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Optimal bank bailout policy and merger control in an uncertain economic environment

Glen Vermeulen

Thesis submitted in order to obtain the degree of Doctor in Applied Economics

Supervisors: Prof. dr. Jan Bouckaert and Prof. dr. Peter M. Kort

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Members of the doctoral jury

Prof. dr. Jan Annaert (chairperson) – University of Antwerp

Prof. dr. Jan Bouckaert (supervisor) – University of Antwerp

Prof. dr. Peter M. Kort (supervisor) – University of Antwerp

Prof. dr. Bruno De Borger – University of Antwerp

Dr. Tine Compernolle – University of Antwerp

Prof. dr. Hans Degryse – KU Leuven

Prof. dr. Kuno J.M. Huisman – Tilburg University

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Table of contents

List of tables

List of figures

Nederlandstalige samenvatting

Deze thesis introduceert onzekerheidsoverwegingen in de analyse van bank bailout en fusiecontrole. Meer bepaald onderzoeken we in welke situaties het optimaal is voor een overheid om een falende bank te redden en hoe groot het gerelateerde reddingspakket dient te zijn. Daarnaast gaan we ook na welk remedietype, opgelegd bij mogelijk concurrentieschadende fusies, de voorkeur geniet vanuit een welvaartsoogpunt: omkeerbare gedragsremedies of onomkeerbare structurele remedies?

Hoewel beide beleidsdomeinen op zich weinig met elkaar te maken lijken te hebben, geldt dit niet voor de gestelde vragen. Deze vragen leiden traditioneel immers naar tijdsafhankelijke antwoorden die onderhevig zijn aan veranderingen in de economische omgeving. Dit heeft tot gevolg dat een antwoord dat optimaal is op een zeker punt in de tijd incorrect kan zijn zodra de waarde van een gerelateerde economische variabele wijzigt. Gegeven de snelheid waarmee dit kan gebeuren en de (op zijn minst gedeeltelijke) onomkeerbaarheid van de betrokken beslissingen (bailout, liquiditeitssteun, liquidatie en structurele remedies) is het dan ook nodig om de onzekere economische toestand rechtstreeks in de economische analyse te betrekken. Dit is het onderwerp van deze thesis, met name de dynamische behandeling van de eerder vermelde onderzoeksvragen.

Het eerste hoofdstuk van de thesis ("Reële opties en bank bailouts") start met een uiteenzetting van een door ons voorgestelde bailout beslissingsregel. De regel is gebaseerd op reële optietheorie, een alternatieve methode voor de analyse van investeringsbeslissingen onder onzekerheid die tot betere resultaten leidt dan de traditionele netto huidige waarde technieken indien er sprake is van onomkeerbare en uitstelbare beslissingen. Omdat bailoutbeslissingen kunnen aanzien worden als een investering van de overheid in de economie en bovendien uitstelbaar en onomkeerbaar zijn, is reële optietheorie dan ook een zeer geschikte methode voor het beantwoorden van de beschouwde onderzoeksvraag: onder welke condities is het voor een overheid optimaal om over te gaan op liquiditeitssteun, bank bailout of liquidatie ?

De beslissingsregel gaat uit van de liquiditeitscreërende functie van banken en houdt rekening met de optiewaarde van het wachten op meer informatie inherent aan de onzekere economische toestand die heerst rond mogelijke bankfalingen. Hierdoor komt men tot beslissingen die rekening houden met de mogelijkheid van een zelfstandig economisch herstel/verval om een optimale beslissing vanuit een dynamisch oogpunt te bekomen. In eenvoudige termen uitgedrukt is onze regel er effectief toe in staat om de situaties te identificeren waarin het optimaal is voor de overheid om over te gaan tot liquiditeitssteun, bank bailout of liquidatie, gegeven informatie over verscheidene externe parameterwaarde. Naast de identificatie van deze situaties wordt de regel ook toegepast op 75 bailout cases uit de EU-15 in het crisisjaar 2008 om de correctheid van de geobserveerde beslissingen te bepalen.

Onze resultaten tonen aan dat het effectief mogelijk is om de drempelwaarden te berekenen die noodzakelijk zijn om een oordeel te vellen over de gepastheid van de geobserveerde beslissing. Indien de liquiditeitscreatie van een bank onder de berekende isoleringsdrempel valt is het optimaal voor de overheid om over te gaan op liquiditeitssteun. Eens 'geïsoleerd' is het optimaal om over te gaan op reactivatie (i.e. bailout) indien de de liquiditeitscreatie op termijn terug stijgt tot boven de berekende reactivatiedrempel. Deze houdt net als al de andere drempelwaarden reeds rekening met normale fluctuaties in liquiditeitscreatie. Mocht de situatie inzake de liquiditeitscreatie van de bank echter blijven verslechteren in die mate dat de liquidatiedrempel overschreden wordt, dan is het optimaal voor de overheid om over te gaan op liquidatie. Interessant om hierbij op te merken is dat de liquidatiethreshold niet altijd bestaat, wat wijst op het feit dat een bank effectief te groot kan zijn om te falen (too-big-to-fail) wegens de te grote kost die de overheid aan depositogarantie moet betalen in geval van faling. De drempelwaarden zelf zijn stabiel inzake veranderingen in externe parameterwaarden, wat de robuustheid van onze resultaten versterkt. Vanuit een empirisch oogpunt kunnen we ten slotte besluiten dat de overheden van de EU-15 in het crisisjaar van 2008 in grote lijnen de correcte bailout- en/of liquiditeitssteunbeslissingen hebben gemaakt: in 70 van de 75 onderzocht casussen kunnen de geobserveerde beslissingen als optimaal worden beschouwd.

In hoofdstuk 2 ("Reële opties en bank bailoutgrootte") bekijken we optimaal bank bailout beleid vanuit een ander oogpunt. Terwijl de beslissingsregel van hoofdstuk 1 zich afvroeg of er een bailout zou moeten gebeuren van een gegeven bailoutgrootte, beschouwen we in dit hoofdstuk de bailoutbeslissing als gegeven terwijl we ons afvragen wat de optimale grootte van het bailoutpakket is. Net zoals in hoofdstuk 1 is onze methodologie gebaseerd op de welvaartscontributie van liquiditeitscreatie op de samenleving. Daarnaast bouwen we voort op de reële optieliteratuur inzake capaciteitsbeslissingen om ook deze keer ervoor te zorgen dat er rekening wordt gehouden met de optiewaarde voor het wachten op meer informatie. In tegenstelling tot de vorige keer zal onze methodologie ons nu in staat stellen om niet alleen te bepalen of en wanneer een bailout moet plaatsvinden, maar ook - voor mogelijk de eerste keer binnen de literatuur - hoe groot deze bailout zou moeten zijn.

Onze analyse toont aan dat hogere onzekerheid niet alleen leidt tot een grotere optimale bailoutgrootte, maar ook tot een vertraagde interventie. Dit vertaalt zich in een beleidsimplicatie: wanneer men geconfronteerd wordt met een zeer volatiele en onzekere economische toestand, dan zal de optiewaarde van het wachten hoog zijn net zoals de optimale bailoutgroote. Daarnaast blijkt het soort bank en diens afhankelijkheid van deposito's voor liquiditeitscreatie slechts een zeer kleine invloed uit te oefenen op de optimale bailoutgrootte. Dit betekent dat de bailoutgrootte tussen bv. commerciële banken en zakenbanken niet te veel zou mogen verschillen. Het optimale tijdstip van interventie wordt hierdoor wel beïnvloed, met een later optimaal interventiepunt voor commerciële banken vanwege de grotere efficiëntie van het bailoutmechanisme in dat type banken. Ook vermeldenswaardig is de sleutelrol die het publieke vertrouwen in de capaciteit van de regering om met de crisis om te gaan speelt. Indien dit vertrouwen te laag is, is het zelfs niet eens optimaal om tot bailout over te gaan. Hierdoor is het voor de overheid ook aangeraden om een goede reputatie in crisismanagement op te bouwen, daar dit kan helpen om een crisis efficiënter op te lossen. Tot slot suggereren onze resultaten dat de relatie tussen het optimale interventietijdstip en de optimale bailoutgrootte niet duidelijk is. Indien je je zou focussen op één van deze twee elementen voor de bepaling van het optimale bailoutbeleid, kom je waarschijnlijk tot een suboptimale beslissing vanuit een dynamisch perspectief.

In het laatste hoofdstuk ("Gedragsremedies vs. structurele remedies in fusiecontrole") introduceren we de waarde van flexibiliteit, gerelateerd met de mogelijkheid om opgelegde gedragsremedies in geval van slechte economische omstandigheden op te heffen, in de keuze voor het optimale fusieremedietype. Fusieremedies worden door de concurrentieautoriteit vaak opgelegd indien een fusie zonder beperking aanleiding zou geven tot een significante daling van de concurrentie. Door oplegging van een remedie kan men deze anticompetitieve impact echter vermijden en toch de fusie laten doorgaan. Dit hoofdstuk is er op gericht de voorwaarden te identificeren waaronder de omkeerbare gedragsremedies betere resultaten voortbrengen dan de alomtegenwoordige structurele remedies vanuit een welvaartsoogpunt. We starten hierbij vanuit de assumptie dat na de fusie, de verandering in het verwachte consumentensurplus gelijk moet blijven aan nul - wat in lijn licht met de vaak gebruikte consumentensurplus standaard. Deze aanname leidt ons tot de benoeming van een structureel remedievoordeel: gegeven dat een gedragsremedie kan omgekeerd worden in slechte economische toestanden (met een verlies voor de outsider en mogelijk ook de consument als gevolg) en monitoringskosten vereisen, zullen de vereisten voor een structurele remedie lager liggen als de vereisten voor een gedragsremedie. De volgende stap is dan de identificatie van de situaties waarin de voorkeur voor een bepaald type remedie van zowel de fusiepartijen als de concurrentieautoriteit overeenkomt.

Enerzijds vinden we dat de winstmaximaliserende keuze van de fuserende partijen voor een gedragsremedie ook optimaal blijkt te zijn voor de concurrentieautoriteit zolang dat de waarde van flexibiliteit groter is dan het sociale structurele remedievoordeel (i.e. het gewone structurele remedievoordeel zoals hiervoor vermeld met expliciete aandacht voor de gevolgen voor de winst van de outsider en de monitoringskosten). Anderzijds vinden we dat een structurele remedie wordt verkozen door beide partijen indien de waarde van flexibiliteit kleiner is dan het gewone structurele remedievoordeel. Enkel in het geval dat de waarde van flexibiliteit tussen het sociale structurele remedievoordeel en het normale structurele remedievoordeel ligt zal de optimale keuze van de concurrentieautoriteit verschillen met deze van de fuserende partijen. Aan de hand van een numeriek voorbeeld op basis van Cournot concurrentie bekomen we dat er verschillende situaties bestaan waar de keuze voor een gedragsremedie effectief optimaal is voor beide partijen. Dit betekent dat de huidige dominantie van structurele remedies, mogelijk veroorzaakt door de vermelde voorkeur van de concurrentieautoriteit voor structurele remedies, misplaatst kan zijn. Men kan dus argumenteren dat het flexibele gedragsremedietype in de praktijk meer toegepast zou kunnen worden.

Introduction

This thesis introduces uncertainty considerations in the policy areas of bank bailout and merger control. On the one hand, we will ask ourselves whether and when governments should save failing bank and how large the rescue package in case of bailout should be. On the other hand, we will investigate whether reversible behavioral or irreversible structural remedies should be used when a proposed merger raises anti-competitive concerns.

While these two policy areas may seem unrelated to one another, the posed questions do share a common characteristic: they traditionally yield time-dependent answers that change with the economic environment. This implies that an optimal answer at one point in time may turn out to be incorrect as soon as the related economic variables change. Given the speed with which this can occur and the (at least partial) irreversibility of some of the actions involved (e.g. bailout, emergency liquidity support, liquidation and structural remedies), one thus requires an effective incorporation of the uncertain environment in the economic analysis to arrive at answers that are optimal from a dynamic perspective. This is where this thesis comes in, with a dynamic treatment of the aforementioned bank bailout and merger control issues.

To incorporate uncertainty in the analysis of bank bailout decisions, we make use of the real options methodology, which has undergone quite an evolution over the years. Starting with the evaluation of traditional investment decisions under uncertainty in a monopoly context (with a focus on the optimal timing of investment ; see e.g. McDonald and Siegel (1985 & 1986) and Dixit & Pindyck (1994)), various authors have expanded upon the original model by incorporating elements like competition, multiple stochastic determinants, capacity considerations, step-wise investments, embedded options, ... This progress has shaped the real options approach into a much needed and flexible improvement over traditional net present value (NPV) analysis that effectively incorporates the value of waiting associated with delayable and irreversible investment projects in the decision process.

The methods and insights provided by real options also hold for various policy-related issues, an avenue that is much less explored. In that respect, our text fills an additional caveat by incorporating real options analysis and its insights in the evaluation of bank bailout decisions. In particular:

1. We formulate a real-options consistent bailout decision rule that specifies under which conditions it is optimal for a government to engage in emergency liquidity support, bank bailout and liquidation (chapter 1)
2. We develop a methodology based on real options theory involved with capacity choice that not only determines whether and when it is optimal to bail out a bank (assuming a bailout is the optimal choice), but also provides guidelines w.r.t. the optimal size of the bailout package (chapter 2).

The relevancy of incorporating uncertainty in these issues cannot be underestimated. In times of financial turmoil for example, when a bank starts to get into trouble, one often observes that bailout decisions are taken 'overnight', without taking into account the value of flexibility associated with waiting for more information. This may lead to situations where one decides to bail out a bank, even though the situation would have been restored on their own or scenario's where the situation has not been deemed worthy of intervention, even though it becomes irreparable due to unforeseen changes later on. With real options theory, one accounts for the uncertain economic environment surrounding bank crises to arrive at optimal decisions from a dynamic perspective.

The same holds for situations where one has to decide on bailout size. Once it is known that a bailout will occur, one has to decide how large the rescue package should be. On the one hand, one wants to minimize the costs for the taxpayer, thus providing an argument for a small rescue package. On the other hand, one must make sure that the size of the intervention is sufficient to restore the situation and prevent further bailouts down the line. This provides a rationale for a larger bailout package. By utilizing real options theory, one can introduce the uncertain economic environment in the analysis to arrive at a solution that provides the optimal mix in this trade-off.

The incorporation of uncertainty in merger control is treated in the third part of this thesis and, while different, is not less relevant. In many cases, merger remedies are required to overcome the anti-competitive effects originating from a competitor leaving the market to join with another firm (see e.g. Davies & Lyons, 2008). The most common form of merger remedy is structural, i.e. a divestiture of assets. Unlike the lesser used behavioral remedies, which put constraints on what the merged firm is allowed to do (e.g. maximum price, separation of information flows; ...), these remedies are irreversible and thus quite risky in case the economic situation deteriorates. Behavioral remedies can however be reversed, leading to a value of flexibility that should be incorporated in the decision between the remedy types. From this perspective, one can identify a variety of cases where behavioral remedies are in the best interest of both the competition authority and the merging parties despite the prevailing dominance of structural remedies. In other words, the value of flexibility may well offset the increased requirements of the behavioral remedy type inherent to a consumer surplus standard, thus promoting a wider use of this merger remedy format. Compared to the real options approach used in the analysis of bank bailouts, the analysis here is in discrete time, with the key factor being the possible occurrence of a negative industrywide demand shock and the consequences this will have in case the remedy cannot be reversed.

The thesis is structured as follows. We start in chapter 1 ("Real options and bank bailouts") with the exposition of our proposed real options consistent bailout decision rule. This rule - based on the liquidity creation function of banks as described in e.g. Berger & Bouwman (2009) - takes into account the option value of waiting associated with the uncertain environment surrounding impending bank failures. As such, it advocates decisions that take into account the possibility of economic recovery/deterioration to ensure an optimal solution from a dynamic perspective. In simple terms, our rule identifies the situations in which it is optimal for a government to engage in emergency liquidity support, bank bailout and liquidation, given various external parameters like the bailout size. The rule is also applied to 75 bailout cases in the EU-15 in order to evaluate whether observed bailout policy can effectively be justified for the crisis year of 2008.

Our results show that it is effectively possible to calculate the threshold values necessary to pass judgement on the appropriateness of the concerned decisions. If the liquidity creation value of a bank drops below the calculated containment threshold, it is optimal for the government to engage in emergency liquidity support. Afterwards, should liquidity creation over time rise by such an amount needed to cross the calculated reactivation threshold (which like the other threshold values takes the normal fluctuations in liquidity creation in account), it is optimal for the government to engage in bailout. In case the liquidity creation value of the bank keeps dropping until it crosses the calculated liquidation threshold, it is optimal to liquidate the bank. Note that the liquidation threshold does not always exist, thereby indicating that a bank can be too-big-to-fail due to the large cost for the government involved with paying out deposit insurance. The threshold values themselves are quite stable w.r.t. changes in exogenous parameters, which reinforces the robustness of our results. From an empirical perspective, we find that the EU-15 governments seem to have mostly made the correct decision - from a liquidity creation point of view - in the financial crisis year of 2008: from the 75 considered cases, 70 decisions could be deemed optimal.

In chapter 2 ("Real options and bank bailout size"), we take a different approach towards optimal bailout policy. While the bailout rule in chapter 1 aimed to determine whether a bailout with given bailout size could be justified, chapter 2 takes the bailout as given and gives instructions on how large the optimal bailout size should be. The approach is once again based on the welfare creating aspect of liquidity creation and rooted in the real options literature w.r.t. capacity choice (see e.g. Huberts, Huisman, Kort & Lavrutich, 2015), therefore ensuring that the option value of waiting for more information is accounted for. This time however, our methodology not only allows us to determine whether and when the bailout should occur, but also - for possibly the first time in the literature - how large the size of the bailout package should be.

Our analysis shows that higher uncertainty not only leads to a larger optimal bailout size, but also to delayed action, indicating that bailout decisions should not be taken overnight. This translates in a policy implication: when faced with a highly volatile and uncertain economic environment, the option value to wait is high and optimal bailout sizes, if they occur, should be large. Additionally, the type of bank and their dependence on deposits for liquidity creation are found to be only minor determinants of bailout size. This implies that bailout sizes between e.g. commercial and investment banks should not differ too much. The optimal timing of bailout does however depend on the type, with a later intervention being desirable for deposit dependent banks due the efficacy of the intervention tool. Also noteworthy is the key role of public confidence in the ability of the government to successfully execute the bailout. If confidence is too low, it is not optimal to even engage in bailout. As such, building a strong reputation in crisis management may help in solving the crisis more efficiently. Last, but not least, our results suggest that the relation between the optimal timing and size of bailout is not clear cut. Focusing on one element while foregoing the other may indeed result in suboptimal decisions from a dynamic perspective.

In the last chapter ("Behavioral vs. structural remedies in merger control"), we introduce the value of flexibility, associated with the possibility of lifting imposed behavioral merger remedies in adverse economic conditions, in the choice for the optimal merger remedy type. In particular, we identify the conditions under which the reversible behavioral merger remedy type outperforms the popular structural merger remedy type from a welfare point of view. Starting from the assumption that the change in expected consumer surplus must remain zero - in line with the well-established consumer surplus standard -, we present the idea of a structural remedy advantage: given that a behavioral remedy can be lifted in adverse economic conditions (to the detriment of the outsider and possibly consumers) and requires monitoring costs (contrary to structural remedies), remedy requirements for a structural remedy are less stringent than those for a behavioral remedy. We then identify the situations in which both the merger parties as well as the competition authority would prefer the same remedy format.

On the one hand, we find that the profit-maximizing choice of the merging parties for a behavioral merger remedy is also optimal for the competition authority as long as the value of flexibility is larger than the social structural remedy advantage (i.e. the structural remedy advantage with the explicit consideration of outsider profits and monitoring costs). On the other hand, we find that a structural merger remedy is preferred by both parties as long as the value of flexibility is lower than the standard structural remedy advantage. Only when the value of flexibility lies between the standard and the social structural remedy advantage does the optimal choice of the merging parties and the competition authority diverge. A numerical example based on Cournot competition indicates that there are numerous situations where the choice for a behavioral merger remedy type is optimal for both parties. As such, the current dominance of the structural remedy type, mayhap due to the stated preference of the competition authority for that specific remedy format may be misplaced. A case can thus be made for a more widespread use of the behavioral remedy format.

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Chapter 1: Real Options and Bank Bailouts[1]

Abstract

This paper develops a real options consistent bailout decision rule that specifies under which conditions it is optimal to liquidate or bail out a bank based on the amount of liquidity it creates. Due to its construction, the rule incorporates the option value of waiting stemming from the irreversibility of liquidation and bailout decisions and the possibility to delay. We use our method to show that the most prominent bailout decisions in the EU-15 were correctly taken during the financial crisis year of 2008.

1.1. Introduction

During the recent financial crisis, large attention has been given to the sizeable bailouts used by governments to save distressed banks. Be it in the form of loans, recapitalizations, altered legislation or even nationalization, bank bailouts seem to be the most common policy response in times of financial turmoil. Many questions however remain concerning the validity of the various interventions. Do the benefits of bailout truly outweigh the significant direct and indirect costs? Do the receiving banks truly fit the too-big-to-fail or, more general, the too-important-to-fail label they receive? In this paper, we develop a real options consistent bailout decision rule that specifies under which conditions it is optimal - from a social welfare perspective - to liquidate or bail out a bank based on the amount of liquidity it creates. Due to

[1]This chapter is a slightly adjusted copy of the most recent version of the working paper "Real Options and Bank Bailouts: how Uncertainty affects Optimal Bank Bailout Policy" by Glen Vermeulen & Peter M. Kort. The related electronic appendix has been added to the end of this chapter.

its construction, the rule incorporates the option value of waiting stemming from the (at least partial) irreversibility of liquidation and bailout decisions and the possibility to delay. As such, it advocates a more cautionary approach that adequately deals with the uncertain economic environment accompanying a crisis. It also lends itself to practical applications, including the evaluation of past bailout decisions. Were the conditions met in case a bailout was observed? How well did e.g. the EU-15 perform? These and other questions can and will be answered by applying the developed rule to various cases from the past.

This paper is of course not the first attempt to guide optimal bank bailout policy. Cordella & Yeyati (2003) argue that a bailout regime has two offsetting effects, namely a moral hazard effect (bailout increases risk-taking incentives) and a value effect (bailout decreases risk-taking incentives). Given this trade-off, they argue that governments should commit ex-ante to bail out banks in adverse macroeconomic conditions - where the value effect is dominant - but not otherwise. Freixas (1999) on the other hand considers the cost difference between rescue and liquidation cost as the driving force behind a government's choice for bailout. If the bank under consideration has a large amount of uninsured debt (and consequently low deposit funding), the cost of rescue is much higher compared to the cost of liquidation as in the latter case, the uninsured debt does not have to be compensated. In general, one can then calculate "a critical level of uninsured debt beyond which the lender of last resort will not rescue any bank" (p. 24). Goodhart & Huang (2005) determine a critical value for a banks' deposit volume beyond which bailout is always optimal, with the main underlying assumption being that liquidation costs rise at a faster rate than bailout costs with respect to bank size. Acharya & Yorulmazer (2007) take a too-many-to-fail approach and determine a rule based on the amount of bank failures. Given that banking assets should ideally remain in the hands of a bank for most efficient use, they argue that bailout is only optimal when the total number of failing banks is so large that the surviving banks are not able to keep the assets in the industry via purchases and take-overs. Aghion, Bolton & Fries (1999) expand the analysis by taking the effects of bailout on the reporting incentives of bank managers into account while Gong & Jones (2013) characterize a three-tiered bailout rule based on the systemic costs a bank imposes in the case of failure. More recently, Bianchi (2016) developed a quantitative equilibrium model of financial crises that shows how systemic and broad-based bailouts can avoid part of the moral hazard effect associated with idiosyncratic and targeted bailouts.

Most similar to our goal is the paper of Goodhart & Segoviano(2015), which identifies the intervention point at which it is optimal for the government to engage in recovery. These authors determine the institutions which should be subjected to intervention via a quantification and comparison of the respective banks loss absorption buffer and potential extreme losses. Afterwards, they introduce four degrees of intervention, namely frequent oversight, a fine, a limit on pay and the most severe recovery (e.g. bailout). For each severity, a threshold in terms of distance-to-default is set in order to determine the most appropriate action. The authors however do not identify the situations in which liquidation would be the appropriate choice, even though this situation could very well occur. For a dynamic model with respect to the decision to close a bank, one can take a look at Kang, Lowery & Wardlaw (2015). Here, the authors utilize conditional choice probability estimation to determine the monetary and nonmonetary cost for the regulator of allowing a bank to continue operations. Key is the trade-off between a governments aversion to closing the bank and the possible increase in eventual resolution costs should the bank be allowed to survive. They find that, in their sample spanning the 1980s and 1990s, regulators appeared to have waited longer than would have been the case strictly minimizing monetary costs. This indicates that other nonmonetary and bank characteristics - including the value of waiting for more information that is key in our analysis - affects the liquidation decision.

The rule we develop here will contribute to this literature by introducing real options theory in the analysis of bank bailout and liquidation decisions. In doing so, we are able to adequately deal with the uncertain economic environment accompanying a crisis via the incorporation of the option value of waiting - a key concept that has always been neglected in the aforementioned research. While a decision may indeed seem optimal at one point in time, ignoring the possibility of economic recovery/deterioration in the future may lead to suboptimal decisions from a dynamic perspective. Only when the value of waiting is completely accounted for - as in a real options consistent bailout decision rule - can this bias be avoided and efficient decisions be possible. In general, our model shows that it is not required to make bailout decisions 'overnight', as has been often observed in practice, but that there is room for waiting in order to make well-informed decisions.

In the following section we start the development of the bailout decision rule by discussing the model setup. Note that a bailout is considered to be an investment of the government in the economy.

1.2. Model Setup

We seek to formulate a real options consistent bailout decision rule that determines when a government should save or liquidate a failing bank. The starting point here is one of the main economic functions banks perform in the economy, namely liquidity creation[2]. As described in the seminal article by Diamond & Dybvig (1983) and in Diamond (2007), banks create liquidity on the balance sheet by transforming illiquid assets[3] into liquid liabilities. Imagine e.g. a world where one can invest €1 at time 0 in either an illiquid asset - with a value of $r1 < 1$ in time 1 and $r2 > 1$ in time 2 - or a liquid assets that only preserves the value of the investment ($r = 1$ in all periods) so that one can always withdraw the funds when needed. While the illiquid asset is more profitable in case one does not need the funds in period 1, one does not know whether this will be the case. This encourages risk-averse investors to invest in the liquid asset. Banks however, by taking advantage of the pooling of resources and knowledge about the fraction of people that will require funds prematurely, can offer 'new' deposit contracts by distributing the pooled funds over the two types of assets. This results in a contract (which takes the form of a liquid liability on the bank's balance sheet) with e.g. a value in period 1 of $d1 > 1$ and a value of $d2$ in period 2 with $1 < d2 < r2$, which provides a smoother pattern of returns over time than the existing illiquid assets offer. This is welfare-improving, as at least some losses associated with the premature selling of assets can be avoided and risk-averse investors/depositors are basically insured against liquidity risk.

[2]The other main function of banks is risk transformation: "banks transform risk by issuing riskless deposits to finance risky loans" (Berger & Bouwman, 2009, p. 3779-3780). Liquidity creation and risk transformation often coincide (riskless deposits are often more liquid than risky illiquid loans) but the relation is not perfect (Berger & Bouwman, 2009). For the simplicity of the analysis, we only focus on liquidity creation. This also opens the route to empirical applications, as there exist measures that can determine the actual liquidity creation of a bank.

[3]From a purely theoretical point of view, an illiquid asset is an asset where the premature selling of that asset results in a loss. In practice, there is a more continual interpretation where the general ease of selling the asset and the extent of the losses determines the degree of liquidity of an asset.

The rule developed below assumes exactly this: welfare is increasing in the amount of liquidity a bank creates, with the quantification being based on the liquidity creation measures of Berger & Bouwman (2009). As such, the government has an interest in the performance of banks as the liquidity they create - simply by being active in the market and executing their core activity - contributes to social welfare. A too high liquidity creation can however be considered as an indicator of higher bank fragility - as is e.g. postulated in the "high liquidity creation hypothesis" of Fungacova, Turk & Weill (2015). This hypothesis states that "a proliferation in the core activity of bank liquidity creation increases failure probability". From an empirical point of view, using the same Berger & Bouwman (2009) liquidity creation measures that we use here, the authors effectively find that "high liquidity creation significantly increases the probability of bank failure". To account for this (potential) negative effect, we capture the contribution of liquidity creation (L) to welfare (W) as a function with decreasing marginal returns:

$$W = f(L) = a(L - \bar{L}) - z(L - \bar{L})^2, \tag{1}$$

where $\bar{L} > 0$ denotes the opportunity value of the operating costs of the bank. A larger $a > 0$ signifies a larger positive effect of liquidity creation on welfare. A larger $z > 0$ would imply a larger risk correction for liquidity creation. We do assume that $\frac{a}{z} > 2L$, i.e. the first derivative stays positive, so that an additional unit of liquidity creation still remains beneficial, though not as much if L is already large. Overall, this assumptions implies that there is a value of liquidity creation, depending on the size of a and z, beyond which there is no marginal contribution to welfare.

Only the liquidity creation of a bank that is in excess of the amount of liquidity that is required to cover the opportunity value of a bank's operating cost ($\bar{L}$) - including its use of personnel that could have been employed in other welfare-creating activities - is considered to be contributive. As such, even with a large a, the welfare contribution can still be negative if $L < \bar{L}$ due to the bank using resources without creating 'surplus liquidity'. Note that $\bar{L}$ is depicted as a constant, due to it being an opportunity cost that depends on factors that are external to banking. As such, whether or not a bank has a high or low liquidity creation, the assets it uses to continue its operations will have the same value outside of the banking sector. Note also that liquidity creation is assumed to be related to the financial health of the bank: the healthier a bank is, the better deposit contracts it can offer (e.g. because more and better investment opportunities open up as its health/financial strength increases) and the more liquidity it creates.

To model the uncertainty surrounding bailout decisions, we assume that liquidity creation is not constant, but varies over time due to different influences. In particular, we assume that L follows a Geometric Brownian Motion (GBM)(Dixit & Pindyck, 1994) :

$$dL = \alpha L dt + \sigma L dz. \tag{2}$$

In this expression, α - the drift parameter - and σ - the variance parameter - are known constants and dz is the increment of a Wiener process. The first term indicates the growth rate in liquidity creation over time. α is assumed to be negative in times of financial turmoil, positive in times of high economic activity or 0 in a neutral/baseline scenario. L on the other hand is always non-negative, which is a key characteristic of the GBM. The second term, which includes the Brownian motion process, captures normal fluctuation in liquidity creation due to factors such as fluctuations in asset prices on which the individual bank has no influence. These concern relatively small changes where a priori the sign of the change is unknown, making the Brownian motion with its zero mean a good modelling choice[4].

