LUISS Guido Carli

LIBERA UNIVERSITÀ INTERNAZIONALE DEGLI STUDI SOCIALI

PhD THESIS

PhD Candidate: *Annalaura Ianiro*

Thesis Title:
Facing Loss: Reactions of Microeconomic Agents

Keywords:

Banking, Industrial Organization, TBTF Subsidy, Loss, Response Time, Social Preferences

PhD in Economics

XXX Cycle

LUISS Guido Carli

Supervisor: Prof. *Albrto Franco Pozzolo*

November 2018

DISCLAIMER - LIBERATORIA

To Siria,

for her support through it all.

Thank you.

Contents

Foreword

The thesis you are about to read contains two works dealing with very different topics. The first paper develops a theoretical model to explain the competition dynamics between two banks, when one of them can "enjoy" a too-big-to-fail subsidy in case of bankruptcy. The second one analyses the response times of the experiment described in Angino (2017), in order to understand the cognitive effort in a context of losses. Indeed, the two papers couldn't be more different.

Nevertheless, a thin thread linking them could be found in the concept of loss. Both the banks (in the first paper) and the subjects of the experiment (in the second one) face a situation of potential loss. This work, therefore, is a journey into the loss realm and the reactions of the microeconomic agents facing it. I hope my raders will follow me through it.

I A Bank Competition Model with TBTF Subsidy

Abstract

The aim of this work is to analyse the effect of the too-big-to-fail subsidy on the competition of the banking sector. Starting from Martinez-Miera and Repullo (2010), I develop a model with two banks, competing à la Bertrand over the bond market and the loan market. Taking inspiration from Stahl (1988), I consider a static game where the first stage (bond market decision) acts as a capacity constraint for the second stage (loan market decision). The analysis entails a comparison between a partial asymmetric case, with no subsidy involved, and a fully asymmetric one, where only one bank has the subsidy. Once the different equilibria are characterised, the subsidy effects will be discussed.

Keywords: Banking, Industrial Organization, TBTF subsidy

1 Introduction

This work is an attempt at studying the too-big-to-fail (TBTF) phenomenon from a competition dynamics point of view. Instead of analysing its impacts on financial stability, I try to investigate how the presence of a TBTF subsidy, implicitly granted to a systemic bank, distorts the banks' risk taking behaviour when competing with each other. My purpose is building a theoretical model which could capture this key characteristic of the subsidy: giving a competitive advantage to the bank which can receive it.

The 2007 financial crisis exposed the many weaknesses of the financial industry and in particular of a banking sector with some institutions so big, interconnected and complex to pose a significant threat to financial stability should they go bankrupt. These banks, known as "too-big-to-fail", soon found themselves at the centre of the financial collapse, forcing governments to rescue them using public money[1]. The political, economic and social implications of the bail-out system have sparked a long debate among regulators to find a way to prevent taxpayers from bearing the costs of bank failures. In the EU, the Bank Recovery and Resolution Directive (BRRD) introduced the bail-in

[1] For some examples see: https://www.thebalance.com/too-big-to-fail-3305617

tool, for which the costs of a bank bankruptcy are born by its shareholders and creditors, with the limitation of government intervention only as a last resort under special circumstances, in an effort to protect the institutions' small savers and the general public. Nevertheless, as witnessed by recent events[2], banking crises still see massive State intervention, especially when the creditors expected to shoulder the losses of the failing bank belong to the same categories of people whom the bail-in system was introduced to protect. Therefore, the issue of state subsidies to systemic banks remains relevant, and even after more than ten years since the last financial crisis.

The TBTF issue was not born with the last financial crisis. It was object of discussion already in 1984, when the Federal Deposit Insurance Corporation (FDIC) bought stocks in Continental Illinois Corporation because its main asset, Continental Illinois National Bank, was bankrupt. Continental Illinois National Bank was at the time the seventh largest bank in the U.S. and the FDIC's intervention was seen as a significantly generous government protection of the bank's uninsured creditors. The reason behind this move was that the failure of Continental Bank could have led to the failure of countless other smaller commercial banks which had deposits in it. Therefore, the Comptroller of the Currency and the FDCI enacted a plan to rescue both bank depositors and stock and bond investors. Due to such controversial rescue, the Comptroller was called to testify in front of the Congress and admitted there were other large banks needing this type of support in case of bankruptcy. During the hearing, Congressman McKinney stated:
"*...we have a new kind of bank. And today there is another type created. We found it in the thrift institutions, and now we have given approval for a $1 billion brokerage deal to Financial Corporation of America. Mr. Chairman, let us not bandy words. We have a new kind of bank. It is called too big to fail. TBTF, and it is a wonderful bank.*" (Inquiry into Continental Illinois Corp. and Continental Illinois National Bank, 1984, p. 300).

Classifying an institution as TBTF is a matter deeply linked to its systemic importance and revolves around creditors' expectations. Indeed, the TBTF bank's creditors, feeling safer behind this unofficial government shield, lose some of their incentive to monitor and price the riskiness of the institutions. Usually, if a bank is too risky, creditors accept to fund it only at a higher price or, in extreme cases, they do not fund it at all. A TBTF policy changes this risk-cost balance: investors will demand a lower risk premium, since they expect the government to shoulder the downside of their investment. This creates a distortion in the financial sector competition, as well as moral hazard in the intermediary, whose eventual bailout costs are going to be shouldered by society.

I believe the debate around bail-out and bail-in systems is, nowadays, more relevant than ever,

[2]In Italy, several banks faced collapse: Banca delle Marche, Banca Popolare dell'Etruria e del Lazio, Cassa di Risparmio di Ferrara, Cassa di Risparmio della Provincia di Chieti, Veneto Banca, Banca Popolare di Vicenza and Monte dei Paschi di Siena. The latter three, in particular, were of systemic importance to the country's economy and very delicate to resolve.

but there is still work to do towards an efficient and effective implementation of one of those systems. This is why I think it's important to keep the discussion going and improve our current regulations on the subject. Indeed, this work tries to bring its own contribution, highlighting the distorsions in the banks' risk incentives that the subsidy creates. In particular, one of the main "strengths" of the TBTF status is that there is no need for any authorities' commitment, as long as the markets believes an institution will be bailed out, they will give it "special treatment".

