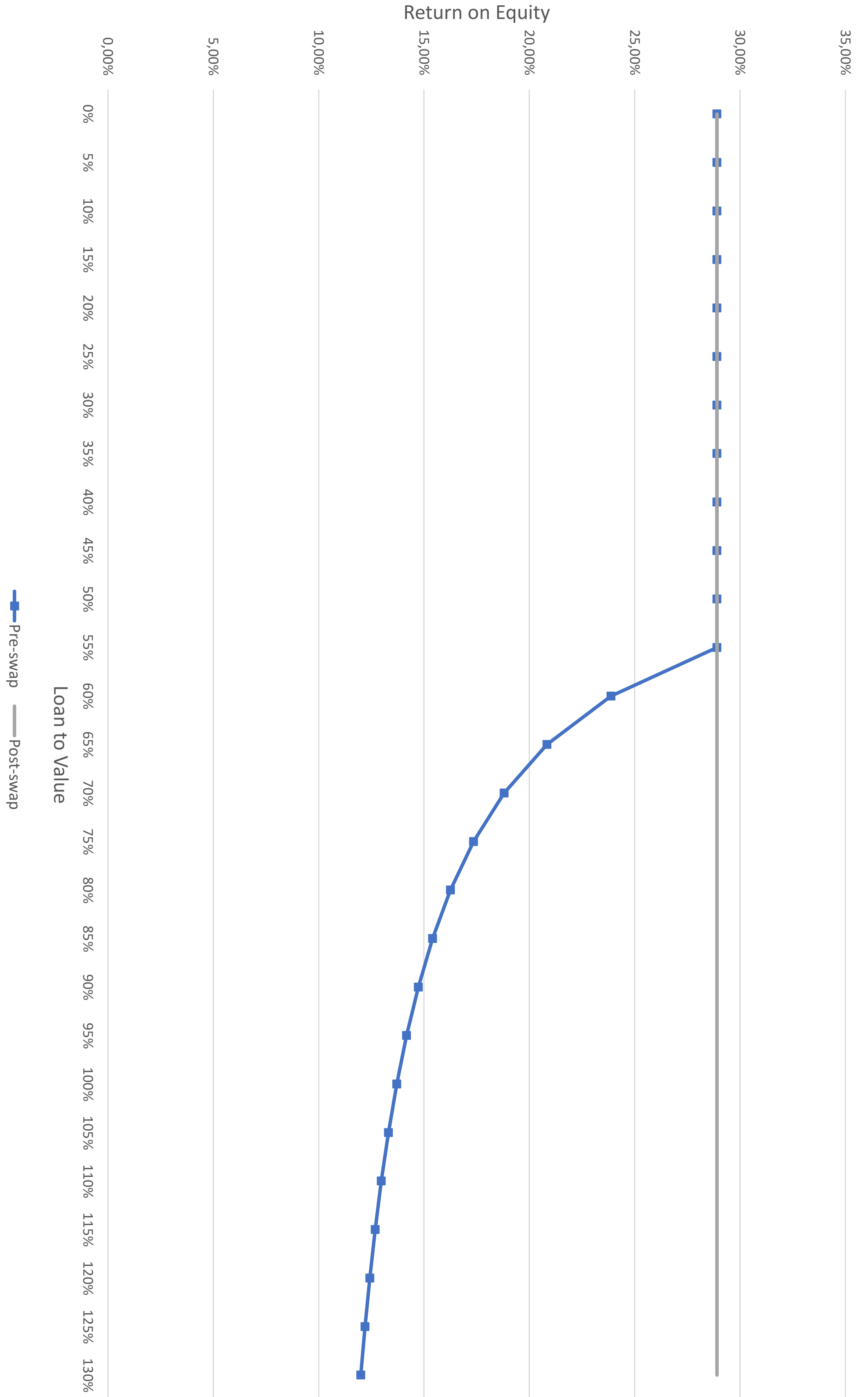
Assets	Rate	Income	Liabilities & Equity	Rate	Cost
Reserves	0,00%	€0	Deposits	0,77%	€2,7m
Securities	1,26%	€0,3m	Debt	0,88%	€1,8m
Loans	1,26%	€6,7m	Equity	0,00%	€0
TOTAL		€7,1m	**TOTAL**		€4,5m
			ROE		28,9%

5.3. LTV Variation

In this section we will take a look at the effect of different LTVs in the case of mortgage swapping. Graph 5.2 shows the ROEs for different LTVs pre-swap and post-swap. We see that:

- ROEs are equal between the two portfolios for a LTV smaller than or equal to 55%. This is to be expected as the risk weights are equal.
- For higher LTVs the gap between the two portfolios increases as the Risk Weight differs more and more.

Figure 5.2.: The ROE of a pre-swap and post-swap portfolio for various LTV ratios



5.4. Re-financing Limitations

In the previous section we have seen the benefits of mortgage swapping. The ROE of the bank was increased from 13,9% to 29,2%. An absolutely vast increase that is not completely realistic. We will comment on an important caveat in this section.

Very important in mortgage swapping is the fixed-interest lifetime of a mortgage. A mortgage is commonly signed with a fixed interest of five to ten years. After this period is up, the customer can close a new mortgage deal which might be more beneficial to them. This will not only depend on the interest rates at that time, but also on the new LTV. Banks offer more competitive interest rates for a mortgage with a lower LTV. Whilst a mortgage with a 100% LTV might have an interest rate of 1,26% (2,26% minus 1% mortgage specific costs), an interest rate with a 55% LTV will have an interest rate of 0,91% (1,91% minus 1% mortgages specific costs) (ABN AMRO, 2019a).

We must thus re-consider how beneficial a swap might be. What if a bank is swapping for a portfolio that has mortgage with a LTV of 55%, but whose interest rate income has been adjusted to 0,91%? The capital requirements vastly decrease, but so does the interest rate income. We recreate our post-swap income statement with the new interest rate figures:

Table 5.6.: Income statement - post-swap with a mortgage interest rate of 1,26%

Assets	Rate	Income	Liabilities & Equity	Rate	Cost
Reserves	0,00%	€0	Deposits	0,77%	€2,8m
Securities	1,26%	€0,3m	Debt	0,88%	€1,6m
Loans	0,91%	€4,9m	Equity	0,00%	€0
TOTAL		€5,2m	**TOTAL**		€4,4m
			ROE		8,1%

The results are stark, greatly decreasing the ROE.

It sheds some important light on the results obtained in the previous section, and shows a vast limitation: under current market prices, a renegotiated interest rate might make mortgage swapping unprofitable.

The example we drew in the previous section is an extreme one. It is a best case scenario. However, as we found in this section, the applicability of mortgage swapping is limited to specific conditions and must perhaps be more fluid than we imagined earlier. Swapping might have to occur not once a mortgage reaches a LTV of 55% (and a renegotiated interest rate becomes likely) but perhaps earlier when the LTV has dropped but the mortgage interest rate is still 1,26%.

We have made clear one essential thing: an increased ROE is possible as long as interest rates remain constant. Once they vary however this benefit might disappear. It is within these constraints that mortgage swapping must operate. The vast ROE increase (from 13,9% to 29,2%) that we have obtained in the last section however is rather misleading in this regard, though does illustrate the benefits in a best case scenario.

5.5. Sensitivity Analysis

As done in the previous chapters we will vary the interest rate of the mortgage and the interest rate of the funding. The Graphs D.5 and D.6 for mortgage rate and funding rate analysis are shown in the appendix.

Mortgage rate
As the mortgage rate increases we see that the difference in ROE between the pre-swapping and post-swapping portfolio increases greatly. The order does not change.

Funding rate
Again, we see that the difference in ROE increases greatly as the funding rate is decreased. The order does not change.

Mortgage rate and funding rate variations for a 0,91% interest rate mortgage
Given the absolute vast differences in ROE that we saw in the previous section if the interest rate of a mortgage is changed to 0,91% for the 55% LTV portfolio, we will also perform a sensitivity analysis on this scenario. Graphs 5.3 and 5.4 show this variation. It's not included in the appendix as we deem the results very interesting.

Shown clearly is that as the mortgage interest rate increases or the funding rate decreases that the post-swap portfolio attains the higher ROE. Otherwise said: if the gap between the mortgage interest rate and the funding rate increases sufficiently then the post-swap portfolio becomes the more attractive one.

This is a result of the ROE of the post-swap portfolio being more sensitive to higher profits on the mortgages as the required capital is lower. These sensitivity analyses show that in different market conditions the re-financing of a mortgage and the attainment of a lower interest rate will not necessarily make mortgage swapping unattractive.

Figure 5.3.: The ROE of a pre-swap and post-swap portfolio for various mortgage interest rates where the post-swap portfolio has a 0,35% lower mortgage interest rate

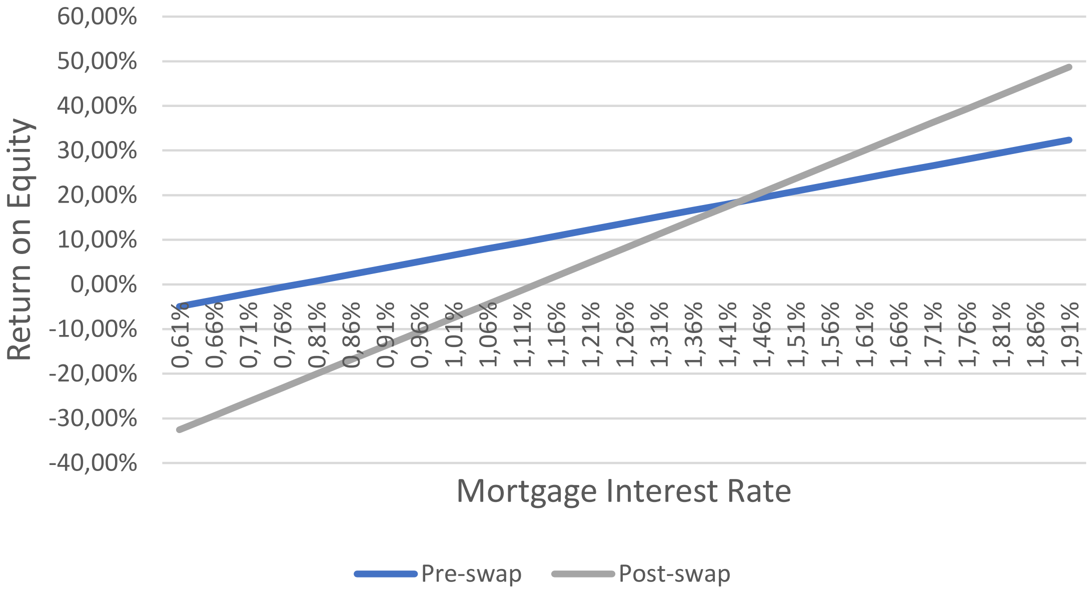
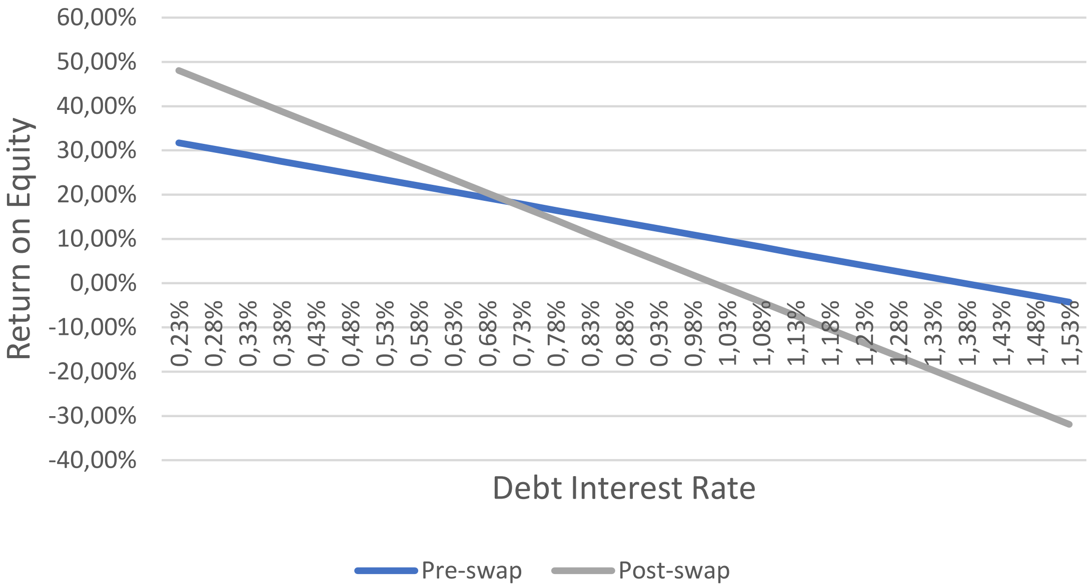


Figure 5.4.: ROE of a pre-swap and post-swap portfolio for various debt interest rates (with a proportionally adjusted deposit interest rate) where the post-swap portfolio has a 0,35% lower mortgage interest rate



5.6. Modelling Increased Risk

A standard securitisation product has a mortgage portfolio with a vast range of different LTVs. For a mortgage swapping product this will not be the case as the mortgages owned by an investor will be of a LTV above a certain threshold (for example 55%). As a result the risk of this product will be higher than that of a standard security.