The model analyzes bailout decision making concerning a single bank, where the related decisions are taken by a government that has full control on central bank behavior. As in Valencia & Laeven (2008), we make a distinction between the containment phase - in which "governments tend to implement policies aimed at restoring public confidence ..." - and the restructuring phase - which "involves the actual financial, and to a lesser extent operational, restructuring [in this case bailout or liquidation] of financial institutions and corporations". Within these phases, the authors find that emergency liquidity support (provided in 71% of the cases) and bank recapitalizations/bailouts (provided in 78.6% of the cases) are, among various other measures, the most observed policy responses, rendering them the most suitable decisions for use in the model. Of interest is the fact that the containment phase can be seen as a situation wherein the government is able to stabilize the situation and provide a period of opportunity to wait for more information. As such, more informed decisions regarding future developments can be made. Inherent to this interpretation is the lack of dividends given by the bank: it is assumed that no dividend are given out during periods of financial difficulty (which is characteristic of situations where bailout/emergency liquidity support is considered) given that they could enable shareholder to worsen the situation by draining the resources of

[4] Other reasons for the use of the GBM include the compatibility with the real options methodology, the relative simplicity and the empirical method we use later one. In particular, we will measure liquidity creation by using the cat fat measure of Berger & Bouwman (2009), which is based on a bank's balance sheet. Liquidity creation will therefore be influenced by changes in stock prices, which are often assumed to follow a GBM. Note that, due to the balance sheet based calculation of liquidity creation, there is not enough data to make an econometric estimate of the changes over time.

the bank.

The practical implementation of the distinction between containment and restructuring phase occurs by assuming that a bank can be in two different states: a bank can be either in an active state - where it generates a welfare contribution of $L - \bar{L}$ per unit of time - or in a contained state where it produces $-b < 0$ per unit of time. The parameter b here represents the recurrent welfare cost of emergency liquidity support the government has to incur to keep the bank in containment. Assuming that liquidity support takes the form of collateral loans[5], this opportunity cost of b in welfare terms could be approximated as the difference between the return on investment the government would have received by using the funds on the best alternative project minus the expected monetary return of ELA, which percentage-wise is most likely lower. Intuitively, a larger liquidity gap would require larger government input, which would be reflected in an increasing b. However, if one assumes that the required monetary return on ELA also increases as more means are required to cover the liquidity gap, the use of a constant b is justified. In containment, the government provides emergency liquidity support in such a way that the bank's liquidity creation is set to $\bar{L}$, so that no activity-related losses are incurred when $L < \bar{L}$. Given that the government has full flexibility over the transitions between the two states and

[5] In the Eurozone, ELA [= Emergency Liquidity Assistance] can be defined as "emergency loans given by euro zone national central banks to strapped commercial banks. The loans are given at the discretion of the national central bank although they have to be approved by the ECB. [This implies, among others, that] national central banks may provide ELA 'against adequate collateral' and only to 'illiquid but solvent' credit institutions". Source: Suoninen, S., & Jones, M. (2013, March 21). Factbox - How ECB's emergency liquidity assistance works. Reuters. Retrieved from: http://uk.reuters.com/article/2013/03/21/uk-factbox-ecbs-emergency-idUKBRE92K0DT20130321

can additionally opt to liquidate the bank at a welfare cost of ϖD - where D stands for the total amount of deposits held by the bank and $\varpi \in [0,1]$ refers to the extent deposits are guaranteed - the government will choose at every t the state in which the social value of the bank is largest:

$$\begin{cases} Max\{W_a(L_t), W_c(L_t)\} \text{ in case the bank is currently active,} \\ Max\{W_a(L_t) - B, W_c(L_t), -\varpi D\} \text{ in case the bank is currently contained,} \end{cases}$$

where $W_a(L)$ is the social value of the bank when it is active, $W_c(L)$ is the social value of the bank when it is contained and B is the social value of the bailout amount required to switch from the contained to the active state. Note that while we assume that a bailout is required to successfully complete the transition from contained to active bank, one can loosen this assumption by choosing a very low value for B. In the model, we keep the value of B constant, but later on, we analyze the impact of varying this parameter.

Our bailout decision rule consists of three threshold values that govern the transition from the active to the contained state (= containment threshold L_c), the transition from the contained to the active state (= reactivation / bailout threshold L_r) and the transition from the contained state to liquidation of the bank (= liquidation threshold L_l)[6]. Switching from the active to contained state is optimal when $L < L_c$ and is assumed to be costless while switching from the contained to the active state is optimal when $L > L_r$ and requires a sunk investment equal to B. Liquidation is optimal when $L < L_c$ and requires incurring the liquidation cost of ϖD. The rule itself can be schematically represented as in figure 1.1.

The values of the specific thresholds - which basically characterize the bailout decision rule - can be determined by using so-called value-matching and smooth-

[6]In general, $L_l < L_c < L_r$.

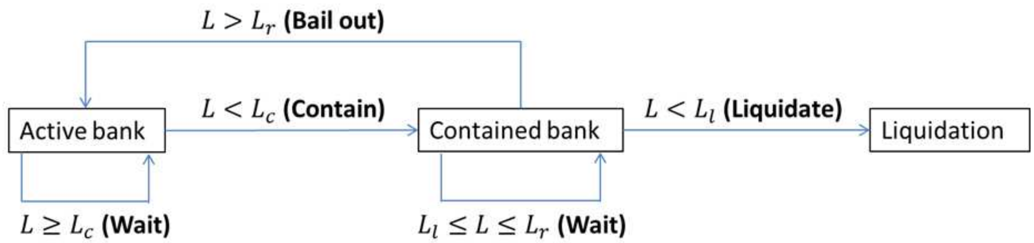

Figure 1.1: Bailout decision tree

pasting conditions, similar to the ones used in the 'mothballing model' described in Dixit & Pindyck, 1994, section 7.2. Basically, the value-matching conditions are used to specify at which point the value of a firm in one state (e.g. active) is equal to the value of the same firm in the other state (e.g. contained), taking into account possible costs required to change from one state to the other. The smooth-pasting conditions on the other hand are technical conditions that require the respective derivatives to match at that point. In total, we have three sets of equations that characterize the different threshold values.

- For the transition from active bank to contained bank, we have:

$$W_a(L_c) = W_c(L_c), \tag{3}$$

$$W_a'(L_c) = W_c'(L_c). \tag{4}$$

In normal situations, banks are most productive when they are active, as W_a contains the present value of the bank's future welfare contributions and the option value of containing the bank. The exogenously specified discount rate is hereby depicted by ρ. In times of distress however, the welfare contributions may turn negative ($L < \bar{L}$) so that W_c - which consist of a) the negative present value of the liquidity support in welfare terms, assuming it lasts forever ; b) the option value of reactivating the contained bank and c) the option value of liquidation - can become higher than W_a. In general, one can therefore say that the value-matching condition (3) and smooth-pasting condition (4) basically determine the point where this switch from normal conduct (LHS) to containment is desirable, which starts being the case from L_c and lower[7].

- For the transition from contained bank to active bank, one gets:

$$W_c(L_r) = W_a(L_r) - B, \tag{5}$$

$$W_c^{'}(L_r) = W_a^{'}(L_r). \tag{6}$$

Value-matching condition (5) thus basically requires that L should be large enough so that market liquidity creation outperforms liquidity creation under containment with a margin at least as large as the net bailout cost, which occurs from L_r and onwards. Only then is it optimal to execute the bailout.

- For the transition from contained bank to liquidation, one obtains:

$$W_c(L_l) = -\varpi D, \tag{7}$$

$$W_c^{'}(L_l) = 0. \tag{8}$$

Here, the value-matching condition requires that one should liquidate the bank when the option value of waiting - encompassed in W_c - is eroded by the sustained welfare

[7]Note that, similar to Dixit & Pindyck (1994), one could also include a sunk policy development cost in the value-matching condition in order to stress the partial irreversibility of the containment decision.

cost of liquidity support in such a way that it becomes lower than the amount of deposit insurance the government has to pay out in case of liquidation. In clearer terms, Only when $W_c(L)$ falls below the net cost of liquidation is it optimal to liquidate the bank ; which starts being the case from L_l and lower.

In the following section, we use dynamic programming techniques to analytically solve for W_a and W_c. This will clear the way for the determination of the thresholds L_c, L_r and L_l.

1.3. Solving the model

The first step in the determination of the threshold values consists of the determination of the value of the bank in the different states. This is done with the help of standard dynamic programming techniques as e.g. found in Dixit & Pindyck (1994), which among others involve the use of the Bellman equation, Ito's lemma and solving differential equations. The choice for a dynamic programming approach, rather than the alternative contingent claims analysis, should have no impact on the shape of the solution itself[8]. It does impact the way the discount rate, which is introduced in the calculations below, is interpreted. In particular, the discount rate, used to calculate present values, will take the form of an arbitrary and constant rate ρ. Compared to contingent claims analysis, where the discount rate is derived from overall equilibrium in capital markets and only the riskless rate of return is assumed to be exogenous, this may seem like a crude method. By opting for dynamic programming however, we require less data, reduce the complexity of the calculations

[8]Note that the contingent claims solution is equivalent to the dynamic programming solution under the assumption of a risk-neutral government, which has a 'true' discount rate equal to the risk-free rate (Dixit & Pindyck, 1994).

and are still able to account for inaccuracies by manually changing the discount rate in a separate robustness section. The calculations can be found in appendix A and result in the following propositions:

Proposition 1. *The social value of the active bank is given by*

$$W_a(L) = A_2 L^{\beta_2} - \frac{zL^2}{\rho - 2\alpha - \sigma^2} + \frac{2z\bar{L} + a}{\rho - \alpha} L - \frac{az\bar{L} + \bar{L}^2}{\rho}, \tag{9}$$

with A_2 being a constant to be determined and

$$\beta_2 = \frac{1}{2} - \frac{\alpha}{\sigma^2} - \sqrt[2]{(\frac{\alpha}{\sigma^2} - \frac{1}{2})^2 + \frac{2\rho}{\sigma^2}}. \tag{10}$$

The first term in (9) represents the value of the option to contain while the second part can be interpreted as the expected present value of the bank if it continues operations forever.

Proposition 2. *The social value of the contained bank is given by*

$$W_c(L) = B_1 L^{\beta_1} + B_2 L^{\beta_2} - \frac{b}{\rho}, \tag{11}$$

with B_1 and B_2 being two constants to be determined and

$$\beta_1 = \frac{1}{2} - \frac{\alpha}{\sigma^2} + \sqrt[2]{(\frac{\alpha}{\sigma^2} - \frac{1}{2})^2 + \frac{2\rho}{\sigma^2}}. \tag{12}$$

Here, the first term in (11) represents the value of the option to reactivate the contained bank ; the second term represents the value of the option to liquidate the bank and the last term represents the present value of the liquidity support cost assuming the support lasts forever.

Substituting the social value of both the active as well as the contained bank in the value-matching and smooth-pasting conditions [(3), (4), (5), (6), (7), (8)] yields the following six equation system:

$$\begin{cases} A_2 L_c^{\beta_2} - \frac{zL_c^2}{\rho-2\alpha-\sigma^2} + \frac{2z\bar{L}+a}{\rho-\alpha} L_c - \frac{az\bar{L}+\bar{L}^2}{\rho} = B_1 L_c^{\beta_1} + B_2 L_c^{\beta_2} - \frac{b}{\rho}, \\ A_2 \beta_2 L_c^{\beta_2 - 1} - \frac{2zL_c}{\rho-2\alpha-\sigma^2} + \frac{2z\bar{L}+a}{\rho-\alpha} = B_1 \beta_1 L_c^{\beta_1 - 1} + B_2 \beta_2 L_c^{\beta_2 - 1}, \\ B_1 L_r^{\beta_1} + B_2 L_r^{\beta_2} - \frac{b}{\rho} = A_2 L_r^{\beta_2} - \frac{zL_r^2}{\rho-2\alpha-\sigma^2} + \frac{2z\bar{L}+a}{\rho-\alpha} L_r - \frac{az\bar{L}+\bar{L}^2}{\rho} - B, \\ B_1 \beta_1 L_r^{\beta_1 - 1} + B_2 \beta_2 L_r^{\beta_2 - 1} = A_2 \beta_2 L_r^{\beta_2 - 1} - \frac{2zL_r}{\rho-2\alpha-\sigma^2} + \frac{2z\bar{L}+a}{\rho-\alpha}, \\ B_1 L_l^{\beta_1} + B_2 L_l^{\beta_2} - \frac{b}{\rho} = -\varpi D, \\ B_1 \beta_1 L_l^{\beta_1 - 1} + B_2 \beta_2 L_l^{\beta_2 - 1} = 0. \end{cases}$$

Intuitively, the system characterizes the three thresholds where the social values of the banks in each state (including liquidation) that we calculated in proposition 1 and 2 are equal to one another. This occurs by definition at L_c, L_r and L_l. By grouping the equations together, we are able to determine the yet unknown values for A_2, B_1, B_2 that are present in the expressions for the social values of the bank, as well as the threshold values themselves due to having a six equation system with six unknowns. This enables us to fully solve the system, although numerical tools are required[9]. Given the complexity of the system, it takes a three-step procedure before one is able to (efficiently) obtain the results. The procedure basically encompasses a reduction from a six equation system via a four equation system to a two equation system of which the results are extrapolated to arrive at a solution for all unknowns. More detailed information can be found in appendix B. The end result is that we now possess a methodology that can be utilized to evaluate bailout decisions from the past. In particular, use of case study data will lead to the determination of the different threshold values, thus specifying the conditions under which liquidity support, bailout and/or liquidation could be deemed optimal. The position of the bank

[9]In particular, we make use of the FindRoot function found in Mathematica 10 in order to arrive at a solution.

vis-à-vis these thresholds can then be found by using a liquidity creation measure: if this measure is larger(lower) than the calculated reactivation(liquidation) threshold, the bailout(liquidation) under scrutiny can be deemed justified[10]. In the next section, we illustrate the application of this rule. Here, for calculation and implementation purposes, all welfare terms are approximated by their monetary equivalents.

1.4. Case studies

1.4.1. The case of Dexia

We start our study with the case of Dexia, a Franco-Belgian bank insurer oriented towards retail and commercial banking as well as public finance. In 2008 (September 30), Dexia fell victim to the financial crisis and was saved by the Belgian, French and Luxembourgian government by means of a bailout/ recapitalization amounting to €6.376 billion[11]. While this was not the only bailout the bank received (the European sovereign debt crisis led to a second and even a third bailout in 2011 and 2012 respectively), it is the most interesting one to study, given that it started the question whether it was justified to save them. The goal here is to scrutinize whether - if we should face the same situation today - a bailout would effectively be the most appropriate choice: was the liquidity creation of Dexia sufficiently high compared to the reactivation threshold at that time?

[10]Here, one assumes that emergency liquidity support is already provided, i.e. the bank is already in the contained state before bailout is considered. As such, in order for this particular decision rule to work, one needs to have evidence that liquidity support is provided, which in practice is often the case.

[11]See e.g. http://www.telegraph.co.uk/finance/financialcrisis/3108159/Financial-crisis-Dexia-gets-5bn-bailout-from-Belgium-France-and-Luxembourg.html .

In order to determine the three threshold values, we need to gather information concerning 10 parameters, namely: α, σ, ρ, ϖ, a, b, z, B, D and $\bar{L}$. In order to simplify interpretation later on, we normalize $\bar{L}$ - the amount of liquidity that is required to cover the opportunity value of a bank's operating cost - to one. Its corresponding 'real' value, as was mentioned above, is approximated by its monetary equivalent, namely the operating costs of Dexia in 2008 that amounted to € 4.1178 billion[12]. Using this as a reference, one can easily arrive at the parameter values of B and D. In particular, customer borrowings and deposits (D) amounted to €114.728 billion in 2008, resulting in a normalized value of 27.8615 (=114.728 / 4.1178) while the bailout/recapitalization amount (B) is normalized to 1.5484 (=6.376/4.1178). In accordance to Directive 2009/14/EC, deposits are insured for up to €100,000. For an initial estimate of ϖ - the degree of deposit insurance - we therefore base ourselves on the following statement found on the website of the National Bank of Belgium:

> "As a result of the increased guarantee level of €100,000, individuals in Belgium now have virtually complete coverage. At the beginning of 2010 they held an average of around €22,500 in bank deposits. Although the deposit balances are unevenly distributed, with a small percentage of the population holding very large amounts, that average nevertheless indicates a high level of coverage implying that roughly 95% of deposits are fully guaranteed" [13].

[12] Dexia (2008). Annual report 2008. Retrieved from http://www.dexia.com/EN/shareholder_investor/individual_shareholders/publications/Documents/annual_report_2008_UK.pdf. The value is calculated using the cost-income ratio.

[13] NBB (2010). The Belgian deposit guarantee scheme in a European perspective. Retrieved

If we assume that the average savings and the distribution of savings is more or less the same for France and Luxembourg, we can safely set ϖ to 0.95. With respect to b - the cost incurred for each period the bank is in the contained state - we base ourselves on the collateral loan interpretation discussed above. Key ingredients are therefore the return on investment of the best alternative project - which we approximate by the average return on large-cap stocks between 1926 and 2008, namely 9.62% per annum[14] - and the average interest rate charged on ELA, which is estimated to be 100-150 basis points above the ECB's overnight lending rate[15]. The size of the support is approximated by the balance sheet post 'liabilities due to the central bank'. Given that the marginal lending facility of the ECB in September 2008 amounted to 5.25% per annum[16], b amounts to (9.62% - 6.25%) * €120,559 million = €4.0628 million. Normalization would then yield $b = 0.001$.

Finally, we assume α - the drift parameter - to be negative due to the financial crisis with an initial value of α = -0.05. ρ - the discount rate / payout rate of the project - is initially set at 10% (i.e. $\rho = 0.1$) in accordance with our earlier approximation of the return on investment of the best alternative project. The starting value for σ - the uncertainty parameter - is based on the standard deviation

from: http://www.nbb.be/pub/01_00_00_00_00/01_06_00_00_00/
01_06_01_00_00/20101206_edepositogarantiestelsel.htm

[14]Paulson, E. (2009). Long Term Average Returns: Lessons from the Past. Retrieved from: http://blog.ctnews.com/paulson/2009/09/08/long-term-average-returns-lessons-from-the-past/

[15]Suoninen, S., & Jones, M. (2013, March 21). Factbox - How ECB's emergency liquidity assistance works. Reuters. Retrieved from: http://uk.reuters.com/article/2013/03/21/uk-factbox-ecbs-emergency-idUKBRE92K0DT20130321

[16]ECB (2014). Key ECB interest rates. Retrieved from: http://www.ecb.europa.eu/stats/monetary/rates/html/index.en.html

of the rate on return on the stock market, which has been about 20% (i.e. $\sigma = 0.2$) on average (Dixit & Pindyck, 1994). a - the parameter that determines the importance of liquidity creation to welfare - is set at 200, while z - the parameter that determines the size of the risk correction to the welfare contribution is set at 1. The reasoning lies with the assumption that the marginal contribution of liquidity creation must remain positive ($\frac{\alpha}{z} > 2L$) and with our measure of liquidity creation, which shows that for most of the banks considered later on, it holds that $L \in [0, 100[$[17].

While some of these values may seem arbitrary, we vary these and all other parameter values in the robustness section below to account for inaccuracies. Special attention is given to the parameter b, which is our most 'random' estimate given the unknown nature of return on investment of the best alternative project.

The above discussion can be summarized by taking a look at table 1.1, which depicts all parameter values used in this baseline scenario. With this information, we are able to determine the relevant threshold values, which are $L_c = 0.9132$ and $L_r = 1.0724$. L_l turns out to be non-existent[18], i.e. it is never optimal to liquidate. In a sense, the size of the liquidation costs render Dexia too-big-to-fail: it is just too costly for the government to liquidate given the large amount of deposit insurance they would have to pay.

Having determined the relevant threshold values via our model, we now turn to the data in order to measure the liquidity creation of Dexia at that point in time. One possible measure would be the liquidity transformation gap proposed by Deep & Schaefer (2004) , which is calculated as (liquid liabilities - liquid assets)/total assets.

[17] In our sample discussed below, we consider a liquidity creation of 100 as an absolute maximum. Any units of liquidity creation above this value does not contribute to welfare.

[18] This result stems from the fact that L, due to it following a GBM cannot drop below 0. A negative value for L is however required to render liquidation optimal in this particular case.

Variable	Value	Variable	Value
α	-0.05	$\bar{L}$	1
σ	0.2	B	1.55
ρ	0.1	D	27.86
ϖ	0.95	b	0.001
a	200	z	1

Table 1.1: Parameter values Dexia case

However, due to the fact that the liquidity attribute is derived from maturity rather than category (so that it does not truly reflect the ease at which certain assets can be disposed to meet liquidity needs) and the exclusion of off-balance sheet items (which also affect liquidity creation), we prefer the cat fat measure of liquidity creation proposed by Berger & Bouwman (2009). This methodology follows a three-step approach, with the first step involving a classification of all bank assets and liabilities as 'liquid', 'semi-liquid' or 'illiquid' and summing them within each category. For the case at hand, this is done by making use of the consolidated balance sheet as well as the accompanying notes found in the annual report of Dexia of 2008. Afterwards, a weighting is applied based on the main theoretical principle of liquidity creation: illiquid assets(+1/2) are used to create liquid liabilities(+1/2) while liquidity is destroyed when liquid assets(-1/2) are transformed in illiquid liabilities(-1/2). The weighting factor of 1/2 is hereby used to maintain a creation volume of one: to create € 1 of liquidity, one indeed has to transform € 1 of illiquid assets to € 1 of liquid liabilities. Semi-liquid assets and liabilities are weighted by 0. Summing up the weighted categories constitutes the last step and results in a practical measure of liquidity creation. In the case of Dexia, one finds a cat fat score of €196,455.5

million (normalized: €196,455.5 million / €4117.8 million = 47.7088) and a cat non-fat measure[19] of €146,459 million (normalized: €146,459.5 million/ €4117.8 million = 35.5674). More details concerning the classification [20] and the calculation can be found in section E.1 of the electronic appendix, which can be consulted at the end of this chapter. Seeing that both measures exceed the reactivation threshold by a large margin[21], we can conclude that the bailout executed to save Dexia in 2008 was effectively justified from a liquidity creation point of view. Further calculations show that for 2007, the normalized cat fat measure (basis year of 2008) amounted to 68.1114, which indicates that liquidity creation before the crisis was even higher. Calculated normalized cat fat scores for 2009 (28.3471), 2010 (19.6950), 2011 (5.2501) and 2012 (7.9317) on the contrary show a decreasing trend that only slightly picks up near the end. This renders the decisions w.r.t. the second and third bailout of Dexia in 2011 and 2012 less clear cut, as the margin w.r.t. their respective reactivation threshold may well disappear.

[19]The difference between 'fat' and 'non-fat' lies in the inclusion of off-balance sheet activities in the fat measure (Berger & Bouwman, 2009). The 'cat' part refers to a category-based classification system rather than a maturity-based one ('mat').

[20]Note that the article of Berger & Bouwman (2009) was applied to the banking sector in the US so that some balance sheet classifications may be different for a US vs. a EU bank, e.g. due to the absence of a secondary market for a specific type of asset in one region compared to the other. While we utilize the original cat fat measure in the text, for the case of Dexia, it can be argued that "loans and advances to public customers" are illiquid rather than semi-liquid as is the case in the original classification scheme. This would lead to a normalized cat fat score of 71.5576, which strengthens the result we obtain.

[21]We hereby assume that Dexia already received emergency liquidity support before bailout was considered, which seems plausible given various sources (e.g. http://europa.eu/rapid/press-release_IP-11-1592_en.htm).

1.4.2. Robustness

Here we investigate to what extent results remain the same if some of the parameter values of the baseline scenario were altered. In particular, we perform a robustness check, the results of which can be found in tables 1.2-1.5. These tables depict the value of the various thresholds (L_c in table 1.2, L_r in table 1.3 and L_l in table 1.4) in a variety of scenarios where compared to the initial situation a key parameter (e.g. α, σ, ...) as well as b - our most unreliable parameter estimate - is altered. In doing so, we are able to determine the movements in threshold values arriving from changes in a single parameter value while also controlling for the potential disrupting impact of a badly estimated b. The size of the variation range from small to 'extreme' (e.g. a ρ of 0.5 ; a σ of 1) in order to truly assess the robustness of the results. Table 1.5 additionally depicts how the three different thresholds change when the parameters a and z are changed. Note that a "/" signifies that the respective threshold does not exist. From the tables we can conclude that:

1. The threshold values are relatively stable when faced with changing parameter values. In almost all cases, the decision advocated above (bailout is justified) is still taken by a large margin while the values do not differ that much from the initial ones.
2. The changes in the threshold values are intuitive. For example:
    - If α increases (economic situation improves), it is better to delay containment and speed up bailout, resulting in lower values of L_c and L_r respectively. If the economic growth turns significantly positive, the containment and reactivation thresholds even cease to exist as a natural recovery is very likely. Do note, however, that for $\alpha \in [-0.05, 0.1]$, a higher α seems to delay bailout. This can be explained by the fact that for alpha

large enough it is worthwhile to wait for better circumstances under which the bailout should take place.

- A higher uncertainty (σ) increases the option value of waiting, thus delaying both containment and bailout decisions (lower L_c and higher L_r). This relationship is however not monotonic for the containment threshold L_c: for very high values of σ, the relation is inverse due to the existence of the liquidation option. The intuition here lies in the fact that, as argued by e.g. Kwon (2010), a higher volatility also implies an increase in the option value of exit/liquidation, rendering the value of the bank in (and as such the attractiveness of) the contained state higher.

- A higher discount rate ρ (and therefore a lower valuation of the future) accelerates containment (higher L_c due to a decreasing periodic cost of liquidity support) and speeds up bailout (lower L_r). The latter relation between ρ and L_r is not monotonic: once ρ starts to take on high values, a higher ρ effectively delays bailout. One possible explanation may lie in the fact that initially, the benefits from a higher discounted liquidity support before bailout are still significantly lower than the higher discounted benefits after bailout while the bailout cost itself is comparably stable. When the discount rate becomes very high, one only focuses on the immediate cost of bailout (as future benefits/costs become very small), which one would like to avoid for as long as possible.

- A larger a signifies a larger valuation of liquidity creation in terms of welfare. As such, it makes sense to contain sooner (to avoid larger losses) and bail out faster, resulting in a higher L_c and a lower L_r. The thresholds do not exist for $a = 1$ as the welfare contribution of liquidity creation is very low, thus advising against intervention (except when b is very high).

- A larger z signifies a larger 'risk correction' to liquidity creation. As such, governments value a certain liquidity creation level less than would otherwise be the case. This advices against the use of public funds to provide both emergency liquidity support (lower L_c) and bailout (higher L_r).

3. The threshold values are not greatly influenced by b, our most 'random' estimate. Even when the periodic cost of emergency liquidity support would be 500 times as large (from the initial 0.001 to 0.5), there are no big changes. In addition, the movements make sense: as the cost of liquidity support increases, it becomes less desirable to contain the bank (lower containment threshold) and it becomes more attractive to bail out the bank (reactivation threshold decreases).
4. The containment threshold and reactivation threshold do not depend on the size of the bank or, more generally, the liquidation cost because containment is assumed to not affect deposit size. The containment threshold however does respond to changes in the bailout amount (B), highlighting the fact that the irreversibility of containment is (at least partially) determined by the reactivation cost. The movements are intuitive: the higher the cost of bailout (B) , the better it is to avoid it (lower L_c and higher L_r).
5. The liquidation threshold exists for very low values of ϖ and/or D but not otherwise[22]. As such, liquidation seems to be a sub-optimal decision in many situations.

[22] We did not report the robustness check for D as it works via the same channel as ϖ (i.e. it affects the liquidation cost).

In general, we can thus conclude that our results are relatively robust and do not significantly depend on the different parameter estimates. The largest changes are due to changes in B or D, both of which we have exact information on. Given this result, we can further investigate the implications of this rule by considering a larger sample of banks, namely the top 5 banks for each country within the EU-15.

1.4.3. Bailout performance in the EU-15

One advantage of our model is that the methodology can be easily applied to a large number of banks: almost all of the required data are found on the balance sheet - an integral part of the annual report that each bank is forced to make public. Additionally, the standardization w.r.t. the operating cost within each bank provides a simple answer to the issue of different currencies or unit sizes and allows for safe comparisons. To illustrate the wider appeal of the model, we now examine the quality of bailout policy observed during 2008 in all EU-15 countries. In particular, we consider for the five largest banks in each of these 15 countries[23] whether the observed decisions (liquidation, bailout or nothing) are justified by the model: a bailout would be justified from a liquidity creation point of view if liquidity creation would be larger than the reactivation threshold (as we assume that banks are already contained when bailout is considered) ; liquidation would be commendable in case liquidity creation lies below the liquidation threshold and the absence of any bailout policy would be optimal in case liquidity creation never fell below the containment threshold. A higher proportion of correct decisions would imply a higher quality of bailout policy for the respective country. This way, inter-country differences in bailout performance can be observed and displayed.

[23]'Largest' refers to the banks which have the highest number of total assets on the balance sheet.