This paper is structured as following: Section 2 gives a brief overview of the literature on the topic; Section 3 describes the model, Sections 4 and 5 presents the solutions of the static symmetric game and the static asymmetric game, respectively; in Section 6 the effects of the systemic subsidy are discussed; Section 7 concludes.

2 Literature Review

Since the US Comptroller of the Currency's announcement in 1984, which started the debate on the existence of TBTF and the related implications, there have been many studies contributing to the topic. Although they would all deserve to be properly mentioned here, as this work would not be possible without their important contributions, I will focus my attention on those that, to the best of my knowledge, could be deemed as the most representative. I hope my readers (and the authors) will forgive me, if I failed to include someone I should have.

As highlighted in Zardkoohi et al. (2018), the literature on systemic subsidies to the banks can be divided into two strands. The first one analyses the TBTF issue in the more general context of systemic risk. The existence of the subsidy, as well as the level of interconnection among banks, influence the overall amount of risk in financial markets and have important implications for financial stability. This strand of research aims at studying three important issues: (i) finding alternative measures of systemic risk; (ii) measuring the marginal effect of a bank failure on the overall systemic risk; and (iii) requiring systemically important financial institutions to maintain adequate capital buffers.

Zhou (2009)addressed the first two points. The author analyses whether the size of a bank is truly important for the systemic impact of its failure. He builds a measure of the systemic importance of a bank based on the level of interconnection among credit institutions and finds out that systemic importance is not always related with banks' size.

Also Huang et al. (2012) defines a new systemic risk measure for the banking sector, as the insurance cost to protect against distressed losses. The authors then apply their methodology to a portfolio of twenty-two major banks in Asia and the Pacific to illustrate the dynamics of the spillover effects of the global financial crisis to the region. Their research also shows that the increase in the perceived systemic risk was mainly driven by heightened risk aversion in the markets and squeezed liquidity. Furthermore they suggest that TBTF is a valid concern for a macroprudential perspective of bank regulation.

Black et al. (2016), as well, provides a measure of systemic risk as a hypothetical insurance premium against catastrophic losses in a banking system, which the authors apply on a broad range of European banks. They show that there was significant risk posed by the European banks, which reached its peak in November 2011. Their methodology identifies the individual contributions of over 50 major European banks to the systemic risk measure, capturing the large contribution of a number of systemically important European banks, especially Italian and Spanish ones.

The second strand analyses the systemic subsidy issue from a moral hazard perspective and looks at the implications on banks' risk-taking behaviour. It does so by measuring changes in debt and equity prices for TBTF banks. Indeed, acting as a risk subsidy which lowers costs for the bank or increases their equity value, the TBTF subsidy could represent an incentive for banks to take on more risk.

One of the first works in this direction is O'hara and Shaw (1990), a seminal paper in the TBTF literature. The authors used an event study methodology to investigate the effect on banks' equity values of the 1984 Comptroller of the Currency's announcement (as it was reported by the Wall Street Journal), which declared, for the first time, the eleven largest banks in the US (at the time) as too-big-to-fail (without explicitly mention their names). The authors conclude that the announcement significantly increased the equity prices of these eleven banks compared to the equity values of the rest of the industry, highlighting the iniquities of a TBTF policy.

The Comptroller's announcement was an ideal event to measure the existence and the effect of the TBTF subsidy, but as the years went by, other works have found alternative ways to achieve the same result. A noteworthy example is Penas and Unal (2004). The authors estimate the value of the TBTF subsidy in terms of extra gains on the bonds of merging banks. Indeed, they show that the adjusted returns of merging banks' bonds are positive and significant across pre-merger and announcement months. Achieving the TBTF status with the merger is one of the main determinants of such gains (the others being diversification gains and, to a lesser extent, synergy gains). This is also the first study that shows acquirers benefit by the lower cost of funds on post-merger debt issues.

Brewer and Jagtiani (2013)look at merging banks, as well. They estimate the value of the TBTF subsidy in terms of an extra premium payed on the merger price, using data from the US merger boom of 1991–2004. The authors find proof that credit institutions paid an added premium for mergers that would put them over the asset sizes that are commonly viewed as the thresholds for being TBTF. Since becoming TBTF entails a series of privileges for which banks are willing to pay extra, the authors hope that policies on this issue will make banks pay the social costs implied in those privileges.

Some studies have tried to prove the existence of the subsidy looking at the spreads over bank bonds, such as Flannery and Sorescu (1996) and Balasubramnian and Cyree (2011).

Santos (2014) has an interesting take on this method. Albeit focusing on the primary bond market, as well, the paper investigates whether systemic banks benefit from a cost advantage when raising fund in the bond market compared to smaller banks.

Another noteworthy method used to estimate the subsidy can be found in Ueda and Di Mauro (2013). They look at bank bond ratings as a proxy for difference in structural funding costs, taking a sample with data pre-crisis (2007) and after-crisis (2009). The authors find out that the subsidy has increased over the two time intervals, lowering the average funding costs for systemic banks.

More recently, Kleinow et al. (2014) assumes that, when a regulator declares a bank systemic, the bank's equity value increases. To prove this claim, the authors employ an event study analysis on a set of regulatory announcements in 2009, 2011 and 2012, finding out that indeed financial market participants react to these announcements (which are judgements that a certain credit institution is systemically important), but they do so in a heterogeneous way.

As already said, the literature on the topic is rich. The analysis presented in this paper aspires to be grouped into this second set of works, as it tries to offer some insights on the risk-taking incentives of the credit institutions. However, it does so from an unusual perspective, since it does not look at changes in debt and equity prices, but it focuses on competition dynamics[3]. As proven in different studies (some of which I mentioned above), the TBTF status lowers funding costs for the bank which has it, granting the institution a competitive advantage towards non-systemic banks. Studying this issue in a classic competition framework allows us to look at the behaviour of both types of banks, systemic and non-systemic, as a function of each other's choices and status. After all, real-life banks are not islands, but interact and compete with one another.