This additional risk will be caused both by the higher potential Loss Given Default and the slightly higher rate of delinquencies for a higher LTV (ABN AMRO, 2016).

The risk of this product can also be higher due to the chance of declining housing prices. This matter is also addressed in the ABN AMRO Dolphin securitisation Prospectus, and titled "Risks of losses associated with declining values of Mortgaged Assets". It clearly states that any potential risks or additional losses are for the investor. (ABN AMRO, 2017).

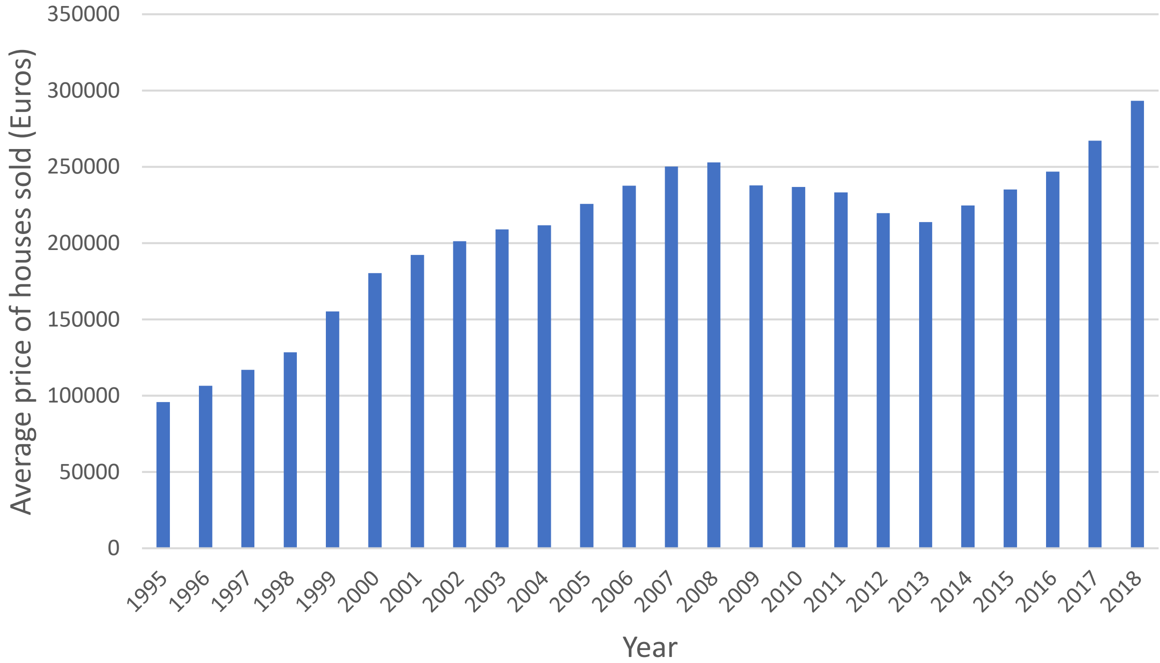
To better illustrate these risk effect we have modelled the effect that changing property prices will have on the Current Loan to Current Market Value ratios of the mortgage and the LGD. It is important to note that we solely model the CLTCMV to illustrate the risk for the investor. For banks these are -at least as it pertains to capital requirements- of a lesser concern as per the new Basel III reforms they make use of the CLTOMV and not the CLTCMV:

"The LTV ratio is the amount of the loan divided by the value of the property. The value of the property will be maintained at the value measured at origination unless national supervisors elect to require banks to revise the property value downward." (Committee on Banking Supervision, 2017).

5.6.1. Changing house prices

To model the effect of changing house prices on the risk of the product we will take a look at the Dutch housing prices in the past. Shown in Figure 5.5 are the average house sales prices in the Netherlands over the past 23 years with information provided by the CBS (CBS, 2019).

Figure 5.5.: Housing prices in the Netherlands from 1995 to 2018



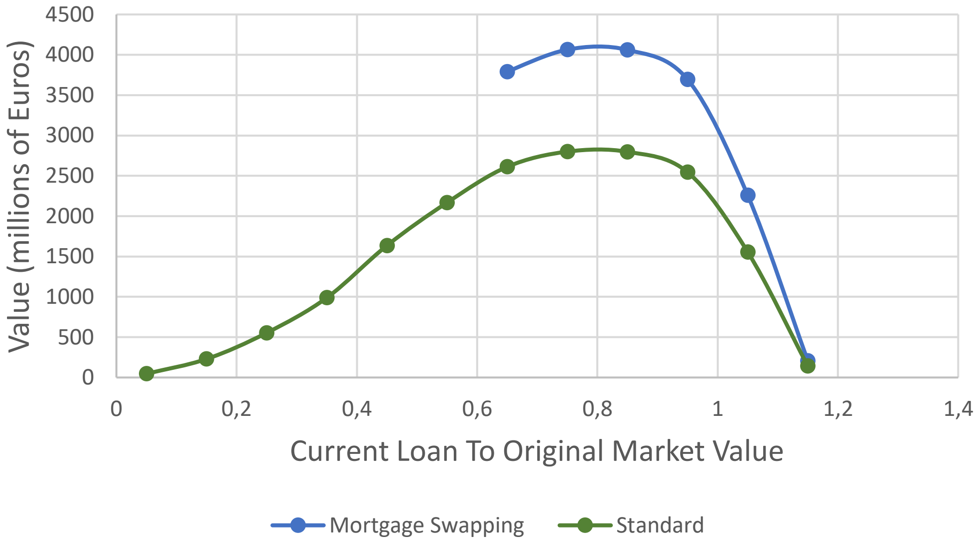
A decrease can be seen in the years following in 2008, with 2013 marking a turning point and a subsequent recovery. In 2013 the price of the average house sold was 19,97% below the house price in 2008. We will use this percentage as both a possible future property price increase and decrease compared to 2019 when modeling risk.

5.6.2. Effect of house prices on CLTCMV

To illustrate the difference between a standard securitisation and a mortgage swapping securitisation we will plot the CLTCMVs of both in the case of a market price decline and a market price rise.

Before doing so, the base scenario (2019) is shown in Figure 5.6. The standard securitisation is a reflection of the CLTOMV distribution of a security issued by ABN AMRO. The mortgage swapping securitisation is the exact same portfolio but only with CLTOMVs higher than 55%. The total value of the two portfolios are set to be the same, as this will allow for clearer calculations later on. In order to achieve this, the the values of the mortgages with LTVs higher than 55% were proportionally increased until the portfolio value equalled that of the standard portfolio.

Figure 5.6.: Standard portfolio and Mortgage Swapping portfolio



Shown in Figure 5.7 and Figure 5.8 are respectively the effects of changing housing prices on the CLTCMV of a standard portfolio and the effects changing housing prices on the CLTCMV of a mortgage swapping portfolio.

Figure 5.7.: Effects of changing housing prices on CLTCMVs of a Standard portfolio

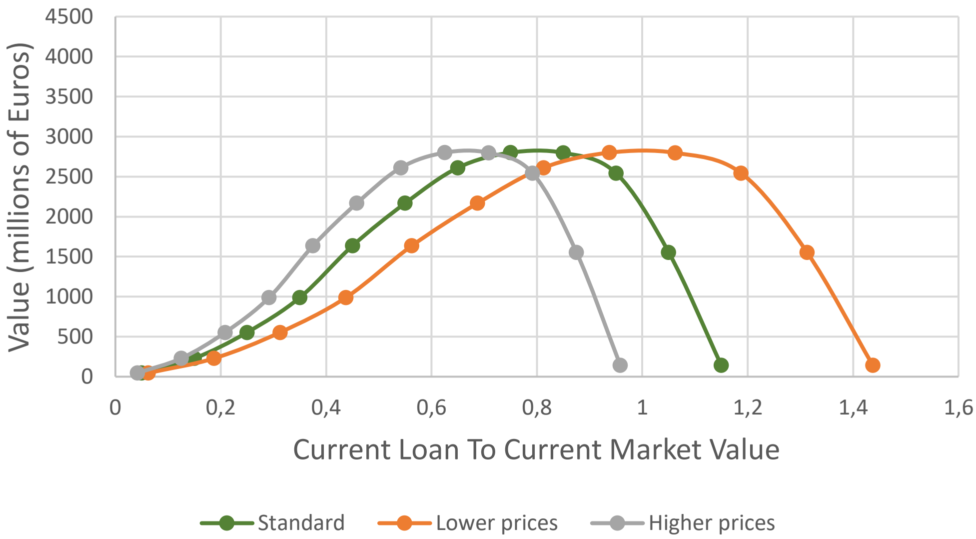
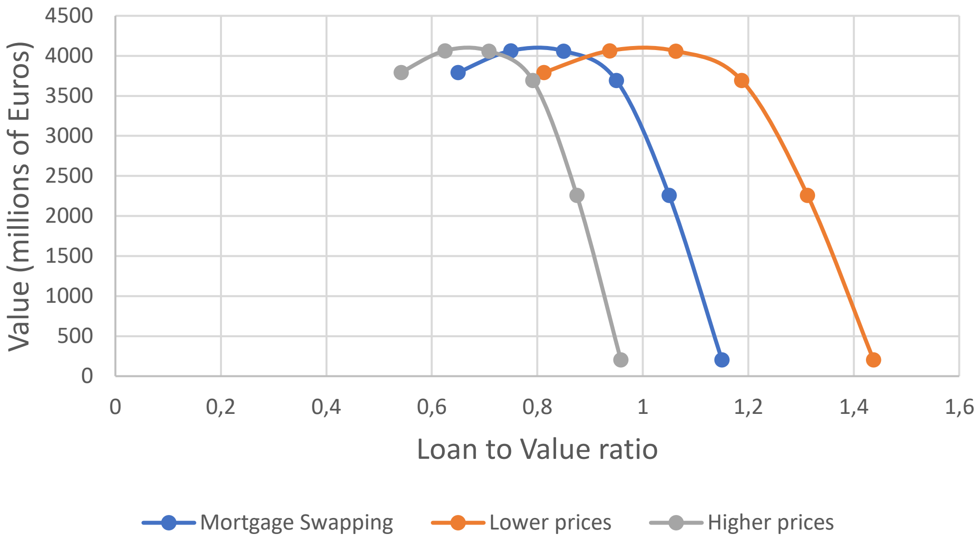


Figure 5.8.: Effects of changing housing prices on CLTCMVs of a Mortgage Swapping portfolio



The results shown in these graphs have been quantified by determining the average weighted CLTCMV for each scenario. These are shown in Table 5.7.

Table 5.7.: Average weighted CLTCMV ratios for changing housing prices of a Standard and a Mortgage Swapping portfolio

House price change	Standard	Mortgage Swapping
-19,97%	0,888	1,043
0,00%	0,710	0,834
19,97%	0,592	0,695

We see that the swapping portfolio is more sensitive to changes in housing prices in terms of CLTCMV. Also, the weighted average CLTCMV becomes greater than 1,0, further indicating the greater risk of the portfolio.