	$b = 0.0001$	$b = 0.001$	$b = 0.01$	$b = 0.1$	$b = 0.5$
$\alpha = -0.09$	0.923477	0.923473	0.923432	0.923021	0.921197
$\alpha = -0.05$	0.913156	0.913152	0.913111	0.912708	0.910917
$\alpha = 0$	0.878703	0.878699	0.878662	0.878284	0.876604
$\alpha = 0.01$	0.859178	0.859175	0.859138	0.858774	0.857154
$\alpha = 0.05$	/	/	/	/	/
	$b = 0.0001$	$b = 0.001$	$b = 0.01$	$b = 0.1$	$b = 0.5$
$\sigma = 0.01$	0.99405	0.994045	0.994001	0.993556	0.991577
$\sigma = 0.1$	0.95404	0.954036	0.953993	0.953567	0.951671
$\sigma = 0.2$	0.913156	0.913152	0.913111	0.912708	0.910917
$\sigma = 0.4$	0.758897	0.758894	0.758863	0.758558	0.757202
$\sigma = 1$	0.90054	0.900536	0.900488	0.900011	0.897893
	$b = 0.0001$	$b = 0.001$	$b = 0.01$	$b = 0.1$	$b = 0.5$
$\rho = 0.01$	0.885128	0.885124	0.885086	0.884705	0.88301
$\rho = 0.04$	0.8989	0.8989	0.89888	0.89849	0.89675
$\rho = 0.1$	0.913156	0.913152	0.913111	0.912708	0.910917
$\rho = 0.2$	0.923843	0.923839	0.923798	0.923386	0.921553
$\rho = 0.5$	0.934653	0.934648	0.934606	0.934184	0.930095
	$b = 0.0001$	$b = 0.001$	$b = 0.01$	$b = 0.1$	$b = 0.5$
$\varpi = 0$	0.913156	0.913152	0.913111	0.912708	0.910917
$\varpi = 0.2$	0.913156	0.913152	0.913111	0.912708	0.910917
$\varpi = 0.5$	0.913156	0.913152	0.913111	0.912708	0.910917
$\varpi = 0.95$	0.913156	0.913152	0.913111	0.912708	0.910917
$\varpi = 1$	0.913156	0.913152	0.913111	0.912708	0.910917
	$b = 0.0001$	$b = 0.001$	$b = 0.01$	$b = 0.1$	$b = 0.5$
$B = 0.1$	0.923784	0.92378	0.92374	0.923339	0.921557
$B = 1.55$	0.913156	0.913152	0.913111	0.912708	0.910917
$B = 2$	0.91076	0.910756	0.910716	0.910313	0.908521
$B = 5$	0.899068	0.899064	0.899024	0.898621	0.896833
$B = 20$	0.871525	0.871521	0.871481	0.871085	0.869322

Table 1.2: Values of the containment threshold (Lc) for varying combinations of parameter values (unmentioned parameter values are those detailed in table 1.1)

	$b = 0.0001$	$b = 0.001$	$b = 0.01$	$b = 0.1$	$b = 0.5$
$\alpha = -0.09$	1.07328	1.07327	1.07323	1.07275	1.07065
$\alpha = -0.05$	1.0724	1.0724	1.07235	1.07187	1.06976
$\alpha = 0$	1.07957	1.07956	1.07952	1.07903	1.07686
$\alpha = 0.01$	1.08694	1.08693	1.08689	1.08639	1.08419
$\alpha = 0.05$	/	/	/	/	/
	$b = 0.0001$	$b = 0.001$	$b = 0.01$	$b = 0.1$	$b = 0.5$
$\sigma = 0.01$	1.02885	1.02885	1.0288	1.02834	1.02631
$\sigma = 0.1$	1.04685	1.04684	1.0468	1.04633	1.04427
$\sigma = 0.2$	1.0724	1.0724	1.07235	1.07187	1.06976
$\sigma = 0.4$	1.16627	1.16626	1.16621	1.16567	1.16326
$\sigma = 1$	1.21267	1.21266	1.21261	1.21208	1.20975
	$b = 0.0001$	$b = 0.001$	$b = 0.01$	$b = 0.1$	$b = 0.5$
$\rho = 0.01$	1.0824	1.0824	1.08235	1.08186	1.07969
$\rho = 0.04$	1.0767	1.0767	1.07669	1.0762	1.07406
$\rho = 0.1$	1.0724	1.0724	1.07235	1.07187	1.06976
$\rho = 0.2$	1.07049	1.07048	1.07043	1.06996	1.06786
$\rho = 0.5$	1.07067	1.07066	1.07061	1.07014	1.06772
	$b = 0.0001$	$b = 0.001$	$b = 0.01$	$b = 0.1$	$b = 0.5$
$\varpi = 0$	1.0724	1.0724	1.07235	1.07187	1.06976
$\varpi = 0.2$	1.0724	1.0724	1.07235	1.07187	1.06976
$\varpi = 0.5$	1.0724	1.0724	1.07235	1.07187	1.06976
$\varpi = 0.95$	1.0724	1.0724	1.07235	1.07187	1.06976
$\varpi = 1$	1.0724	1.0724	1.07235	1.07187	1.06976
	$b = 0.0001$	$b = 0.001$	$b = 0.01$	$b = 0.1$	$b = 0.5$
$B = 0.1$	1.04428	1.04427	1.04423	1.04375	1.04163
$B = 1.55$	1.0724	1.0724	1.07235	1.07187	1.06976
$B = 2$	1.07838	1.07837	1.07833	1.07785	1.07573
$B = 5$	1.10766	1.10765	1.1076	1.10712	1.10498
$B = 20$	1.18679	1.18678	1.18673	1.18623	1.18402

Table 1.3: Values of the reactivation threshold (Lr) for varying combinations of parameter values (unmentioned parameter values are those detailed in table 1.1)

	$b = 0.0001$	$b = 0.001$	$b = 0.01$	$b = 0.1$	$b = 0.5$
$\alpha = -0.09$	/	/	/	/	/
$\alpha = -0.05$	/	/	/	/	/
$\alpha = 0$	/	/	/	/	/
$\alpha = 0.01$	/	/	/	/	/
$\alpha = 0.05$	/	/	/	/	/
	$b = 0.0001$	$b = 0.001$	$b = 0.01$	$b = 0.1$	$b = 0.5$
$\sigma = 0.01$	/	/	/	/	/
$\sigma = 0.1$	/	/	/	/	/
$\sigma = 0.2$	/	/	/	/	/
$\sigma = 0.4$	/	/	/	/	/
$\sigma = 1$	/	/	/	/	/
	$b = 0.0001$	$b = 0.001$	$b = 0.01$	$b = 0.1$	$b = 0.5$
$\rho = 0.01$	/	/	/	/	/
$\rho = 0.04$	/	/	/	/	/
$\rho = 0.1$	/	/	/	/	/
$\rho = 0.2$	/	/	/	/	/
$\rho = 0.5$	/	/	/	/	/
	$b = 0.0001$	$b = 0.001$	$b = 0.01$	$b = 0.1$	$b = 0.5$
$\varpi = 0$	0.177269	0.292767	0.483502	0.798249	1.1318
$\varpi = 0.2$	/	/	/	/	/
$\varpi = 0.5$	/	/	/	/	/
$\varpi = 0.95$	/	/	/	/	/
$\varpi = 1$	/	/	/	/	/
	$b = 0.0001$	$b = 0.001$	$b = 0.01$	$b = 0.1$	$b = 0.5$
$B = 0.1$	/	/	/	/	/
$B = 1.55$	/	/	/	/	/
$B = 2$	/	/	/	/	/
$B = 5$	/	/	/	/	/
$B = 20$	/	/	/	/	/

Table 1.4: Values of the liquidation threshold (Ll) for varying combinations of parameter values (unmentioned parameter values are those detailed in table 1.1)

Lc	$b = 0.0001$	$b = 0.001$	$b = 0.01$	$b = 0.1$	$b = 0.5$
$a = 1$	/	/	/	/	0.372654
$a = 10$	0.726229	0.726173	0.725614	0.720017	0.695084
$a = 50$	0.849742	0.849727	0.849582	0.848132	0.841685
$a = 200$	0.913156	0.913152	0.913111	0.912708	0.910917
$a = 400$	0.934094	0.934092	0.934072	0.933864	0.932939
Lc	$b = 0.0001$	$b = 0.001$	$b = 0.01$	$b = 0.1$	$b = 0.5$
$z = 0$	0.944124	0.94412	0.944077	0.943644	0.941722
$z = 0.1$	0.940445	0.94044	0.940397	0.939969	0.938064
$z = 1$	0.913156	0.913152	0.913111	0.912708	0.910917
$z = 5$	0.843765	0.843761	0.843726	0.843375	0.841814
$z = 10$	0.794159	0.794156	0.794124	0.793806	0.792393
Lr	$b = 0.0001$	$b = 0.001$	$b = 0.01$	$b = 0.1$	$b = 0.5$
$a = 1$	/	/	/	/	1.18762
$a = 10$	1.27388	1.27376	1.27261	1.26112	1.21046
$a = 50$	1.12929	1.12927	1.12907	1.12706	1.11815
$a = 200$	1.0724	1.0724	1.07235	1.07187	1.06976
$a = 400$	1.05519	1.05519	1.05516	1.05493	1.05389
Lr	$b = 0.0001$	$b = 0.001$	$b = 0.01$	$b = 0.1$	$b = 0.5$
$z = 0$	1.06798	1.06798	1.06793	1.06746	1.06537
$z = 0.1$	1.06805	1.06804	1.068	1.06753	1.06544
$z = 1$	1.0724	1.0724	1.07235	1.07187	1.06976
$z = 5$	1.10478	1.10478	1.10473	1.10421	1.10195
$z = 10$	1.13835	1.13834	1.13829	1.13775	1.13536
Ll	$b = 0.0001$	$b = 0.001$	$b = 0.01$	$b = 0.1$	$b = 0.5$
$a = 0.1$	/	/	/	/	/
$a = 1$	/	/	/	/	/
$a = 10$	/	/	/	/	/
$a = 20$	/	/	/	/	/
$a = 50$	/	/	/	/	/

Table 1.5: Values of the containment, reactivation and liquidation threshold for varying combinations of parameter values (unmentioned parameter values are those detailed in table 1.1). For the liquidation threshold, changes in z are also found to have no effect.

In order to perform this analysis, we make use of the Bankscope database, which provides detailed information about banks and financial institutions around the globe. This allows for easy access to the financial data required to calculate the liquidity creation measures. The database is also used to identify our sample of banks: in a first step, we use the database to sort all banks in each considered country by total asset size. The five banks with the largest balance sheets are selected, though additional procedures are taken into account. For each bank it was checked on their annual report whether the asset size was the same (in order to 'guarantee' the correctness of the data) and whether reporting was done in millions rather than thousands (in case of the latter, the bank was dropped in favour of the next in line). Secondly, additional factors like the specific activity of the bank (e.g. retail banking) and the company structure (i.e. already being part of a previously considered group) were also taken into account in order to avoid double counting and keep the sample as relevant as possible. Priority was given to the parent company (in case multiple branches were active in the country) as well as to banks which had a clear relation with the country under scrutiny (e.g. for the United Kingdom, we opted to include "HBOS plc" rather than "Credit Suisse International", even though the latter was ranked higher on the charts). The final selection of banks, listed by country, can be found in section E.2 of the electronic appendix that is located at the end of this chapter.

Inspired by Xu (2010), a method is used to efficiently calculate the cat fat measure. This methodology does not consider the full balance sheet of the bank but rather elects to focus on the key components. Given that the cat fat measure is calculated as:

$$\begin{aligned} L &= cat\ fat = 0.5 * illiquid\ assets + 0 * semi - liquid\ assets - \\ &\quad 0.5 * liquid\ assets + 0.5 * liquid\ liabilities + 0 * semi - \\ &\quad liquid\ liabilities - 0.5 * illiquid\ liabilities - \\ &\quad 0.5 * equity + 0.5 * illiquid\ guarantees \end{aligned}$$

and these components consist of the elements described in table 1.6, one can easily determine the liquidity creation measures of the banks in the sample[24]. Compared with the full analysis performed earlier, this method results in a normalized cat fat score of 58.4024 for Dexia, which is not too far from the 47.7088 we found above.

To consider whether the observed decisions were the appropriate ones from a liquidity creation point of view, we compare the cat fat measure of liquidity creation with the respective thresholds of each bank. These thresholds are calculated the same way as before, taking into account the considered bank's operating costs (= 'personnel expenses' + 'other operating expenses') w.r.t. the normalization and the differing bailout amounts and deposit sizes (= 'total customer deposits'). Additionally, for those banks who did not receive a bailout, B was set to the average of bailout amounts that were effectively observed. Gathered data on the bailout amount used in the considered cases can be consulted in section E.4. of the electronic appendix.

Both the cat fat score and the threshold values can be found in section E.3 of the electronic appendix, together with their evaluation. From this we learn that,

[24]Compared to Xu (2010), we a) redefined the 'illiquid loans' portion ; b) ignored the separate posts of "non-listed securities" and "commercial deposits" (the latter should be found among the other categories) and c) assume that "treasury bills", "other bills" and "bonds" are part of total securities. All elements can be directly obtained from Bankscope or be derived from the formulas between brackets. Semi-(il)liquid assets were not calculated due to the weighting coefficient of 0.

Illiquid assets =
Illiquid loans (=Residential mortgage loans + Other mortgage loans + Other consumer/retail loans
+ Corporate & financial loans + Other loans)
+ Other investments (= At-equity investments in associates + Investments in property)
+ [Non-earning assets – Cash and due from banks]
+ Fixed assets

Liquid assets =
Total securities
+ Cash and due from banks
+ Equity investments (= Equity investments deducted from regulatory capital)

Liquid liabilities =
Demand deposits (=Customer deposits-current)
+ Savings deposits (= Customer deposits-savings)
+ Deposits with banks (=Deposits from banks)

Illiquid liabilities =
Other funding
+ Total loan loss and other reserves (= loan loss reserves + other reserves)
+ Other liabilities
+ Total equity

Illiquid guarantees =
Guarantees
+ Committed credit lines
+ Other contingent liabilities

Table 1.6: Composition of illiquid assets, liquid assets, liquid liabilities, iliquid liabilities and illiquid guarantees; partially adapted from Xu (2010, p. 131)

generally speaking,from a liquidity creation point of view, the EU-15 has performed admirably during the financial crisis: from the 75 cases that were scrutinized, 70 decisions could be deemed optimal. Mistakes were made with respect to:

1. the bailout to BNP Paribas by the French government (cat fat $<L_r$; as such, no bailout should have been given)
2. the nationalization of ABN Amro by the Dutch government (cat fat $>L_r$; as such, a normal bailout would have sufficed. In the model, nationalization is indeed interpreted as a situation where both L_l and L_r do not exist, i.e. a situation of eternal containment where the bank continues to operate with the help of government funding)
3. the negligence of the financial situation at Argenta Spaarbank (Belgium), Deutsche Bank (Germany) and Barclays Bank (United Kingdom) (cat fat $<L_c$; as such the banks should have gone into containment).

In general however, based on this (relatively small) sample of cases, we can conclude that, from a liquidity creation point of view, the EU-15 countries have executed optimal bank bailout policy in the crisis year of 2008.

1.5. Possible model extensions

While the model presented above incorporates the main mechanisms involved in bailout decision making, the framework is flexible enough to allow for the incorporation of additional elements. For instance, up to now, no mention was made concerning so-called contagion effects - the impact of the failure of a bank on the other banks in the industry - and moral hazard. Another issue may lie in the use of a GBM, which has a fixed trend, even though the financial situation of banks may turn abruptly. In this section, we will show how one could incorporate these elements.

1.5.1. Accounting for moral hazard and contagion

Up to now, we have only considered the direct cost of bailout and liquidation decisions, namely the monetary costs involved in their execution. Bailout and liquidation however also bring along indirect costs, the most important of which are moral hazard and the possibility of contagion to other banks. A simple way to incorporate these elements in the model is by altering the value-matching conditions. For example, the value matching condition that governs the transition from contained to active bank (5) could be rewritten as:

$$W_c(L_r) = W_a(L_r) - B(1 + pN), \tag{13}$$

where N is the exogenous number of assumed to be symmetric[25] banks in the industry and p is the expected fraction of banks that will require bailout in the future due to increased risk-taking incentives following the current decision [26]. By introducing this last term, one basically enlarges the bailout cost by taking into account the cost of additional bailout cases in the future. As such, the indirect costs of moral hazard are captured, though it may prove difficult to find a good approximation for p.

In order to capture contagion effects, one can write value matching condition (7) as:

$$W_c(L_l) = -\varpi D - \lambda NB, \tag{14}$$

where λ can be defined as the expected fraction of banks of which the financial

[25]Note that the symmetry is in size and not in liquidity. In particular, note that the other banks are still unaffected by the problems faced by the bank under scrutiny ; reminiscent of the situation where a general crisis only really starts when the first 'domino brick' falls.

[26]This formulation of moral hazard is reminiscent to the one used in Goodhart & Huang (2005).

soundness depends on the survival of the bank under consideration. If the government liquidates the bank, it will likely encounter additional bailout cases in the future with their own costs. This implicitly drives up the cost of the current liquidation decision and increases the option value of waiting. As in the case of moral hazard, it may be difficult to arrive at good values for λ. By using a large enough range of values however, the impact of its inclusion can be assessed.

Once one has replaced value-matching conditions (5) and (7) by the previously mentioned substitutes, one can recalculate the model using the same procedure as before. This time however, the resulting thresholds will have taken into account both moral hazard and contagion effects. As such, one would expect a lower containment threshold (as the decision becomes more costly to reverse), a lower liquidation threshold (taking into account the increased cost of liquidation) and a higher reactivation threshold (taking into account the increased cost of bailout).

1.5.2. Allowing for conjunctural variation

Here we relax the assumption that α is constant, i.e. that the trend is eternally upward or downward sloping. We do so by recognizing two specific states the general economy may be in, namely in a normal situation - characterized by a positive growth trend α - or in a crisis/bank run, in which α turns negative. The normal situation is hereby labeled with 0 while a bank run is indicated by the number 1. If we are in a normal situation, the occurrence of a bank run (moving from state 0 to state 1) occurs with probability $\lambda_1 dt$ while an economic recovery (moving from state 1 to state 0) occurs with probability $\lambda_0 dt$. In fact, the bank now faces two sources of uncertainty, namely the basic GBM from above, as well as a Poisson process, which governs the transitions between the normal and bank run 'state'.

Redoing the calculations with this additional uncertainty process would now result in six thresholds, namely a containment, reactivation and liquidation threshold for both the normal and the bank run state. Generally speaking, the thresholds found in state 0 would typically be lower than their counterparts in state 1 due to the impact of a higher α, which delays containment and liquidation (lower L_c and lower L_l) and hastens bailout (lower L_r). However, all thresholds would also be affected by the change in the option value of waiting that originates from the possibility of economic recovery/deterioration. In state 1 for example, there is a probability $\lambda_0 dt$ that the trend becomes positive, which would most likely result in a decrease of the containment threshold relative to the constant growth rate scenario due to the larger option value of waiting. Similarly, one would expect a decrease in the liquidation threshold and an increase in the reactivation threshold. As a similar effect is likely to be observed in state 0, it is rather difficult to determine the relative positions of the six threshold values without executing the associated numerical exercises. This will require a specification of both λ_0 and λ_1, for which a wide range of values should be considered.

1.6. Conclusion

In this paper, we have formulated a real options consistent bailout decision rule that determines when a government should save or liquidate a failing bank. This rule - based on the liquidity creation function of banks - takes into account the option value of waiting associated with the uncertain environment surrounding impending bank failures. As such, it advocates decisions that take into account the possibility of economic recovery/deterioration to ensure an optimal solution from a dynamic perspective.

The rule has numerous advantages. Compared to its (mostly static) competitors, the real options construction ensures a full incorporation of the uncertain economic environment. Secondly, data requirements are pretty low, given that almost all of the required data are found on the balance sheet - an integral part of the annual report that each bank is forced to make public. Thirdly, obtained results are quite stable w.r.t. changes in exogenous parameters, reinforcing their robustness. Lastly, the framework is flexible: while the basic model only includes the main mechanics involved in bailout decision making, it is relatively easy to expand the model to render it more realistic.

Application of the rule to 75 bailout cases in the EU-15 has shown that governments seem to have consistently made the correct decision - from a liquidity creation point of view - in times of financial turmoil. The rare 'mistakes' consist of the bailout of BNP Paribas, the nationalization of ABN Amro and the negligence of the financial situation at Argenta Spaarbank, Barclays Bank and Deutsche Bank. In general however, the rule suggests that governments are able to make the right decisions when bank bailouts are considered.

Appendix A.

A.1. Proof of proposition 1

To determine the social value of the active bank, we start from the corresponding Bellman equation, which splits the value of the bank in the current welfare contribution ($= a(L-\bar{L}) - z(L-\bar{L})^2$) and its continuation/future value :

$$W_a(L) = (a(L-\bar{L}) - z(L-\bar{L})^2)dt + E[W_a(L+dL)e^{-\rho dt}]. \tag{A.1}$$

As $E[dW_a(L)] = E[W_a(L+dL)] - E[W_a(L)]$, one can write (A.1) as

$$W_a(L) = (a(L-\bar{L}) - z(L-\bar{L}))dt + \{E[dW_a(L)] + E[W_a(L)]\}e^{-\rho dt}. \tag{A.2}$$

Making use of Ito's lemma for an Ito process as well as equation (2), one can then expand $E[dW_a(L)]$ as follows (Dixit & Pindyck, 1994, p. 80):

$$E[dW_a(L)] = [\frac{\partial W_a}{\partial t} + \alpha L \frac{\partial W_a}{\partial L} + \frac{1}{2}\sigma^2 L^2 \frac{\partial^2 W_a}{\partial L^2}]dt, \tag{A.3}$$

where $\frac{\partial W_a}{\partial t} = 0$ and $\frac{\partial W_a}{\partial L}$ and $\frac{\partial^2 W_a}{\partial L^2}$ will be denoted as $W_a^{'}$ and $W_a^{''}$ respectively. Substituting (A.3) in (A.2) while writing $e^{-\rho dt}$ as $(1-\rho dt)$ by using the approximation of an e-power yields:

$$W_a(L) = (a(L-\bar{L})-z(L-\bar{L})^2)dt+[\alpha L W_a' + \frac{1}{2}\sigma^2 L^2 W_a'']dt + W_a(L)*(1-\rho dt). \tag{A.4}$$

Dividing by dt and rearranging yields the following non-homogeneous linear second-order differential equation :

$$\frac{1}{2}\sigma^2 L^2 W'' + \alpha L W' - \rho * W + (a(L-\bar{L}) - z(L-\bar{L})^2) = 0. \tag{A.5}$$

This equation can be solved in three steps:

- Step 1) solving the homogeneous equation

The homogeneous part of the equation is

$$\frac{1}{2}\sigma^2 L^2 W_a'' + \alpha L W_a' - \rho W_a(L) = 0. \tag{A.6}$$

Given the particular form of the equation, one might guess the form of the solution, namely $W_a(L) = A * L^\beta$ with $W_a^{'}(L) = \beta * A * L^{\beta-1}$ and $W_a^{'}(L) = \beta(\beta-1) * A * L^{\beta-2}$. Substituting this in (A.6) yields that:

$$\frac{1}{2}\sigma^2 L^2 \beta(\beta-1) A L^{\beta-2} + \alpha L \beta A L^{\beta-1} - \rho A L^\beta = 0, \tag{A.7}$$

$$\Leftrightarrow \frac{1}{2}\sigma^2\beta(\beta-1)+\alpha\beta-\rho=0. \tag{A.8}$$

This is a quadratic equation which can be solved using the basic discriminant rule and yields the following two roots:

$$\beta_1=\frac{1}{2}-\frac{\alpha}{\sigma^2}+\sqrt[2]{(\frac{\alpha}{\sigma^2}-\frac{1}{2})^2+\frac{2\rho}{\sigma^2}} \tag{A.9}$$

$$\beta_2=\frac{1}{2}-\frac{\alpha}{\sigma^2}-\sqrt[2]{(\frac{\alpha}{\sigma^2}-\frac{1}{2})^2+\frac{2\rho}{\sigma^2}}. \tag{A.10}$$

The general solution to the homogeneous equation is therefore

$$W_a(L)=A_1L^{\beta_1}+A_2L^{\beta_2}. \tag{A.11}$$

- Step 2) finding a particular solution to the non-homogeneous equation

For a particular solution, propose $W_a^p(L)=uL^2+vL+w$ with $W_a^{p'}(L)=2uL+v$ and $W_a^{p''}(L)=2u$. Putting this in the non-homogeneous differential equation (A.5) yields:

$$u\sigma^2L^2+2u\alpha L^2+v\alpha L-\rho uL^2-\rho vL-\rho w+aL-a\bar{L}-zL^2+2zL\bar{L}-z\bar{L}^2=0. \tag{A.12}$$

This is only true if:

- Terms related to L^2 are 0:

$$(u\sigma^2+2u\alpha-\rho u-z)L^2=0 \tag{A.13}$$

$$\Leftrightarrow u=-\frac{z}{\rho-2\alpha-\sigma^2}. \tag{A.14}$$

- Terms related to L are 0:

$$(v\alpha - \rho v + a + 2z\bar{L})L = 0 \tag{A.15}$$

$$\Leftrightarrow v = \frac{2z\bar{L} + a}{\rho - \alpha}. \tag{A.16}$$

- Terms unrelated to L are 0:

$$-\rho w - a\bar{L} - z\bar{L}^2 = 0 \tag{A.17}$$

$$\Leftrightarrow w = -\frac{a\bar{L} + z\bar{L}^2}{\rho}. \tag{A.18}$$

This implies that the particular solution to the non-homogeneous differential equation is

$$W_a^p(L) = -\frac{zL^2}{\rho - 2\alpha - \sigma^2} + \frac{2z\bar{L} + a}{\rho - \alpha}L - \frac{a\bar{L} + z\bar{L}^2}{\rho}. \tag{A.19}$$

- Step 3) finding the general solution to the non-homogeneous equation

The general solution is found by simply summing up the solution of the homogeneous equation and the particular solution. Hence the social value of the active bank is equal to

$$W_a(L) = A_1 L^{\beta_1} + A_2 L^{\beta_2} - \frac{zL^2}{\rho - 2\alpha - \sigma^2} + \frac{2z\bar{L} + a}{\rho - \alpha}L - \frac{a\bar{L} + z\bar{L}^2}{\rho}. \tag{A.20}$$

The first two terms on their turn can be interpreted as the value of the option to contain. Note that the bank remains active for $L \in (L_c, \infty)$. However, as L goes to infinity, the probability of containment goes to zero. Hence, the coefficient associated with the positive root (β_1) should be zero (Dixit & Pindyck, 1994, p. 218). As such, equation (A.20) simplifies to

$$W_a(L) = A_2 L^{\beta_2} - \frac{zL^2}{\rho - 2\alpha - \sigma^2} + \frac{2z\bar{L} + a}{\rho - \alpha} L - \frac{az\bar{L} + \bar{L}^2}{\rho}. \tag{A.21}$$

A.2. Proof of proposition 2

To determine the social value of the contained bank, we make use of the same methodology as used in proposition 1, although this time, several of the assumptions made above have to be taken into account. These include the postulates that a contained bank is enabled to create exactly the amount of liquidity needed to cover its operational welfare costs ($\bar{L}$) and the fact that containment is upheld at the expense of a periodic cash flow in the form of liquidity support, namely b, which in itself hurts welfare. As such, the relevant Bellman equation takes the following form:

$$W_c(L) = -bdt + E[W_c(L + dL)e^{-\rho dt}]. \tag{A.22}$$

which differs only from (A.1) in the sense that the current contribution is $-b$ instead of $L - \bar{L}$. Following the same techniques as above, one therefore finds a very similar non-homogeneous linear second order differential equation:

$$\frac{1}{2}\sigma^2 L^2 W'' + \alpha L W' - \rho W - b = 0, \tag{A.23}$$

with the same solution and accompanying expressions for the homogeneous equation

$$W_c(L) = B_1 L^{\beta_1} + B_2 L^{\beta_2}. \tag{A.24}$$

For a particular solution, propose $W_c^p(L) = kL + m$ with $W_c^{p'}(L) = k$ and $W_c^{p''}(L) = 0$. Substituting this in (A.23) yields

$$0 + kLa - \rho(kL + m) - b = 0. \tag{A.25}$$

This is only true if:

- Terms related to L are 0:

$$[k(\alpha - \rho)]L = 0 \tag{A.26}$$
$$\Leftrightarrow k = 0.$$

- Terms unrelated to L are 0:

$$-\rho m - b = 0 \tag{A.27}$$
$$\Leftrightarrow m = \frac{-b}{\rho}. \tag{A.28}$$

Hence, the particular solution to the non-homogeneous differential equation is:

$$W_c^p(L) = \frac{-b}{\rho}. \tag{A.29}$$

The social value of the contained bank is then given by

$$W_c(L) = B_1 L^{\beta_1} + B_2 L^{\beta_2} - \frac{b}{\rho}. \tag{A.30}$$

Here, $\frac{b}{\rho}$ represents the present value of the liquidity support cost assuming the support lasts forever. $B_1 L^{\beta_1}$ represents the value of the option to reactivate the contained bank while $B_2 L^{\beta_2}$represents the value of the option to liquidate the bank. Unlike before, both roots are used in the expression as $L \in (L_l, L_r)$, which does not include infinity nor 0.

Appendix B.

The problem at hand is to reduce the complexity of the six-equation system discussed above. In a first step, we split the system in two and only consider the first four equations, which are rewritten as follows:

$$(A_2 - B_2)L_c^{\beta_2} - B_1 L_c^{\beta_1} - \frac{zL_c^2}{\rho - 2\alpha - \sigma^2} + \frac{2z\bar{L} + a}{\rho - \alpha}L_c - \frac{a\bar{L} + z\bar{L}^2 - b}{\rho} = 0, \quad \text{(B.1)}$$

$$(A_2 - B_2)\beta_2 L_c^{\beta_2 - 1} - B_1\beta_1 L_c^{\beta_1 - 1} - \frac{2zL_c}{\rho - 2\alpha - \sigma^2} + \frac{2z\bar{L} + a}{\rho - \alpha} = 0, \quad \text{(B.2)}$$

$$(A_2 - B_2)L_r^{\beta_2} - B_1 L_r^{\beta_1} - \frac{zL_r^2}{\rho - 2\alpha - \sigma^2} + \frac{2z\bar{L} + a}{\rho - \alpha}L_r - \frac{a\bar{L} + z\bar{L}^2 - b}{\rho} - B = 0, \quad \text{(B.3)}$$

$$(A_2 - B_2)\beta_2 L_r^{\beta_2 - 1} - B_1\beta_1 L_r^{\beta_1 - 1} - \frac{2zL_r}{\rho - 2\alpha - \sigma^2} + \frac{2z\bar{L} + a}{\rho - \alpha} = 0. \quad \text{(B.4)}$$

Replacing $(A_2 - B_2)$ by D then results in a four equation system in four unknowns.

The second step, inspired by Martzoukos(2001), consists of writing D and B_1 in terms of L_c and L_r to further simplify the system. First note that the smooth pasting conditions (B.2) and (B.4) can be written as:

$$D\beta_2 L_c^{\beta_2} - B_1\beta_1 L_c^{\beta_1} - \frac{2zL_c^2}{\rho - 2\alpha - \sigma^2} + \frac{2z\bar{L} + a}{\rho - \alpha}L_c = 0, \quad \text{(B.5)}$$

$$D\beta_2 L_r^{\beta_2} - B_1\beta_1 L_r^{\beta_1} - \frac{2zL_r^2}{\rho - 2\alpha - \sigma^2} + \frac{2z\bar{L} + a}{\rho - \alpha}L_r = 0. \quad \text{(B.6)}$$

From these equations one can obtain that:

$$D = \frac{B_1\beta_1 L_c^{\beta_1 - \beta_2} + \frac{2zL_c^{2-\beta_2}}{\rho - 2\alpha - \sigma^2} - \frac{(2z\bar{L} + a)L_c^{1-\beta_2}}{\rho - \alpha}}{\beta_2}, \quad \text{(B.7)}$$

$$B_1 = \frac{D\beta_2 L_r^{\beta_2-\beta_1} - \frac{2zL_r^{2-\beta_1}}{\rho-2\alpha-\sigma^2} + \frac{(2z\bar{L}+a)L_r^{1-\beta_1}}{\rho-\alpha}}{\beta_1}. \tag{B.8}$$

and via substitution in each other that:

$$D = \frac{(D\beta_2 L_r^{\beta_2-\beta_1} - \frac{2zL_r^{2-\beta_1}}{\rho-2\alpha-\sigma^2} + \frac{(2z\bar{L}+a)L_r^{1-\beta_1}}{\rho-\alpha})L_c^{\beta_1-\beta_2} + \frac{2zL_c^{2-\beta_2}}{\rho-2\alpha-\sigma^2} - \frac{(2z\bar{L}+a)L_c^{1-\beta_2}}{\rho-\alpha}}{\beta_2}, \tag{B.9}$$

$$D = \frac{-\frac{2zL_r^{2-\beta_1}L_c^{\beta_1-\beta_2} - 2zL_c^{2-\beta_2}}{\rho-2\alpha-\sigma^2} + \frac{(2z\bar{L}+a)L_r^{1-\beta_1}L_c^{\beta_1-\beta_2} - (2z\bar{L}+a)L_c^{1-\beta_2}}{\rho-\alpha}}{(1-L_r^{\beta_2-\beta_1}L_c^{\beta_1-\beta_2})\beta_2}, \tag{B.10}$$

$$B_1 = \frac{\frac{-\frac{2zL_r^{2-\beta_1}L_c^{\beta_1-\beta_2} - 2zL_c^{2-\beta_2}}{\rho-2\alpha-\sigma^2} + \frac{(2z\bar{L}+a)L_r^{1-\beta_1}L_c^{\beta_1-\beta_2} - (2z\bar{L}+a)L_c^{1-\beta_2}}{\rho-\alpha}}{(1-L_r^{\beta_2-\beta_1}L_c^{\beta_1-\beta_2})\beta_2}\beta_2 L_r^{\beta_2-\beta_1} - \frac{2zL_r^{2-\beta_1}}{\rho-2\alpha-\sigma^2} + \frac{(2z\bar{L}+a)L_r^{1-\beta_1}}{\rho-\alpha}}{\beta_1}. \tag{B.11}$$

Putting these values in (B.1) and (B.3) then results in a two equation system in two unknowns (L_c and L_r) which a computer can easily solve. The last step then involves the determination of the previously ignored elements via the knowledge about the threshold values.