3 The Model

The baseline structure for the model is taken from Martinez-Miera and Repullo (2010), henceforth MMR (2010). This paper investigates the effect of competition in the banking sector on the risk of bank failure. Traditional bank competition literature[4] argues that competition reduces banks' franchise values and induces them to take more risk, thus increasing the likelihood of banks' failures. However, Boyd and De Nicolo (2005) highlighted a risk-shifting effect in the loans the banks invest into: since the risk of these loans is increasing in the loan interest rate, a reduction in loan rates, due to greater bank competition, reduces the loans' probability of default. MMR identified another effect, the margin one: more competition leads to lower loan rates, and consequently lower revenues from performing loans, which provide a buffer against loan losses, so banks are riskier. MMR's model

[3] For relevant contributions on the matter, see White (2014) and Bertsch et al. (2015).

[4] Some of the main contributions to this literature are: Berger and Hannan (1989), Keeley (1990), Besanko and Thakor (1993), Petersen and Rajan (1995), Hellmann et al. (2000), Demirguc-Kunt et al. (2003).

showed that the risk-shifting effect tends to dominate in monopolistic markets(therefore, more competition can reduce the overall risk), whereas the margin effect dominates in competitive markets (therefore, further increasing competition is harmful), so the relationship between competition and the risk of bank failure is U-shaped.

As in MMR's framework, there are three types of agent interacting with each others: banks, bond holders[5] and entrepreneurs. Each one of them is perfectly informed. The interactions among the agents develops in two periods, $t = 0, 1$, in a static game setting.

Traditionally, models simplify banking activities into two main ones, deposits and loans, since one of the essential function of a credit institution is collecting deposits and transforming them into loans. In my model, however, I deliberately choose to focus on bonds, instead of deposits, in order to describe the liability side of the bank's balance sheet. There are several reasons behind this choice:

- In the literature, one of the main effects of the TBTF subsidy, the decrease in funding costs, is often measured through bond spreads [6].
- In Europe and in the US there are deposits guarantee schemes which ensure deposits up to a certain amount from banks' failures. Therefore, whether the bank is systemic or not does not change the level of protection for the depositors. Moreover, knowing the threshold up to which the protection applies, depositors have the incentive not to keep excess money in their accounts, but rather to invest it in other activities, both financial and non.
- As witnessed in the recent Italian banking sector crisis, the major issue linked with the resolution of the failing banks was the fact that the depositors invested a significant part of their savings into the banks' subordinated bonds, which made them liable in case of a bail-in. This is why the institutions had to be bailed out.
- After the introduction of MREL in the EU,[7]eligible instruments like subordinated bonds are crucial for banks' capital requirements and for the impact and effectiveness of the whole bail-in system.

Given the above, I deemed best to focus on bonds rather than deposits. One might rightly argue that, without the latter, a bank is not a bank. My main objective, however, is to analyse how the subsidy affects competition dynamics among banks. Since the subsidy manifests its effects through bonds, the addition of depositors, in my opinion, would have not altered the main results of the model.

[5] In MMR (2010) there are depositors instead of bond holders.

[6] Flannery and Sorescu (1996), Balasubramnian and Cyree (2011), Acharya et al. (2016), Santos (2014).

[7] The Minimum Requirement for own funds and Eligible Liabilities (MREL) is a requisite for EU banks, introduced through the Bank Recovery and Resolution Directive (BRRD) in 2014 to ensure the effective implementation of the bail -in tool , i.e. that shareholders and creditors are the first to absorb losses when a bank fails.

3.1 Banks

There are two banks in this economy, bank i and bank j, competing à la Bertrand both in the bond market and in the loan market in $t = 0$.

The competition is modelled with a two-stage game. In the first stage they compete in the bond market, choosing strategically the yield to offer for their bonds. Once they acquire a bond supply, in the second stage they use it to sell loans to entrepreneurs, competing on the loan rate. Basically, the decisions taken in the bond market act as a capacity constraint for the choices in the loan market.

In $t = 1$ there are no strategical decisions to take. The investment project of the entrepreneurs (who borrowed money from the banks) comes to maturity, leading to two possible scenarios:

- Good scenario: the project succeeds, thus the entrepreneurs repay their loans to the banks, which can repay the bond holders. This happens with probability $1 - \omega$.

- Bad scenario: entrepreneurs default on their loans and cannot repay the banks. This happens with probability ω. At this point, two things may happen: neither institution is systemic, thus they both go bankrupt and fail to repay their bond investors; or one institution is systemic - without loss of generality we assume it is bank i -, leading to the following scenario:

  - The non-systemic bank goes bankrupt. It cannot pay back its bond holders and exits the market;
  - The systemic bank can receive a subsidy, with probability $1 - \sigma$, or not, with probability σ. If it does receive it, the State or the central bank wipes its balance sheet clean and pays back the bond holders only their initial investment (alternatively, the bank becomes state owned, i.e. Monte dei Paschi di Siena, to mention one). Otherwise, the bank goes bankrupt.

	$1-\omega$	ω		
i	good scenario	bad scenario	$1-\sigma$ subsidy	σ no subsidy
j	good scenario	bad scenario		

Bank i is the systemic bank

As explained above, being systemic does not imply certain rescue for the credit institution. I believe this assumption is rather realistic. Indeed, there have been some cases in which systemic banks have been left to fail (i.e. Leheman Brothers); moreover, there are examples of regulations set to avoid State rescues of banks (bail-out), favouring, instead, bail-in solutions (i.e. the Single Resolution Mechanism in the European banking union area). Nevertheless, in recent years we have been witnessing some bail-out situation, proving that the practice, in spite of fierce opposition, is still spread.

3.2 Bond Holders

In this economy there is a finite continuum B of bond holders. In order to model their behaviour and derive the bond supply schedule, I use a spatial competition model, as in Hotelling (1929), and take from the literature of consumer inertia models with switching costs, with some modifications to suit my needs.