5.6.3. Effect of house prices on LGD

We also measure the Loss Given Default (LGD) as this gives a better idea of how the CLTCMV ratios actually translate to real financial risk, where:

$$\text{LGD} = \text{Value Loan} - \text{Market Value Asset} \tag{5.1}$$

The LGDs are shown in Table 5.8:

Table 5.8.: Loss Given Default in millions for changing housing prices of a Standard and a Mortgage Swapping portfolio

House price change	Standard	Mortgage Swapping
-19,97%	979	1422
0,00%	92	134
19,97%	0	0

Here, we see the greater LGD of the mortgage swapping portfolio. However, the ratio between the LGD for the mortgage swapping portfolio and the standard portfolio remains constant for both the 0% change and the -19,97% change scenario. In this regard, the mortgage swapping portfolio is not more sensitive to pricing changes than the standard portfolio. The LGD is greater, but the securitisation will -in terms of LGD- not behave any differently than a standard portfolio and in this regard should be familiar to a potential investor in terms of risk behaviour.

5.7. Risk Effects in Practice

5.7.1. Risk Premium

In the previous section we have shown that whilst the effects on the CLTCMV are amplified in a mortgage swapping security, this is actually not the case for the LGD. The risk of the security is higher, but the risk is not more sensitive to house pricing changes than a standard security.

Of course, an investor will still expect a premium to compensate for the increased risk. While we leave product pricing outside of the scope of this thesis, we have clearly shown the financial benefits of mortgage swapping for the bank in Section 5.2. In this regard, there is a room to offer investors a premium. This premium will continue to exist as long as the rules imposed by supervisors do not properly reflect the risk of the product to which they assign a risk weight.

5.7.2. Housing Price Changes and Mortgage Distribution

In the previous section we have considered the impact of housing prices on the LTVs and LGD of a mortgage portfolio and how this reflects the risk. However, thought should be given as to the impact of house price changes on the distribution and transfer of mortgages between the bank and the SPV. What happens if market prices increase sharply? Would mortgages be transferred to the bank immediately?

This would depend on the design of the mortgage swapping rules. As stated in the previous section the value of the property used for the determination of the LTV for the bank will be the value measured at origination. Any price chances would thus not be reflected in the LTV.

However, for the mortgage swapping system -in an attempt to more properly reflect risk- one might make use of the current market value of the asset. In this case, housing price increases will decrease the LTV and mortgages might be automatically moved from the SPV to the bank. What happens if -following this increase- the market falls again, prices decrease, and these same mortgages return to their previous LTV levels?

In this case we might imagine one of two things happening depending on the design of the system. In one case, the bank might simply accept that the LTV levels have increased and accept the higher capital costs that accompanies that.

We might also imagine that mortgage swapping is continuous in both directions. If housing prices fall to such a degree that LTVs rise, then mortgages might simply be transferred from the bank to the SPV again.

Overall, we deem the risk in this LTV bucket (∼50% - 60%) not very important as the LGD is zero. Also, any changes in short time-spans will be rather minor and will be likely be trumped by other effects such as loan pre-payment or annuity payments.

6 The Effects of Different Methodologies on the RW of a Mortgage Portfolio

In the previous chapters we have seen the effects that securitisation, mortgage splitting and mortgage swapping might have on a bank's balance sheet and ROE. We have worked mostly with simple "micro-scenarios" as to illustrate the impact clearly. In this chapter we will look at the effects of these methodologies on the RW of a bank and translate these effects to a representation of reality by examining an ABN AMRO securitisation portfolio.

This will be done in order to answer the third research subquestion:

What effect do different new securitisation methodologies have on the risk weighted assets of a bank's mortgage portfolio?

In the first three sections we will analyse the effect that the changing Output Floor in Basel IV will have on the RWA of this portfolio as compared to Basel III if it were not to be securitised.

In the sections that follow we will securitise this portfolio and determine the effects it has on the RW.

6.1. ABN AMRO Security

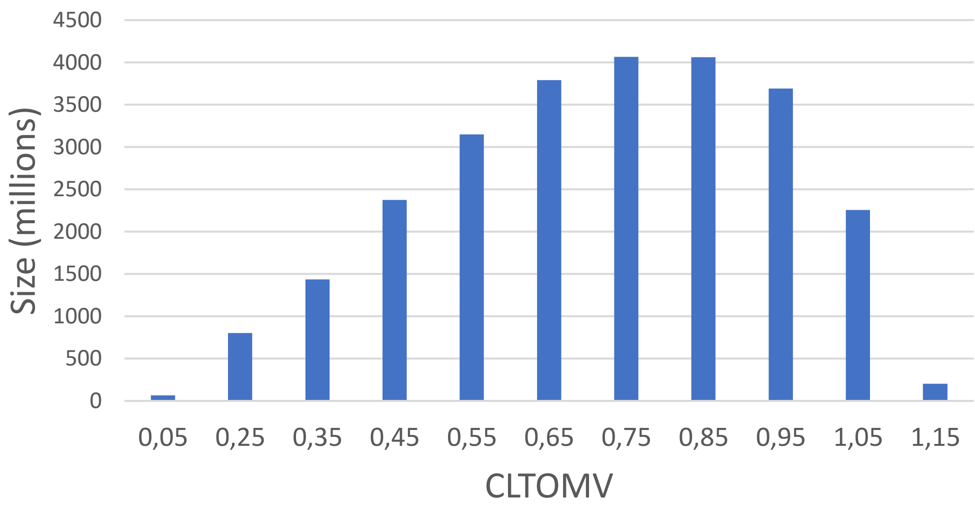
ABN AMRO has a "Dolphin Master Issuer Programme" with a total outstanding amount of 22 billion euros consisting of around 150,000 mortgages. Data on this mortgage is published monthly and consists of a variety of distribution data (both in regards to number of mortgages and total value of mortgages) in various tranches of LTV, Tenor, IR, Loan size, etc.

Using the data on the distribution of the 'Current Loan to Original Market Value' (CLTOMV) amongst their mortgages we built a model which reflects the reality of a bank's mortgage portfolio and its effect on the RWA. This in order to determine the effects of the SA versus the LSA as well as the effects of securitisation.

Ideally, we would have used a large sample of real mortgages for this scenario. However, this data was unavailable at Deloitte and its attainment was not considered worthwhile. We consider the ABN AMRO Security to be a proper reflection of the Dutch mortgage market. A large sample of real mortgages would have allowed for more granularity in our results as the ABN AMRO Security solely provides averages and data buckets. While less ideal, the data it provides is sufficient and allows us to answer our research questions and provide proper insight.

Presented in Figure 6.1 is the distribution of the CLTOMV of the mortgages. These were given in ranges (0-10%, 10-20%, etc) but the midpoint was chosen to allow for easier calculations in the steps that follow.

Figure 6.1.: ABN AMRO security mortgage size distribution



6.2. A-IRB

As we have briefly described in Section 1.1.1 the effect of Basel IV on the capital requirements will be driven by the introduction of a capital floor. From 2027 hence 72.5% of the Standardised RWA will be set as the floor of a bank's RWA, even if the banks A-IRB approach sets the total RWA lower.

To be able to compare the two we will first determine the RWA floor of the previously described mortgage portfolio as given by an A-IRB approach.

A-IRB approaches can be incredibly complex and will differ depending on a great range of variables, both of which are mostly unknown to us. In this case we will determine the A-IRB RWA by multiplying the total portfolio size by the industry's average A-IRB weight for residential mortgages. While ABN AMRO's specific A-IRB weight could have been used we will use the industry weighted average as to give a better picture of the entire industry. This is done as ABN AMRO is a bit of an outlier with an absolute difference of roughly 3% compared to the other banks. The A-IRB of the residential mortgage portfolio of a bank is found as follows:

$$\text{A-IRB Weight} = \frac{\text{Risk exposure amount}}{\text{Exposure Value}} \tag{6.1}$$

The data for these values were pulled from the 2018 EU-wide transparency exercise results. (EBA, 2018a, 2018b, 2018c)

Table 6.1.: A-IRB weights of Dutch banks

Bank	Exposure value	Risk exposure amount	Risk weight
ABN AMRO	158,092	16,481	10,42%
ING	280,753	38319	13,65%
Rabobank	198,584	26591	13,39
		Weighted average	**12,77%**

The multiplication of the weighted average A-IRB weight by the total portfolio size of 26,232 million gives a RWA value of 3,350 million.

6.3. Capital Floors of the different RW Approaches

From the CLTOMV distribution of the portfolio we can calculate the RWA of each CLTOMV tranch and from that the total RWA by summing all tranches. We do this using the Basel III SA, the Basel IV SA, and the Basel IV LSA. The formulas used for calculating these are given below, where:

c stands for a CLTOMV tranche,

V_c stands for the total value of the mortgages in tranche c,

and the range of values for CLTOMV and their total values are given in Figure 6.1.

$$\text{RWA Basel III Standard approach} = \sum_{c=0,05}^{1,15} V_c \cdot 35\% \tag{6.2}$$

$$\text{RWA Basel IV Standard approach} = \sum_{c=0,05}^{1,15} V_c \cdot RW_c \tag{6.3}$$

For the LSA different formulas will apply to different LTV buckets. For this reason, the calculation is done in multiple parts. First, we will determine the sizes of the <55% share and the >55% share separately.

Where CLTOMV=0,55 a slightly different approach has to be used as originally the data was given in ranges (e.g. 50%-60%.). To try to be as accurate as possible half the CLTOMV of 0,55 is therefore considered to have a CLTOMV of 0,5 and half is considered to have a CLTOMV of 0,6.

Table 6.2.: Basel IV LSA formulas for different LTV buckets

LTV	20% RW	75% RW
$< 0,55$	$\sum_{c=0,05}^{0,45} V_c$ (6.4)	0
0,55	$(0.5 + (1 - \frac{0,6-0,55}{0,6})) \cdot V_{c=0,55}$ (6.5)	$\frac{0,55}{0,6} \cdot V_{c=0,55}$ (6.6)
$> 0,55$	$\sum_{c=0,65}^{1,15} (1 - \frac{c-0,55}{c}) \cdot V_c$ (6.7)	$\sum_{c=0,65}^{1,15} (\frac{c-0,55}{c}) \cdot V_c$ (6.8)

The RWA for the LSA is then:

$$\text{RWA LSA} = 20\% \cdot (eq(6.4) + eq(6.5) + eq(6.7)) + 75\% \cdot (eq(6.6) + eq(6.8)) \tag{6.9}$$

Using formulas 6.2, 6.3 and 6.9 we can populate Table 6.3. We can determine the capital floor by multiplying the RWAs by 72,5%.

Table 6.3.: RWA for the different RW measuring approaches

Method	RWA	Floor at 72,5%	Relative difference with IRB
IRB	3,350		
Basel III Standard	9,181	6,656	98,7%
Basel IV Standard	9,340	6,772	102,2%
Basel IV Loan Splitting	8,529	6,183	84,60%

The large effects that Basel IV might have upon the capital requirements of bank's mortgage portfolios is once again clear.

6.4. Mitigation

Through the use of securitisation these effects can be mitigated and the capital floor can be lowered. We will use three different forms of securitisation each ranging from 10% securitisation of the total portfolio value to 100% of the total portfolio value.

A description of how the three methods are applied and some caveats are given below.

- Standard securitisation
  Securitisation is applied blindly with no preference for any LTV tranches. Any decrease in RWA will thus be linear.

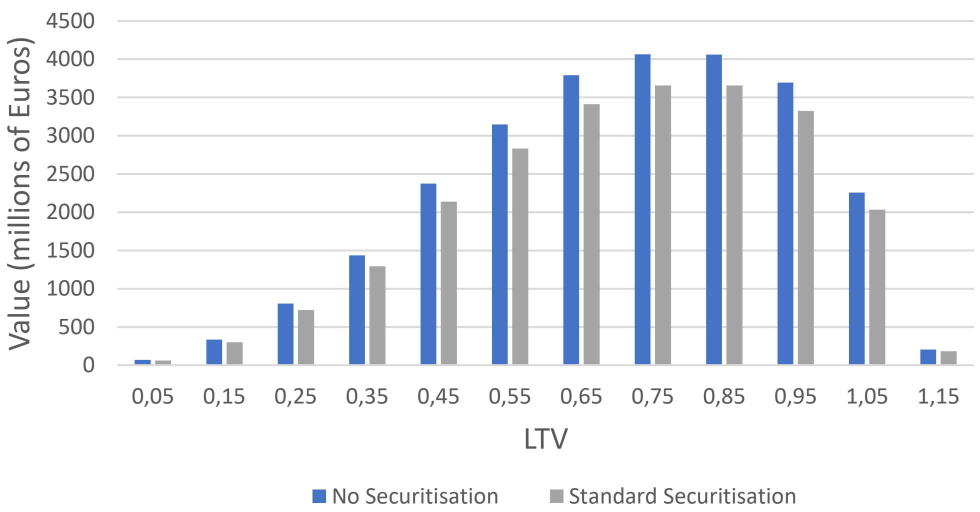
- Mortgage Swapping
  Securitisation is applied starting with the mortgages with the highest LTVs first. As the percentage of securitisation is increased mortgages with lower LTVs are securitised as well. This until the point is reached where no mortgages with a LTV lower than 55% are available after which securitisation with mortgage swapping is no longer deemed possible and further securitisation has no effect.