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Electronic Appendix

E.1. Calculation liquidity creation Dexia

The first step in the creation of the liquidity creation measures is the classification of the bank's assets and liabilities as 'liquid', 'semi-liquid' and 'illiquid'. Tables E.1-E.3 give an overview of all of the posts found on the consolidated balance sheet of Dexia, their 2008 value and their classification (based on the categorization scheme in the Berger & Bouwman article). In the next step, all posts within the same category are summed up. Finally, these sums are weighted and combined according to the scheme of Berger & Bouwman (2009, p. 3790-3791) in order to arrive at the two liquidity creation measures[1]. As such, one has that:

- Cat fat measure:

Liquidity creation $= \frac{1}{2} *$€ 317792 million $+0*$€ 258457 million $-\frac{1}{2}*$€ 74757 million $+\frac{1}{2}*$€ 272500 million $+0*$€ 155891million $-\frac{1}{2}*$€ 222615 million $+\frac{1}{2}*$€ 99991 million $=$ € 196455.5 million

- Cat non-fat measure

Liquidity creation $= \frac{1}{2} *$€ 317792 million $+0*$€ 258457 million $-\frac{1}{2}*$€ 74757 million $+\frac{1}{2}*$€ 272500 million $+0*$€ 155891million $-\frac{1}{2}*$€ 222615 million $=$ € 146459.5 million

[1] A weight of 0 is given to each semi-liquid category. Illiquid assets and liquid liabilities receive a weight of +1/2 while liquid assets and illiquid liabilities receive a weight of -1/2

Year	2008	Classification
Assets (in millions of euros)		
Cash and balances with central banks	2448	**Liquid**
Loans and advances due from banks	61864	**Semi-liquid**
Loans and advances to customers:		
Public	196409	**Semi-liquid**
Other	172426	**Illiquid**
Impaired (calculated: subtracted impaired losses)	10	**Illiquid**
Financial assets measured at fair value through profit or loss:		
For trading	10836	**Liquid**
Bonds issued by public bodies (by category division)	184	**Semi-liquid**
Loans ; other bonds and fixed- income instruments	5024	**Illiquid**
Financial investments:		
Public sector	53359	**Illiquid**
Banks	55876	**Illiquid**
Other	14842	**Illiquid**
Impaired	952	**Illiquid**
Derivatives (only on actual balance sheet)	55213	**Liquid**
Fair value revaluation of portfolio hedge	3938	**Illiquid**
Investments in associates (/carrying value)	682	**Illiquid**
Tangible fixed assets (net book value)	2353	**Illiquid**
Intangible assets and goodwill	2193	**Illiquid**
Tax assets	4139	**Illiquid**
Other assets	1998	**Illiquid**
Non-current assets held for sale	6260	**Liquid**
Liquid assets total	74757	
Semi-liquid assets total	258457	
Illiquid assets total	317792	
Total	651006	

Table E.1: Classification of assets Dexia 2008

Year	2008	Classification
Liabilities (in millions of euros)		
Due to banks:		
On demand	13197	**Liquid**
Term	12393	**Semiliquid**
Repo	35331	**Semiliquid**
Central banks	120559	**Liquid**
Other borrowings	31712	**Semiliquid**
Customer borrowings and deposits:		
Demand deposits	30874	**Liquid**
Savings deposits	26072	**Liquid**
Term deposits	42587	**Semiliquid**
Other customer deposits	2807	**Illiquid**
Repo (borrowing)	9314	**Semiliquid**
Other borrowings	3074	**Semiliquid**
Financial liabilities measured at fair value through profit or loss:		
Financial liabilities held for trading	273	**Liquid**
Non subordinated liabilities	15135	**Illiquid**
Subordinated liabilities	347	**Illiquid**
Unit linked products	3197	**Illiquid**
Derivatives	75834	**Liquid**
Fair value revaluation of portfolio hedge	1543	**Illiquid**
Debt securities		
Certificates of deposits	16466	**Semiliquid**
Customer savings certificates	5011	**Semiliquid**
Convertible debt	3	**Semiliquid**
Non-convertible bonds	166640	**Illiquid**
Subordinated debts (includes hybrid debt)	4407	**Illiquid**
Technical provisions of insurance companies	16739	**Illiquid**
Provisions and other obligations (retirement, litigation, ...)	1487	**Illiquid**

Table E.2: Classification of liabilities Dexia 2008

Year	2008	Classification
Liabilities (in millions of euros)		
Tax liabilities	302	**Illiquid**
Other liabilities	4393	**Illiquid**
Liabilities included in disposal groups held for sale	5691	**Liquid**
Liquid liabilities total	272500	
Semi-liquid liabilities total	155891	
Illiquid liabilities total	222615	
Total equity	5618	
Total	651006	
Off- balance sheet guarantees (in millions of euros)		
Regular way trade		
Loans to be delivered and purchases of assets	7129	**Illiquid**
Borrowings to be received and sales of assets	17707	**Illiquid**
Guarantees		
Guarantees given	17104	**Illiquid**
Guarantees received	110045	**Illiquid**
Loan commitments		
Unused lines granted	87163	**Illiquid**
Unused lines obtained ('revaluation' 2009)	9654	**Illiquid**
Other commitments		
Insurance activity- commitments given	-25	**Illiquid**
Banking activity: commitments given (different definition for 2006)	126026	**Illiquid**
Illiquid guarantees total	99991	

Table E.3: Classification of liabilities (continued) and off-balance sheet guarantees Dexia 2008

E.2. Sample composition

Tables E.4 and E.5 contain the names of all the banks considered in the EU-15 sample per country (which are ranked alphabetically). For each bank it was checked on their annual report whether the total asset size was the same as given by Bankscope in order to 'guarantee' the correctness of the data. Priority was given to size ; although specific activity and company structure (i.e. being part of a group) were also considered to avoid double counting and keep the sample as relevant as possible. Priority was also given to banks which had a clear relation with the country under scrutiny. In any case, within each country, the number before the name of the bank indicates its relative size compared to each other. A * sign indicates that the bank was either directly or indirectly (i.e. via its parent company) bailed out in the year 2008/beginning 2009. Information concerning the bailout, including its cost, was obtained from various newspapers and reports[2].

[2]For more information, consult section 4 of this appendix.

Austria	Belgium
1)UniCredit Bank Austria AG-Bank Austria	1)Dexia*
2)Erste Group Bank AG*	2)BNP Paribas Fortis SA/ NV (=Fortis 2008)*
3)Raiffeisen Zentralbank Oesterreich AG – RZB*	3)KBC Groep NV/ KBC Groupe SA-KBC Group*
4)Volksbanken Verbund*	4)Argenta Spaarbank-ASPA
5)Hypo Alpe-Adria Bank International AG*	5)AXA Bank Europe SA/NV
Denmark	**Finland**
1)Danske Bank A/S	1)Nordea Bank Finland Plc
2)Nykredit Realkredit A/S	2)OP-Pohjola Group
3)Nordea Bank Danmark Group-Nordea Bank	3)Municipality Finance Plc-Kuntarahoitus Oyj
4)Jyske Bank A/S	4)Aktia Bank Plc
5)BRF Kredit A/S	5)Alandsbanken Abp-Bank of Aland Plc
France	**Germany**
1)BNP Paribas*	1)Deutsche Bank AG
2)Crédit Agricole-Crédit Agricole Group*	2)Sparkassen-Finanzgruppen
3)Société Générale*	3)Commerzbank AG*
4)Groupe Caisse d'Epargne*	4)UniCredit Bank AG (= Hypovereinsbank)
5)Crédit Mutuel*	5)Landesbank Baden-Wuerttemberg*
Greece	**Ireland**
1)Eurobank Ergasias SA*	1)Depfa Bank Plc*
2)Alpha Bank AE*	2)Bank of Ireland*
3)Piraeus Bank SA*	3)Allied Irish Banks plc*
4)Emporiki Bank of Greece SA*	4)Permanent TSB Plc
5)Agricultural Bank of Greece*	5)Ulster Bank Ireland Limited*
Italy	**Luxembourg**
1)UniCredit SpA	1)Banque Internationale à Luxembourg SA*
2)Intesa Sanpaolo	2)Deutsche Bank Luxembourg SA
3)Cassa Depositi e Prestiti	3)BGL BNP Paribas*
4)Banca Monte dei Paschi di Siena SpA	4)Société Générale Bank & Trust*
5)Unione di Banche Italiane Scpa (=UBI Banca)	5)Banque et Caisse d'Epargne de l'Etat Luxembourg

Table E.4: List of banks in EU-15 sample per country

Portugal	Spain
1)Caixa Geral de Depositos	1)Banco Santander SA
2)Banco Comercial Português SA-Millennium bcp	2)Banco Bilbao Vizcaya Argentaria SA
3)Banco Espirito Santo SA	3)Caja de Ahorros y Pensiones de Barc.(La Caixa)
4)Banco BPI SA	4)Banco Popular Espanol SA
5)Banco Santander Totta SA	5)Banco de Sabadell SA
Sweden	**The Netherlands**
1)Skandinaviska Enskilda Banken AB	1)ING Groep NV*
2)Svenska Handelsbanken	2)RBS Holdings NV (=ABN Amro 2008)**
3)Swedbank AB*	3)Rabobank Nederland
4)Nordea Bank AB	4)Fortis Bank (Nederland) N.V.*
5)SBAB Bank AB	5)SNS Reaal NV*
United Kingdom	
1)HSBC Holdings Plc	
2)Royal Bank of Scotland Group Plc*	
3)Barclays Bank Plc	
4)Bank of Scotland Plc*	
5)HBOS Plc*	

Table E.5: List of banks in EU-15 sample per country (continued)

E.3. Bailout evaluation EU-15 sample

In tables E.6-E.8, one can find the normalized cat fat measure of liquidity creation as well as the threshold values for each considered bank in the sample. In case a bailout was observed, the cat fat score was compared to the reactivation threshold (L_r) and deemed optimal if cat fat $>L_r$. In the absence of a bailout, the cat fat was compared with the containment threshold (L_c) and deemed optimal if cat fat $>L_c$. Nationalization, according to this model is interpreted as a situation where both L_l and L_r do not exist, i.e. a situation of eternal containment where the bank continues to operate with the help of government funding. Banks are listed alphabetically. In case no bailout was observed, B was set to the standardized average bailout amount for calculation purposes.

Bank Name	**Cat fat score**	**L_c**	**L_r**	**L_l**	**Bailout?**	**Correct?**
Agricultural Bank of Greece	31.98	0.9157	1.0660	/	YES	YES
Aktia Bank Plc	89.79	0.9047	1.0934	/	NO	YES
Alandsbanken Abp	35.55	0.9047	1.0934	/	NO	YES
Allied Irish Banks plc	41.03	0.9135	1.0715	/	YES	YES
Alpha Bank AE	34.82	0.9178	1.0605	/	YES	YES
Argenta Spaarbank	**-284.61**	**0.9047**	**1.0934**	**/**	**NO**	**NO**
AXA Bank Europe SA/NV	54.24	0.9047	1.0934	/	NO	YES
Banca Monte dei Paschi di Siena	32.09	0.9047	1.0934	/	NO	YES
Banco Bilbao Vizcaya Argentaria	23.63	0.9047	1.0934	/	NO	YES
Banco BPI SA	27.51	0.9047	1.0934	/	NO	YES
Banco de Sabadell SA	40.38	0.9047	1.0934	/	NO	YES
Banco Espirito Santo SA	27.98	0.9047	1.0934	/	NO	YES
Banco Popular Espanol SA	51.24	0.9047	1.0934	/	NO	YES
Banco Santander SA	28.41	0.9047	1.0934	/	NO	YES
Banco Santander Totta SA	38.21	0.9047	1.0934	/	NO	YES
Bank of Ireland	40.28	0.9128	1.0734	/	YES	YES
Bank of Scotland Plc	136.77	0.9007	1.1035	/	YES	YES
Banque et Caisse d'Epargne Lux.	31.09	0.9047	1.0934	/	NO	YES
Banque Internationale à Lux.	315.71	0.9212	1.0515	/	YES	YES
Barclays Bank Plc	**-0.83**	**0.9047**	**1.0934**	**/**	**NO**	**NO**
BGL BNP Paribas	29.23	0.9017	1.1011	/	YES	YES
BNP Paribas	**-3.90**	**0.9233**	**1.0454**	**/**	**YES**	**NO**
BNP Paribas Fortis SA/ NV	26.81	0.9182	1.0596	/	YES	YES
BRF Kredit A/S	119.30	0.9047	1.0934	/	NO	YES
Caixa Geral de Depositos	26.74	0.9047	1.0934	/	NO	YES
Cassa Depositi e Prestiti	32.25	0.9047	1.0934	/	NO	YES
Commerzbank AG	28.54	0.9046	1.0938	/	YES	YES
Crédit Agricole	13.22	0.9232	1.0456	/	YES	YES
Crédit Mutuel	27.85	0.9230	1.0466	/	YES	YES

Table E.6: Liquidity creation and bailout evaluation for EU-15 sample

Bank Name	**Cat fat score**	**L_c**	**L_r**	**L_l**	**Bailout?**	**Correct?**
Danske Bank A/S	51.11	0.9047	1.0934	/	NO	YES
Depfa Bank Plc	339.31	0.8566	1.2417	/	YES	YES
Deutsche Bank AG	**-32.07**	**0.9047**	**1.0934**	**/**	**NO**	**NO**
Deutsche Bank Luxembourg	686.67	0.9047	1.0934	/	NO	YES
Dexia	58.40	0.9126	1.0739	/	YES	YES
Emporiki Bank of Greece SA	24.95	0.9007	1.1036	/	YES	YES
Erste Group Bank AG	28.81	0.9226	1.0478	/	YES	YES
Eurobank Ergasias SA	16.71	0.9193	1.0566	/	YES	YES
Fortis Bank (Nederland)	52.30	0.9104	1.0792	/	YES	YES
Groupe Caisse d'Epargne	24.38	0.9235	1.0452	/	YES	YES
HBOS Plc	47.59	0.9082	1.0846	/	YES	YES
HSBC Holdings Plc	19.08	0.9047	1.0934	/	NO	YES
Hypo Alpe-Adria Bank International	37.97	0.9132	1.0722	/	YES	YES
ING Groep NV	24.09	0.9191	1.0572	/	YES	YES
Intesa Sanpaolo	24.32	0.9047	1.0934	/	NO	YES
Jyske Bank A/S	21.78	0.9047	1.0934	/	NO	YES
KBC Groep NV/ KBC Groupe SA	13.85	0.9149	1.0677	/	YES	YES
Kuntarahoitus Oyj	766.45	0.9047	1.0934	/	NO	YES
La Caixa	34.88	0.9047	1.0934	/	NO	YES
Landesbank Baden-Wuerttemberg	54.47	0.9071	1.0875	/	YES	YES
Millennium bcp	32.72	0.9047	1.0934	/	NO	YES
Nordea Bank AB	41.07	0.9047	1.0934	/	NO	YES
Nordea Bank Danmark Group	66.02	0.9047	1.0934	/	NO	YES
Nordea Bank Finland Plc	35.34	0.9047	1.0934	/	NO	YES
Nykredit Realkredit	79.21	0.9047	1.0934	/	NO	YES
OP-Pohjola Group	29.86	0.9047	1.0934	/	NO	YES
Permanent TSB Plc	29.41	0.9047	1.0934	/	NO	YES
Piraeus Bank SA	30.86	0.9209	1.0523	/	YES	YES
Rabobank Nederland	38.51	0.9047	1.0934	/	NO	YES

Table E.7: Liquidity creation and bailout evaluation for EU-15 sample (continued)

Bank Name	**Cat fat score**	$\mathbf{L}_c$	$\mathbf{L}_r$	$\mathbf{L}_l$	**Bailout?**	**Correct?**
Raiffeisen Zentralbank Oesterreich AG	20.97	0.9197	1.0557	/	YES	YES
RBS Holdings NV (ABN Amro)	**5.89**	**0.9054**	**1.0917**	**/**	**Bought**	**NO**
Royal Bank of Scotland	23.05	0.9159	1.0656	/	YES	YES
SBAB Bank AB	219.32	0.9047	1.0934	/	NO	YES
Skandinaviska Enskilda Banken AB	46.66	0.9047	1.0934	/	NO	YES
SNS Reaal NV	31.91	0.9191	1.0570	/	YES	YES
Société Générale	8.49	0.9237	1.0446	/	YES	YES
Société Générale Bank & Trust	17.72	0.9017	1.1009	/	YES	YES
Sparkassen-Finanzgruppen	25.62	0.9047	1.0934	/	NO	YES
Svenska Handelsbanken	82.08	0.9047	1.0934	/	NO	YES
Swedbank AB	49.55	0.9047	1.0934	/	YES	YES
UBI Banca	26.96	0.9047	1.0934	/	NO	YES
Ulster Bank Ireland	70.97	0.8638	1.2137	/	YES	YES
UniCredit Bank AG	15.94	0.9047	1.0934	/	NO	YES
UniCredit Bank Austria AG	26.35	0.9047	1.0934	/	NO	YES
UniCredit SpA	21.74	0.9047	1.0934	/	NO	YES
Volksbanken Verbund	31.57	0.9174	1.0615	/	YES	YES

Table E.8: Liquidity creation and bailout evaluation for EU-15 sample (continued (2))

E.4. Bailout data

In this section, we provide an overview of various quotes from newspapers and reports concerning the considered cases. From these quotes, we derived the bailout amounts (parameter B) that were normalized according to the respective bank's operating costs. Countries are listed alphabetically.

E.4.1. Austria (number of bailouts : 4/5)

The Government purchased participation capital securities of: **Erste Group Bank** on 10 March 2009 in the amount of EUR 1 billion, **Hypo Alpe Adria** on 23 December 2008 in the amount of EUR 900 million, **sterreichische Volksbanken**in March 2009 in the amount of EUR 1 billion, and **Raiffeisen Zentralbank sterreich** in March 2009 in the amount of EUR 1.75 billion

Source: http://www.ecb.europa.eu/pub/pdf/scplps/ecblwp8.pdf

Investors in Austrias **Erste Bank** enjoyed a respite from the financial market turmoil on Thursday as the Eastern Europe-focused bank announced that it would take part in relatively painless government bailout deal.

Source: http://www.forbes.com/2008/10/30/erste-austria-capital-markets-equity-cx_vr_1030markets20.html

In December 2008, **Hypo** cheerfully declared itself bankrupt and got another 900 million, this time from Austrian tax payers just in time for the canny investors to loot the bank in January 2010 by using their secret repurchase agreement with Hypo

Source: http://birdflu666.wordpress.com/2011/03/01/how-to-make-a-fast-buck-the-hypo-alpe-adria-bank-scam-is-the-model-for-the-euimf-loan-to-ireland/

E.4.2. Belgium (3/5)

Under the hastily arranged rescue, Belgium will make the biggest contribution, taking a 49 percent stake in the Belgian arm of the company, **Fortis Bank NV/SA**, for 4.7 billion euros.

Source: http://articles.economictimes.indiatimes.com/2008-09-29/news/28488602_1_herman-verwilst-fortis-benelux

Under the terms, various Belgian authorities and some big Belgian shareholders will contribute 3bn to the rescue [of **Dexia**] by subscribing to a capital increase, a statement from the Belgian prime minister's office said. The French government and the French state financial institution Caisse des Depots will add another 3bn, while Luxembourg will invest 376m via a convertible loan (September 2008)

Source: http://www.telegraph.co.uk/finance/financialcrisis/3108159/Financial-crisis-Dexia-gets-5bn-bailout-from-Belgium-France-and-Luxembourg.html .

Belgian lender **KBC Bank NV** on Thursday said it would sell Antwerp Diamond Bank (ADB) to a Chinese investor. ADB is the final unit KBC agreed to sell for approval of a 7 billion (9.5 billion) aid package it received at the height of the financial crisis.

Source: http://www.vcpost.com/articles/20008/20131219/belgian-bank-kbc-sell-antwerp-diamond-exchange-government-bailout-2008.htm

E.4.3. Denmark (0/5 ; mostly small banks were in trouble)

At the start of October, as financial markets crashed across the world, the government offered an unlimited guarantee on bank deposits, including some forms of unsecured debt, and set up a bank rescue fund worth DKK35 billion that the banks would pay in to over a three year period. This followed moves by Denmarks central bank to take over EBH bank, the countrys **sixth largest**, as well as the collapsed Roskilde bank, the countrys **tenth largest**, last summer. Since then the government has been forced to admit that the economy will be in recession throughout 2009, and that levels of unemployment will increase.

Source: http://www.wsws.org/en/articles/2009/01/denm-j23.html

Several of Denmarks small banks are struggling to stay liquid as wholesale funding dries up. Many small banks expanded their balance sheets aggressively in recent years using wholesale funding to take advantage of the countrys real estate boom. Two have already been rescued and five other small banks have been pushed into mergers

Source: http://www.ft.com/intl/cms/s/0/f4e2f0e6-93c9-11dd-9a63-0000779fd18c.html

As such, the top 5 banks remained safe.

E.4.4. Finland (0/5 ; no emergencies identified)

The global financial crisis has led to a number of restructuring measures within the US and European financial sectors and many financial institutions have had to rely on government bailout programs. In October, the Finnish government alongside the other EU governments agreed to guarantee interbank lending, if necessary, and make fixed-term capital investments in banks. **However, Finnish banks have announced that they are in no need of financial aid in the current situation**. (september 2008)

Source: https://www.op.fi/media/liitteet?cid=150946378&srcpl=3

A binding agreement was signed earlier today on the purchase of Kaupthing in Sweden by Finnish Alandsbanken, based on the Aland Islands. Alandsbanken purchased Kaupthing Bank Sverige AB.

http://www.icenews.is/2009/02/16/kaupthing-sweden-sold-to-finns/

E.4.5. France (5/5)

BNP Paribas will get 2.6 billion euros ($3.4 billion), **Credit Agricole** 3.0 billion euros ($4.0 billion) and **Societe Generale** 1.7 billion euros ($2.3 billion).

Source: http://www.forbes.com/2008/10/21/bnp-banks-update-markets-equity-cx_ll_1021markets14.html

Under the plan, the state will subscribe to subordinated five-year debt totalling EUR10.5bn (USD13.75bn) issued by the country's six largest banks: EUR3bn by **Credit Agricole** (CAGR.PA), EUR2.55bn by **BNP Paribas** (BNPP.PA) (LSE: BNP) (OTC: BNPQY), EUR1.7bn by **Societe Generale** (SocGen) (SOGN.PA) (OTC: SCGLY), EUR1.2bn by **Credit Mutuel**, EUR1.1bn by **Caisses d'Epargne** and EUR0.95bn by Banques Populaires (BCP.PA).

Source: http://www.thefreelibrary.com/France+begins+implementation+of+bank+bail-out.-a0190341102

E.4.6. Germany (2/5)

The bank [=**Commerzbank**]said it would take an 8.2 billion injection from the state and another 15 billion in guaranteed funding to secure refinancing.

Source: http://www.businessweek.com/stories/2008-11-03/commerzbank-taps-german-bailout-fundbusinessweek-business-news-stock-market-and-financial-advice

Commerzbank has benefited from a capital increase in the amount of EUR 10 billion and a dormant equity holding in the amount of EUR 8.2 billion

Source: http://www.ecb.europa.eu/pub/pdf/scplps/ecblwp8.pdf

Deutsche bank did not get a direct bailout.

Source: http://www.dbriskalert.org/2011/08/was-deutsche-bank-bailed-out/

Stuttgart-based **LBBW** earlier this year (April) received a capital injection of euro 5 billion from the bank's shareholders, all of them public authorities or state-owned, including the state of Baden-Wuerttemberg, the region's savings bank association and the city of Stuttgart (December 2009). LBBW, Germany's fifth largest bank, focuses lending on small businesses and acts as a central bank for savings banks in the regions of Baden-Wuerttemberg, Rhineland Palatinate and Saxony.

Source: http://seattletimes.com/html/businesstechnology/2010512245_apeueugermanylbbw.html

E.4.7. Greece (5/5)

The following institutions have adopted a resolution to increase their capital through this scheme: **Agricultural Bank of Greece S.A.** with an increase of EUR 675 million122; **Alpha Bank S.A.** with an increase of a maximum amount of EUR 950 million; Aspis Bank S.A. with an increase of a maximum amount of EUR 90 million; Attica Bank S.A. with an increase of EUR 100 million; **EFG Eurobank Ergasias S.A.** with an increase of EUR 950 million; General Bank of Greece S.A. with an increase of EUR 180 million; Millennium Bank S.A. with an increase of EUR 65 million; National Bank of Greece S.A. with an increase of EUR 350 million; **Piraeus Bank S.A.** with an increase of EUR 370 million; and Proton Bank S.A. with an increase of EUR 79 million.

Source: http://www.ecb.europa.eu/pub/pdf/scplps/ecblwp8.pdf

Crdit Agricole, which once had grand ambitions in southern Europe, has been badly bruised by the sovereign-debt crisis. The acquisition of **Emporiki Bank of Greece** in 2006 saddled the bank with billions of euros in losses as bad loans rose and fears over an eventual Greek exit from the 17-nation currency bloc shattered consumer confidence. [As Emporiki Bank was part of Crdit Agricole, I take 3 billion as bailout amount]

Source: http://online.wsj.com/news/articles/SB10000872396390444506004577616653992023394

E.4.8. Ireland (4/5)

Based on the above business strategy, the Commission decided on 18 July 2011 (5) that Germanys State aid to HRE, consisting of capital injections of approximately EUR 9.95 billion . [As HRE was the parent company of **Depfa**, I take 9.95 billion as the bailout amount].

Source: http://ec.europa.eu/competition/publications/cpn/2011_3_9_en.pdf

with a view to strengthening market perceptions of the capital adequacy of the two main banks the Government injected 3.5 billion each in cash into AIB and **Bank of Ireland** in February 2009 in return for preference shares

Source: http://www.bis.org/review/r120907j.pdf

Recapitalisation has been provided for **Allied Irish Banks** in the amount of EUR 2 billion, Anglo Irish Bank in the amount of EUR 1.5 billion and **Bank of Ireland** in the amount of EUR 3.5 billion.

Source: http://www.ecb.europa.eu/pub/pdf/scplps/ecblwp8.pdf

ROYAL Bank of Scotland (RBS) has pumped the equivalent of almost a third of its 45bn (EUR 53bn) UK government rescue into bailing out **Ulster Bank**. RBS's Irish division received a 2.93bn (EUR 3.45bn) capital injection from its parent last year, bringing the total since 2009 to 14.3bn (EUR 16.84bn). Estimation: EUR 16.84 minus EUR 3.45 = EUR 13.39 billion. (article is from 2013)

Source: http://www.independent.ie/business/world/ulster-bank-soaks-up-a-third-of-rbss-45bn-government-bailout-29177658.html

During 2008 the group [=**Permanent**] was severely tested as economic conditions in our core market of Ireland deteriorated and the international credit crisis worsened. However there were important successes; our key life and pensions businesses and our investment management business actually increased market share during the period and posted very creditable performances and in the bank, we again grew new current account numbers strongly and delivered a very strong performance in attracting over 1 billion in new retail deposits.

Source: annual report Permanent TSB 2008

E.4.9. Italy (0/5)

Unlike British banks such as Royal Bank of Scotland, or French ones such as BNP Paribas, which have repeatedly turned to their governments for aid after multi-billion dollar write-downs on toxic asset, this is an issue that Italian banks have managed to circumvent. With the exception of Unicredito , they had hardly dabbled in investment banking or derivatives, focusing instead on more traditional retail banking sources of revenue. (See Italys Banking Bliss.)

Source: http://www.forbes.com/2009/03/10/banco-popolare-bailout-markets-equity-italy.html

Italy's biggest bank, **UniCredit SpA**, announced a 6.6-billion-euro [**non-governmental**] capital increase last week. Prime Minister Silvio Berlusconi said yesterday that no other Italian banks were facing cash problems.

Source: http://www.bloomberg.com/apps/news?pid=newsarchive&sid=abDNqy86viis&refer=home

We have, however, still been able to report a substantial profit, thanks to our choice to remain focused on our core mission of intermediating and lending. As the crisis points to a back to basics for the global banking system, we believe our strategy has been vindicated.

Source: annual report UniCredit group 2008

The scale of the losses forced the lender to step up its negotiations for a second state bailout, which it sought last year after failing to meet capital requirements set by European regulators. (2013 article so no bailout for **Gruppo Monte dei Paschi di Siena**). They did hid their losses, which emerged later.

Source: http://www.telegraph.co.uk/finance/newsbysector/banksandfinance/9830447/Bank-of-Italy-approves-3.9bn-loans-for-controversial-bailout-of-Monte-dei-Paschi-di-Siena.html

E.4.10. Luxembourg (3/5)

On 29 September 2008, the Belgian, Luxembourg and Dutch governments bailed out the Fortis group. As part of this bail-out, the Luxembourg government invested EUR 2.5bn in **Fortis Banque Luxembourg S.A.** in the form of a mandatory convertible loan. Fortis Banque Luxembourg would become BGL-BNP Paribas and the Luxembourg state would hold the presidency of the board of directors of this bank in Luxembourg.

Source: http://www.mayerbrown.com/public_docs/0210fin_Luxembourg.pdf

The Luxembourg government invested EUR 376m in **Dexia Banque Internationale Luxembourg S.A.** in the form of convertible bonds.

Source: http://www.mayerbrown.com/public_docs/0210fin_Luxembourg.pdf

During the financial crisis, German banking behemoth Deutsche Bank seemed like one of the few banks in the U.S. and Europe strong enough to weather the crisis without a bailout. A new report suggests that strength may have been a mirage.