As in the traditional model, the B bond holders are uniformly distributed on a line going from 0 to 1; however, instead of representing a linear city, along which consumers are distributed and the firms are located at a certain distance, the line represent the level of "risk preference" of the bond holders[8], which I call γ, going from very risk loving individuals ($\gamma = 0$) to highly risk averse ones ($\gamma = 1$). This parameter must not be considered as traditional risk aversion, it is simply a taste for risk, a behavioural characteristic. Bond holders are distributed over the line according to their taste for risk and, depending on the way they perceive each bank's risk profile (a perception which is commong among all B bond holders), they place the banks on the line too. The perceived risk profile of each bank depends from a mix of the bank's own characteristics, exogenous to the model, like the banks' regulatory capital (the banks' loan policies in the second stage game do not change the perception bond holders have on the riskiness of the bank[9]), and the presence of the TBTF subsidy. One might ask, why not simply assume that the position of the banks on the line depends simply on each bond holders' preferences about a bank (i.e.: it's physically closer, or it's the family bank, etc.). It this were the case, than the presence of the subsidy would not influence the place of the banks on the line; therefore, the subsidy would not be important for bond holders at all. If I go to a bank because it has been my family bank for generations, whether it is systemic or not would not particularly concern me: its riskiness is only one of the main factor determining my choice of that specific bank. Instead, assuming that the line is the space of risk taste, and risk taste is what determines the position of the bank on the line, allows to link the bond holders' choice to the presence of the subsidy or not and to isolate the subsidy effect in the competition among banks.

In the case represented in Figure 3.2.1 below, bank i is seen as safer, so it is placed toward the right end of the line, in position $1 - b$, while bank j is perceived as riskier, so it is placed toward the left end of the line, in position a. This perception is common among all B bond holders. As far as the positions of the banks are concerned, there are only two assumption:

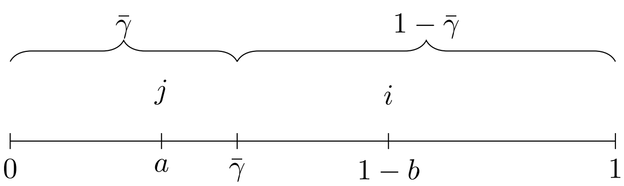
[8] In inertia models, the line represents the taste for the product of the firm.

[9] The model develops around a static game. Once the game is over and the entrepreneurs pay or not their loan back, the model ends. There is no repetition; therefore, bond holders cannot update their risk perception based on the loan policies previously chosen by the banks. Their perception is the result of the status of each bank at the beginning of the game, in $t = 0$.

1. $a \leq 1-b \Rightarrow a+b \leq 1$. This is to ensure that in position a there is always the bank perceived as riskier, which cannot be to the right of the "safer" bank, placed in $1-b$ (remember, the closer we are to 1, the more the individuals are risk averse). From this, we can derive that:
   - $a \in [0, 1)$;
   - $(1-b) \in (0, 1]$;
2. a, $b \leq \frac{1}{2}$. This assumption ensures no bank begins with a turf of clients greater than half the entire supply, making competition for bond holders in the middle more meaningful.

Each bond holder would like to invest in the unit bond of the bank that is closer to its level of risk preference, since moving away (i.e. switching from one position to another) entails a cost, $m > 0$. This cost can be seen as a compromise cost, which the bond holder pays when she has to "compromise" for a bank whose risk profile does not perfectly match her own. The cost is such that the bond holders in the space between one extremum and the bank have no incentive to choose the bank further away, rather than the closest one, even if the former were to offer a better yield.

Figure 3.2.1: The γ-line



As we can see from Figure 1, bond holders to the left of a are going to invest in bank j, those to the right of $1-b$, are going to invest in bank i. As far as the middle segment is concerned, we need to determine which share of bond holders are going to invest in which bank. In order to do so, we need to find the level of risk preference of the indifferent bond holder, $\bar{\gamma}$; in other words we need to find, the position of the bond holder who is indifferent from investing in a unit bond of either banks. In this way, we can determine the bond supply fractions and each bank's bond supply: $b_i = (1-\bar{\gamma})B$ and $b_j = \bar{\gamma}B$.

3.3 Entrepreneurs

There is a finite continuum of moneyless, risk neutral entrepreneurs.

At $t = 0$, each one of them wishes to borrow a unit loan from one of the banks to fund a risky investment project, which at $t = 1$ will either return a positive profit, or fail and return zero. For simplicity, I assume no screening or monitoring process of the entrepreneurs by the bank.

I assume a linear loan demand specification, $L - cr^l$, as in MMR (2010), where L is the total loan demand (the loan demand at zero interest rate) and c is a linear coefficient representing the sensitivity of the loan demand to changes in the interest rate. The loan demand schedule for bank i is:

$$l_i(r_i^l, r_j^l, b_i) = \begin{cases} min\left\{b_i, L - cr_i^l\right\} & \text{if } r_i^l < r_j^l \\ min\left\{b_i, \frac{L - cr_i^l}{2}\right\} & \text{if } r_i^l = r_j^l \\ min\left\{b_i, RD_i(r_i^l, r_j^l, b_i)\right\} & \text{if } r_i^l > r_j^l \end{cases} \quad (3.3.1)$$

where r_i^l is the loan rate charged by bank i, r_j^l is the one charged by bank j and $RD_i(r_i^l, r_j^l, b_i)$ is the residual demand of bank i.

As far as the residual demand (the loan demand remaining to the "looser" after the competition "winner" exhausts its loan supply) is concerned, I follow Stahl (1988) in not choosing a specific rationing rule, but instead I define three conditions the residual demand must fulfil, in order for equilibria to exists:

1. $RD_i(r_i^l, r_j^l, b_i)$ is jointly continuous in (r_i^l, r_j^l) and decreasing in r_i^l;
2. $\lim\limits_{r_i^l \to r_j^l} RD_i(r_i^l, r_j^l, b_i) = max\left\{l_j(r_j^l) - b_j, 0\right\}$;
3. $RD_i(r_i^l, r_j^l, b_i) \leq \dfrac{l_i(r_i^l)}{2}$ for all $r_i^l > r_j^l \geq l_j^{-1}(b_i + b_j)$;

The first conditions is standard for every demand function. The second one ensures that at the limit the residual demand is equal to the entire demand at r_j^l minus the demand satisfied by bank j or it's 0 because bank j has supplied all the demand. The third one guarantees that the residual demand of the high rate bank cannot be grater than half the demand it would face on its own.

Bank j's loan demand schedule and residual demand conditions are perfectly symmetrical.