- Mortgage Splitting
  Securitisation is applied starting with the top parts of the highest LTV mortgages first. This is applied until there are no longer any top parts left after which further securitisation has no effect.

At first we will present three graphs showing the effects of these securitisations on the values of the different LTV tranches by securitising 10%. Subsequently we will present a graph with the effect of different securitisation levels on the RWA.

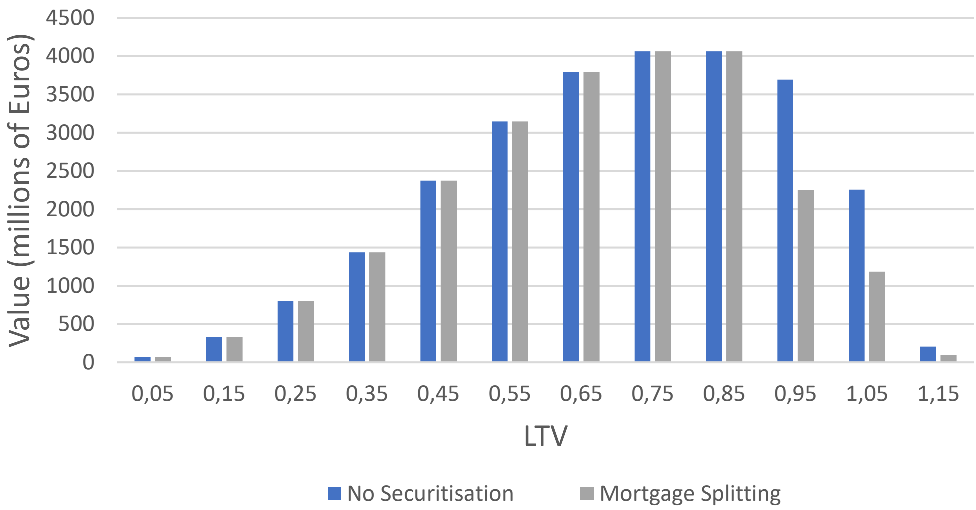
Shown in Figure 6.2 is the distribution of the original mortgage portfolio and the mortgage portfolio after standard securitisation of 10% of the total value. Effects are similar for mortgages of all LTVs: they all decrease in size by 10%.

Figure 6.2.: Securitisation of 10% of Value - Standard Securitisation



In Figure 6.3 10% is securitised but only of mortgages with a high LTV. Mortgages with a LTV of 1,05 and 1,15 are all securitised as well as a small fraction of mortgages with a LTV of 0,95.

Figure 6.3.: Securitisation of 10% of Value - Mortgage Swapping



In Figure 6.4 10% is securitised but only the parts of mortgages with a high risk weight according to the LSA, starting from the highest LTV mortgages. It can be seen, as compared to the mortgage swapping approach, that part of the 1,05 and 1,15 LTV mortgages still remain but now the 0,95 LTV mortgages are also partially securitised.

Figure 6.4.: Securitisation of 10% of Value - Mortgage Splitting (top)

6.5. The RWA effects

The effects on the RWA of the security with different degrees of securitisation are shown in Figure 6.5. The RWAs were calculated using the method and formulas described in Section 6.3.

Plotted are:

For the A-IRB approach

- Standard Securitisation

For the SA (with a 72.5% loan floor)

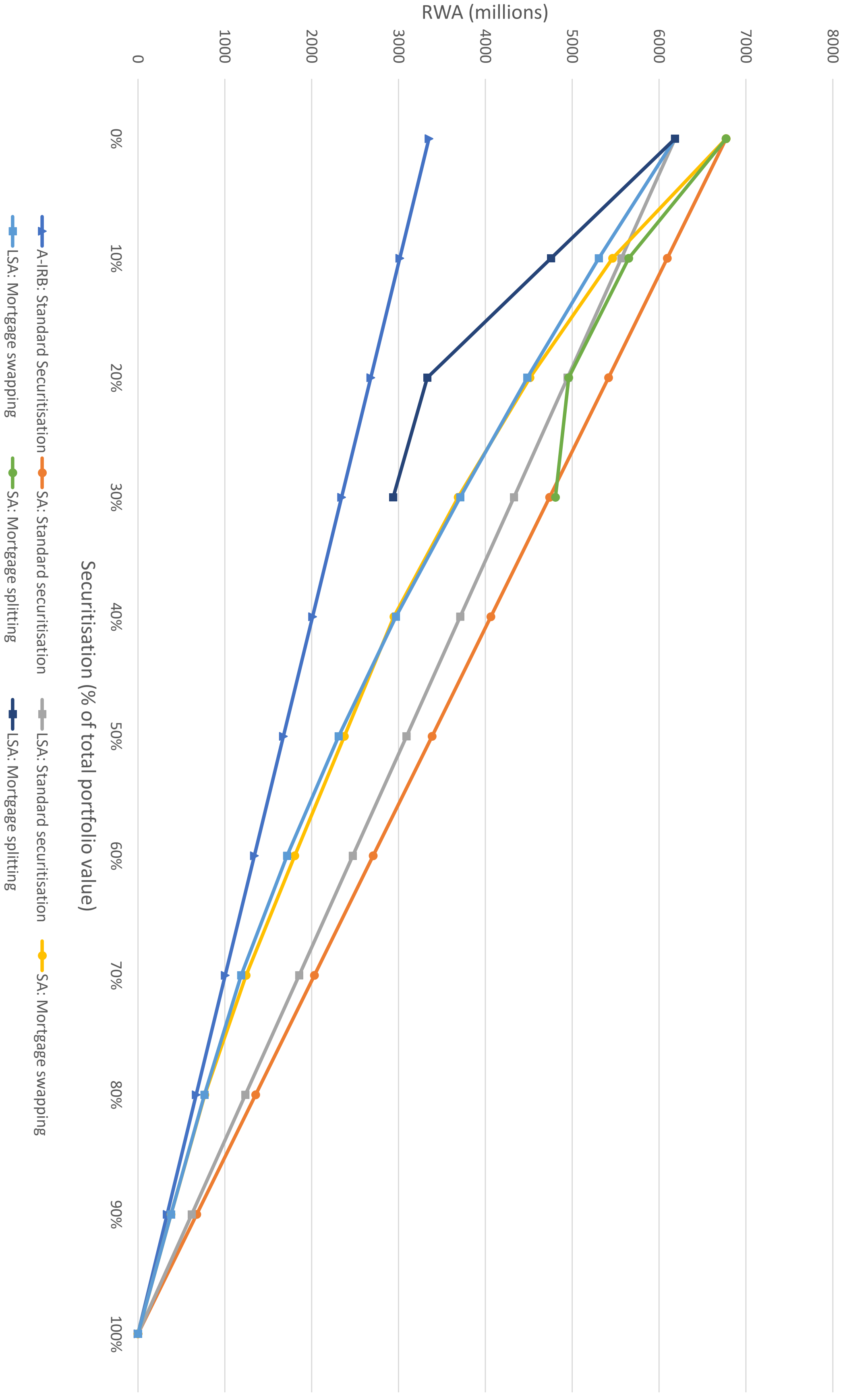
- Standard securitisation
- Mortgage swapping
- Mortgage splitting

For the LSA (with a 72.5% loan floor)

- Standard securitisation
- Mortgage swapping
- Mortgage splitting

For the A-IRB approach only standard securitisation is plotted as this is the only method that we can provide estimates for. The A-IRB approach would definitely give different values given the use of mortgage swapping or mortgage splitting, but as we are not able to use a bank's actually internal models we can not calculate these. Even if we were able to, these are not deemed very relevant. The reality is that the 72.5% floor will soon be active and will be higher than the A-IRB for all scenarios. Mortgage swapping and mortgage splitting might provide decreased A-IRB weights as compared to Standard Securitisation but this is irrelevant given the upcoming regulatory changes.

Figure 6.5.: The value of RWA of a mortgage portfolio as measured by the A-IRB approach for various degrees of standard securitisation and the implied value of RWA floors of various securitisation methods as weighed by the LSA and the SA



In Figure 6.5 we see that the A-IRB is lowest at all securitisation percentages, showing us that there will always be an increase for banks when the capital floor is introduced no matter the method of securitisation.

The mortgage splitting methods end at 30% securitisation due to the fact that only loan parts above a LTV of 55% are sold and those are of course finite. At this point one could opt to continue with standard securitisation.

We see that in almost all cases the LSA gives a lower RWA than its SA counterpart. This was as to be expected, as we saw in Figure 4.1 that for most LTVs the LSA had the lower overall RW as compared to the SA. Especially for mortgage splitting this difference is pronounced as this methodology was designed to take advantage of the LSA.

It is clear that mortgage splitting results in the fastest decrease in RWA for the mortgage portfolio. This is followed by mortgage swapping and then Standard Securitisation. This is as to be expected, as mortgage splitting gets rid of the highest RW mortgages (or mortgage parts) first followed by mortgage swapping and standard securitisation.

The most interesting part of this graph is the part at 20%-30% securitisation, as this is where the LS: mortgage splitting line approaches the IRB line. It is at this point where the gap between IRB and the upcoming floor is smallest without having to sell a very significant portion of all mortgages. The use of this method might thus allow a bank to minimise the impact of Basel IV and get results close to the A-IRB.

7 Conclusion

The goal of this thesis was to investigate the mitigation of Basel IV's effects on the mortgage portfolios of Dutch banks through the use of innovation securitisation methodologies as supported by a Blockchain environment.

In this chapter, we will evaluate whether we have reached this goal by presenting our main findings in our attempt to answer the research question we have posed. We will do so by going through each subquestion individually, finally concluding this research by answering our main research question.

7.1. Conclusions to the First Research Question

What are the benefits and possibilities of securitisation in a Blockchain environment?

In our first chapter we have laid out the current state of securitisation in Europe and the drive of various institutions to improve the securitisation market. This acted as a diving board from which we could analyse the benefits that the Blockchain might provide in this regard and how such a system might function. These benefits were listed but the three most important areas were highlighted:

The **data sharing, transparancy and reliability** that Blockchain provides allows for a better and more secure system in which data can be trusted to be current and correct.

Smart contracts will allow for the automation of the securitisation environment and increase the reliability of the various processes.

Tokenisation will allow for the easier and definite tracking of individual mortgages and their properties.

Using these three different areas we imagined an improved securitisation environment and discussed various methodologies.

From our research it is clear that if implemented the Blockchain might introduce a wide range of benefits and possibilities to the current securitisation environment. These align very well with the current needs of the securitisation environment as well as the wants of regulators for “Simple, Transparent and Standardised” securitisation which would easily be ensured through the use of Blockchain. Factors such as increased reliability and decreased costs through clarity and automation will make securitisation more attractive to both originators and investors.

Also, the digital environment would allow for improvements upon the current securitisation methodology. The complexity of current securitisations, the lack of liquidity and the time it takes to follow a securitsation process limits certain interesting other options. Here we introduced the new possibilities of mortgage swapping and mortgage splitting.

7.2. Conclusions to the Second Research Question

What effect do different new securitisation methodologies have on the return of equity of a bank looking to fund additional mortgages?

In Chapters 3, 4 and 5 we sought to answer the second research question. This was done by first constructing a model on which various securitisation methodologies could be tested. A model which to our knowledge is based on the methods applied by the industry.

The theoretical ROEs for the new methodologies were not only tested but the methodologies were also examined and explained as to get an understanding of their functioning and the possible risks involved.

From the ROE results we can conclude that there are clear financial benefits to both mortgage splitting and mortgage swapping.