Source: http://www.huffingtonpost.com/2012/12/05/deutsche-bank-12-billion-losses_n_2247360.html

BCEE [**Banque et Caisse d'Epargne de l'Etat Luxembourg**] is fully owned by the Grand Duchy of Luxembourg, whose commitment to remaining the sole shareholder is a key factor supporting the rating on BCCE

Source: http://www.standardandpoors.com/ratings/articles/en/us/?assetID=12451 86185756

E.4.11. Portugal (0/5)

One factor is the more risk-averse stance of the major Portuguese banks, leading to a more conservative investment profile overall. This meant that they had relatively low exposure to highly complex financial products that were affected in the original subprime crisis. Moreover, the spillover effects to the economy from the instability of world financial markets were at this stage less severe in Portugal than in other European countries.

Source: https://www.repository.utl.pt/bitstream/10400.5/4647/1/wp%20de26-12.pdf

It [=Banco Comercial Portugus] has nearly 4.3 million customers throughout the world and over 900 branches in Portugal. In 2008, it reported a profit of 201 million. It was ranked at number 453 in the 2007 Forbes Global 2000 list.

Source: http://www.csridentity.com/portugal/bancocomercialportugues.asp

Overview of Portugese responses in the financial crisis "Oct 2008 (PT): Portuguese Government increases the guarantees on deposits from 25.000 to 100.000 and set a 20 billion facility to be used in guarantees to banks. Nov 2008 (PT): Nationalization of BPN and provision of a 4 billion facility to buy preferential shares in order to reinforce the financial systems capital ratios. Dec 2008 (PT): Portuguese Government announces a fiscal stimulus package, the Investment and Employment Initiative, amounting to 0.8% of GDP (around 1.3 billion)". As such, there were no bailout for banks other than BNP.

Source: https://www.repository.utl.pt/bitstream/10400.5/4647/1/wp%20de26-12.pdf

E.4.12. Spain (0/5)

When the global financial crisis hit in 2008, Madrid was relatively calm. Spain's banks were hit, but they had not invested in the toxic off-balance-sheet products that sank banks elsewhere. **The then prime minister, Jos Luis Rodrguez Zapatero, boasted that Spain had perhaps the most solid financial system in the world**.

Source: http://www.economist.com/node/21556953

While other Spanish banks are deluged by losses, **Banco Santander** has been one of the more robust players to emerge from the credit crisis. It steered clear of many of the problems tied to American subprime mortgages and other complex investments, and it is now seizing opportunities on the global stage. On Friday, it completed a purchase of Alliance & Leicester of Britain at a bargain-basement price of 1.3 billion pounds ($2.2 billion). It was also among the early bidders for Washington Mutual and Wachovia in the United States.

Source: http://www.theyeshivaworld.com/news/general/24573/santander-to-bail-out-sovereign-bank.html

Barcelona-based **La Caixa**, founded over 100 years ago, is one of Spains biggest and strongest banks. Unlike many of the regional banking groups it is seen by analysts as being in a relatively strong position to attract private cash and is therefore expected to lead the way for its weaker brethren (2011).

Source: http://news.kyero.com/2011/02/spains-la-caixa-to-create-new-listed-bank/3771

E.4.13. Sweden (1/5)

Swedens Parliament on Wednesday approved a 1.5 trillion kronor ($200 billion) rescue package for the nations financial sector. The measure allows the government to give 1.5 trillion kronor ($200 billion) in credit guarantees to banks and mortgage lenders to improve liquidity amid the global financial turmoil. It also creates a 15 billion kronor ($2 billion) stability fund to bail out any Swedish banks that run into solvency problems.

Source: http://www.nbcnews.com/id/27432848/ns/business-world_business/t/sweden-approves-billion-bailout-plan/

Swedbank is the only Swedish bank to take advantage of the funding, which has been shunned by other banks due to the strict rules attached to the loans. Banks are also unhappy with the obligatory stability fund, which calculates the amount each bank owes the national fund based on their lending in Sweden (April 2009).

Source: http://www.icenews.is/2009/04/09/swedish-bank-bailout-extended/

E.4.14. The Netherlands (4/5)

Shares of **ING Groep** soared by 18.6%, or 1.36 euros ($1.82), to 8.69 euros ($11.65), in Amsterdam on Monday, after the Dutch government said it would spend

10.0 billion euros ($13.5 billion) for a stake in the Dutch bank/insurance firmbuying 1 billion Tier-1 preferred shares for 10.00 euros ($13.50) eachto help strengthen its balance sheet.

Source: http://www.forbes.com/2008/10/20/ing-netherlands-bailout-markets-equity-cx_po_vr_1020markets11.html

The bank (=**Rabobank**) didnt receive state aid during the financial crisis or the European debt crisis that followed. ING Groep NV (INGA), the biggest Dutch financial-services company, got a taxpayer bailout in 2008 while ABN Amro Group NV and SNS Reaal NV were nationalized.

Source: http://www.bloomberg.com/news/2013-06-20/rabobank-groep-chairman-piet-moerland-will-retire-next-year.html

SNS Reaal, which received 750-million of state aid in 2008, said its top executives chairman Rob Zwartendijk, chief executive Ronald Latenstein and finance chief Ference Lamp had resigned, as they had wanted to find a private sector solution.

Source: http://www.theglobeandmail.com/report-on-business/international-business/european-business/dutch-nationalize-sns-reaal-in-14-billion-rescue/article8102760/

The Dutch government will take a 49 per cent stake in the Dutch arm, **Fortis Bank Nederland Holding**, for 4.0 billion euros and Luxembourg will buy a 49 per cent stake in Fortis Banque Luxembourg for 2.5 billion euros through a convertible loan.

Source: http://articles.economictimes.indiatimes.com/2008-09-29/news/28488602_-1_herman-verwilst-fortis-benelux

The bailout comes on top of a $3.5 billion cash injection in June and the $25.1 billion the state paid to buy the banks' (=**ABN AMRO/ RBS holdings NV**) Dutch businesses to save them from an impending bankruptcy in October 2008.

Source: http://www.nbcnews.com/id/34038891/ns/business-world_business/t/dutch-give-abn-amro-billions-new-bailout/

E.4.15. United Kingdom (3/5)

Under the plan, **RBS** got 20bn and Lloyds TSB and **HBOS** got 17bn

Source: http://www.telegraph.co.uk/finance/newsbysector/banksandfinance/4285063/Bail-out-Britains-banks-A-timeline.html

There are some clear winners and losers in the British government bailout of U.K. banks. **Barclays**, for a start, seems to have done well in escaping partial-nationalization by the skin of its teeth. It has promised to place 3 billion pounds ($5.2 billion) worth of preferred shares with private investors, rather than take on the government as an investor. It is also not alone: **HSBC** , Banco Santanders Abbey National and Standard Chartered have also opted out of the governments $63.4 billion recapitalization offer, leaving them freer and better-placed to compete against those who are taking part in the offer and now face government restrictions on dividends, lending practices and executive pay.

Source: http://www.forbes.com/2008/10/13/barclays-banks-britain-markets-equity-cx_ll_1013markets09.html

HBOS plc is a banking and insurance company in the United Kingdom, a wholly owned subsidiary of the Lloyds Banking Group, having been taken over in January 2009. It is the holding company for Bank of Scotland plc, which operates the **Bank of Scotland** and Halifax brands in the UK, as well as HBOS Australia and HBOS Insurance & Investment Group Limited, the group's insurance division

Source: http://en.wikipedia.org/wiki/HBOS

Chapter 2: Real Options and Bank Bailout Size[1]

Abstract

In this paper, we develop a methodology that not only determines whether and when it is optimal to bail out a bank, but also provides guidelines w.r.t. the optimal size of the bailout package. Our benchmark case shows that it is effectively optimal to engage in bailout, with the exact bailout timing and investment size being determined. Interestingly enough, the optimal bailout size is not very dependent on the deposit dependence of the bank under scrutiny, though the optimal timing does differ. We do find that higher uncertainty leads to higher, but delayed, bailouts and that the success of the intervention depends crucially on how the population will react to the government intervention.

2.1. Introduction

Much has been written about bank bailouts since the outbreak of the financial crisis in 2007-2008. Many emphasize the total cost of bailout and the impact they have on the economy, while others seek to scrutinize whether bailouts can be justified or which form they should take. One thing that seems to escape attention however is the determination of the bailout size. Bank bailouts include cases where governments rescue banks by buying equity (recapitalization), providing long-term loan guarantees to the banks or buying bank loans at favourable conditions (Gorton & Huang, 2004). Oftentimes however, little to no information is given on how the size of the considered

[1]This chapter is a slightly adjusted copy of the most recent version of the work-in-progress "Determining Bank Bailout Size: A Real Options Approach" by Glen Vermeulen.

rescue package is determined. Does the chosen bailout size maximize welfare? Does it take into account the uncertain situation surrounding bank crises? Is it sufficient to stabilize the industry? At the moment, few means exist to evaluate these concerns.

This paper introduces a method for determining both the optimal timing and the optimal size of bank bailout, given that bailout (and not liquidation) is the appropriate decision[2]. The methodology relies on real options theory to fully account for the (at least partial) irreversibility and delayability of bailout decisions: while bailout may seem optimal at one point in time, neglecting the possibility of economic recovery in the future may lead to suboptimal decisions from a dynamic perspective. The key elements of the model are the desire to keep the bailout as low as possible to put a low strain on the taxpayer, and the need for the bailout to be large enough to restore consumer confidence, allow banks to get back on their feet and prevent future bailout decisions. In particular, the optimal timing of bailout will refer to the point where it is optimal to switch from a regime without bailout to a regime with bailout while taking into account uncertain movements in deposit size and the bailout cost. The optimal bank bailout size on its turn is defined as the amount which maximizes the social value of the bank while accounting for the strain it puts on the taxpayer.

Our benchmark case shows that it is effectively optimal to engage in bailout, with the optimal time and size being exactly determined. The results are fairly robust, with the major factor being the capability of the government to successfully restore consumer confidence and counter the crisis. Further analysis suggests that higher uncertainty not only leads to a larger optimal bailout, but also to delayed action, indicating that bailout decisions should not be taken overnight. Additionally, the type of bank and their dependence on deposits for liquidity creation are not deemed

[2]This is for example the case when a bank is considered to be 'too-big-to-fail'.

key factors of bailout size, with the optimal size being almost independent of the respective variable. They do however affect policy by way of timing, with a later intervention being desirable for deposit dependent banks due to the efficacy of the intervention tool. Overall, the analysis shows that it is important to consider both bailout size and timing while determining the optimal bailout package, as focusing on one while foregoing the other may result in suboptimal decisions from a dynamic perspective. This is reflected in a divergence of the direction of correlation between optimal timing and size w.r.t. the exogenous model parameters.

In the following, we will briefly discuss related literature, the model setup and the solution method after which the model is effectively solved. A sensitivity analysis is then executed to determine the robustness of the results. The last section summarizes our findings and formulates policy recommendations.

2.2. Related literature

This paper is related to two strands of literature, the first being the literature on optimal bank bailout policy. In particular, our methodology will provide an answer to three questions:

1. Should a troubled bank be bailed out (or is it better to do nothing) ?
2. What is the optimal timing of the bailout (i.e. at which point does the situation call for an intervention) ?
3. What is the optimal size of the bailout (i.e. how much funding should the government provide for a recapitalization)?

Various papers have attempted to tackle these issues in a number of ways, though not all questions are answered to the same extent. Cordella & Yeyati (2003) for example scrutinize the trade-off between a moral hazard and value effect that occurs when announcing a contingent ex-ante bailout regime. Given this trade-off, they argue that governments should commit ex-ante to bail out banks (which in their model is a continuation choice, thus providing no answer to question 3) in adverse macroeconomic conditions - where the value effect is dominant - but not otherwise. Gong & Jones (2013) on the other hand characterize a three-tiered bailout rule based on the systematic costs a bank can impose on the economy: ex-post monitoring and bailout for large impact banks, randomized bailouts for middle impact bank and no bailout for low impact banks. The bailout size is hereby used as a model parameter that 'subsidizes' the decisions made by banks with a significant systemic impact and that at the same time is necessary to avoid the related costs of failure. As such, its size would be determined by how large the systemic cost of a specific bank failure would be. Aghion, Bolton & Fries (1999) on their turn explicitly take bank managers' incentives to under-or overreport losses w.r.t. bailout applications into account by, among others, modelling the bailout size to be the one that brings the distressed banks' net worth back to zero. Their analysis promotes the conditioning of bank recapitalization on observable and verifiable actions of bank managers (in particular the liquidation of non-performing loans) to increase ex post bank bailout efficiency. As a last example, Acharya & Jorulmazer (2007) propose a bailout rule that depends on how many banks fail: assuming that banks are the best possible users of banking assets, a bailout is only optimal if the number of surviving banks is too low to purchase all 'lost' banking assets. The bailout cost of the government thus depends on the foregone value of bank sales or liquidations. These examples show that, while many articles touch upon the aforementioned three issues, it is rare to find a methodology that tackles all three of them. Especially the optimal bailout size is often considered as an instrumental assumption in the respective model that not necessarily maximizes welfare. This paper however does take the societal impact of the bailout size into account.

The second strand of literature this paper relates to is the real options literature involved with capacity choice. Unlike the traditional real options literature - which only determines the optimal timing of an investment project under uncertainty of given size - the capacity choice literature also directs the amount one should invest in case investment is optimal. This presents us with the means to analyze the three mentioned aspects of optimal bailout policy. Real options theory is indeed well suited to bailout decisions, given that bailout can be deemed at least partially irreversible (due to the negative situation surrounding bailout, it is unlikely that a government could immediately retrieve all its support) and can be delayed. More importantly, a bailout can be seen as an investment in the economy, rendering the analogy complete. In that respect, this paper is complementary to Vermeulen & Kort (2014). Here, the authors "develop a real options consistent bailout decision rule that specifies under which conditions it is optimal to liquidate or bail out a bank based on the amount of liquidity it creates". In doing so, the authors are able to incorporate the option value of waiting stemming from the irreversibility of liquidation and bailout decisions and the possibility to delay in the bailout decision process, leading to better results from a dynamic perspective. The model is subsequently used to evaluate 75 bank bailout decisions in the EU-15 during the crisis year of 2008 and concludes that most decisions taken were indeed optimal. The methodology we develop here extends the applicability of this bailout rule to forecasting, as we are able to determine future optimal bailout sizes whereas the evaluations of Vermeulen & Kort (2014) are limited to bailouts with observable exogenous bailout sizes in the past.

The real option literature w.r.t. optimal capacity choice is a relatively new field of study that has expanded greatly over the recent years. Papers using this methodology include Dangl (1999), Hagspiel, Huisman & Kort (2016) and Della, Gryglewicz

& Kort (2012) for monopoly situations and Huisman & Kort (2015), Boonman & Hagspiel (2013), Huberts, e.a. (2015) and Lavrutich, Huisman & Kort (2016) for duopoly situations, all of which are thoroughly discussed in Huberts, Huisman, Kort & Lavrutich (2015). One of the main insights obtained from the latter paper is the following:

> "The real options literature that concentrates on investment timing only has a standard result in that uncertainty generates a value of waiting with investment. When also size needs to be determined, the papers reviewed here have a common result that, in a more uncertain economic environment, firms invest later and in a larger capacity size. So, where from the traditional real options literature it could easily be concluded that uncertainty is bad for growth, this is not so clear anymore when also capacity size needs to be determined. This illustrates how important it is to study the capacity issue next to the timing decision" (Huberts, Huisman, Kort & Lavrutich (2015)).

As such, one would expect that in the case of bailouts - seen as an investment by the government in the bank/economy - a more turbulent and high risk environment would imply a slower, but larger intervention. Our findings are conform to this result, with the size effect being the dominant factor. This implies that in high risk environments, for the bailout to be optimal, it should be large. This issue will be expanded upon once the model is developed and solved in the next sections.

2.3. Model setup

In our model, similar to the approach taken in Vermeulen & Kort (2014), we assume that a bank contributes to societal welfare by creating liquidity. As described in e.g. Diamond & Dybvig (1983), banks - once given knowledge about the fraction of people that will require funds prematurely- are able to offer 'new' deposit contracts due to a pooling of resources. These contracts provide better returns than liquid assets and have a much smoother pattern of returns than the existing illiquid assets[3]. As such, depositors can be deemed insured against liquidity risk and at least some losses associated with the premature selling of assets can be avoided, leading to gains for society. At the same time, banks enable loans to illiquid borrowers, resulting in credit flows that would not have occurred in their absence (Diamond & Rajan, 2001). We therefore follow Gorton (2010) and DeAngelo & Stulz (2015) in their characterization of banks as "producers of safe/liquid debt".

The amount of liquidity that is created by a bank can be measured by e.g. the liquidity transformation gap proposed by Deep & Schaefer (2004) or the cat fat measure of Berger & Bouwman (2009). In both measures, liquidity creation is heavily influenced by deposits (D). Hence, we can safely assume that liquidity creation (L) adheres to the following function:

$$L(D) = a + bD, \tag{1}$$

where a depicts the aggregated liquidity creation attributed to elements other than deposits and b depicts the sensitivity of liquidity creation with respect to changes in deposits. These parameters determine the type of bank under scrutiny: generally speaking, if b is large while a is small, the bank is very deposit dependent and could be characterized as a commercial bank. If instead b is small and a is large, the bank could be characterized as an investment bank. The aforementioned changes in deposits are driven by everyday transactions, unexpected events and changes in

[3]An illiquid asset is an asset where the premature selling of that asset results in a loss.

e.g. consumer confidence and are assumed to follow a Geometric Brownian motion (GBM) (Dixit & Pindyck, 1994):

$$dD = \alpha D dt + \sigma D dz. \tag{2}$$

Here, α is a drift parameter, which is negative in times of financial turmoil - the case considered here. σ on the other hand is a variance parameter, while dz is the increment of a Wiener process. Note that, due to the inherent nature of the GBM, D can never drop below 0, which is not an unreasonable assumption to make. Overall, the welfare contribution of the bank to the economy in a state without bailout can be represented as

$$W = f(L(D)) = x(L(D) - \bar{L}) - z(L(D) - \bar{L})^2, \tag{3}$$

where $\bar{L}$ is the opportunity value of the operating cost of the bank, incorporating - among others - the welfare contribution bank employees could have created elsewhere. This specification with decreasing marginal returns takes into account that a too high liquidity creation, while having its advantages for the economy, can also be considered as an indicator of higher bank fragility - as is e.g. postulated in the " high liquidity creation hypothesis" of Fungacova, Turk & Weill (2015)[4]. By utilizing this type of function, one mitigates the benefits of liquidity creation: while a larger $x > 0$ does signify a larger positive effect of liquidity creation on welfare, a larger $z > 0$ encompasses a larger risk correction. We do assume that $\frac{x}{z} > 2L$, i.e. the first

[4]This hypothesis states that "a proliferation in the core activity of bank liquidity creation increases failure probability". From an empirical point of view, the authors effectively find that "high liquidity creation significantly increases the probability of bank failure" (Fungacova, Turk & Weill, 2015).

derivative stays positive, so that an additional unit of liquidity creation still remains beneficial, though not as much if L is already large. Overall, this assumptions implies that there is a value of liquidity creation, depending on the size of x and z, beyond which there is no marginal contribution to welfare.

In a crisis, banks may not be able to execute their liquidity creation function properly due to declines in deposit sizes resulting from, among others, declines in consumer confidence. This may lead to negative welfare contributions, as liquidity creation should be in excess of $\bar{L}$ in order to affect welfare positively. To prevent this, governments can opt to engage in bailout, which has two direct effects. Firstly, a bailout may raise consumer confidence[5], which positively affects the trend parameter α in equation (2) by an amount $g(B)$, where B indicates the size of the bailout. This function is increasing in B (a larger bailout evokes larger restoration in consumer confidence), but faces diminishing returns (the effect of a bailout itself is large, but the marginal increases in α when increasing the bailout size become smaller the larger B gets). Secondly, the bailout imposes costs on the taxpayer and welfare in general. *As such, a government will seek to minimize the bailout size while still allowing it to be large enough to stabilize the situation (i.e. prevent negative social welfare contributions) taking into account possible changes in the economic situation to prevent a second bailout and avoid wasteful interventions.* Mathematically, one can represent the effects of a bailout as follows. For the first effect, equation (2) is

[5]The effect of a bailout is not necessarily limited to an increase in consumer confidence. Provided the bailout is large enough, the bank itself may gain the means to improve/restore its services, therefore drawing in new customers and additional deposits. Additionally, from a macro-economic point of view, a bailout could even be interpreted as expansionary fiscal policy, which would boost general economic activity.

replaced by

$$dD = (\alpha + g(B))Ddt + \sigma Ddz. \tag{4}$$

The second effect occurs when the bank switches from "bank without bailout" to "bank with bailout" at a cost of B. In the following section, we will determine the optimal timing and size of the bailout[6].

2.4. Solving the model

2.4.1. Determining the value of the bank

We start the calculations by determining the social value of the bank in each specific state. This is done with the help of dynamic programming techniques as e.g. detailed in Dixit & Pindyck (1994) that involve the determination of the Bellman equation, application of Ito's Lemma and solving a non-homogeneous linear second-order differential equation. The calculations can be found in Appendix C and yield the following result:

Proposition 1. *The social value of the bank without bailout (W_0) consists of the value of the option to bail out the bank and a term representing the expected present value of the bank assuming it continues operations forever. The social value of the*

[6]Note that for this problem to make sense, the standard real options assumption that $\alpha < \rho$ must hold, where ρ represents the discount rate that is used in the calculations below. Otherwise, it will never be optimal to engage in bailout given the net positive growth rate. As α is negative in times of financial turmoil, this condition is automatically met. Execution of a bailout may however lead to a new growth rate that does exceed the discount rate. While this may seem problematic, it is not the case due to the fact that the optimal stopping problem is solved once the bailout is executed and the option to wait has disappeared.

bank with bailout (W_b) on the other hand does no longer contain an option value (as the option has effectively been executed or 'killed') but still consists of the expected present value of the bank adjusted for the new growth rate. Mathematically, one has that

$$W_0(D) = A_2 D^{\beta_2} - \frac{zb^2}{\rho - \sigma^2 - 2\alpha} D^2 + \frac{bx - 2zab + 2zb\bar{L}}{\rho - \alpha} D + \frac{xa - x\bar{L} - za^2 + 2za\bar{L} - z\bar{L}^2}{\rho}, \quad (5)$$

$$W_b(D) = -\frac{zb^2}{\rho - \sigma^2 - 2\alpha - 2g(B)} D^2 + \frac{bx - 2zab + 2zb\bar{L}}{\rho - \alpha - g(B)} D + \frac{xa - x\bar{L} - za^2 + 2za\bar{L} - z\bar{L}^2}{\rho}, \quad (6)$$

with A_2 being a constant to be determined and

$$\beta_2 = \frac{1}{2} - \frac{\alpha}{\sigma^2} - \sqrt[2]{(\frac{\alpha}{\sigma^2} - \frac{1}{2})^2 + \frac{2\rho}{\sigma^2}}. \quad (7)$$

2.4.2. Optimal bailout size and timing

In case of bailout, a government will choose the level of B that maximizes the social value of the bank $W_b(D)$ while taking into account the size of the bailout cost (B). This results in the following first-order condition:

$$\frac{\partial(W_b(D) - B)}{\partial B} = 0 \quad (8)$$

$$\Leftrightarrow \frac{zb^2}{(\rho - \sigma^2 - 2\alpha - 2g(B))^2}(-2\frac{\partial g(B)}{\partial B})D^2 - \frac{bx - 2zab + 2zb\bar{L}}{(\rho - \alpha - g(B))^2}(-\frac{\partial g(B)}{\partial B})D - 1 = 0 \quad (9)$$

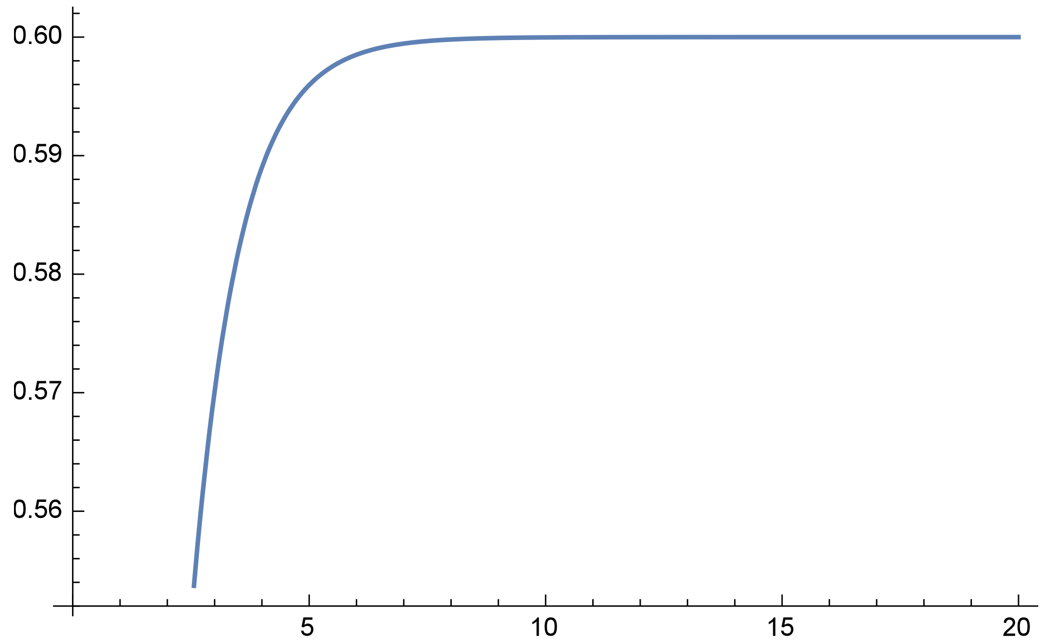

Figure 2.1: Graph of $g(B) = (1 - e^{-B}) * y$ with $y = 0.6$ and B on the horizontal axis

$$\Leftrightarrow (-\frac{2zb^2}{(\rho - \sigma^2 - 2\alpha - 2g(B))^2}D^2 + \frac{bx - 2zab + 2zb\bar{L}}{(\rho - \alpha - g(B))^2}D)(\frac{\partial g(B)}{\partial B}) = 1 \qquad (10)$$

We assume that $g(B) = (1 - e^{-B})y$ $(\Rightarrow \frac{\partial g(B)}{\partial B} = ye^{-B})$. Figure 2.1 represents the form of this function for $y = 0.6$. Aside from adhering to the principle of diminishing returns, the advantage of this functional form lies in its asymptotic nature: one always knows the maximum boost in growth rate that can be achieved.

Given the form of the bailout impact function ($g(B)$), the parameter y is of major importance. Not only does this variable determines the maximum effect a bailout can have on the deposit growth rate, it also determines the ease with which a certain growth rate increase can be achieved. Overall, y represents how large of an impact a bailout can have on consumer confidence and the deposit growth rate. The parameter can therefore be considered as an indicator of public confidence in the capability of the government to resolve the crisis. This value can be influenced by the track record of the government in dealing with past crises. As such, a successful bailout in the past (/present) may render the use of a new bailout in the present (/future) more effective. Finally, note that y can be modelled to also affect the uncertainty parameter σ. A higher confidence level in the government to deal with potential crises can indeed lead to less responsive reactions from market participants when the situation starts to deteriorate. This would imply less movements in deposits and thus a lower σ. To keep the calculations tractable, we will however continue with a constant uncertainty parameter.

Substituting $g(B) = (1 - e^{-B})y$ in equation (10) yields the following equation, one out of three that are necessary to arrive at the optimal bailout size and timing:

$$(-\frac{2zb^2}{(\rho - \sigma^2 - 2\alpha - 2(1 - e^{-B})y)^2} D^2 + \frac{bx - 2zab + 2zb\bar{L}}{(\rho - \alpha - (1 - e^{-B})y)^2} D) y e^{-B} = 1, \quad (11)$$

The other two equations are the relevant value-matching and smooth-pasting conditions. The former condition determines the point at which the social value of the bank with and without bailout are equal, while also taking into account the bailout cost that is required to complete the transition. This thus indicates at which point (deposit size D^*) a switch from 'no bailout', which in normal times provides the best value, to 'bailout' is optimal. The latter condition is a technical condition that requires the derivative to be equal at that point. As such, we have that:

$$\begin{cases} W_0(D^*) = W_b(D^*) - B \\ W_0'(D^*) = W_b'(D^*) \end{cases} \quad (12)$$

Substituting expression (5) , (6) and the functional form of $g(B(D))$ in (12) while adding the rewritten FOC of size optimization (11) yields the following system of

Parameter	Value	Parameter	Value
α	-2	$\bar{L}$	1
ρ	0.1	x	200
σ	0.2	y	4
a	10	z	1
b	5		

Table 2.1: Parameter values base scenario

equations:

$$\begin{cases} (-\frac{2zb^2}{(\rho-\sigma^2-2\alpha-2(1-e^{-B})y)^2}D^2 + \frac{bx-2zab+2zb\bar{L}}{(\rho-\alpha-(1-e^{-B})y)^2}D)ye^{-B} = 1, \\ A_2D^{\beta_2} - \frac{zb^2}{\rho-\sigma^2-2\alpha}D^2 + \frac{bx-2zab+2zb\bar{L}}{\rho-\alpha}D = -\frac{zb^2}{\rho-\sigma^2-2\alpha-2(1-e^{-B})y}D^2 + \frac{bx-2zab+2zb\bar{L}}{\rho-\alpha-(1-e^{-B})y}D \\ -B, \\ A_2\beta_2D^{*\beta_2-1} - \frac{2zb^2}{\rho-\sigma^2-2\alpha}D + \frac{bx-2zab+2zb\bar{L}}{\rho-\alpha} = -\frac{2zb^2}{\rho-\sigma^2-2\alpha-2(1-e^{-B})y}D + \frac{bx-2zab+2zb\bar{L}}{\rho-\alpha-(1-e^{-B})y}. \end{cases} \tag{13}$$

Given that this is a three-equation system in three unknowns (A_2, B and D), it can be solved, though numerical methods are required. As a baseline scenario, we utilize the values as depicted in table 2.1. While the parameter choices may seem arbitrary, all values are varied below to assess the robustness of the results.

Note that we assign a value of 1 to the opportunity value of the operating cost of the bank ($\bar{L}$), so that it facilitates interpretation later on. The parameter z, indicative of the weigh of risk correction in assessing the contribution of liquidity creation to welfare also receives a value of 1, while the weight of liquidity creation itself (x) is set at 200 so that the condition of $\frac{x}{z} > 2L$ is easily satisfied even when we start to vary the parameter values. The parameter a - which depicts the aggregated liquidity creation attributed to elements other than deposits - receives a value of 10 while b -which depicts the sensitivity of liquidity creation with respect to changes in deposits - is set at a value of 5. The negative trend rate (α) in deposits is initially equal to -2 and can be increased to a maximum of 2 (as $y = 4$) depending on how large the possible bailout is. In specific cases, the size of y will be determined by the confidence the public has in the government to successfully handle the bailout. Finally, ρ - the discount rate - and σ- the uncertainty parameter- take on the same values as found in Vermeulen & Kort (2014). When solving the three-equation system according to this initial scenario[7], one arrives at a deposit threshold (D^*) of 37.3645 and an optimal bailout size (B^*) of 9.88799. As such, it is effectively optimal for the government to intervene[8]. In particular, it is optimal for a government to engage in bailout once the deposits of the bank fall below this threshold (the size of which can be determined via a monetary approximation of $\bar{L}$) and invest the optimal bailout size in order to boost consumer confidence. In the section below, we execute a sensitivity analysis that will determine how both the bailout threshold as well as the optimal bailout size change when some of the parameters are altered.