4 Static Symmetric Game

The main assumption in this case is that the two banks are exactly the same. Neither of them is systemic, thus there is no subsidy in the model. This implies:

1. Banks' expected profits functions are perfectly symmetrical:

$$E[\Pi_i] = (1-\omega)\left[l_i(r_i^l, r_j^l, b_i)(1+r_i^l) - b_i(r_i^b, r_j^b, \gamma)(1+r_i^b)\right] + \\ +\omega\left\{\sigma\left[-b_i(r_i^b, r_j^b, \gamma)(1+r_i^b)\right]\right\} \tag{4.1}$$

$$E[\Pi_j] = (1-\omega)\left[l_j(r_i^l, r_j^l, b_i)(1+r_j^l) - b_j(r_i^b, r_j^b, \gamma)(1+r_j^b)\right] + \\ +\omega\left\{\sigma\left[-b_j(r_i^b, r_j^b, \gamma)(1+r_j^b)\right]\right\} \tag{4.2}$$

2. Bond holders perceive both banks having the same risk profile (i.e. they are placed in the same position over the γ-line).

In order to find the sub-game perfect Nash equilibrium of this case, I will use backward induction, finding first the Nash Equilibrium in the loan market, taking bond market decisions as given; then the one in the bond market and check whether the two are compatible.

4.1 Loan Market

Entrepreneurs only care about the cheapest loan rate, hence they choose to buy the unit loan from the less expensive bank. Assuming bank i offers the best loan rate, all the loan demand at that rate, $L - cr_i^l$ will go to bank i. The latter can either supply it all, if $b_i \geq L - cr_i^l$, or up to its capacity. Bank j in the first case will be out of the market, in the second case will either supply the residual demand or its capacity b_j, whichever is the smallest. As far as banks are concerned, they both would like to exhaust their capacity, since any capacity left unsold it has still to be payed for, even if it doesn't bear any gain.

Given these premises, the second stage game Nash Equilibrium is:

$$r_i^l = r_j^l = \bar{r}^l : \ L - c\bar{r}^l = b_i + b_j \tag{4.1.1}$$

The two banks will charge the same interest rate, $\bar{r}^l$, which is the rate that equates the loan demand to the aggregate bond supply.

Proof:

- $r_i^l < r_j^l$ is not feasible. Indeed, the low rate bank would like to raise its rate as long as it is capacity constrained, since at this rate the actual demand is over its capacity (it could still sell all its capacity by charging more). If instead bank i is able to supply the entire demand at such rate, than bank j has an incentive to undercutting charging $r_i^l - \varepsilon$. The same reasoning applies if we assume $r_j^l < r_i^l$. Therefore the two rates must be equal.

- $r_i^l = r_j^l < r^l$ means that they are selling over-capacity. Both bank could raise their rates and still sell all their capacity.
- $r_i^l = r_j^l > r^l$ means that the institutions are selling under-capacity. Taking bank i in consideration, for example, since $l_i(r_i^l) < b_i$ it has an incentive to undercut bank j by a small ε: $l_i(r_i^l)r_i^l < b_i(r_i^l - \varepsilon)$.

Q.E.D.

4.2 Bond Market

As I said before, when the banks are symmetric they are perceived by the bond holders as having the same risk profile, in other words $a = 1 - b$. The first thing to look for is the location of the indifferent bond holder, $\bar{\gamma}$. To do so, we need to equate the expected wealth of investing in a unit bond of bank i, with the expected wealth of investing in a unit bond of bank j. The expected wealth of investing in any bond will be the probability weighted average of the profits in each scenario. Both scenarios have in common the "compromise" cost, m, which the bond holder pays when she has to "compromise" for a bank whose risk profile does not perfectly match her own, moving from $\bar{\gamma}$ to $(1-b)$.

$$EW_i = EW_j \Rightarrow$$

$$\begin{gathered}(1-\omega)\left\{r_i^b - m\left[\bar{\gamma}-(1-b)\right]^2\right\} + \omega\left\{-1 - m\left[\bar{\gamma}-(1-b)\right]^2\right\} = \\ (1-\omega)\left\{r_j^b - m\left[\bar{\gamma}-(1-b)\right]^2\right\} + \omega\left\{-1 - m\left[\bar{\gamma}-(1-b)\right]^2\right\} \Rightarrow\end{gathered} \tag{4.2.1}$$

$$r_i^b = r_j^b$$

There is no specific level of γ for which it exists an indifferent bond holder: bond holders are indifferent among the two banks as long as they offer the same bond yield. Therefore, bond market competitions becomes, in the symmetric case, a winner-takes-it-all competition, with this type of bond supply schedule:

$$b_i(r_i^b, r_j^b) = \begin{cases} 0 & \text{if } r_i^b < r_j^b \\ \dfrac{1}{2}B & \text{if } r_i^b = r_j^b \\ B & \text{if } r_i^b > r_j^b \end{cases} \qquad (4.2.2)$$

Following Stahl (1985) let's define $\bar{r}^b$ as the zero-monopoly-rent yield, the highest yield that can guarantee non-negative profits for the winner of the bond market competition. Therefore, no bank will have an incentive to offer a rate higher than $\bar{r}^b$.

Given the above premises, $r_i^b = r_j^b = \bar{r}^b$ is a Nash Equilibrium for the first stage sub-game.

Proof:
Here we are in a typical Bertrand situation with costs instead of prices. Any yield level different from the zero-monopoly-rent yield give the lower bank rate an incentive to raise its rate up to $\bar{r}^b$.
Q.E.D.

This result implies the each bank gets half of the total bond supply: $b_i^* = b_j^* = \frac{1}{2}B$. Therefore, in the second stage we have $r_i^l = r_j^l = \bar{r}^l : L - c\bar{r}^l = b_i^* + b_j^*$, in particular $\bar{r}^l = \frac{L-B}{c}$.
The pure strategy Sub-game Perfect Nash Equilibrium (SPNE) of this game is $r^{b,*} = \bar{r}^b$ and $r^{l,*} = \bar{r}^l$ (4.2.3).