As for mortgage splitting, in Table 4.11 we’ve shown an increase of 2,3% if mortgage-splitting is used instead of standard securitisation as both measured by the LSA. Although not the goal of this thesis, the same table also shows the increased ROE when the LSA is employed overall. This holds up for most LTVs as is shown by the LTV variation graph in Section 5.3.

The benefits for mortgage swapping were shown to be even greater, increasing the ROE by 15,2% as shown in Section 5.2. However, in the Mortgage Swapping chapter we also examined the very important caveat that a re-financing of mortgages would actually lead to a decrease in ROE if mortgage swapping is employed.

Both methods are dependent on whether they will be technically feasibly, allowed by the regulator, and finally if these products can be marketed to and bought by investors. In our qualitative analysis we found no significant problems. As for their financial feasibility there are a number of shortcomings to the methods we used and thus the ROEs we calculated, though we will comment on these in the next chapter.

7.3. Conclusions to the Third Research Question

What effect do different new securitisation methodologies have on the risk weighted assets of a bank's mortgage portfolio?

In order to answer our third research question we moved from our own imaginary balance sheets towards a model consisting of data from ABN AMRO's current security portfolio.

We first re-identified the large effects that Basel IV's output floor might have on the capital requirements of banks. Subsequently we identified the effects of different securitisation methodologies on the RWA of ABN AMRO's current security portfolio.

Mortgage splitting and mortgage swapping were shown to more than proportionally reduce the RW of a bank's mortgage portfolio, as opposed to the linear effect of standard securitisation. For mortgage splitting the effect was so pronounced that we neared the RWA of the A-IRB approach. In mortgage splitting (and to a lesser extent mortgage swapping) we thus find a possible means of mitigating these new capital requirements.

7.4. Conclusion

To what degree do innovative securitisation methodologies as supported by a Blockchain environment allow for the remediation of Basel IV's effects on the mortgage portfolios of Dutch banks?

From our findings we have answered the three subquestions, and we can state that a Blockchain environment might provide a great range of benefits, of which most interesting for the scope of this thesis are the new securitisation methodologies that we identified.

We have -through methods also used by the industry- shown the positive effects of mortgage splitting and mortgage swapping on the ROE of mortgages and the large effects that they have on the total RWA of a bank's mortgage portfolio. The effects on the RWA floor were so pronounced for mortgage splitting especially that the RWA given by the A-IRB approach was approached. We find this the most important finding of our research, as it is the introduction of the capital floor that will have such a large impact on Dutch banks.

In this research we have also identified various factors that are vital for these methodologies to become possible, such as how assets might be split amongst investors or the effects on the risk level of the product. These were found to be reassuring and from a risk-perspective enforce the possibility of these methodologies.

We thus conclude that the innovative methodologies we have researched are in theory incredibly promising, and to a great degree they might allow for the mitigation of Basel IV's effects.

From our findings, we conclude that securitisation in the Blockchain and the new methodologies amplify the current benefits of securitisation without compromising the regulator's goal of safer and more stable banks.

8 Discussion and Future Research

The methods used in this research are thought to reflect well the financial implications of securitisation. However, some factors were unaccounted for. Amongst these are the present value and the costs of securitisation. As we have commented before, given the lack of knowledge, know-how and existing models (especially in the new Blockchain environment) these were not possible for us to determine. In this regard we see our research as exploratory, though for more reliable figures on the matter a bank must do its own research as to determine how these factors might determine the attractiveness of some securitisation methodologies.

Some other factors were also not properly taken into account, such as the liquidity risk involved in financing a mortgage (which we simplified), certain more qualitative benefits of securitisation such as freeing up capital for growth, or the benefits of securitisation being an alternative source of funding when other sources might be unavailable. These will strongly differ per bank and per current economic environment.

These effects should be analysed and if possible quantified, though we see no reason as to why the lack of inclusion of these factors might harm the reliability of this research. They are factors mostly relating to the attractiveness of securitisation overall. It is a given that securitisation is employed by Dutch banks, and this research merely identifies that relatively other securitisation methodologies might provide greater benefits as compared to the standard form of securitisation currently employed.

A very important factor that does pertain to our particular securitisation methodologies is the increased risk that these offer to investors. For this, investors will demand a premium as to compensate for these risks. This will increase the costs for the bank and thus decrease the ROE. The ROEs illustrated here do not take this premium into account and can thus be considered inflated. However, as long as the regulator overestimates the risk of Dutch mortgages a benefit to risk transferral will continue to exist.

Another omission in this research were interest rate variations and their effects. The cost of interest rate risk were incorporated into the cost of funding through the use of interest rate swaps, but the possibilities of interest rate mitigation through securitisation were not identified. These possibilities lie in part already in standard securitisation, but the methodologies introduced might also prove attractive in this regard. Mortgage swapping will likely move mortgages with a high tenor to the SPV, while mortgage splitting could not just be performed on the loan itself but perhaps on the tenor of the loan. We leave further considerations of these possibilities to future research.

We must acknowledge in our writing a relative lacking knowledge of the operational benefits that the Blockchain might provide. Whilst the theoretical benefits and the workings of a Blockchain are understood, the actual practical effects of "Securitisation in the Blockchain" are understood only superficially. While we don't deem this necessary for the scope of this paper, a better understanding of these effects or perhaps even a testing ground for these new methodologies would have greatly increased the reliability of the results and confirm that these methodologies are attainable.

For both methodologies introduced the legal ramifications (e.g. true sale) as well as the approval from banking regulators remain completely unknown. Further research on this topic must be performed before further considerations as to the implementation of these methodologies can be made.

Thought has been given in this thesis to the possible attractiveness of these products, but this has been mere speculation. Similarly, no quantitative analysis has been done on the possible pricing of these products and what effect this might have on their attractiveness to investors. The increased risk of the products investigated will surely have an effect, though we can also imagine that the benefits provided by the Blockchain such as increased liquidity and increased reliability might make securities more attractive and affect their pricing, as well as possibly open up investments in securities to new parties. This remains a point yet to be researched.

Finally, if the industry interest is sufficient, some simulation should occur as to the exact benefits of each methodology encompassing more than just the ROE as a result of a static balance sheet and income statement. If factors such as present value, operational costs, liquidity risk, and interest rate risk are included a proper study could be done as to the benefits of the securitisation methodologies. This modelling would have to be done with proper support from a bank both in regards to the methods used and the data required.

Basel

A

In this appendix chapter we give a quick overview of the banking book and of Basel. Given that Basel IV is introduced rather elaborately in the main body of this thesis it is not a necessary read but might give the reader some wanted background knowledge.

A.1. The Banking Book

The instruments of a bank are held either in the banking book or the trading book, a distinction made as a response to regulatory demands.

Instruments in the banking book are meant to be held to maturity, while instruments in the trading book might be actively traded. For this reason the current market value of an instrument in the trading book is highly relevant, while that of an instrument in the banking book is not. The value of instruments in the trading book must be determined daily and any changes must be recognised in the profit and loss account of the bank (Basel Committee on Banking Supervision, 2016). Instruments held in the trading book are -amongst others- meant for short-term resale, profiting from short-term price movements, locking in arbitrage profits, or for hedging the risk to which the bank is exposed to by the types of instruments previously mentioned. Examples of instruments held in the banking book are instruments designated for securitisation warehousing, real estate holdings, or retail and SME credit (Basel Committee on Banking Supervision, 2016).

Given their different natures, instruments in the banking book and the trading book are subject to different regulatory requirements and laws, which are typically outlined through regulatory frameworks. The most important regulatory frameworks are those of “Basel”.

A.2. Basel I, II, III

The Basel Committee was established in 1974 by the central bank governors of 10 different countries as a response to disturbances in international currency and banking markets. Their focus was to both ensure that all banking establishments would fall under supervision as well as to ensure that that supervision would be adequate and consistent across member jurisdictions (Basel, 2018).

The first documents drafted by the committee focused on its basic principles, but in the early 80s it was recognised that there was a need for international capital requirements which was worked towards in 1988 by the issuance of the Basel Capital Accord. In this, a framework was presented for capital adequacy calculations (such as risk weights by category of on-balance and off-balance sheet assets) as well as a requirement to hold a total capital equivalent equal to at least 8% of the risk-weighted assets (RWAs). This later became known as Basel I (Basel Committee, 1988).

In 2004 Basel I was revised in order to strengthen the international banking system as well as to ensure that the capital adequacy regulations would not lead to competitive inequality among banks. This rework became known as Basel II. In it, the three pillars were introduced, namely: minimal capital requirements, supervisory review, and market discipline. On these pillars the new and revised framework was based. It also introduced a range of options for determining the capital requirements for credit risk through an internal ratings based model and addressed market risk and operational risk (Basel Committee on Banking Supervision, 2004).

Basel III was a response by the Basel Committee to the 2008 financial crisis. Logically, the main focus was the avoidance of a similar crisis in the future. Implemented changes include a counter-cyclical buffer that is to be held by banks to prepare for downturns in the economy as well as a SA for measuring counterparty credit risk exposure. Also, new standards were defined for margin requirements for non-centrally cleared derivatives as well as capital requirements for bank exposures to central counterparties. In the current year of 2019 Basel III is still being fully deployed (Basel Committee on Banking Supervision, 2018).

All different forms of Basel are not law, they are merely sets of internationally agreed standards. For it to become law it has to be applied by national governments or for example the EU, as is done in the Capital Requirements Regulation 2013 (CRR), which reflects Basel III rules on both capital measurement and capital standards. As such, it is the status quo for banks in regards to these two factors.

B Securitisation

As stated in the previous chapter on Basel, assets on the banking book such as loans and mortgages are subject to regulatory oversight. This mandates a bank to hold a certain percentage of the value of these risky assets in Common Equity Tier 1 Capital as a risk buffer. Whilst these regulations are rightly put in place for the stability of the financial system, it puts pressure on the banks margins as holding capital is costly. Given these costs, banks might be forced to adapt their business models unless some of these effects can be mitigated.

There are two options for a bank to attain the required capital requirements as explained by Affinito and Tagliaferri. It is an alteration of either the numerator or enumerator of the required capital formula:

$$\text{Required capital ratio} > \frac{\text{Common Equity Tier 1 capital}}{\text{Required capital}} \tag{B.1}$$

The the first option would be to adjust the numerator by simply -though costly- retaining more capital. This would bar a bank from investing the capital into profit-generating projects. The second option would be to decrease the level of required capital, either by decreasing the assets held or shifting into lower risk-weighted assets or making the assets more profitable. For example, a bank could move away from the mortgage market or increase the interest rates on mortgages and thus transfer the increased costs to the consumer (Affinito & Tagliaferri, 2010).

It goes without question that shifting away from the mortgage market or increasing costs are not preferred by the bank, as currently the mortgage market is still vastly profitable and they want to maintain their market share. Another option however is to reduce the denominator through a different method: through the use of a process called securitisation. In this process financial products called securities are created from the cash flows of assets, which can amongst others include loans, mortgages, or bands. These securities are then sold to investors. Securities based on mortgages are called Mortgage-Backed Securities while those backed by other assets are called Asset-Backed Securities. Owning a security gives the right to a certain return with the underlying asset as collateral. For a bank, the securitisation process serves as an instrument for transferring credit risk (Hull, 2015). The use of processes such as securitisation and other financial innovations for the reduction of the regulatory perceived risk and the lowering of the costs associated with this risk is termed 'regulatory capital arbitrage' (RCA). In it, a trade-off has to be made between the benefits of RCA and the structuring costs involved with it (Jones, 2000). An additional benefit of securitisation is the liquidity it provides, as it allows for the conversion of illiquid, hard-to-sell loans into marketable securities (Loutskina, 2011). The benefits to an investor are that if combined in the thousands these assets will be a stable asset base with a low risk profile. Any risk in for example individual mortgages are diversified.

Before the 2008 credit crisis securtisations were becoming increasingly popular. Often in the States banks were no longer the holders of loans as in the "old" banking model, but were the originators and distributors. This led to a model dubbed the "originate-to-distribute" model. Unfortunately, the fact that bankers were no longer the primary holders of these assets meant that there was a bigger incentive to take larger risks on loans and less of an incentive to monitor borrowers. This was an important instigator of the financial crisis (Affinito & Tagliaferri, 2010).