2.5. Sensitivity analysis

In order to determine whether the results are robust w.r.t. changes in the parameter values, we perform a sensitivity analysis by varying some of the values of

[7]We make use of the FindRoot function found in Mathematica 10 in order to arrive at a solution.

[8]As indicated by Mathematica, the obtained solution is unique. The intuition behind this lies with the fact that for a given value of B, the value-matching and smooth-pasting condition constitute a standard real options investment problem, which has been shown to result in a unique solution (see e.g. Dixit & Pindyck, 1994). Substituting this solution in the remaining FOC with one variable should therefore also result in a unique solution.

α	-6	-4	-2.5	-2	-1	-0.5	0
B^*	/	1.72185*10ˆ-17	0.955233	9.88799	9.01793	/	/
D^*	/	0.00461844	17.9101	37.3645	36.5354	/	/

Table 2.2: Changes in the growth trend

the baseline scenario. Variations occur for one variable at a time. The tables below summarize the results[9]. Recall that banks provide deposit contracts, which creates liquidity, which on its turn contributes to welfare.

From table 2.2, it becomes clear that the results are quite heavily influenced by the size of the growth rate, though these results also depend on the size of y, which determines how easily a situation is rectified by a bailout. In any case, a lower growth rate (/bigger crisis) implies a later and smaller intervention, thus indicating that the restoration of consumer confidence must be sufficiently possible before a bailout is even considered (e.g. if α is equal to -6 and the maximum increase in growth rate resulting from a bailout is 4 (= y), the bailout is not worth it due to the trend remaining negative. The bailout will be postponed indefinitely, contrary to a situation with α = -2, which is a situation that can be salvaged by bailing out). In case there is no crisis (= very low decline), it is also not optimal to intervene, as it is still possible the situation resolves itself over time. Finally, note that bank runs can be incorporated either explicitly as a sudden decrease in the growth rate via a Poisson jump process or implicitly by taking the expectation of the growth parameter in the bank run and no bank run scenario[10]. In the latter case, α will

[9] A "/" implies that the result is imaginary/does not exist. In other words, parameter values that lead to this result imply that it is not optimal to bail out the bank in the considered scenario.

[10] The modelling of a bank run is not required if the negative growth rate is the result of a run.

ρ	0.001	0.01	0.05	0.1	0.25	0.4	0.5
B^*	9.73611	9.7496	9.81032	9.88799	10.134	10.402	10.5952
D^*	36.4056	36.4888	36.868	37.3645	39.0238	40.994	42.5261

Table 2.3: Changes in the discount rate

σ	0.001	0.01	0.1	0.2	0.5	1	1.25
B^*	9.86897	9.86902	9.87381	9.88799	9.97369	10.1356	10.1466
D^*	37.3585	37.3585	37.3607	37.3645	37.2762	35.319	32.1671

Table 2.4: Changes in the uncertainty parameter

generally be lower, thus necessitating a capable government (/large enough y) for recovery to be possible. In the former case, a lot will depend on the probability, size and possible directions of the jump.

From table 2.3, we can derive that an increase in the discount rate (and thus a lower valuation of the future) implies an earlier and larger intervention. This is intuitive, given that an increase in the discount rate decreases the option value of waiting for more information.

In table 2.4, one can observe a result that is typical for the real options literature w.r.t. capital choice: starting from $\sigma = 0.2$, in case of increased uncertainty, it is better to delay investment and increase investment size (see e.g. Huberts, Huisman, Kort & Lavrutich (2015)). For values of σ below 0.2, a (small) inverse relation is observed w.r.t. investment timing, indicating that the relation is dominant for the bailout size.

Table 2.5 shows that an increased autonomous liquidity creation contribution with no ties to deposits from a bank results in a lower optimal bailout size and later

a	1	2	5	10	15	20	30
B^*	10.0766	10.0565	9.99495	9.88799	9.77499	9.65523	9.39178
D^*	41.0598	40.6492	39.4174	37.3645	35.3116	33.2586	29.1528

Table 2.5: Changes in autonomic liquidity creation

b	0.1	1	2	5	7.5	10	20
B^*	/	9.88799	9.88799	9.88799	9.88799	9.88799	9.88799
D^*	/	186.822	93.4112	37.3645	24.9097	18.6822	9.34112

Table 2.6: Changes in the deposit sensitivity of liquidity creation

interventions. The intuition here lies in the fact that a bailout does not directly impact this factor while it itself counteracts the need for it: a larger a implies a lower dependence on deposits for liquidity creation.

Table 2.6 on the other hand indicates that when the significance of deposits towards liquidity creation increases, this has no implication for the optimal bailout size and actually delays intervention. One possible explanation may lie in the fact that a larger significance implies that the same result can be reached in a lesser amount of time. Hence why it is possible to wait longer and bail out later. The fact that there is no impact of a changing b on the bailout size is quite peculiar, as it implies that different types of banks (those with and without a large focus on deposits) would receive the same bailout package in terms of size, just at a different point in time.

From table 2.7, we learn that the higher the operating costs of the bank are (which need to be compensated before liquidity creation truly contributes to welfare), the higher the bailout and the sooner the intervention. This may be indicative of a larger

$\bar{L}$	0	0.2	0.5	1	2	5	10
B^*	9.8659	9.87034	9.87697	9.88799	9.90985	9.97401	10.0766
D^*	36.9539	37.036	37.1592	37.3645	37.7751	39.0068	41.0598

Table 2.7: Changes in the opportunity value of the operating cost of the bank

x	10	100	150	200	250	300	400
B^*	/	8.29429	9.24578	9.88799	10.3734	10.7637	11.3706
D^*	/	16.8355	27.0999	37.3645	47.6291	57.8939	78.4233

Table 2.8: Changes in the weight of liquidity creation contribution to welfare

need to be saved.

Table 2.8 stresses the importance of the welfare contribution of liquidity creation. The more weight liquidity creation has, the sooner one will intervene with a larger bailout size. As such, the extent to which society values liquidity creation will partially determine the importance of intervention.

Table 2.9 on the other hand shows that a larger effectiveness of bailout on the growth rate (including a higher maximum growth rate that can be achieved) implies a reduced bailout size (as less means are necessary to reach the same result) with a slightly delayed intervention time. For example, with α equal to -2, a y of 4 implies a maximum growth rate after the bailout of 2, while a y of 6 yields a maximum

y	1	2	3	4	5	6	7
B^*	/	2.32639*10ˆ-17	-7.48932*10ˆ-17	9.88799	9.24182	8.81996	8.51069
D^*	/	0.00242316	0.00161542	37.3645	36.9067	36.6838	36.5518

Table 2.9: Changes in bailout effectiveness

z	0.1	0.5	0.75	1	5	10	20
B^*	12.3609	10.6776	10.2245	9.88799	7.27431	3.331	/
D^*	406.897	78.4236	51.0509	37.3645	4.51736	0.413276	/

Table 2.10: Changes in risk weight of liquidity creation

post bailout growth rate of 4. Additionally, due to the shape of the bailout impact function (see figure 2.1), a higher y allows the same current effect to be reached with less resources. Do note that, as was the case with the growth rate, the bailout must have a certain chance of success for it to be undertaken. Additionally, as an indicator of public confidence in the capability of the government to resolve the crisis, the value of y may be influenced by the way previous or other simultaneous crises were/are handled.

Table 2.10 lastly shows that a larger risk correction on the welfare contribution of liquidity creation implies a later (or even no) intervention and a smaller bailout size, which is complementary to the results obtained w.r.t. the variation of x.

Overall, one could say that the results are heavily reliant on the specification of α and y, which denote the severeness of - and recoverability from a crisis. W.r.t. the other parameters, the results are fairly robust while observed changes are intuitive. One thing to note is the dominance of a positive correlation between optimal bailout time and size, implying that both variables are mostly complementary tools (i.e. larger bailouts imply earlier intervention while smaller bailouts go together with later interventions). This is summarized in Table 2.11. Only with respect to uncertainty and deposit dependence does this relationship differ.

Exogenous parameter	Associated correlation
α	Positive
ρ	Positive
σ	Negative
a	Positive
b	No correlation
$\bar{L}$	Positive
x	Positive
y	Positive
z	Positive

Table 2.11: Observed correlation between optimal bailout size and timing w.r.t. changes in exogenous parameters

2.6. Policy implications

What can we learn from these results? First of all, our analysis shows that, for our baseline scenario, it is optimal for the government to engage in bailout. What is more is that there exists an optimal threshold for intervention that specifies the exact timing and size of the bailout that would yield the best results. As these results are fairly robust, our methodology is clearly capable of providing an answer to the three elements of optimal bailout policy described above. This implies that, given information on the case at hand, one can use the model to guide bailout decisions should they emerge.

Secondly, the standard real options result w.r.t. capacity choice is confirmed, with a dominance showing for the bailout size. As such, this implies that when faced with a highly volatile and uncertain economic environment, bailouts should not necessarily be executed overnight, as there is a value of waiting associated with waiting for more information and observing the evolution of the situation. In case a bailout occurs, the bailout should be large in order to effectively combat the negative market sentiments.

Thirdly, the sensitivity analysis shows that variations in the bank-specific b parameter - which represents the sensitivity of liquidity creation towards changes in deposits - have no impact on the bailout size. This implies that, for our model specification, banks that are very reliant on deposits for liquidity creation (i.e. commercial banks) do not require a larger bailout compared to those banks with a lower importance of deposits to their contribution (e.g. investment banks). The difference in dealing with these situations lies in timing, with deposit intensive banks receiving a later bailout due to the higher effectiveness of the policy tool. This effect is somewhat mitigated by the size of their deposit-independent activities (e.g. insurance, securities), as a a larger a leads to a delayed and lower bailout size. Pure deposit banks, with a low a and a high b are therefore wont to receive the highest, but slowest, bailout, though the size difference will be small compared to other types of banks.

Fourthly, public confidence in the ability of the government to successfully execute a bailout (implying a larger y) will critically determine whether such a bailout can actually succeed. If confidence is too low (i.e. low y), it is not optimal to even engage in bailout. At medium levels, a higher confidence in the government's ability will result in lower optimal bailout sizes and more postponed interventions. Generally low confidence levels lead to higher bailout sizes and faster interventions to reach the same effect. Building up a strong reputation in crisis management may therefore help the government in solving the crisis more efficiently.

Lastly, it is worth emphasizing that both bailout size and timing are very important elements of the bailout package that do not have a clear cut relationship. Focusing on one element while foregoing the other may indeed result in suboptimal decisions from a dynamic perspective. This is reflected in a divergence of the direction of correlation between optimal timing and size w.r.t. the exogenous model parameters.

2.7. Conclusion

In this paper, we expanded upon the existing optimal bank bailout literature by developing a methodology that not only determines whether and when it is optimal to bail out a bank, but also determines optimal bailout size. The approach is based on the welfare creating aspect of liquidity creation and rooted in the real options literature w.r.t. capacity choice, therefore ensuring that the option value of waiting for more information is fully accounted for - a significant advantage. Our results w.r.t. the benchmark case have shown that it is effectively optimal to engage in bailout, with the model being able to exactly determine both the optimal timing and size. These results are fairly robust, with the major factor being the capability of the government to successfully restore consumer confidence and counter the crisis. Further analysis provided evidence that higher uncertainty not only leads to a larger optimal bailout size, but also to delayed action, indicating that bailout decisions should not be taken overnight. Additionally, the type of bank and their dependence on deposits for liquidity creation were found to be only minor determinants of bailout size. These factors however do affect policy by way of timing, with a later intervention being desirable for deposit dependent banks due the the efficacy of the intervention tool. Overall, the analysis has shown that it is important to consider both bailout size and timing while determining the optimal bailout package, as focusing on one while foregoing the other may result in suboptimal decisions from a dynamic perspective.

Various ways exist to expand upon the current model. An application of the methodology on specific cases with proper calibration may for instance lead to insights on whether past bailout amounts could be deemed justified. A closer look to the way government intervention affects consumer confidence may also improve the overall quality of the work. Lastly, it could be interesting to explicitly measure the mismatch concerning timing decisions when size considerations are not part of the model. In general, we do consider the current version of the model as a significant first step in the determination and study of optimal bank bailout size.

Appendix C

C.1. Proof of proposition 1

C.1.1. Calculating the social value of the bank without bailout

To determine the social value of the bank without bailout (W_0), we start from the corresponding Bellman equation, which splits the value of the bank in the current welfare contribution ($W = f(L(D) = x(a + bD - \bar{L}) - z(a + bD - \bar{L})^2$) and its continuation/future value:

$$W_0(D) = (x(a + bD - \bar{L}) - z(a + bD - \bar{L})^2)dt + E[W_0(D + dD)e^{-\rho dt}]. \tag{14}$$

As $E[dW_0(D)] = E[W_w(D + dD)] - E[W_0(D)]$, one can write (14) as

$$W_0(D) = (x(a+bD-\bar{L})-z(a+bD-\bar{L})^2)dt+\{E[dW_0(D)]+E[W_0(D)]\}e^{-\rho dt}. \tag{15}$$

Making use of Ito's lemma for an Ito process, one can expand $E[dW_0(D)]$ as follows (Dixit & Pindyck, 1994, p. 80):

$$E[dW_0(D)] = [\frac{\partial W_0(D)}{\partial t} + \alpha D\frac{\partial W_0(D)}{\partial D} + \frac{1}{2}\sigma^2 D^2\frac{\partial^2 W_0(D)}{\partial D^2}]dt, \tag{16}$$

where $\frac{\partial W_0(D)}{\partial t} = 0$ and $\frac{\partial W_0(D)}{\partial D}$ and $\frac{\partial^2 W_0(D)}{\partial D^2}$ will be denoted as $W_0^{'}$ and $W_0^{''}$ respectively.

Substituting (16) in (15) while writing $e^{-\rho dt}$ as $(1-\rho dt)$ by using the approximation of an e-power yields:

$$W_0(D) = (x(a+bD-\bar{L}) - z(a+bD-\bar{L})^2)dt + [\alpha D W_0^{'} + \frac{1}{2}\sigma^2 D^2 W_0^{''}]dt + W_w(D)(1-\rho dt). \quad (17)$$

Dividing by dt and rearranging yields the following non-homogeneous linear second-order differential equation :

$$\frac{1}{2}\sigma^2 D^2 W_0^{"} + \alpha D W_0^{\prime} - \rho * W_0(D) + (x(a+bD-\bar{L}) - z(a+bD-\bar{L})^2) = 0. \quad (18)$$

This equation can be solved in three steps:

- Step 1) solving the homogeneous equation

The homogeneous part of the equation is

$$\frac{1}{2}\sigma^2 D^2 W_0^{\prime\prime} + \alpha D W_0^{\prime} - \rho W_0(D) = 0. \quad (19)$$

Given the particular form of the equation, one might guess the form of the solution, namely $W_0(D) = A * D^{\beta}$ with $W_0^{'}(D) = \beta * A * D^{\beta-1}$ and $W_0^{'}(D) = \beta(\beta-1) * A * D^{\beta-2}$. Substituting this in (18) yields that:

$$\frac{1}{2}\sigma^2 D^2 \beta(\beta-1) A D^{\beta-2} + \alpha D \beta A D^{\beta-1} - \rho A D^{\beta} = 0, \quad (20)$$

$$\Leftrightarrow \frac{1}{2}\sigma^2 \beta(\beta-1) + \alpha\beta - \rho = 0. \quad (21)$$

This is a quadratic equation which can be solved using the basic discriminant rule and yields the following two roots:

$$\beta_1 = \frac{1}{2} - \frac{\alpha}{\sigma^2} + \sqrt[2]{(\frac{\alpha}{\sigma^2} - \frac{1}{2})^2 + \frac{2\rho}{\sigma^2}}, \tag{22}$$

$$\beta_2 = \frac{1}{2} - \frac{\alpha}{\sigma^2} - \sqrt[2]{(\frac{\alpha}{\sigma^2} - \frac{1}{2})^2 + \frac{2\rho}{\sigma^2}}. \tag{23}$$

The general solution to the homogeneous equation is therefore

$$W_0(D) = A_1 D^{\beta_1} + A_2 D^{\beta_2}. \tag{24}$$

- Step 2) finding a particular solution to the non-homogeneous equation

For a particular solution, propose $W_0^p(D) = uD^2 + vD + w$ with $W_0^{p'}(D) = 2uD + v$ and $W_0^{p''}(D) = 2u$. Putting this in the non-homogeneous differential equation (18) yields:

$$u\sigma^2 D^2 + 2u\alpha D^2 + \alpha vD \; - \rho u D^2 - \rho v D - \rho w + xa + bxD - x\bar{L} - za^2 - 2zabD - \\ zb^2 D^2 + 2za\bar{L} + 2zbD\bar{L} - z\bar{L}^2 = 0. \tag{25}$$

This is only true if:

- Terms related to D^2 are 0:

$$\Leftrightarrow u\sigma^2 + 2u\alpha - \rho u - zb^2 = 0 \tag{26}$$

$$\Leftrightarrow u = -\frac{zb^2}{\rho - \sigma^2 - 2\alpha}$$

- Terms related to D are 0:

$$\Leftrightarrow \alpha v - \rho v + bx - 2zab + 2zb\bar{L} = 0, \tag{27}$$

$$\Leftrightarrow v = \frac{bx - 2zab + 2zb\bar{L}}{\rho - \alpha}. \tag{28}$$

- Terms unrelated to D are 0:

$$\Leftrightarrow -\rho w + xa - x\bar{L} - za^2 + 2za\bar{L} - z\bar{L}^2 = 0, \tag{29}$$

$$\Leftrightarrow w = \frac{xa - x\bar{L} - za^2 + 2za\bar{L} - z\bar{L}^2}{\rho}. \tag{30}$$

This implies that the particular solution to the non-homogeneous differential equation is

$$W_0^p(D) = -\frac{zb^2}{\rho - \sigma^2 - 2\alpha}D^2 + \frac{bx - 2zab + 2zb\bar{L}}{\rho - \alpha}D + \frac{xa - x\bar{L} - za^2 + 2za\bar{L} - z\bar{L}^2}{\rho}. \tag{31}$$

- Step 3) finding the general solution to the non-homogeneous equation

The general solution is found by simply summing up the solution of the homogeneous equation and the particular solution. Hence the social value of the active bank is equal to

$$W_0(D) = A_1 D^{\beta_1} + A_2 D^{\beta_2} - \frac{zb^2}{\rho - \sigma^2 - 2\alpha}D^2 + \frac{bx - 2zab + 2zb\bar{L}}{\rho - \alpha}D + \frac{xa - x\bar{L} - za^2 + 2za\bar{L} - z\bar{L}^2}{\rho}. \tag{32}$$

Here, $-\frac{zb^2}{\rho-\sigma^2-2\alpha}D^2+\frac{bx-2zab}{\rho-\alpha}D+\frac{xa-za^2}{\rho}$ represents the expected present value of the bank if it continues operations forever (recall that $L=a+bD$) . The first two terms on their turn can be interpreted as the value of the option to bail out the bank. Note that a bailout will only occur in case $D\in(0,D^*)$, with D^* being the threshold at which it becomes optimal for the government to bail out the bank. As D goes to infinity, the probability of bailout goes to zero. Hence, the coefficient associated with the positive root (β_1) should be zero (Dixit & Pindyck, 1994, p. 218). As such, equation (32) simplifies to

$$W_0(D)=A_2D^{\beta_2}-\frac{zb^2}{\rho-\sigma^2-2\alpha}D^2+\frac{bx-2zab+2zb\bar{L}}{\rho-\alpha}D+\frac{xa-x\bar{L}-za^2+2za\bar{L}-z\bar{L}^2}{\rho}. \quad (33)$$

C.1.2. Calculating the social value of the bank with bailout

To determine the social value of the bank with bailout (W_b), we again start from the corresponding Bellman equation, which splits the value of the bank in the current welfare contribution ($W=f(L(D)=x(a+bD-\bar{L})-z(a+bD-\bar{L})^2$) and its continuation/future value:

$$W_b(D)=x(a+bD-\bar{L})-z(a+bD-\bar{L})^2dt+E[W_b(D+dD)e^{-\rho dt}]. \quad (34)$$

As $E[dW_b(D)]=E[W_b(D+dD)]-E[W_b(D)]$, one can write (34) as

$$W_b(D)=(x(a+bD-\bar{L})-z(a+bD-\bar{L})^2)dt+\{E[dW_b(D)]+E[W_b(D)]\}e^{-\rho dt}. \quad (35)$$

Making use of Ito's lemma for an Ito process, one can expand $E[dW_b(D)]$ as follows (Dixit & Pindyck, 1994, p. 80):

$$E[dW_b(D)] = [\frac{\partial W_b(D)}{\partial t} + (\alpha + g(B))D\frac{\partial W_b(D)}{\partial D} + \frac{1}{2}\sigma^2 D^2 \frac{\partial^2 W_b(D)}{\partial D^2}]dt, \tag{36}$$

where $\frac{\partial W_b(D)}{\partial t} = 0$ and $\frac{\partial W_b(D)}{\partial D}$ and $\frac{\partial^2 W_b(D)}{\partial D^2}$ will be denoted as $W_b^{'}$ and $W_b^{''}$ respectively.

Substituting (36) in (35) while writing $e^{-\rho dt}$ as $(1 - \rho dt)$ by using the approximation of an e-power yields:

$$W_b(D) = (x(a + bD - \bar{L}) - z(a + bD - \bar{L})^2)dt + [(\alpha + g(B))DW_b^{'} + \frac{1}{2}\sigma^2 D^2 W_b^{''}]dt + W_b(D)(1 - \rho dt). \tag{37}$$

Dividing by dt and rearranging yields the following non-homogeneous linear second-order differential equation :

$$\frac{1}{2}\sigma^2 D^2 W_b^{"} + (\alpha + g(B))DW_b' - \rho * W_b(D) + x(a + bD - \bar{L}) - z(a + bD - \bar{L})^2 = 0. \tag{38}$$

This equation can be solved in three steps:

- Step 1) solving the homogeneous equation

The homogeneous part of the equation is

$$\frac{1}{2}\sigma^2 D^2 W_b^{"} + (\alpha + g(B))DW_b' - \rho W_b(D) = 0. \tag{39}$$

Given the particular form of the equation, one might guess the form of the solution, namely $W_b(D) = C * D^{\beta}$ with $W_b^{'}(D) = \beta * C * D^{\beta-1}$ and $W_b^{'}(D) = \beta(\beta - 1) * C * D^{\beta-2}$. Substituting this in (39) yields that:

$$\frac{1}{2}\sigma^2 D^2\beta(\beta-1)CD^{\beta-2} + (\alpha + g(B))D\beta CD^{\beta-1} - \rho CD^{\beta} = 0, \tag{40}$$

$$\Leftrightarrow \frac{1}{2}\sigma^2\beta(\beta-1) + (\alpha + g(B))\beta - \rho = 0. \tag{41}$$

This is a quadratic equation which can be solved using the basic discriminant rule and yields the following two roots:

$$\beta_3 = \frac{1}{2} - \frac{(\alpha + g(B))}{\sigma^2} + \sqrt[2]{(\frac{(\alpha + g(B))}{\sigma^2} - \frac{1}{2})^2 + \frac{2\rho}{\sigma^2}}, \tag{42}$$

$$\beta_4 = \frac{1}{2} - \frac{(\alpha + g(B))}{\sigma^2} - \sqrt[2]{(\frac{(\alpha + g(B))}{\sigma^2} - \frac{1}{2})^2 + \frac{2\rho}{\sigma^2}}. \tag{43}$$

The general solution to the homogeneous equation is therefore

$$W_b(D) = C_1 D^{\beta_3} + C_2 D^{\beta_4}. \tag{44}$$

- Step 2) finding a particular solution to the non-homogeneous equation

For a particular solution, propose $W_b^p(D) = kD^2 + lD + m$ with $W_b^{p'}(D) = 2kD + l$ and $W_b^{p''}(D) = 2k$. Putting this in the non-homogeneous differential equation (38) yields:

$$k\sigma^2 D^2 + 2k\alpha D^2 + l\alpha D + g(B)2kD^2 + g(B)lD - \rho kD^2 - \rho lD - \rho m + xa + bxD - x\bar{L} - za^2 - 2zabD - zb^2D^2 + 2za\bar{L} + 2zbD\bar{L} - z\bar{L}^2 = 0. \tag{45}$$

This is only true if:

- Terms related to D^2 are 0:

$$\Leftrightarrow k\sigma^2 + 2k\alpha + g(B)2k - \rho k - zb^2 = 0 \tag{46}$$

$$\Leftrightarrow k = -\frac{zb^2}{\rho - \sigma^2 - 2\alpha - 2g(B)} \tag{47}$$

- Terms related to D are 0:

$$\Leftrightarrow l\alpha + g(B)l - \rho l + bx - 2zab + 2zb\bar{L} = 0, \tag{48}$$

$$\Leftrightarrow l = \frac{bx - 2zab + 2zb\bar{L}}{\rho - \alpha - g(B)}. \tag{49}$$

- Terms unrelated to D are 0:

$$\Leftrightarrow -\rho m + xa - x\bar{L} - za^2 + 2za\bar{L} - z\bar{L}^2 = 0, \tag{50}$$

$$\Leftrightarrow m = \frac{xa - x\bar{L} - za^2 + 2za\bar{L} - z\bar{L}^2}{\rho}. \tag{51}$$

This implies that the particular solution to the non-homogeneous differential equation is

$$W_b^p(D) = -\frac{zb^2}{\rho - \sigma^2 - 2\alpha - 2g(B)}D^2 + \frac{bx - 2zab + 2zb\bar{L}}{\rho - \alpha - g(B)}D + \frac{xa - x\bar{L} - za^2 + 2za\bar{L} - z\bar{L}^2}{\rho}. \tag{52}$$

- Step 3) finding the general solution to the non-homogeneous equation

The general solution is found by simply summing up the solution of the homogeneous equation and the particular solution. Hence the social value of the bank with is equal to

$$W_b(D) = C_1 D^{\beta_3} + C_2 D^{\beta_4} - \frac{zb^2}{\rho - \sigma^2 - 2\alpha - 2g(B)} D^2 + \frac{bx - 2zab + 2zb\bar{L}}{\rho - \alpha - g(B)} D + \frac{xa - x\bar{L} - za^2 + 2za\bar{L} - z\bar{L}^2}{\rho}. \quad (53)$$

Note however that, since there is no option value for waiting once the bailout has been executed, C_1 and C_2 are both 0. As such, the social value of the bank with bailout is

$$W_b(D) = -\frac{zb^2}{\rho - \sigma^2 - 2\alpha - 2g(B)} D^2 + \frac{bx - 2zab + 2zb\bar{L}}{\rho - \alpha - g(B)} D + \frac{xa - x\bar{L} - za^2 + 2za\bar{L} - z\bar{L}^2}{\rho} \quad (54)$$

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Chapter 3: Behavioral vs. Structural Remedies in Merger Control[1]

Abstract

This paper scrutinizes which party should have the final say on the type of remedy used in merger control. With competition authorities emphasizing the ease of implementation of structural remedies, merging parties often forego the value of flexibility associated with behavioral remedies to hasten merger approval. A careful balancing of the implications of each remedy type however shows that this favoritism may be misplaced and that the merging parties' preferred remedy type can be considered optimal in a variety of situations.

3.1. Introduction

In this paper, we seek to analyze whether the type of merger remedy should optimally be determined by the competition authority or the merging parties. As is currently specified in EU and US regulation, when anticompetitive concerns arise, it are the merging parties that are required to *design and propose* remedies that can alleviate any competitive concerns the competition authority may have in clearing the merger (EU, 2013, p. 215 ; US Antitrust division, 2011, p. 3). The most commonly *accepted* type of remedy is structural (i.e. a divestiture of assets or brands to competitors) due to the ease of implementation and low monitoring requirements (Vergé,

[1] This chapter is a slightly adjusted copy of the most recent version of the work-in-progress "Behavioral vs. Structural Remedies in Merger Control" by Jan Bouckaert, Peter M. Kort & Glen Vermeulen.

2010). Structural remedies are however irreversible[2], implying that in uncertain economic environments, firms may not be willing to engage in a potentially profitable merger. This drawback can be addressed by employing behavioral remedies, "which set constraints on the merged firms' property [and may consist of] engagements by the merging parties not to abuse certain assets available to them, or to enter into specific contractual arrangements" (Motta, 2004). Compared to structural remedies, these constraints can be reversed and can thus encourage firms to go forward with otherwise cancelled mergers. Competition authorities, however, are not keen on accepting behavioral remedies due to, among others, the difficulty and costs associated with monitoring firm behavior. As a result, firms that seek to speed up the approval process will be inclined to propose the structural remedy type, even though the value of flexibility provided by a behavioral remedy may well render the latter type superior from a welfare point of view.

Here, we want to scrutinize under which conditions the optimal choice for a specific remedy type coincides for the competition authority and the merging parties. In particular, we examine whether the profit-maximizing remedy type chosen by the merging parties would also be optimal for a competition authority seeking to maximize total surplus. If this would be the case, one could argue that the merging parties should effectively have the final say on remedy type ; without needing specific approval *regarding format*. This would promote the use of behavioral remedies, which is currently a bit discouraged due to preference of competition authorities for the structural type. If the optimal choices do not overlap, there is an argument for an expansion of the authority's decision power towards the specification of merger

[2]While it is technically possible to repurchase the divested assets, this may be legally prohibited, not acceptable for the current owner and/or imply significant sunk costs

remedy format in order to protect the interests of society. The current dominance of structural remedies could then be justified.

What we find is the following. Starting from the assumption that, compared to the situation before the merger, expected consumer surplus must remain constant for the merger remedy to be accepted by the competition authority, we arrive at a set of constraints that indicate under which conditions a behavioral remedy type is preferred by each respective party. The merging parties will propose a behavioral remedy as soon as the value of flexibility it provides - i.e. the expected reduction in losses that can be attained by reversing the remedy - is larger than the combined probability of a negative demand shock not occurring times the structural remedy profit advantage - i.e. the advantage resulting from a lower required concession size for structural vis-à-vis behavioral remedies to keep expected consumer surplus constant. The competition authority's constraint is more stringent, with a behavioral remedy only being preferred if the value of flexibility is larger than the sum of the combined probability of a negative demand shock not occurring times the structural remedy *surplus* advantage (including the profits of the outsiders), the probability of a negative demand shock effectively occurring times the competitors' structural advantage (resulting from the loss of protection they experience once the remedy is lifted) and the monitoring costs. Nevertheless, one can clearly identify the situations in which the optimal decision of the two parties overlap: only when the value of flexibility is larger than the structural remedy advantage *and* lower than the social structural remedy advantage (incorporating the impact on the other actors in the industry) will the preference of a behavioral remedy for the merging parties be suboptimal for the competition authority. In all other situations, the merging parties' choice is also the optimal choice of the competition authority.