5 Static Asymmetric Game

5.1 Introducing the Subsidy

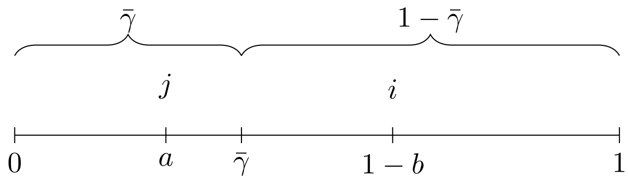
Before proceeding any further with the analysis, we need to understand what happens when we introduce the subsidy in the model. The first immediate effect is a direct one: the rescued bank's profit functions change, because now there is the subsidy that changes its profit expectation in the bad scenario. More precisely:

$$\begin{aligned} E\Pi_i = (1-\omega)\left[l_i(r_i^l, r_j^l, b_i)(1+r_i^l) - b_i(r_i^b, r_j^b, \gamma)(1+r_i^b)\right] + \\ +\omega\left\{(1-\sigma)\cdot 0 + \sigma\left[-b_i(r_i^b, r_j^b, \gamma)(1+r_i^b)\right]\right\} \end{aligned} \qquad (5.1.1)$$

As we can see in the formula above, the subsidy brings bank i's profits to zero: the State bails out the institution, wiping its balance sheet clean and taking charge of bond holders reimbursement.

The second effect of the subsidy concerns banks positions over the γ-line: bank i, which is perceived as safer for being the one with the subsidy, is placed towards the right end of the line, where more risk averse bond holders are; bank j, not having the subsidy, is seen as riskier, so it is located towards the left end of the line (see Figure 5.1.1).

Figure 5.1.1: The γ-line with the TBTF subsidy



Now, the indifferent individual, located at $\bar{\gamma}$, will care not only about the yields, but also about the distance and the fact that one bank has the subsidy, while the other does not. Bond holders will compare the expected wealth they obtain from a unit bond of bank i with the one obtained from a unit bond of bank j. Solving the system below allows us to find the location of the indifferent bond holder, $\bar{\gamma}$, and each bank bond supply, $b_i = (1-\bar{\gamma})B$ and $b_j = \bar{\gamma}B$:

$$\begin{cases} EW_i = (1-\omega)\left\{r_i^b - m\left[\gamma-(1-b)\right]^2\right\} + \\ \omega\left\{(1-\sigma)(1-1-m\left[\gamma-(1-b)\right]^2) + \sigma(-1-m\left[\gamma-(1-b)\right]^2)\right\} \\ \\ EW_j = (1-\omega)\left[r_j^b - m(\gamma-a)^2\right] + \omega\left[-1-m(\gamma-a)^2\right] \end{cases} \quad (5.1.2)$$

If we compare the results of the symmetric case with the ones of the asymmetric case, we would deal with both the effects I described above: the asymmetry due to the position and the one due to the subsidy itself. What I am truly interested in is the latter, the former is simply due to the way I chose to model bank competition. In order to isolate the pure subsidy effect, I will compare the results of the asymmetric case with the results of a partial asymmetric game, in which I keep the position asymmetry, but neither banks have the subsidy. The partial asymmetric case is shown in Appendix I. I will proceed to find the asymmetric case equilibrium using backward induction, as in the symmetric case.

5.2 Loan Market

Nothing changes from the symmetric game case: the subsidy has no effects on the loan market, therefore entrepreneurs only care about the cheapest loan rate, while banks would like to exhaust their own capacity. Given these premises, the second stage game Nash Equilibrium is:

$$r_i^l = r_j^l = \bar{r}^l : \; L - c\bar{r}^l = b_i + b_j = B \qquad (5.2.1)$$

and each bank loan demand will be equal to its own bond supply:$l_i = b_i$ and $l_j = b_j$. The proof is the same as in the symmetric case.

5.3 Bond Market

As for the symmetric game, the first thing to do is finding $\bar{\gamma}$. This can be done solving the following equation (the parts in red are the ones specific to the asymmetric case with subsidy, while the ones in black are in common between the asymmetric case and the partial asymmetric one):

$$EW_i = EW_j$$

$$(1-\omega)\left\{r_i^b - m[\gamma-(1-b)]^2\right\} + \omega\left\{(1-\sigma)(1-1-m[\gamma-(1-b)]^2) + \sigma(-1-m[\gamma-(1-b)]^2)\right\} =$$

$$(1-\omega)\left[r_j^b - m(\gamma-a)^2\right] + \omega\left[-1-m(\gamma-a)^2\right] \Rightarrow$$

$$\bar{\gamma}^S = a + \frac{(1-a-b)}{2} + \frac{(1-\omega)}{2m(1-a-b)}(r_j^b - r_i^b) - \frac{\omega(1-\sigma)}{2m(1-a-b)} = h_a + s(r_j^b - r_i^b) - sub \qquad (5.3.1)$$

$$1-\bar{\gamma}^S = b + \frac{(1-a-b)}{2} + \frac{(1-\omega)}{2m(1-a-b)}(r_i^b - r_j^b) + \frac{\omega(1-\sigma)}{2m(1-a-b)} = h_b + s(r_j^b - r_i^b) + sub \qquad (5.3.2)$$

Where:

$$h_a = a + \frac{(1-a-b)}{2}$$

$$h_b = b + \frac{(1-a-b)}{2}$$

$$s = \frac{(1-\omega)}{2m(1-a-b)}$$

$$sub = \frac{\omega(1-\sigma)}{2m(1-a-b)}$$

It should be highlighted that, if not for the subsidy component, $\bar{\gamma}$ and $1-\bar{\gamma}$, would be specular. The red part in the function $E[W_i]$ represents the presence of the subsidy: investing in a unit bond of bank i, should the bad scenario realise, will give the bond holders the chance to recover their

initial investment in the bond with probability $1-\sigma$. Notice that they will bear the "compromise" cost, $m\left[\gamma-(1-b)\right]^2$, anyways. This, indeed, is to be seen as a psychological cost, born from the fact that they could not invest in the bank with their ideal characteristic and risk profile (i.e. in their same position on the line); instead they had to compromise with a second-best choice.
Differently from what happens in the symmetric game, where there is no specific level of γ for which it exists an indifferent bond holder (indifference is achieved as long as the bond yields are equals), with the subsidy, even if the credit institutions offered the same bond yield, the position of the indifferent bond holder is clearly defined. In particular, ceteris paribus, the *sub* component increases the portion of investors going to bank i (the systemic one), at the expenses of the portion of investors going to the other bank. This subsidy component does not depend from the optimal strategy of the bank, but is representative of an intrinsic characteristic the systemic institution starts with, for which the State gives it a competitive advantage towards the non-systemic institution.