B.1. The Process

The securitisation of assets is not as clear-cut as simply selling off the loans to an investor. The securitisation process usually involves the originator setting up a Special Purpose Vehicle (SPV), an alien entity which buys from the originator (usually a bank) a pool of assets, thus completely transferring these assets to the SPV and removing them from the balance sheet. There are different demands and limitations imposed on a SPV. For one, the bankruptcy of the originator should have no effect on the SPV, due to which the transfer of the assets is set up as a 'true sale'. The SPV might also only be allowed to engage in this one securitisation so that it would not be forced into bankruptcy by other creditors. Also, the SPV is to remain reasonably independent of the originator, for which it might be required to have one or more directors who are independent of the originator (Schwarcz, 2013).

In turn, the SPV finances the purchase of these loans through the sale of asset-backed securities which are bought by an investor.

Before being able to sell these securities they must be evaluated by rating agencies. It is normal for securities to be of good to high-investment grade, with most securities in Europe being rated AAA/Aaa. In order to further ensure a good rating additional credit enhancement might be performed by a credit enhancer. This is a third party who guarantees the credit quality (Choudhry, 2004; Kimber, 2003). Also, to further convince investors and credit enhancers to accept the risk, an originator might transfer assets with a nominal value that is higher than the nominal value of the issued securities. This is called 'overcollateralisation'. A surplus value which can later be recovered (Schwarcz, 2013; Choudhry, 2004).

Typically, the originator also acts as the servicer of the loan portfolio, which means that they are the party tasked with receiving the monthly payments and dealing with the clients. The interest and principle payments are transferred to the SPV which in turn transfers it to investors (Carbó-Valverde, Marques-Ibanez, & Rodríguez-Fernández, 2012; Farruggio & Uhde, 2015).

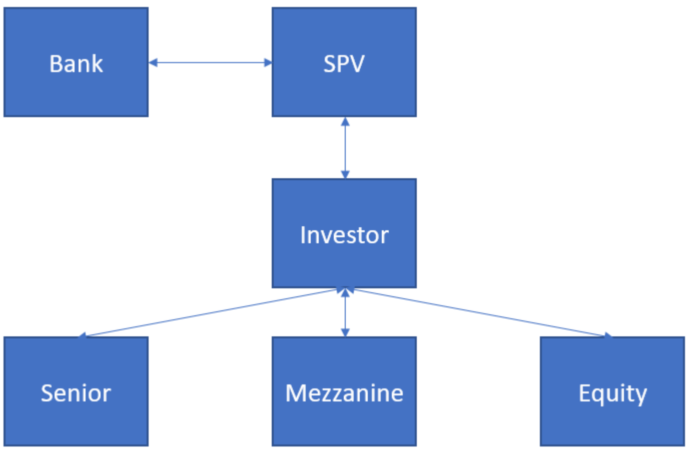
B.2. Senior-Subordinated Structure

The cash flows sold by the SPV are not sold as a single product but are divided into so-called tranches. Often, three tranches are used but this could be any number and the tranches can be subdivided further. These trances are called the senior, the mezzanine, and the equity tranche. A representation of these tranches and a very simplified diagram of securitisation is shown in Figure B.1.

The importance of these tranches is that cash flow is allocated to them in order of seniority. The senior tranche's interest is repaid first, followed by the mezzanine tranch, followed by the equity tranch. The same is done for the principal repayment. This process is often dubbed a "waterfall" or a "cascade". For bearing the risk, the equity tranche and the mezzanine tranche earn a higher interest rate.

A reason for developing these tranches is so that different risk profiles are created for interested investors. Generally, tranches are structured in such a way so that the senior tranch receives an AAA rating and the mezzanine tranche receives a still viable BBB rating (Hull, 2015).

Figure B.1.: Securitisation Structure and Tranches



Blockchain

C

In 2008 Satoshi Nakamoto published his white paper on the Bitcoin protocol and network. Along with it, he introduced the first proper digital currency: Bitcoin. Since then, cryptocurrencies have exploded, not only in the number of cryptocurrencies offered but also in their price. Those who held cryptocurrencies ten years ago might very well be millionaires today. The rising price of these digital coins led to large-scale interest, not only from investors but also from the media.

However, while cryptocurrencies are very exciting, what might be of even more interest is the technology that lies beneath it and the possibilities that it might provide in different business applications: the Blockchain and Distributed Ledger Technology (DLT).

DLT can best be described as a decentralised database or record keeping system with a consensus system (Lai & LEE Kuo Chuen, 2018). It is a database that is stored across a network, with each node of the network containing an exact copy of the database. These nodes can be held by individuals but also by companies or institutions.

When an update is made to the database then -depending on the type of system- some or all parties have to agree that the update is valid. Following this all copies of the database are updated. This decentralised system ensures that no central party can manipulate the database and the data of all nodes is current and correct.

This database can be a host to "tokens". Virtual items that can represent real-life or digital goods, the most common example of course being a cryptocurrency. The Blockchain maintains the ownership information and transaction history of all tokens.

Tokens can also be asset-based. In this case, the token signifies the ownership of an underlying asset. For example, a token could be linked to a house, or to a mortgage. These tokens can be traded amongst the nodes present in the network and thus act as a virtual marketplace of this asset.

The benefits of the use of tokens and coupling these tokens to real-life or digital goods are vast. They are immutable, traceable, can't be double spent, and can be traded in a secure environment without fear of loss.

DLT and Blockchain are often used interchangeably. They are however not equivalent. Blockchain is a form of DLT. All Blockchains are a form of DLT, but not all forms of DLT are considered a Blockchain.

In this thesis no distinction is made between the two, though an explanation of what makes DLT and Blockchain unique is given in the next sections. While a choice for what form of DLT is to be used would of course have to be made in the case of an actual implementation, there is no need for the distinction in this thesis. The benefits and possibilities mentioned can be considered to be general features of both the Blockchain and DLT with each having their succinct benefits. In this thesis the technology will be referred to as 'Blockchain' as this is more colloquial.

C.1. Distributed Ledger Technology

Blockchain is a form of distributed ledger technology (DLT). To properly reflect upon one aspect of this technology is to understand databases and the different versions that exist.

- Centralised database: a classical database. There is one central party has a server hosts the data, and all other nodes connect to it. This leaves a database open for manipulation and censoring by this central party.
- Decentralised database: in terms of permissions this database works in the same manner as a centralised database, information however is hosted in various servers at various locations and nodes can connect to any of them.
- Distributed database: a database in which information is stored across a network, each node containing an exact copy of the database

The concept of a distributed system such as DLT is not entirely new, as distributed database management systems have existed since the 1990s. These were distributed databases that stored data across a common network instead of at a central location (Meunier, 2018). These databases were controlled environments in which participants could alter or read the database depending on their permissions. However, included in these databases was no form of consensus protocol: any participant could alter the database and act in bad faith. Thus, these systems were limited to a network of trusted participants.

The distributed ledger technology as we now know it from Blockchain can best be described as a decentralised database or record keeping system with a consensus system (Lai & LEE Kuo Chuen, 2018). A database which in this case is referred to as a "ledger" given that it only tracks transactions. This ledger can be updated by various entities (nodes) who have the right permissions to do so. However, for an update to take effect it must be accepted and agreed upon by the other nodes in the system through a consensus algorithm. When all nodes agree, a new version of the ledger is created and each node will replicate and save an identical copy. From there, the process starts again. The type of consensus algorithms or processes used made differ, such as through the concepts of Proof of Work or Proof of Stake. However, all systems are set up in such a manner that participants acting in bad faith will not be able to adjust the ledger successfully. This is reflected upon further in section C.3.

There are three different types of distributed ledger. These are the following:

- Permissionless, public: This is the type of ledger used by for example Bitcoin. Anyone can view the ledger and all transactions and anyone can write on the network.

- Permissioned, public: A ledger where anyone can view the ledger and all transactions, but only whitelisted participants with authentication can write on the network.

- Permissioned, private: A ledger in which a participants has to be whitelisted in order to both view the ledger as well as write on the network.

The great benefit of a public permissionless Blockchain is that the created ledger (or database) is completely decentralised. There is no central party that can manipulate the database and thus deceit others.

In a private ledger certain limitations are put in place by their very nature. They might be controlled by a central company or organisation and subject to rules and regulations as well as liabilities and obligations that are legally enforceable in the real world (Lai & LEE Kuo Chuen, 2018). All participants of the network however are known and they can be assigned different permissions, such as being able to read or create transactions or execute smart contracts. In this regard they function more like traditional distributed databases and some of the benefits are lost. However, some of the benefits of the technology are still in enforcing auditing, accountability and the automation of business processes (Meunier, 2018).

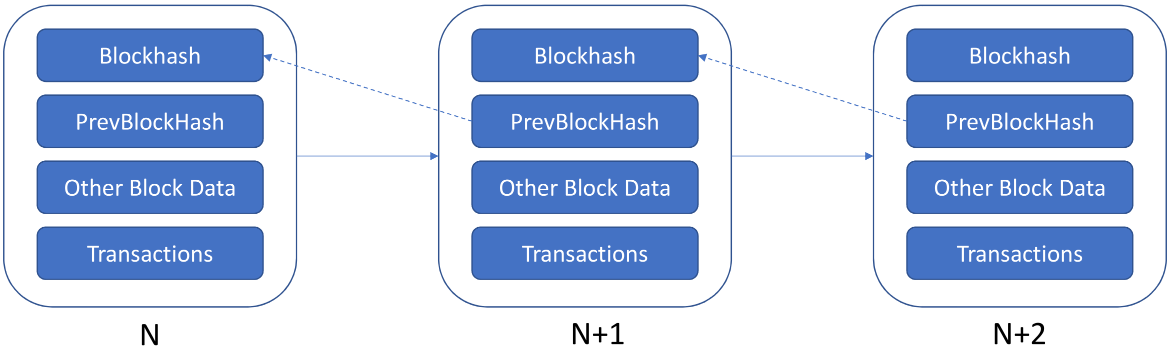
C.2. Chained Blocks

Whilst Distributed Ledger Technology and Blockchain can be used almost synomously, there is one important distinction to make. DLT acts mostly as a database, in which values can be added and altered. However, a Blockchain consists of linked blocks of information and data can only be added in an append-only structure.

A block is a block of data and contains many different elements. While these are all interesting, the only elements that matter to illustrate the workings of a block in a blockchain are the transactions, the BlockHash, and the PrevBlockHash.

Each block contains a certain number of transactions that have occurred. The transactions themselves are given in the "body" of the block, whilst the other fields shown are called the "header". One of the fields in the header of the block is the PrevBlockHash and refers to the BlockHash of the block that came before. In this way, the Blockchain gets the structure of a linked list (Tschorsch & Scheuermann, 2016). This basic principle is illustrated in figure C.1.

Figure C.1.: Structure of the Blockhain



As more blocks are added a longer and longer chain of blocks is formed. At one point the chain was started by the so-called "Genesis Block", the start of the ledger. Each block that is added adds a collection of transactions to this ledger. Together, all blocks in the chain contain the history of every single transaction as well as the order in which they occurred. Through the sum of all these transactions it can be traced not only how much of a cryptocurrency an account owns, but also which specific cryptocurrency coins. A bitcoin can thus be traced from its creation to all the owners it has had over its lifetime.

At any moment in time, mining nodes will attempt to create a block and add this to the existing Blockchain. Whichever mining node manages to do so first will create the new "true" blockchain and further work will be continued based on this chain. However, it is possible that two blocks are created at the same time, thus creating two versions of the same blockchain and "forking" it. In this case, miners can work on either of the forks and add blocks to it. When new blocks are added to these forks a new longest chain is created. Miners will always take the longest chain as the valid one and continue working on it. This introduces a tremendous benefit to the Blockchain version of a DLT. A chain can only grow, and blocks cannot be removed or altered as a block. For a malicious actor to alter any block in the Blockchain, it must not only alter that specific block but also all the blocks that came after it in order to be the longest chain. Given the computational powered involved this is neigh impossible (Lai & LEE Kuo Chuen, 2018). We will comment on this further in the next section.

It is this additional layer of security that in some situations will make Blockchain preferable to other forms of DLT. It mainly allows the environment to be open to anyone, as acting maliciously is made unprofitable due to the work involved to do so.

C.3. Proof of Work and Proof of Stake

In order to alter the ledger a consensus has to reached. However, depending on the system used reaching a consensus might be prone to malicious behaviour. For example, if consensus was simply based on 51% of nodes agreeing, then what would stop someone from setting up thousands of virtual machines, all pretending to be virtual users?