To put everything into perspective, we develop a numerical example based on

Cournot competition, economies of scale, and merger synergies of which the parameter values are altered later on. From this we learn that, for our baseline scenario, both the competition authority and the merging parties would prefer a behavioral remedy as long as monitoring costs are not exorbitantly high[3] (monitoring costs increase the social structural remedy advantage). In this situation, following the merging parties' proposal for a behavioral remedy is effectively the optimal choice for the competition authority. This result is replicated in a number of robustness checks, indicating that the predominant use of structural remedies may not be justified and may actually prevent firms from going with the behavioral option. That is not to say structural remedies do not have any use. In some situations, structural remedies are effectively superior and sometimes even the only viable choice. Especially in low synergy/efficiency mergers and high risk industries (more than 50% probability of industry profits going to decrease over time), structural remedies stay the optimal choice.

In the next section, we provide a discussion of related literature. In section 3.3, we present the model setup, with the analysis following in section 3.4. Section 3.5 develops a numerical example that illustrates our findings and provides robustness results. Section 3.6 concludes this paper.

[3]Monitoring costs are traditionally incurred by society and may take the form of hiring personnel that supervises the implementation and continuation of the behavioral remedy. Reasons for why the government, and not the firm itself, incurs the expenses include the independence of the supervisor and/or asymmetric information, with an information disadvantage by the government that should be kept to a minimum.

3.2. Literature Review

While the analysis of the choice for either behavioral or structural merger remedies - the main topic of this paper - is little researched, this paper does relate to the literature that formally derives optimal merger approval rules (see e.g. Nocke& Whinston, 2013), and the literature on merger remedies (see e.g. Davies & Lyons, 2008). A lot of research has already been done on the approval of merger decisions with or without structural remedies. A standard reference is Farrell & Shapiro (1990), who find that horizontal mergers in a Cournot oligopoly typically raise prices (and thus potentially harms consumer surplus) unless significant economies of scale or learning effects are involved. Additionally, they identify the mathematical conditions (based on initial market shares, the shape of the demand curve and non-decreasing marginal costs) under which a merger can be deemed welfare improving, even when the post-merger price is raised. Making use of a similar framework, Vergé (2010) extends these results, finding that even when structural remedies are imposed, a merger is not likely to be welfare-improving without sufficient technological synergies. We account for these findings by making economies of scale the driving force behind the merger proposals and by introducing variable merger synergies. We also consider behavioral remedies, which were not treated in the aforementioned analyses.

Other branches within this literature include Cabral (2003), which scrutinizes the role of *free entry* in horizontal merger decisions, and finds that cost efficiencies (achieved through a merger) and structural remedies involving a divestiture of assets may limit post-merger entry. This result renders traditional merger control arguments regarding the effectiveness of structural remedies less valid, as the selling of assets (e.g. stores) to competitors prevents the creation of completely new entities. No mention is made w.r.t. behavioral remedies. Gandhi, Froeb, Tschantz & Werden

(2008) account for the role of *product positioning* in analyzing merger effects. To avoid cannibalization of the merged firms' products, the merging parties reposition their products away from each other, causing product-repositioning by non-merger firms between those of the merged firm. "This repositioning greatly reduces the merged firm's incentive to raise prices and thus substantially mitigates the anticompetitive effects of the merger"(Gandhi, Froeb, Tschantz & Werden, 2008, p. 49). Dertwinkel-Kalt & Wey (2014) explore the hypothesis that the existence of merger remedies ("intermediate" choice) is detrimental to the *information acquisition* by competition authorities, as they do not necessarily have to make an "extreme" (yes or no) choice, which can have much larger anti-competitive effects. In other words, allowing a merger with remedies is a much 'safer' option for the competition authority that allows some leeway in the decision process compared to a full clearance, which may e.g. have large price effects. This can lead to a decrease in the quality of information gathering (as competition authorities do bear an information cost) and the use of remedies in situations that do not effectively require them. Lastly, Vasconcelos (2010) shows that structural remedies are only beneficial to consumer welfare if the assets are divested to non-merging competitors already in the market (as to raise their efficiency) and not to new entrants. This signifies the importance of choosing the *purchasing party* when structural remedies are considered. While our paper does not fully incorporates those issues, they may provide fruitful avenues for future research, especially with the current lack of focus on the behavioral remedy type.

An example of a paper where a (continuous) real options theory has been utilized to evaluate merger decisions is Lambrecht (2004), who determines a price threshold above which it is socially optimal to execute the merger and shows that mergers tend be procyclical. Within the article, executing a merger is rightly seen as a right and not an obligation, which can be delayed. Given an uncertain environment and sunk costs, there therefore is an option value associated with the merging decision that should be accounted for when deciding over executing the merger (i.e. "killing the option to wait"). The approach we take here is a bit different: not only do we work in discrete time, we also focus on a different type of decision ('behavioral or structural remedy' vs. 'invest now or later'). Nevertheless, our analysis is inspired by this real options literature (see e.g. Dixit & Pindyck, 1994), with the irreversibility of structural remedies leading to a value of flexibility (VOF) inherent to behavioral remedies. This VOF must be accounted for when deciding on the remedy type, something that has not really been done in practice.

Concerning the actual use and effectiveness of structural versus behavioral remedies, one finds quite a bit of variation depending on the competition authority in charge. In the Merger Remedies Study of the EC (DGComp, 2005), the ex-post effectiveness of 96 merger remedies adopted between 1996-2000 is evaluated. The result of this analysis, which has become a standard reference, can be found in Table 3.1. This table shows how effective the three most used remedy types were, with "fully effective" implying that the remedy was successful in maintaining competition, "partially effective" indicating that the remedy took longer than three to five years to reach the competition goal and ineffective signifying that the remedy did not prevent competition from deteriorating. In some cases, the effects were unclear. For the structural remedies (asset divestitures (64 cases) and exit from a joint venture (JV) (13 cases)), one can conclude that the remedies were quite successful, with the majority of remedies being fully effective. Exits from joint ventures do seem to have had the most success. The access commitments (5 cases), as indicators for behavioral remedies, have a low success rate, though the sample size here is quite small. A short summary of the results of the entire study can be found in CMA (2015).

Type of Remedy	% Fully effective	%Partially effective	% Ineffective	% Unclear
Asset divestitures	56	25	6	13
Exit from a JV	77	8	0	15
Access commitments	40	40	20	0

Table 3.1: DG Comp study: effectiveness of remedy by type ; Source: CMA (2015)

A more recent, US-oriented study (FTC, 2017) performs a similar analysis for 89 merger remedy cases observed during the period 2006-2012. Of those 89 cases, 76 required structural remedies, 6 required non-structural (i.e. behavioral) remedies, 5 necessitated mixed remedies and 2 involved remedies aimed at facilitating entry. Concerning effectiveness, the FTC reports that for the subset of cases (50) evaluated according to a case study approach, 69% can be considered a success, with competition being restored/maintained. In 14% of the cases, one speaks of a partial success while the remaining 17% of cases is deemed to be a failure. For the subset of cases evaluated with questionnaires(15), which are mostly located in industries where the FTC has a lot of experience, 39 of the 43 divested assets remain active in the market. This is indicative of a maintainable competitive position. The last subset of cases involved merger remedies implemented in the pharmaceutical industry and was attributed a failure rate of 25% (15 out of 60 divested products were not marketed). As in the EC merger remedy study, one can conclude that the effectiveness of the scrutinized merger remedies is quite high, with cases where the structural divestitures involved a selling of an entire business (rather than specific assets) yielding the highest success rates.

The discussion above illustrates the relative rarity of behavioral remedies, which renders them an instrument that has been much less explored. While this difference is partially caused by a larger occurrence of horizontal merger cases compared to vertical ones[4] (with behavioral remedies being more easily considered in vertical scenarios), structural remedies are generally preferred, as becomes clear from e.g. EU merger legislation:

> "According to the case law of the Court, the basic aim of commitments[/merger remedies] is to ensure competitive market structures. Accordingly, commitments which are structural in nature, such as the commitment to sell a business unit, are, as a rule, preferable from the point of view of the Merger Regulation's objective, inasmuch as such commitments prevent, durably, the competition concerns which would be raised by the merger as notified, and do not, moreover, require medium or long-term monitoring measures. Nevertheless, the possibility cannot automatically be ruled out that other types of commitments may also be capable of preventing the significant impediment of effective competition" (EU, 2013, p. 216).

As "the Commission is not in a position to impose unilaterally any conditions to an authorization decision, but only on the basis of the parties' commitments", various cases do however involve a proposed behavioral remedy (EU, 2013, p. 214). In the latest Merger Remedies Study of the EC (DGComp, 2005), remedies are classified as either (1) a commitment to transfer a market position (i.e. divestiture of assets, business units, ...) , (2) a commitment to exit from a joint venture (by e.g. selling the stake in the joint venture to the other partner(s)), (3) a commitment to grant

[4] Of the 96 cases studied in the EC merger remedy study discussed above, 80 % involved horizontal competition concerns; 14 % involved both horizontal and vertical concerns while 6 % of the cases involved pure vertical concerns (DGComp, 2005).

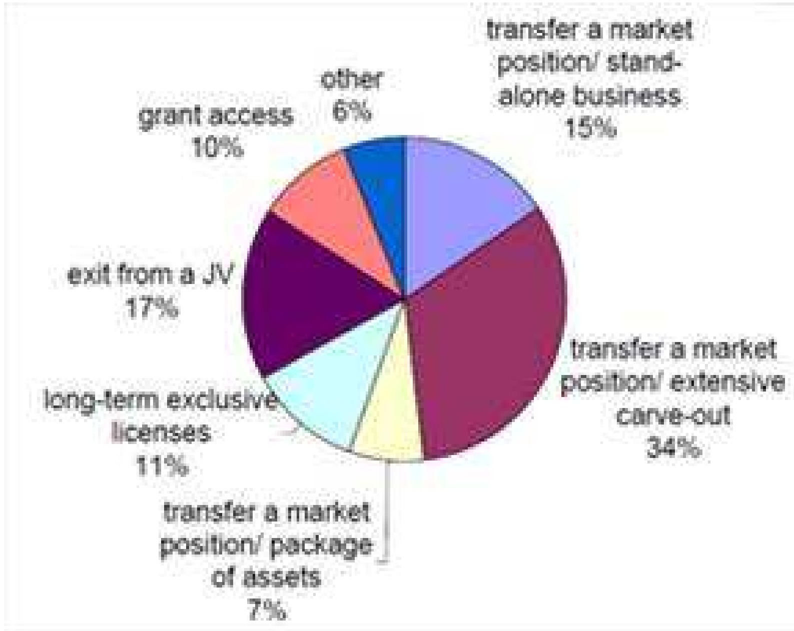

Figure 3.1: Type of remedy - All 227 EU remedies from 1996-2000 ; Source: DG COMP (2005)

access (e.g. access to infrastructure, technology/licenses and/or the termination of exclusive agreements) and (4) 'other' commitments (including brand withdrawal and separation between two collectively dominant competitors). Here, the latter two categories are non-divestiture (i.e. behavioral) commitments. Figure 3.1 shows the distribution of all 227 observed EU remedies during the years 1996-2000. The EC tends to avoid long-term supply contracts, price caps and firewalls (Deisenhofer, 2011).

The UK competition authorities also tend to favor structural remedies above behavioral ones, though the Competition Commission is more inclined towards behavioral remedies than the Office of Fair Trading (Hoehn & Rab, 2009). Figure 3.2 shows the distribution of structural and behavioral remedies in the UK during the period starting from January 2004 until the end of July 2008, excluding outright

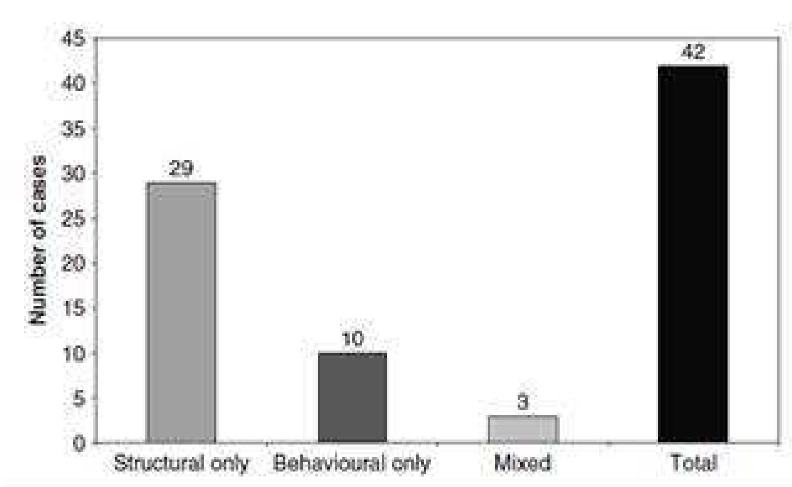

Figure 3.2: Structural versus behavioral remedies between January 2004 and July 2008. Source: Hoehn & Rab (2009)

prohibitions[5]. Of the behavioral remedies, only four (i.e. less than 10% of cases) involved access commitments, with others being related to e.g. pricing[6]. Do note that national competition authorities, compared to supranational ones (e.g. the European Commission), may be more open to behavioral remedies due to greater difficulties in finding a suitable buyer on the national level (Këllezi & Rapin, 2012).

In the US, "[t]he most common forms of conduct relief[/remedies] are firewall, nondiscrimination, mandatory licensing [i.e. access to technology or certain assets],

[5]Note that in the UK, there is no obligation to notify or seek clearance before the merger is completed (Hoehn & Rab, 2009). As such, a prohibition basically involves a divestment of the entire acquired business.

[6]"For example, the CC cleared the Drager/Air-Shields merger in 2004 with remedies including behavioral undertakings from Drager which would require it to maintain current pricing levels until 2007" (Hoehn & Rab, 2009, p. 79).

transparency, and anti-retaliation provisions, as well as prohibitions on certain contracting practices. When considering using these remedies, and other types of conduct remedies, the Division carefully analyzes the particular factual context to ensure that their use will effectively preserve competition" (US Antitrust division, 2011, p. 13). In the policy guide to merger remedies, behavioral remedies are described as a 'valuable tool' for the division, hinting at a more positive disposition towards behavioral commitments . In particular, "Conduct relief can be a particularly effective option when a structural remedy would eliminate the merger's potential efficiencies, but, absent a remedy, the merger would harm competition" (US Antitrust division, 2011, p. 6). Generally speaking, behavioral remedies are more often used in vertical merger cases and in conjunction with structural remedies in horizontal cases (US Antitrust division, 2011).

In the model discussed below, we compare a structural remedy, namely asset divestiture, with a behavioral remedy, in this case a firewall. Note that other types of behavioral remedies could have been chosen. A firewall[7] by its nature however allows a good comparison between the two remedy types (as 'only' the irreversibility and ownership is different), thus improving the quality from the exposition. Do note that while the general consensus seems to be that structural remedies are the most desired type of remedy, authorities do not always fully include the value of flexibility in their analysis. Our results will show that the application of behavioral remedies may often be the optimal choice for *both* competition authorities and the merging parties, thus challenging the current policy preference for structural remedies. Davies & Olczak (2010) additionally find that for almost half their sample, structural remedies result

[7]Also known as "chinese walls", firewalls prevent the dissemination of information between different segments of the merged firm (US Antitrust division, 2011).

in a market structure that would not have been allowed if it would result from a merger rather than a remedy. This provides a challenge to the observed effectiveness for structural remedies.

3.3. Model setup

As was mentioned above, we are looking for a way to compare the value of flexibility provided by behavioral merger remedies with the related (social) structural remedy advantage. This will allow us to identify the situations in which the choice for a behavioral remedy by both the competition authority as well as the merging parties coincides. We assume that the merging parties (labelled as firm 1 and firm 2) are competing in a three-firm Cournot model with homogeneous goods[8]. In particular, the inverse demand function takes the following form:

$$P(Q, Z), \tag{1}$$

with $\frac{\partial P(Q,Z)}{\partial Q} < 0$ and $\frac{\partial P(Q,Z)}{\partial Z} < 0$ so that price (P) is decreasing with total quantity (Q) and with an industrywide negative demand shock ($Z \in \{0, 1\}$), where $Z = 0$ indicates that no shock occurs and $Z = 1$ signals it does occur. The probability of occurrence is denoted by p. The combined capital stock in the industry is fixed,

[8]The analysis can also be executed with a Bertrand model. With homogeneous goods and no capacity restraints, the merged firm will set prices to slightly undercut the lowest cost competitor, thereby capturing the entire market and most likely turning a profit due to their cost advantage. The question here is whether the merging parties find the merger itself profitable, which only happens when the merged firms' cost advantage is very large. This limits the amount of merger scenarios, rendering the Cournot model a more interesting option to study. Changing other model assumptions like heterogeneous goods and capacity constraints may render the Bertrand model the better modelling choice.

with each firm having one unit of capital K (e.g. a factory). As such, the only way to expand the capital stock is merging, giving rise to economies of scale. This is reflected in the cost function for product i, which is increasing with the quantity of the respective product (q_i), and decreasing with the capital stock owned by the firm (K_i), and merger synergies ($s \in [0,1]$ with a lower s implying higher cost reductions and a value of 1 implying no synergies):

$$C_i(q_i, K_i, s), \tag{2}$$

with $\frac{\partial C_i(q_i,K_i,s)}{\partial q_i} > 0$, $\frac{\partial C_i(q_i,K_i,s)}{\partial K_i} < 0$ and $\frac{\partial C_i(q_i,K_i,s)}{\partial s} > 0$. This approach is also used by e.g. Perry & Porter (1985), Vergé (2010) and Dertwinkel-Kalt & Wey (2016), which all invoke a fixed industry capital stock and a lowering of the cost and marginal cost function once the firm acquires more capital.

While the cost efficiencies and synergies have the potential to be welfare-improving, this is not necessarily the case, as they may severely limit the competition received from the outsider (firm 3) and may even drive it out of the market (efficiency offence). The quantity provided by firm 3 is indeed increasing with its own capital stock, and decreasing with the capital stock owned by the merged firm K_m (indicative of a cost disadvantage) and the potential occurrence of the industrywide demand shock.

$$q_3(K_3, K_m, Z). \tag{3}$$

with $\frac{\partial q_3(K_3,K_m,Z)}{\partial K_3} > 0$, $\frac{\partial q_3(K_3,K_m,Z)}{\partial K_m} < 0$ and $\frac{\partial q_3(K_3,K_m,Z)}{\partial Z} < 0$. In the absence of an intervention, the merger can therefore result in higher prices.

To keep everything tractable, we assume that there are two time periods. This is both necessary and sufficient, as there is only one shock and the quantification of the value of flexibility requires just two points in time. At time $t = 1$, firms 1 and 2 decide to merge. At this point in time, there is no demand shock and the merger will result in nonnegative profits for the merging parties. This merger is allowed by the competition authority provided that expected consumer surplus remains unharmed. Otherwise, the merger will simply never be accepted conform to current practice, where most competition authorities wield a consumer surplus standard (see e.g. Dertwinkel-Kalt & Wey, 2016). As such, the following must hold in all situations:

$$\triangle E[CS] \geqq 0. \tag{4}$$

Given that increasing/preserving consumer surplus is costly, the merging parties will in general choose to provide only the minimum requirement. As a result, constraint (4) can be written as:

$$\triangle E[CS] = 0. \tag{5}$$

The constraint can be achieved by implementing a structural or behavioral remedy, both of which are designed as a limitation on capital stock usage. With a structural remedy, the merging parties sell a part of their combined capital stock (K_s) to a new entrant[9] so that the three-firm oligopoly structure can be maintained. The selling price for the assets is hereby assumed to be equal to the profits they would generate by producing independently, leading to a profit-neutral result for both the selling and receiving firm. This is an irreversible act that requires no further monitoring from the part of the competition authority and ensures that all capital stock is used in the industry. A behavioral remedy revolves around the implementation of a reversible firewall, with a fraction of the merged firm (K_b) acting as a separate entity with respect to decision making. Contrary to the structural remedy case, it

[9]Later on, we will consider the case where the assets are divested to the existing competitor.

encompasses a monitoring cost (paid for by society). It does however provide a safety measure for when things go awry and an industrywide negative demand shock occurs. We study a scenario in which the sunk merging costs (F) - encompassing legal fees, restructuring and localization costs,... - are larger than the reduced merger benefits in a shrinking market, thus leading to losses:

$$P(Q_{merged}, 0)q_{merged} - C_{merged} >> F >> P(Q_{merged}, 1)q_{merged} - C_{merged}. \quad (6)$$

With a structural remedy, these losses cannot be avoided. This prevents some mergers from occurring. The flexibility of behavioral remedies however does allow lifting the wall: if the market situation deteriorates, the competition authority can remove the restriction so that profits can still be made by the merging firms. This way, mergers with sizeable synergies and cost-efficiencies can still be allowed to go through. One can speak of a *value of flexibility (VOF):* the expected reduction in losses that can be attained by reversing the remedy. Do note that the lifting of the restriction also implies a loss of consumer protection in the negative scenario. This is compensated by a larger behavioral remedy size compared to its structural equivalent. As this difference in remedy size affects profits in each scenario, one could thus speak of a *structural remedy advantage (SRA)*: as expected consumer surplus must remain constant and a behavioral remedy loses consumer protection in case of a negative demand shock, the merging parties have to compensate by way of a larger remedy size in good times if the behavioral remedy type is chosen. When also incorporating the impact on the profits of the outsiders as well as the monitoring costs (M), the term transforms to a *social structural remedy advantage (SSRA).* These terms are further explored in the calculations below.

The goal is now to determine which type of remedy the merging parties and the competition authority would prefer. Merging parties would be interested in the format that maximized their expected profits for the two periods, while the authority would prefer the format that maximizes expected total surplus[10], including the monitoring costs in case of behavioral remedies. In practice, this means that firms would only prefer structural remedies in case the size of this remedy is low enough compared to the behavioral one (SRA) so that it outweighs the VOF the behavioral remedy provides. On the other hand, the authority would only prefer behavioral remedies over structural ones if the value of flexibility provided by the behavioral remedy outweighs the monitoring costs and the potential loss of outsider protection (SSRA). Overall, we will show that the value of flexibility provided by behavioral remedies can definitely outweigh the structural remedy advantages in certain situations. As such, behavioral remedies may be a better option in merger cases than the current policy stance would suggest. Schematically, the model can be represented as in figure 3.3. In situations where the VOF $<$ SRA, both the competition authority (labelled as CA in the figure) and the merging parties would prefer a structural remedy while in cases where the VOF $>$ SSRA, the behavioral remedy is universally chosen. Only in cases where SRA $<$ VOF $<$ SSRA, will there be a divergence in the interests of both parties.

The next section will prove the aforementioned relations as well as determine the specific values for VOF, SRA and SSRA. Afterward, we develop a numerical example in order to put the model to work. We will find that a behavioral remedy seems the wisest choice of action for both the competition authority as well as the merging parties. This shows that the current dominance of structural remedies in merger control may not be justified.

[10]Recall that consumer surplus is already protected via the constraint, leaving the authority free to act in the best interest of the whole of society.

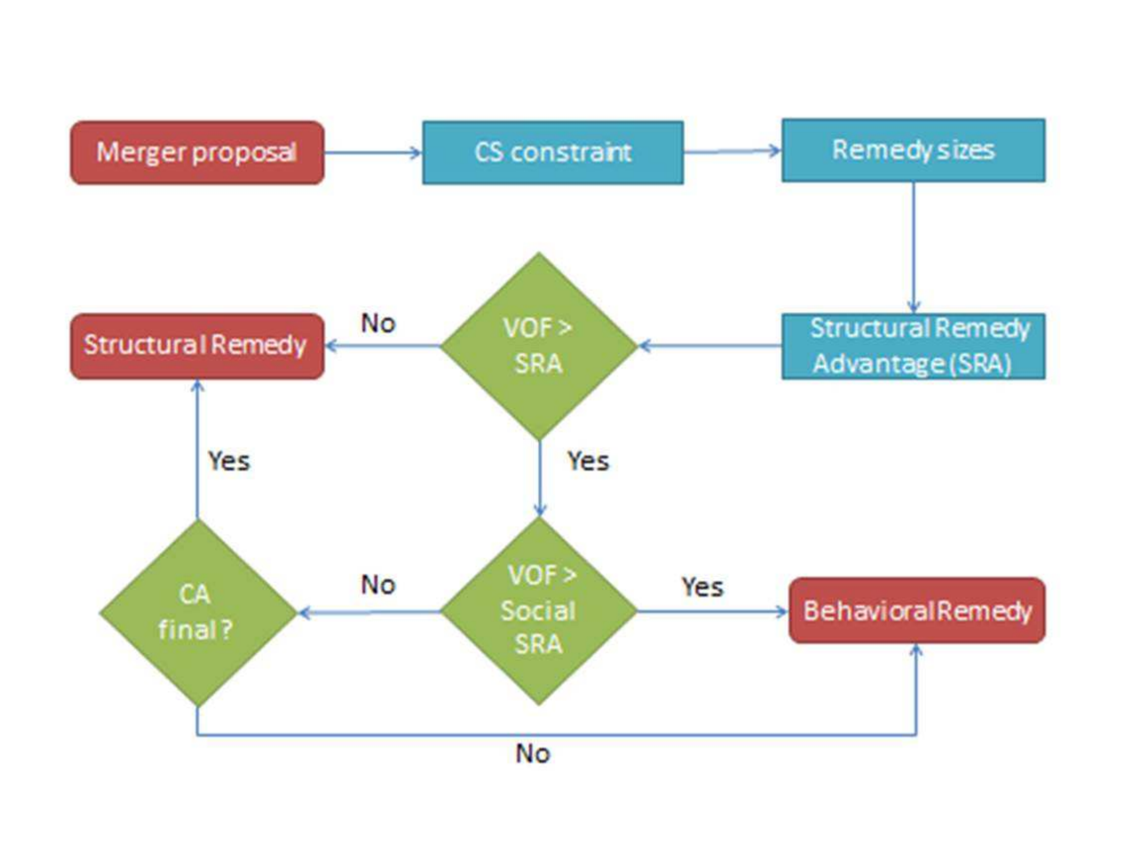

Figure 3.3: The decision process concerning the optimal remedy type

3.4. Analysis

3.4.1. Determining the merging parties' constraint

Mathematically speaking, the first step in solving this model consists of the determination of the merger benefits. The value of a firm is based on its profit flow. In particular, pre-merger profits of firm i are equal to

$$\pi_i(Z) = P(Q, Z)q_i - C_i(q_i, K, 1). \tag{7}$$

Profits in case of a merger with no remedies (NR) take on the following form, with C_m being the cost function of the merged firm:

$$\pi_{mNR}(Z) = P(Q_{NR}, Z)q_{mNR} - C_m(q_{NR}, 2K, s), \tag{8}$$

$$\pi_{3NR}(Z) = P(Q_{NR}, Z)q_{3NR} - C_3(q_{3NR}, K, 1). \tag{9}$$

Profits in case of a merger with structural remedies (SR) take on the form

$$\pi_{mSR}(Z) = P(Q_{SR}, Z)q_{mSR} - C_m(q_{mSR}, 2K - K_s, s), \tag{10}$$

$$\pi_{3SR}(Z) = P(Q_{SR}, Z)q_{3SR} - C_3(q_{3SR}, K, 1), \tag{11}$$

$$\pi_{4SR}(Z) = P(Q_{SR}, Z)q_{4SR} - C_4(q_{4SR}, K_s, 1). \tag{12}$$

In the case of structural remedies, firm 4 originates by the selling of assets to a new entrant. As mentioned before, the selling price for the assets is assumed to be equal to the profits they would generate by producing independently, leading to a profit-neutral result for both the selling and receiving firm. In the case of behavioral remedies, firm 4 is formed by walling off a part of the merged firm. Profits in case of a merger with behavioral remedies (BR) take on the form

$$\pi_{4BR}(Z) = P(Q_{BR}, Z)q_{4BR} - C_4(q_{4BR}, K_b, 1), \quad (13)$$

$$\pi_{mBR}(Z) = P(Q_{BR}, Z)q_{mBR} - C_m(q_{mBR}, 2K - K_b, s) + \pi_{4BR}(Z), \quad (14)$$

$$\pi_{3BR}(Z) = P(Q_{BR}, Z)q_{3BR} - C_3(q_{3BR}, K, 1). \quad (15)$$

Note that the walled off firm does not enjoy the same merger synergies as the main firm as the latter has to cut off its cooperation. Over the two periods, the value of the merged firm - assuming no discounting - equals, for the two scenarios respectively:

$$V_{m,SR} = (2-p)\pi_{mSR}(0) + p\pi_{mSR}(1) - F, \quad (16)$$

$$V_{mBR} = (2-p)\pi_{mBR}(0) + p\pi_{mNR}(1) - F. \quad (17)$$

Note that quantity differs between shock and no shock situations and that $\pi_{mSR}(1) - F < 0$; a loss that can be avoided or at least reduced by allowing a behavioral remedy. The merging parties will propose the type of remedy that yields the largest merger benefits. These equal, for the respective scenarios:

$$MB_{SR} = (2-p)\pi_{mSR}(0) + p\pi_{mSR}(1) - 2[(2-p)\pi(0) + p\pi(1)] - F, \quad (18)$$

$$MB_{BR} = (2-p)\pi_{mBR}(0) + p\pi_{mNR}(1) - 2[(2-p)\pi(0) + p\pi(1)] - F. \quad (19)$$

As such, the merging parties will prefer a behavioral remedy if and only if:

$$MB_{BR} - MB_{SR} > 0$$
$$\Leftrightarrow (2-p)(\pi_{mBR}(0) - \pi_{mSR}(0)) + p(\pi_{mNR}(1) - \pi_{mSR}(1)) > 0. \quad (20)$$

The value of flexibility compared to the structural remedy case can be expressed as[11]:

$$VOF = p(\pi_{mNR}(1) - \pi_{mSR}(1)). \tag{21}$$

This leads to the following proposition.

Proposition 1. *The merging parties will prefer a behavioral over a structural remedy if the value of flexibility is larger than the combined probability of a negative demand shock not occurring times the structural remedy profit advantage, the size of which will depend on the size of the remedies themselves. Mathematically, one has that*

$$VOF > (2 - p)(\underbrace{\pi_{mSR}(0) - \pi_{mBR}(0)}_{SR\ profit\ advantage}). \tag{22}$$

The right hand side (RHS) is the labelled SRA in figure 3.3.