The optimal strategic choice of each bank, in other words the optimal bond yield, can be derived solving the following maximisation problem:

$$\begin{aligned}
&\underset{r_i^b}{max}\ (1-\omega)\left[(1-\bar{\gamma}^S)B(1+\bar{r}^l)-(1-\bar{\gamma}^S)B(1+r_i^b)\right]+\\
&+\omega\left\{(1-\sigma)\cdot 0+\sigma\left[-(1-\bar{\gamma}^S)B(1+r_i^b)\right]\right\}\Rightarrow\\
&\underset{r_i^b}{max}\ (1-\omega)(1-\bar{\gamma}^S)B(1+\bar{r}^l)-\underbrace{[1-\omega+\omega\sigma]}_{t_i}(1-\bar{\gamma}^S)B(1+r_i^b)
\end{aligned} \tag{5.3.3}$$

$$\begin{aligned}
&\underset{r_j^b}{max}\ (1-\omega)\left[\bar{\gamma}^S B(1+\bar{r}^l)-\bar{\gamma}B(1+r_j^b)\right]+\omega\left[-\bar{\gamma}^S B(1+r_j^b)\right]\Rightarrow\\
&\underset{r_j^b}{max}\ (1-\omega)\bar{\gamma}^S B(1+\bar{r}^l)-\bar{\gamma}^S B(1+r_j^b)
\end{aligned} \tag{5.3.4}$$

with $t_i < 1$ as the subsidy component: without it, the two expected profit functions would be specular, the only difference given by the fraction of bond holders in the bond supply, $\bar{\gamma}$ and $1-\bar{\gamma}$.

Finding the first order conditions and substituting equations (5.3.1) and (5.3.2) into them allow us to obtain each bank's best reaction function (BRF), which represent the best yield choice given the competitor's yield choice:

$$r_i^{b,S} = \frac{1}{2}r_j^b + \frac{(1-\omega)(1+\bar{r}^l)}{2t_i} - \frac{(s+h_b+sub)}{2s} \quad (5.3.5)$$

$$r_j^{b,S} = \frac{1}{2}r_i^b + \frac{(1-\omega)(1+\bar{r}^l)}{2} - \frac{(s+h_a-sub)}{2s} \quad (5.3.6)$$

In the above functions, the subsidy component appears twice for the systemic bank and once for the non-systemic one. First of all it is useful clarifying the difference between t_i and sub. The former is the subsidy component coming from the maximisation problems and represents the probability which bank i incurs in its costs. Indeed, differently from bank j, which will incur in its costs with probability 1 (either it repays the bond holders in the good scenario or it goes bankrupt in the bad one), the systemic bank will do so only with probability $1-\omega+\omega\sigma$, since it has a chance to receive the subsidy if things go wrong. The component sub, instead, is the subsidy component due to the bond holders. It can be interpreted as a psychological subsidy, linked to the perception of bank i being safer. Taking the first derivatives of the reaction functions by t_i and sub, we obtain $\frac{\partial r_i^{b,S}}{t_i} < 0$, $\frac{\partial r_i^{b,S}}{sub} < 0$ and $\frac{\partial r_j^{b,S}}{sub} > 0$. Therefore, for the systemic bank, the presence of the subsidy reduces, ceteris paribus, the amount of the yield (a cost) it should choose as a best response to the competitor's yield; for bank j, the subsidy is an additional cost, since it increases, ceteris paribus, the amount of its best response yield.

In order to find the optimal bond yields, we need to solve the system given by equations (5.3.5) and (5.3.6):

$$\begin{cases} r_i^{b,S} = \frac{1}{2}r_j^b + \frac{(1-\omega)(1+\bar{r}^l)}{2t_i} - \frac{(s+h_b+sub)}{2s} \\ \\ r_j^{b,S} = \frac{1}{2}r_i^b + \frac{(1-\omega)(1+\bar{r}^l)}{2} - \frac{(s+h_a-sub)}{2s} \end{cases}$$

$$\begin{cases} r_i^{b,S^*} = (1-\omega)(1+\bar{r}^l)\frac{(2+t_i)}{3t_i} - 1 - \frac{(2h_b+h_a+sub)}{3s} & (5.3.7) \\ \\ r_j^{b,S^*} = (1-\omega)(1+\bar{r}^l)\frac{(1+2t_i)}{3t_i} - 1 - \frac{(2h_a+h_b-sub)}{3s} & (5.3.8) \end{cases}$$

Equations (5.3.7) and (5.3.8) represents the yields that maximise each bank's profit function and are the best reaction to the competitor's yield. Substituting equations (5.3.7) and (5.3.8) into equations (5.3.1) and (5.3.2) allows us to find the optimal demand fractions:

$$\bar{\gamma}^{S*}=\frac{1}{2}+\frac{a-b}{6}-\frac{(1-t_i)}{3t_i}s(1-\omega)(1+\bar{r}^l)-\frac{1}{3}sub \tag{5.3.9}$$

$$1-\bar{\gamma}^{S*}=\frac{1}{2}+\frac{b-a}{6}+\frac{(1-t_i)}{3t_i}s(1-\omega)(1+\bar{r}^l)+\frac{1}{3}sub \tag{5.3.10}$$

The Sub-game perfect Nash Equilibrium of the static asymmetric game is thus given by:

- First stage game:

$$\begin{aligned} r_i^{b,S*} &= (1-\omega)(1+\bar{r}^l)\frac{(2+t_i)}{3t_i} - 1 - \frac{(2h_b+h_a+sub)}{3s} \\ r_j^{b,S*} &= (1-\omega)(1+\bar{r}^l)\frac{(1+2t_i)}{3t_i} - 1 - \frac{(2h_a+h_b-sub)}{3s} \end{aligned} \tag{5.3.11}$$

- Second stage game:

$$r_i^l = r_j^l = \bar{r}^l : \begin{cases} l_i = \left(1-\bar{\gamma}^{S*}\right)B \\ \\ l_j = \bar{\gamma}^{S*}B \end{cases} \tag{5.3.12}$$

6 The Subsidy Effects

Having defined the Sub-game perfect Nash Equilibrium of the static asymmetric game, it is time to analyse and interpret what are the effects of a State aid to the systemic bank in terms of competition dynamics. Does the subsidy distort the competition, and if yes, how so?