To counteract this potential of voter spoofing, "Proof" has to be given by a node. Multiple proof systems exist, the most popular of which are Proof of Work and Proof of Stake.

In a Proof of Work system a node must run computations on their computer of a piece of data in order to find a solution to a cryptographic puzzle. If they find a solution then a new version of the ledger is agreed upon and based on this version new computations are started (Muzammal, Qu, & Nasrulin, 2019). This computation is costly (in terms of electricity) and a lengthy process given the processing power required, averaging a total of 10 minutes. The speed at which this computation is completed is directly related to the computation power used. The process is dubbed "mining" as nodes are rewarded with a cryptocurrency for their computation efforts. Due to the wide-spread adoption of for example Bitcoin, it becomes neigh impossible for an individual or a company to at any time control more than 50% of the mining capacity. A majority is thus not reached and malicious actions are made nearly impossible.

Proof of Stake is an alternative developed for Proof of Work. One of the main reasons for this is the absurd electricity costs involved in Proof of Work mining. Some state that it's electricity consumption might be as much as the entire country of Ireland or even Denmark (BBC, 2017). In Proof of Stake, "proof" is delivered by the stake that an individual has in a cryptocurrency. Or, otherwise said, the amount of cryptocurrency an individual owns. An important benefit of this system is that the more of the cryptocurrency an individual owns the less likely they are to act maliciously, as any malicious acts would lower the value of their own cryptocurrency holdings.

C.4. Smart contracts

Smart contracts have been gained increased attention since 2014 but were first introduced by Nick Szabo in 1997 in anticipation of what the internet might bring us. He called them a means to "formalise and secure relationships over computer networks" (Szabo, 1997). On the Blockchain, smart contracts are a mechanism by which automatic actions can be run depending on pre-set parameters. They are executed through tamper-proof pieces of code through which credit risk is eliminated. It can be summarised by the concept of an "if then" statement which any programmer might recognise.

The importance of smart contracts lies in the fact that contracts can be executed reliably and without any trust between two parties. Smart contracts will allow for the elimination for third parties such as notaries and will allow for the automatic execution of classic contracts in a "cost-effective, transparent and secure manner" (Locher & Pignolet, 2017).

The level of sophistication of the programming language in which a DLT or Blockchain is written will allow for the use of Smart Contracts. This is the case for for example the Ethereum blockchain which is written on the Solidity language which was built around the use of Smart Contracts, while Smart contracts on the Bitcoin blockchain are very limited (Lai & LEE Kuo Chuen, 2018).

A contract might be written due to which a transaction will automatically take place *if* something else happens. For example, one might emulate a call option:

Party A transfers 1 Bitcoin to party B in return for which a smart contract is set up. *If* the AEX reaches 500 points by next week, *then* 2 Bitcoin will be transferred from party B to A. The data source is a third party, and the contract will either expire within the week or be triggered and executed automatically on the blockchain within the week.

C.5. Tokenisation

Bitcoin is a well-known cryptocurrency and its spectacular rise in value has been reported by even the national media. However, its rise in value however is purely speculative. As a "currency" its value is purely based on its perceived value as is more or less the case with many common currencies. Other cryptocurrencies exist as well, such as XRP from the Ripple Blockchain or Ether form the Ethereum Blockchain. These cryptocurrencies are often referred to as "tokens".

However, two types of tokens exist.

1. "Intrinsic" or "built-in" tokens
2. "Asset-backed" tokens

Cryptocurrencies -which only have a perceived value- are intrinsic tokens, they're "built into" a blockchain.

The second type of token are asset-backed token, which are tokens that give a the owner a claim on an underlying asset (Lewis, 2015). They can be used to represent different types of assets, such as securities, properties, loyalty points, or even other currencies (Buterin, 2014).

The great benefits of asset-backed tokens are similar to those of intrinsic tokens. They are immutable, traceable, can't be double spent, and can be traded without fear of loss. The value of a token depends on the value of the underlying asset that the token represents (Chen, 2018). The most important factor of a token is that it is unique. Tokens can represent virtually any asset, whether that be a material asset or a digital one.

An interesting example is the use of the Blockchain for land registry. In different projects being tested at the moment, a piece of land is represented by a token on a Blockchain. Land ownership is a good candidate for tokenisation given the normally high bureaucratic costs and the need for notary services and a government body in any transaction. Also -especially in developing countries- extortion and various forms of corruption are commonplace and with the loss of papers proving ownership might be difficult. The Blockchain would provide a tamper-proof system with permanent records and an immutable transaction history (Miscione, Ziolkowski, Zavolokina, & Schwabe, 2017).

D Sensitivity Analyses

In this Appendix chapter the sensitivity analysis graphs are shown, as referenced to in the main body of this text.

Figure D.1.: The ROE of different standard approach securitisation scenarios for various mortgage interest rates

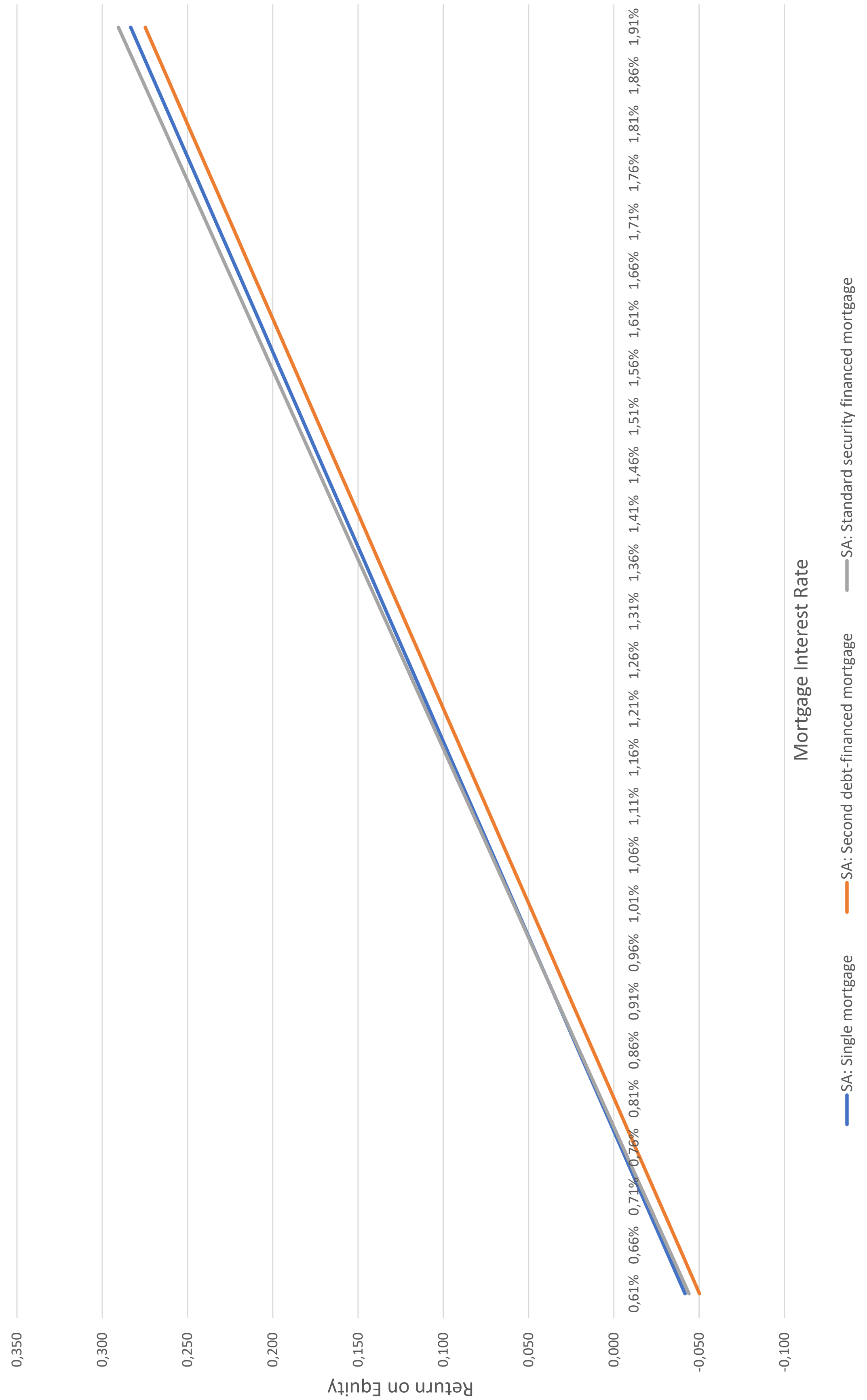


Figure D.2.: The ROE of different standard approach securitisation scenarios for various debt interest rates (with a proportionally adjusted deposit interest rate)

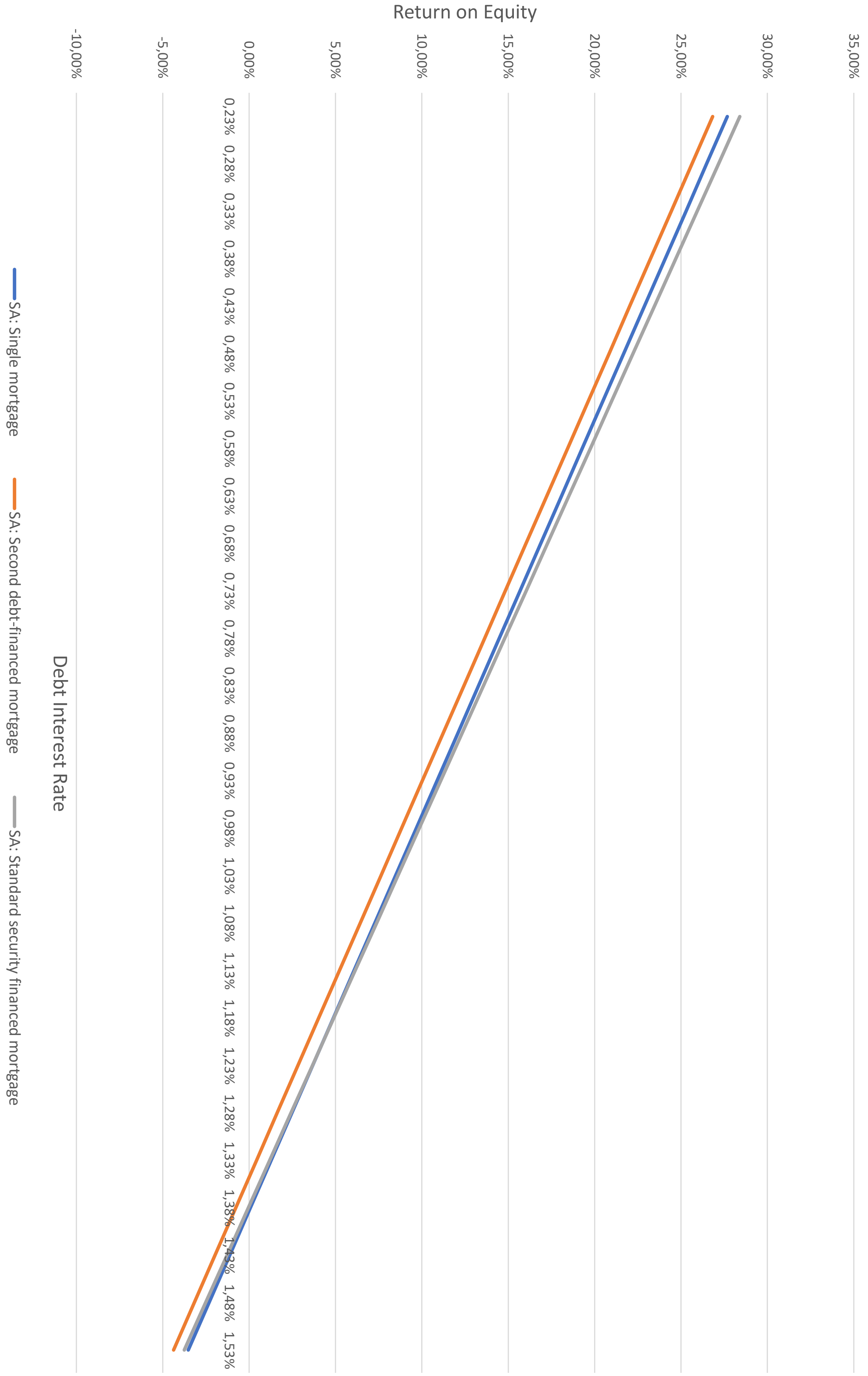


Figure D.3.: The ROE of different mortgage splitting securitisation scenarios for various mortgage interest rates