3.4.2. Determining the competition authority's constraint

The competition authority on the contrary will not only look at merger profits, but also take into account the impact of the merger on the outsider's profits as well as the monitoring costs (M) that need to be incurred in case of a behavioral remedy. As such, assuming that the size of the respective remedy is set in such a way that the change in consumer surplus is always 0, one would have that the total surplus in the two scenarios equal:

[11] In words, the value of flexibility equals the expected reduction in losses that can be attained by reversing the remedy.

$$TS_{SR} = CS + (2-p)(\pi_{mSR}(0) + \pi_{3SR}(0) + \pi_{4SR}(0)) + \\ p(\pi_{mSR}(1) + \pi_{3SR}(1) + \pi_{4SR}(1)) - F, \quad (23)$$

$$TS_{BR} = CS + (2-p)(\pi_{mBR}(0) + \pi_{3BR}(0)) + \\ p(\pi_{mNR}(1) + \pi_{3BR}(1)) - F - M. \quad (24)$$

The competition authority would thus prefer the formula where the positive change in welfare increase (DW) is largest:

$$DW_{SR} = (2-p)(\pi_{mSR}(0) + \pi_{3SR}(0) + \pi_{4SR}(0)) + p(\pi_{mSR}(1) + \pi_{3SR}(1) + \pi_{4SR}(1)) \\ - 3[(2-p)\pi(0) + p\pi(1)] - F, \quad (25)$$

$$DW_{BR} = (2-p)(\pi_{mBR}(0) + \pi_{3BR}(0)) + p(\pi_{mNR}(1) + \pi_{3NR}(1)) \\ - 3[(2-p)\pi(0) + p\pi(1)] - F - M. \quad (26)$$

As such, the competition authority would only endorse a behavioral remedy if

$$DW_{BR} - DW_{SR} > 0 \\ \Leftrightarrow (2-p)(\pi_{mBR}(0) - \pi_{mSR}(0) + \pi_{3BR}(0) - \pi_{3SR}(0) - \pi_{4SR}(0)) + \\ p(\pi_{mNR}(1) - \pi_{mSR}(1) + \pi_{3NR}(1) - \pi_{3SR}(1) - \pi_{4SR}(1)) - M > 0. \quad (27)$$

If one once again utilizes the expression for the value of flexibility, one arrives at proposition 2:

Proposition 2. *The competition authority will prefer a behavioral remedy over a structural remedy if the value of flexibility is larger than the sum of the combined probability of a negative demand shock not occurring times the SR surplus advantage, the probability of a negative demand shock effectively occurring times the competitors' structural advantage (resulting from the protection provided by the remedy[12]) and the monitoring costs. This constraint is much more stringent than the one for the merging parties. Mathematically, one has that:*

$$VOF > (2-p)(\underbrace{\pi_{mSR}(0) + \pi_{3SR}(0) + \pi_{4SR}(0) - \pi_{mBR}(0) - \pi_{3BR}(0)}_{\text{SR surplus advantage}}) + p(\underbrace{\pi_{3SR}(1) + \pi_{4SR}(1) - \pi_{3NR}(1)}_{\text{competitors structural advantage}}) + \underbrace{M}_{\text{Monitoring costs}} . \quad (28)$$

The three terms of the RHS make up the labeled SSRA depicted in figure 3.3.

Overall, this proposition shows that a behavioral remedy is considered to be more valuable to the merging firms than to the competition authority. This difference stems from the fact that the merging parties do not bear the burden of the monitoring costs and, unlike consumer surplus, do not take the impact of the remedy size difference, and a potential reversion of the behavioral remedy on the profits of the other firms into account. Nevertheless, as our numerical example will show, the VOF is able to outweigh these factors in a variety of situations, implying a 'social preference' for behavioral remedies.

[12] If a shock occurs, the outsider would be better off under a structural remedy scenario than a behavioral one, as in the later case, the merged firm is able to fully exploit its economies of scale and resume its efficiency offense.

3.5. Numerical example

To put everything in perspective, we will now solve the model for a numerical example. Here, the demand function takes the form:

$$P(Q,Z) = \begin{cases} \alpha - Q & \text{if } Z = 0, \\ \alpha - z - Q & \text{if } Z = 1. \end{cases} . \tag{29}$$

The cost function of each firm takes the following form also taken by e.g. Belleflamme & Peitz (2015):

$$C_i = cq_i + s[\frac{h}{2}\frac{1}{K}q_i^2]. \tag{30}$$

Here, c and h are positive constants while K depicts the capital stock of each firm (Belleflamme & Peitz, 2015). A merged firm will pool its capital stock, which results in lower marginal costs (economies of scale). The synergies (i.e. additional cost reductions) takes on the form of $s \in [0,1]$, where a lower s implies greater cost savings. In this example, h is set at 1, while c will be varied later on. Initially, every firm has one unit of capital, so $K = 1$ and total capacity is 3.

3.5.1. Determining the remedy size

To determine the required remedy sizes, we calculate expected pre-merger and post-merger consumer surplus for each scenario. As the merging parties are the ones formulating the proposal, they keep into account that a merger will only be allowed if consumer surplus is not harmed. This results in the desire to keep the expected consumer surplus pre- and post-merger constant in both remedy scenario's, the sizes of which can be determined via this constraint. In the pre-merger scenario, we are in a standard three-firm oligopoly with each firm having one unit of capital. In the case of a structural remedy, we are in a Cournot oligopoly where the capital stock for the merged firm equals $2-K_S$, the capital stock for the outsiders equals 1 for firm 3 and equals K_S for the new entrant (firm 4). In the case of a behavioral remedy, a firewall is implemented and we once again have a three-firm Cournot oligopoly where the capital stock equals $2-K_B$ for the main branch, K_B for the separated branch and 1 for the outsider. This leads to the following values for expected consumer surplus (Details about the calculations can be found in Appendix D):

- Expected total consumer surplus in a no merger (NM) scenario equals

$$E[CS_{NM}] = (2-p)\frac{9(c-a)^2}{50} + p\frac{9(c+z-a)^2}{50}. \tag{31}$$

- Expected consumer surplus in the structural remedy (SR) scenario equals

$$E[CS_{SR}] = (2-p)\frac{(6-5K_S^2+s+K_S(7+3s))^2(c-\alpha)^2}{2(10-7K_S^2+3s+K_S(9+5s))^2}+ p\frac{(6-5K_S^2+s+K_S(7+3s))^2(c+z-\alpha)^2}{2(10-7K_S^2+3s+K_S(9+5s))^2}. \tag{32}$$

- Expected consumer surplus in the behavioral remedy (BR) scenario equals

$$E[CS_{BR}] = (2-p)\frac{(6-5K_B^2+s+K_B(7+3s))^2(c-\alpha)^2}{2(10-7K_B^2+3s+K_B(9+5s))^2}+ p\frac{(6+s)^2(c+z-\alpha)^2}{2(10+3s)^2}. \tag{33}$$

As a merger is only allowed so long as the change in consumer surplus is not smaller than zero, the optimal structural remedy size and the optimal behavioral remedy size can be derived from the following conditions:

$$\begin{cases} E[CS_{SR}] - E[CS_{NM}] = 0, \\ E[CS_{BR}] - E[CS_{NM}] = 0. \end{cases} \tag{34}$$

This results in two equations, that can easily be solved with the help of the solve function of Mathematica 10. If one adds numerical values to the external parameters, one can even get precise info on the size of the remedy that is required to keep consumer surplus constant. For this numerical example, we assign the following values: $\alpha = 10, z = 5, p = 0.5, c = 1, s = 0.9$. Solving the system leads to the following remedy sizes:

$$\begin{cases} K_S^* = 0.6838, \\ K_B^* = 0.8772. \end{cases} \quad . \tag{35}$$

These results confirm that the behavioral remedy requirement is effectively more stringent than the structural one. By opting for the behavioral remedy, the merging party incurs an "insurance fee" to compensate the losses it will impose on the consumers should the remedy be reversed. All this points to a structural remedy advantage, where the merged firm is allowed to keep and utilize a larger amount of the merged capital stock, resulting in larger economies of scale.

3.5.2. Behavioral or structural

Now that we have information on the required remedy sizes for the merger, we are able to calculate profits and surplus in each scenario. This will enable us to compare the constraints of the merging party and the competition authority to scrutinize the optimal decision from a welfare point of view. Who should be the one to decide on merger format? Substituting the data obtained in the previous section in the profit functions found in section 4 yields the values found in the second column of Table 3.2. Note that, for the analysis to be relevant, the value of the merging costs (F) must satisfy

$$P(Q_{merged}, 0)q_{merged} - C_{merged} >> F >> P(Q_{merged}, 1)q_{merged} - C_{merged}, \tag{36}$$

	Profits without merging cost F	**Profits with merging cost F**
$\pi_{mNR}(0)$	7.6335	5.6335
$\pi_{mNR}(1)$	7.8071	5.8071
$\pi_{3NR}(0)$	6.3353	6.3353
$\pi_{3NR}(1)$	5.8183	5.8183
$\pi_{mSR}(0)$	5.4113	3.4113
$\pi_{mSR}(1)$	1.0689	-1.0689
$\pi_{3SR}(0)$	4.8560	4.8560
$\pi_{3SR}(1)$	0.9600	0.9600
$\pi_{4SR}(0)$	4.1944	4.1944
$\pi_{4SR}(1)$	0.8285	0.8285
$\pi_{4BR}(0)$	4.5592	4.5592
$\pi_{mBR}(0)$	9.6647	7.6647
$\pi_{mBR}(1)$	1.5078	-1.5078
$\pi_{3BR}(0)$	4.7742	4.7742
$\pi_{3BR}(1)$	1.2514	1.2514

Table 3.2: Value of the profits in each scenario (no remedies, structural remedies and behavioral remedies with or without industrywide demand shock). The value of the exogenous parameters are alpha=10, z=5, p=0.5, c=1, s=0.9, and F=2. Note that in the case of behavioral remedies (BR) with no shock (0), the profit of the merged firm (m) consists of both its own profit as well as the profit of the walled-off firm.

so that

$$1.0689 << F << 5.4113. \tag{37}$$

In words, one has that the size of the merging cost must be larger than the profit the merged firm would earn under a structural remedy and a negative demand shock ($\pi_{mSR}(1)$). This ensures there is a loss that the firm would like to avoid by opting for a behavioral remedy. At the same time, the merging cost must be lower than the profit the merged firm would receive in case of a structural remedy and no demand shock ($\pi_{mSR}(0)$). Otherwise there would be no incentive to merge. For the purpose of this example, we assume that $F = 2$ so that the condition is met, even though any value that satisfies the condition would work. This leads to the profit values found in the third column of Table 3.2, where the merging costs are subtracted from the merging parties' total.

For the merging party, we had the following constraint:

$$VOF > (2-p)(\underbrace{\pi_{mSR}(0) - \pi_{mBR}(0)}_{\text{SR profit advantage}}). \tag{38}$$

with

$$VOF = p(\pi_{mNR}(1) - \pi_{mSR}(1)). \tag{39}$$

Filling in the blanks leaves us with

$$\begin{cases} VOF = 0.5(5.8071 + 1.0689) = 3.4380, \\ RHS = 1.5(3.4113 - 7.6647) = -6.3801. \end{cases} \tag{40}$$

As the constraint is satisfied, we can conclude that the merging party would effectively prefer a behavioral remedy over a structural one.

For the competition authority, we had the following constraint:

$$VOF > (2-p)(\underbrace{\pi_{mSR}(0) + \pi_{3SR}(0) + \pi_{4SR}(0) - \pi_{mBR}(0) - \pi_{3BR}(0)}_{\text{SR surplus advantage}})$$
$$+ p(\underbrace{\pi_{3SR}(1) + \pi_{4SR}(1) - \pi_{3NR}(1)}_{\text{competitors structural advantage}}) + \underbrace{M}_{\text{Monitoring costs}} . \quad (41)$$

Filling in the values yields

$$\begin{aligned} RHS &= 1.5(3.4113 + 4.8560 + 4.1944 - 7.6647 - 4.7742) + \\ & \quad 0.5(0.9600 + 0.8285 - 7.8071) + M, \\ &\Leftrightarrow RHS = 0.0342 - 3.0093 + M, \\ &\Leftrightarrow RHS = -2.9751 + M. \end{aligned} \quad (42)$$

As VOF is the same as before, namely 3.4380, *the competition authority would prefer a behavioral remedy as long a monitoring costs are below 6.4131* (=3.4380+2.9751). For any value below this threshold, the constraint will be met.

In conclusion, we have for this numerical example that the merged firm will always choose a behavioral remedy and that this is effectively the correct decision from a welfare point of view as long as monitoring costs are below 6.4131. This seems likely to occur, as the full value of these monitoring costs is similar to the profit an entire firm (the outsider) would earn in a no remedy scenario. If monitoring costs are larger, the competition authority would go against the decision if it was able to. Note that adding or changing the merger costs does not affect the results in any significant way. With this example, we have shown that when the merging parties propose a behavioral remedy rather than a structural one, it may effectively be optimal for the competition authority to follow suit. In other words, this example promotes a higher decision power for the merging parties when deciding on merger remedy format.

3.5.3. Model variations and robustness

Given our baseline model, we can alter some of the assumptions to scrutinize the impact these would have on the the preferred remedy type. One easy to change assumption is the way how structural remedies work. Before, merging parties sold their assets to a new entrant. It may however be interesting for the merging parties to propose a structural remedy where their assets are instead sold to the existing outsider[13]. That way, the resulting market structure would be a duopoly, with both firms being able to exploit economies of scale. Mathematically, this would result in the following FOCs:

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[13] In EU regulation, the 'standard purchaser requirements' are the following (EC, 2008, paragraph 48):

1. "the purchaser is required to be independent of and unconnected to the parties
2. the purchaser must possess the financial resources, proven relevant expertise and have the incentive and ability to maintain and develop the divested business as a viable and active competitive force in competition with the parties and other competitors
3. the acquisition of the business by a proposed purchaser must neither be likely to create new competition problems nor give rise to a risk that the implementation of the commitments will be delayed. Therefore, the proposed purchaser must reasonably be expected to obtain all necessary approvals from the relevant regulatory authorities for the acquisition of the business to be divested".

As a result, both existing and potential competitors can be considered as purchasing parties.

$$\begin{aligned} \alpha - 2q_m - q_3 - c - \tfrac{s}{2-K_S} q_m &= 0, \\ \alpha - 2q_3 - q_m - c - \tfrac{1}{1+K_S} q_3 &= 0. \end{aligned} \tag{43}$$

Employing a similar calculation method as before, one however finds that the consumer surplus constraint requires a transfer of capital larger than one, namely 2.4818, which exceeds the total capacity the merged firm has available. As such, one can conclude for our example that a structural remedy involving a selling of assets to the existing incumbent is not able to alleviate the concerns the competition authority has w.r.t. consumer surplus. This will lead to an immediate rejection of the structural and an immediate acceptance of the behavioral remedy (as nothing changes here).

A second set of assumptions that we can alter is the values for the various external parameters. We already mentioned that the impact of changes in the merging costs have a negligible impact on the decision for a certain remedy type. Changes in the other parameters, however do seem to have an effect. The results from some of these variations on the required remedy sizes can be found in Table 3.3. Here each parameter is varied one at a time while the others take on their value from the initial scenario discussed above. This leads to the following observations:

1. The size of the structural remedy required to keep expected consumer surplus constant is very robust w.r.t. changes in the exogenous parameters. Only when the size of the synergies changes, one sees an effect: a larger synergy (lower s) allows a lower structural remedy size due to the more beneficial nature of the merger.
2. The required size of the behavioral remedy (if it exists) is always larger than the size required in the case of structural remedies. This is illustrative of the structural remedy advantage we discussed above: as expected consumer surplus

must remain constant and a behavioral remedy loses consumer protection in case of a negative demand shock, the merging parties have to compensate by way of a larger remedy size in good times if the behavioral remedy type is chosen.

3. Changes in the market size (α) and a high probability of a negative demand shock (p) have a large impact on behavioral remedy usage,with the observations showing that both very large market sizes as well as large probabilities of market deterioration[14] imply a sole use for structural remedies. In these situations, behavioral remedies simply cannot meet the expected CS constraint, presumably due to the large likeliness of lost protection of consumer surplus once the market shrinks and the relative importance of consumer surplus in total surplus. This would require a too large compensation in terms of capital transfers. On the contrary, both a lower probability of market decline and a lower market size allow for a less strict behavioral remedy. The former observation exemplifies the lower required compensation in case adverse conditions are rare, while the latter stems from a lower importance of consumer surplus relative to total surplus. For very low market sizes, behavioral remedies are not an option, presumably due to the merged firm driving out its competitors once the behavioral remedy is reversed.

4. A larger market decrease (z) in case of an adverse shock reduces the requirements for a behavioral remedy. It is here that one can notice the value of flexibility a behavioral remedy implies. If the potential market decrease is very small, there is almost no advantage to behavioral over structural remedies

[14]In particular, starting from $p = 0.57$, the required capital transfer required to satisfy the expected CS constraint starts to exceed 1.

and behavioral remedies may even not be worth it. If however a large market decrease can be 'salvaged', the value of flexibility is high and the structural remedy advantage starts to disappear.

5. Behavioral remedies require larger synergies and higher potential cost savings than structural remedies before they are viable. In other words, only sufficiently beneficial mergers will be able to satisfy the expected consumer surplus constraint with behavioral remedies. If the merger does not provide large advantages in synergies or economies of scale, structural remedies will be the better choice.

Overall, one could say that structural remedies are not only easier to monitor by the competition authority, but are also easier to determine w.r.t. data requirements. For mergers with small overall benefits, structural remedies may even be the only choice. Still, this robustness check has shown that behavioral remedies remain a valid option in a large variety of situations. Especially in cases with a large value of flexibility and 'insurable risk', behavioral remedies are still in the running to be the optimal choice.

As a final robustness check, we determine for each scenario detailed in Table 3.3 whether the optimal decisions for the merging parties and the competition authority coincide. Table 3.4 contains the value of the monitoring cost below which the choice for a behavioral remedy is optimal for both of the parties. The fourth column holds the values for our baseline scenario, so the cut-off value (M^*) we established above can be found here again: as long as monitoring costs are below this value (6.4131), both the competition authority and the merging parties would opt for the behavioral remedy type. As was previously argued, this is a 'soft' constraint, i.e. it is very likely

	$\alpha = 1$	$\alpha = 5$	$\alpha = 10$	$\alpha = 15$	$\alpha = 20$
K_S	0.6838	0.6838	0.6838	0.6838	0.6838
K_B	/	0.7288	0.8772	/	/
	$z = 1$	$z = 3$	$z = 5$	$z = 7$	$z = 9.5$
K_S	0.6838	0.6838	0.6838	0.6838	0.6838
K_B	/	/	0.8772	0.7187	0.6858
	$p = 0.1$	$p = 0.3$	$p = 0.5$	$p = 0.7$	$p = 0.95$
K_S	0.6838	0.6838	0.6838	0.6838	0.6838
K_B	0.7053	0.7644	0.8772	/	/
	$c = 0.1$	$c = 0.5$	$c = 1$	$c = 1.5$	$c = 2$
K_S	0.6838	0.6838	0.6838	0.6838	0.6838
K_B	/	0.9422	0.8772	0.8347	0.8002
	$s = 0.5$	$s = 0.75$	$s = 0.9$	$s = 0.95$	$s = 1$
K_S	0.2929	0.5	0.6838	0.7764	1
K_B	0.3219	0.5717	0.8772	/	/

Table 3.3: Required remedy sizes to keep post-merger expected consumer surplus constant. Only one parameter is varied at a time, with the other values being the ones found in the baseline scenario. A "/" signifies that no remedy size between 0 and 1 exists that satisfies the expected consumer surplus constraint.

to be met[15]. This holds for a variety of other situations: of the ten alternate cases for which a behavioral remedy is possible, there are 5 scenarios where the optimal choice for both parties is always a behavioral remedy as long as monitoring costs are above 5. In three specific cases the cut-off point for agreement lies quite a bit lower between 1 and 3, so that more scrutiny is warranted. Lastly, in two cases, namely where $\alpha = 5$ and $z = 9.5$, the cut-off point is negative. As monitoring costs cannot go below zero, the competition authority would prefer a structural remedy, even though merging firms would still propose a behavioral one. In these situations, there is a conflict where the one with the most decision power will determine the final remedy type. Do note that these scenarios are border cases, where the market is/potentially becomes very small. As such, mergers are less likely to be proposed. Overall, we can conclude that our previous finding of coinciding preferences for a particular remedy type is quite robust.

[15]In particular, a value of 6.3353 is comparable to the profits the outsider would get with no remedies and no demand shock.

	$\alpha = 1$	$\alpha = 5$	$\alpha = 10$	$\alpha = 15$	$\alpha = 20$
M^*	/	-0.1834	6.4131	/	/
	$z = 1$	$z = 3$	$z = 5$	$z = 7$	$z = 9.5$
M^*	/	/	6.4131	3.7804	-0.9386
	$p = 0.1$	$p = 0.3$	$p = 0.5$	$p = 0.7$	$p = 0.95$
M^*	1.0684	3.2050	6.4131	/	/
	$c = 0.1$	$c = 0.5$	$c = 1$	$c = 1.5$	$c = 2$
M^*	/	5.4995	6.4131	4.6845	4.0235
	$s = 0.5$	$s = 0.75$	$s = 0.9$	$s = 0.95$	$s = 1$
M^*	5.6112	5.4371	6.4131	/	/

Table 3.4: Cut-off points (M*) for convergence of optimal remedy type decisions. If monitoring costs are below the value denoted in the table, both the competition authority and the merging parties would prefer a behavioral remedy. Only one parameter is varied at a time, with the other values being the ones found in the baseline scenario. A "/" implies that a structural remedy is the only possible choice

3.6. Conclusion

In this paper, we identified the conditions under which a behavioral remedy outperforms a structural remedy from a welfare point of view. Starting from the assumption that expected consumer surplus must remain zero, we found that the profit-maximizing choice of the merging parties for behavioral or structural remedies coincides with what is optimal for a total surplus maximizing competition authority in a variety of situations, namely when the value of flexibility is larger or lower than both the social structural remedy advantage and the structural remedy advantage. As such, current remedy policy, where the merging parties must propose the remedy format in order to alleviate anti-competitive concerns appear to be well-founded and a case can be made for a more frequent use of this flexible remedy format.

Careful consideration of industry characteristics is however required to identify the situations where the conditions are less clear, i.e. situations where merging parties would prefer behavioral remedies over the socially desirable structural ones. This would be the case in situations with very large monitoring costs (though they need to be quite large as our numerical example has shown), less profitable mergers (in terms of synergies and economies of scale) and situations where the probability of decline is very large (as there is less uncertainty about the outcome). In cases with a large value of flexibility and 'insurable risk', behavioral remedies are definitely a contender to be the optimal choice.

Future work can take a closer look at the border zone where behavioral remedies are optimal for the merging parties but not for society. Bargaining power may then enter the fray in order to determine which party can and will make the final choice. Application of the model to existing cases may also provide a promising research avenue. Expanding the model towards multiple firms and incorporating entry effects and product positioning effects should also lead to interesting results. Finally, utilization of a variety of behavioral remedy types next to the firewall type used here could provide additional robustness to our findings.

Appendix D

To determine the required merger remedy sizes, we start by calculating pre-merger consumer surplus for $Z = 0$. To this end, we have the profit function and FOC of each firm:

$$\pi_i = (\alpha - Q)q_i - cq_i - \frac{1}{2}q_i^2, \tag{44}$$

$$\alpha - 2q_i - q_j - q_k - c - q_i = 0, \tag{45}$$

which, assuming pre-merger symmetry results in the following equilibrium price and quantity:

$$\begin{cases} q_i^* = \frac{\alpha - c}{5} \\ Q^* = \frac{3(a-c)}{5} \\ P^* = \frac{2\alpha + 3c}{5} \end{cases}, \tag{46}$$

and a consumer surplus of

$$CS_{NM}(0) = \frac{(\alpha - \frac{2\alpha+3c}{5})\frac{3(a-c)}{5}}{2} = \frac{9(c-a)^2}{50}. \tag{47}$$

In case $Z = 1$, one would have that

$$\begin{cases} q_i^* = \frac{\alpha - z - c}{5} \\ Q^* = \frac{3(a-z-c)}{5} \\ P^* = \frac{2(\alpha - z) + 3c}{5} \end{cases}, \tag{48}$$

and consumer surplus would equal

$$CS_{NM}(1) = \frac{(\alpha - \frac{2(\alpha-z)+3c}{5})\frac{3(a-z-c)}{5}}{2} = \frac{9(c+z-a)^2}{50}. \tag{49}$$

Expected total consumer surplus in a no merger scenario thus equals

$$E[CS_{NM}] = (2-p)\frac{9(c-a)^2}{50} + p\frac{9(c+z-a)^2}{50}. \tag{50}$$

As the merging parties are the ones formulating the proposal, they keep into account that a merger will only be allowed if consumer surplus is not harmed. This results in the desire to keep consumer surplus constant in both remedy scenario's, the sizes of which can be determined via this constraint. In the case of a structural remedy, we are in a Cournot oligopoly where the capital stock for the merged firm equals $2 - K_S$, the capital stock for the outsiders equals 1 for firm 3 and equals K_S for the new entrant (firm 4). The respective profit functions and FOCs are:

$$\begin{cases} \pi_m = (\alpha - Q)q_m - cq_m - \frac{s}{4-2K_S}q_m^2 \\ \pi_3 = (\alpha - Q)q_3 - cq_3 - \frac{1}{2}q_3^2] \\ \pi_4 = (\alpha - Q)q_4 - cq_4 - \frac{1}{2K_S}q_4^2] \end{cases}, \tag{51}$$

$$\begin{cases} \alpha - 2q_m - q_3 - q_4 - c - \frac{s}{2-K_S}q_m = 0 \\ \alpha - 2q_3 - q_4 - q_m - c - q_3 = 0 \\ \alpha - 2q_4 - q_3 - q_m - c - \frac{1}{K_S}q_4 = 0 \end{cases}, \tag{52}$$

which result in the following equilibrium price and quantities:

$$\begin{cases} q_m^* = -\frac{2(-2+K_S)(1+K_S)(c-\alpha)}{-10-9K_S+7K_S^2-3s-5K_Ss} \\ q_3^* = -\frac{(1+K_S)(-2+K_S-s)(c-\alpha)}{-10-9K_S+7K_S^2-3s-5K_Ss} \\ q_4^* = -\frac{2(-2K_S+K_S^2-K_Ss)(c-\alpha)}{-10-9K_S+7K_S^2-3s-5K_Ss} \\ Q^* = -\frac{(-6+5K_S^2-s-K_S(7+3s))(c-\alpha)}{-10-9K_S+7K_S^2-3s-5K_Ss} \\ P^* = \frac{c(-6+5K_S^2-s-K_S(7+3s))+2(1+K_S)(-2+K_S-s)\alpha}{-10-9K_S+7K_S^2-3s-5K_Ss} \end{cases}. \tag{53}$$

This results in a consumer surplus of

$$CS_{SR}(0) = \frac{(\alpha - P^*)Q^*}{2} = \frac{(6-5K_S^2+s+K_S(7+3s))^2(c-\alpha)^2}{2(10-7K_S^2+3s+K_S(9+5s))^2}. \tag{54}$$

In the event of $Z = 1$, we have that

$$\begin{cases} q_m^* = -\frac{2(-2+K_S)(1+K_S)(c+z-\alpha)}{-10-9K_S+7K_S^2-3s-5K_Ss} \\ q_3^* = -\frac{(1+K_S)(-2+K_S-s)(c+z-\alpha)}{-10-9K_S+7K_S^2-3s-5K_Ss} \\ q_4^* = -\frac{2(-2K_S+K_S^2-K_Ss)(c+z-\alpha)}{-10-9K_S+7K_S^2-3s-5K_Ss} \\ Q^* = -\frac{(-6+5K_S^2-s-K_S(7+3s))(c+z-\alpha)}{-10-9K_S+7K_S^2-3s-5K_Ss} \\ P^* = \frac{c(-6+5K_S^2-s-K_S(7+3s))-2(1+K_S)(-2+K_S-s)(z-\alpha)}{-10-9K_S+7K_S^2-3s-5K_Ss} \end{cases}, \tag{55}$$

so that

$$CS_{SR}(1) = \frac{(6-5K_S^2+s+K_S(7+3s))^2(c+z-\alpha)^2}{2(10-7K_S^2+3s+K_S(9+5s))^2}, \tag{56}$$

and the expected consumer surplus in the structural remedy scenario equals

$$\begin{aligned} E[CS_{SR}] = (2-p)&\frac{(6-5K_S^2+s+K_S(7+3s))^2(c-\alpha)^2}{2(10-7K_S^2+3s+K_S(9+5s))^2} + \\ &p\frac{(6-5K_S^2+s+K_S(7+3s))^2(c+z-\alpha)^2}{2(10-7K_S^2+3s+K_S(9+5s))^2}. \end{aligned} \tag{57}$$

In the case of a behavioral remedy, a firewall is implemented and we once again have a three-firm Cournot oligopoly where the capital stock equals $2 - K_B$ for the main branch, K_B for the separated branch and 1 for the outsider. The respective profit functions and FOCs are:

$$\begin{cases} \pi_m = (\alpha - Q)q_m - cq_m - \frac{s}{4-2K_B}q_m^2 \\ \pi_3 = (\alpha - Q)q_3 - cq_3 - \frac{1}{2}q_3^2] \\ \pi_4 = (\alpha - Q)q_4 - cq_4 - \frac{1}{2K_B}q_4^2] \end{cases}, \tag{58}$$

$$\begin{cases} \alpha - 2q_m - q_3 - q_4 - c - \frac{s}{2-K_B}q_m = 0 \\ \alpha - 2q_3 - q_m - q_4 - c - q_3 = 0 \\ \alpha - 2q_4 - q_m - q_3 - c - \frac{1}{K_B}q_4 = 0 \end{cases}, \tag{59}$$

which yield the following results:

$$\begin{cases} q_m^* = -\frac{2(-2+K_B)(1+K_B)(c-\alpha)}{-10-9K_B+7K_B^2-3s-5K_Bs} \\ q_3^* = -\frac{(1+K_B)(-2+K_B-s)(c-\alpha)}{-10-9K_B+7K_B^2-3s-5K_Bs} \\ q_4^* = -\frac{2(-2K_B+K_B^2-K_Bs)(c-\alpha)}{-10-9K_B+7K_B^2-3s-5K_Bs} \\ Q^* = -\frac{(-6+5K_B^2-s-K_B(7+3s))(c+z-\alpha)}{-10-9K_B+7K_B^2-3s-5K_Bs} \\ P^* = \frac{c(-6+5K_B^2-s-K_B(7+3s))+2(1+K_B)(-2+K_B-s)\alpha}{-10-9K_B+7K_B^2-3s-5K_Bs} \end{cases}. \tag{60}$$

As such, consumer surplus under behavioral remedies when $Z = 0$ equals:

$$CS_{BR}(0) = \frac{(6 - 5K_B^2 + s + K_B(7 + 3s))^2(c - \alpha)^2}{2(10 - 7K_B^2 + 3s + K_B(9 + 5s))^2}. \tag{61}$$

In case of $Z = 1$, the firewall is lifted so that the merged firm can fully employ its capital stock in one organization. This leads to:

$$\begin{cases} q_m^* = -\frac{4(c+z-\alpha)}{10+3s} \\ q_3^* = -\frac{(2+s)(c+z-\alpha)}{10+3s} \\ Q^* = -\frac{(6+s)(c+z-\alpha)}{10+3s} \\ P^* = \frac{c(6+s)-2(2+s)(z-\alpha)}{10+3s} \end{cases}, \tag{62}$$

and a consumer surplus of

$$CS_{BR}(1) = \frac{(6+s)^2(c+z-\alpha)^2}{2(10+3s)^2}, \tag{63}$$

leading to an expected consumer surplus of

$$E[CS_{BR}] = (2-p)\frac{(6-5K_B^2+s+K_B(7+3s))^2(c-\alpha)^2}{2(10-7K_B^2+3s+K_B(9+5s))^2} + p\frac{(6+s)^2(c+z-\alpha)^2}{2(10+3s)^2}. \tag{64}$$

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