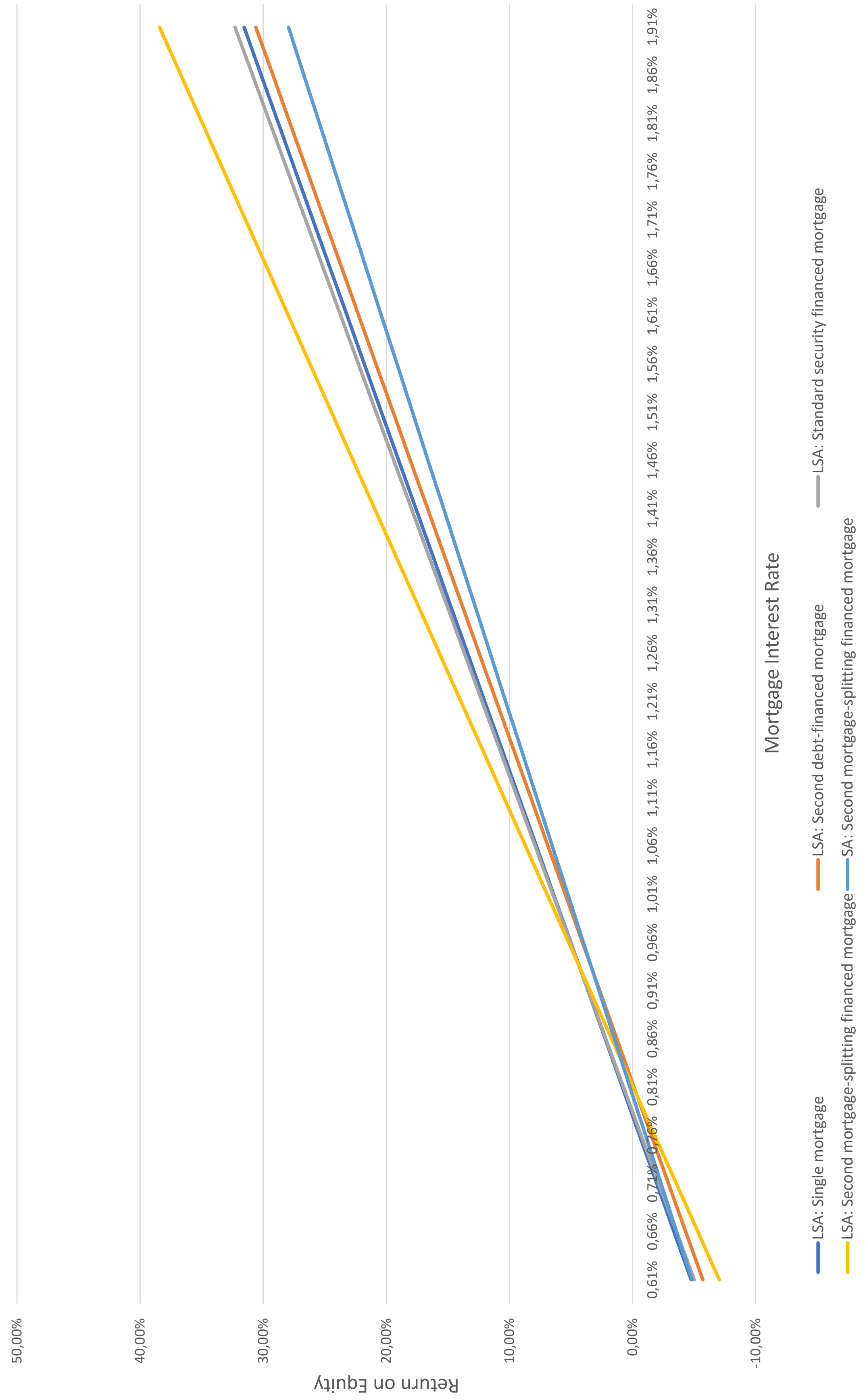


Figure D.4.: The ROE of different mortgage splitting securitisation scenarios for various debt interest rates (with a proportionally adjusted deposit interest rate)

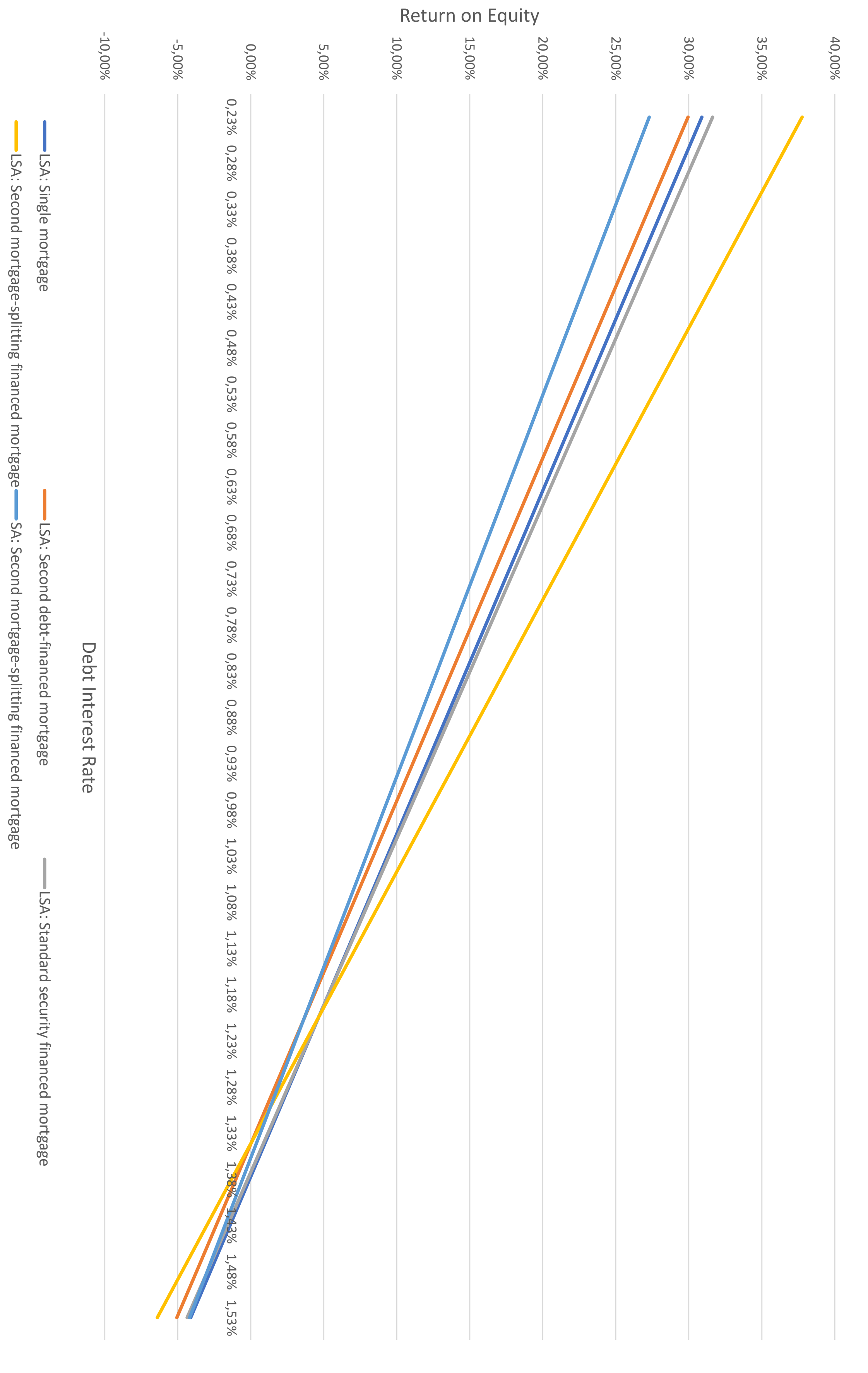
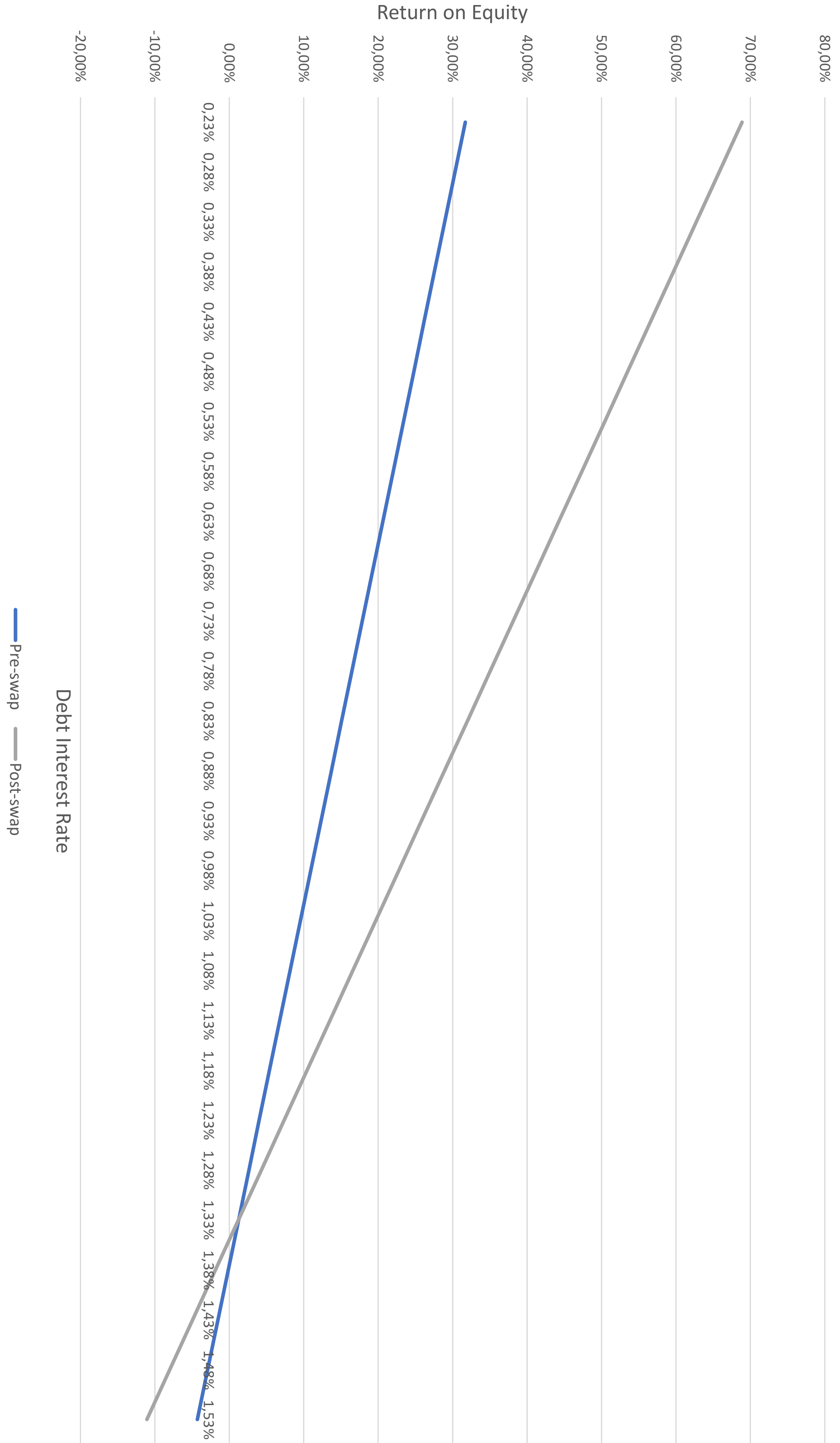


Figure D.5.: The ROE of a pre-swap and post-swap portfolio for various mortgage interest rates

Figure D.6.: The ROE of a pre-swap and post-swap portfolio for various debt interest rates (with a proportionally adjusted deposit interest rate)



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