As explained in the previous section, in order to isolate the subsidy effect (the red part in the equations), we have to compare the static asymmetric game with a partial asymmetric one (for details see Appendix I), where there is only a position asymmetry, but no subsidy.

The first question we can ask ourselves is: how does the choice of the optimal loan interest rate in the second stage game affect the choice of the optimal bond yield when the subsidy comes into play? As we can see from equations (6.1) and (6.2) below, the impact of $\bar{r}^l$ is higher in the game with the subsidy for both banks, not just the systemic one.

$$\frac{\partial r_i^{b,S*}}{\partial \bar{r}^l} = (1-\omega)\frac{(2+t_i)}{3t_i} \quad > \quad \frac{\partial r_i^{b*}}{\partial \bar{r}^l} = (1-\omega) \qquad (6.1)$$

$$\frac{\partial r_j^{b,S^*}}{\partial \bar{r}^l} = (1-\omega)\frac{(1+2t_i)}{3t_i} \quad > \quad \frac{\partial r_j^{b*}}{\partial \bar{r}^l} = (1-\omega) \qquad (6.2)$$

This implies that, in presence of the subsidy, for any given level of $\bar{r}^l$, both banks seek profit more aggressively, by offering a higher bond yields than they would if no State aid were allowed. Furthermore, given that $\frac{(2+t_i)}{3t_i} > \frac{(1+2t_i)}{3t_i}$, bank i is more aggressive than bank j. In case of the systemic bank, this increase in the risk taking behaviour is explained by the subsidy itself: the possibility of being rescued makes the bank less prudent. The non-systemic bank, instead, has to become more aggressive in order to be able to compete with the other. It recognises the advantage in competition its rival has and reacts accordingly.

What about the optimal bond yields? How does the subsidy affect them?

$$r_j^{b,S^*} - r_j^{b*} = (1-\omega)(1+\bar{r}^l) + \frac{t_i}{(1-\omega)} \geq 0$$

$$r_i^{b,S^*} - r_i^{b*} = (1-\omega)(1+\bar{r}^l) - \frac{1}{2}\frac{t_i}{(1-\omega)} \overset{?}{\gtreqless} 0$$

$$\text{if} \quad (1-\omega)(1+\bar{r}^l) > \frac{1}{2}\left[1+\frac{\omega\sigma}{(1-\omega)}\right] \Rightarrow r_i^{b,S^*} > r_i^{b*} \qquad (6.3)$$

$$\text{if} \quad (1-\omega)(1+\bar{r}^l) \leq \frac{1}{2}\left[1+\frac{\omega\sigma}{(1-\omega)}\right] \Rightarrow r_i^{b,S^*} \leq r_i^{b*} \qquad (6.4)$$

As it can be seen in the equations above, the difference between bank j's bond yield in the game with the subsidy and the bond yield the case without it is always non-negative. The subsidy increases the costs for the non-systemic bank without offering any benefits.

As far as the systemic bank is concerned, instead, the difference between the yields in the two games does not have a unique sign. This depends on two components, the expected gains, $(1-\omega)(1+\bar{r}^l)$, and the ratio $\frac{\omega\sigma}{(1-\omega)}$. We could interpret the latter as the riskiness of the economy: how likely not to get the subsidy in the bad scenario is (the worst possible case) versus how likely the good scenario is (the best case). In particular, if the expected gains in the loan market are high enough, compensating the level of risk in the economy, then bank i will offer a higher bond yields in presence of the subsidy, acting more risk seeking. Instead, if the risk level in the economy is too high, the systemic bank will be more careful, choosing an equal or lower bond yield than it would if the subsidy were not available. Indeed, the systemic bank is driven by the fact that, in spite of being possible, the chances of not being bailed-out are too high. Finally, from the above equations we can derive:

$$r_j^{b,S^*} - r_j^{b*} > r_i^{b,S^*} - r_i^{b*} \text{ since } \frac{t_i}{(1-\omega)} > -\frac{1}{2}\frac{t_i}{(1-\omega)} \text{ always} \quad (6.5)$$

The subsidy increases costs more for the non-systemic bank.

Another question we can ask involves a comparison between the two banks in the subsidy game and not a comparison of each banks' choices across the asymmetric game and the partial asymmetric one, as in the previous analyses. In the symmetric game, the optimal bond yields offered by the credit institutions were the same; in the partial asymmetric game (see Appendix I), the two optimal yields are the same as long as the two banks are placed at the same distance from the two ends of the γ-line (i.e. $a = b$). What about the game with the subsidy? Are there any values of a and b for which the optimal bond yields of the equations (5.3.7) and (5.3.8) can be the same?

$$\begin{gathered} r_i^{b,S*} - r_j^{b,S^*} = \\ \frac{1}{3s}(a-b) + \frac{(1-t_i)}{3t_i}(1-\omega)(1+\bar{r}^l) - \frac{2\omega(1-\sigma)}{3(1-\omega)} \end{gathered} \quad (6.6)$$

In order to understand how the above equation behave, we can treat it as a function of the difference between the positions of the two banks and rewrite it as:

$$\begin{gathered} r_i^{b,S*} - r_j^{b,S^*} \equiv \\ \Delta r(x) = zx(x+2a-1) + k \end{gathered} \quad (6.7)$$

where:

- $x \equiv (1-b) - a$
- $z \equiv \dfrac{2m}{3(1-\omega)}$
- $k \equiv \dfrac{(1-t_i)}{3t_i}(1-\omega)(1+\bar{r}^l) - \dfrac{2\omega(1-\sigma)}{3(1-\omega)}$

Δr is a convex parabola whose domain is $x \in [0, 1]$, since the distance between the two banks can either be null, as in the symmetric case, or maximum, with each bank at one extremum of the γ-line. Studying the function can allow us to understand whether it lies above or below the x-axis, thus whether it is greater, smaller or equal to zero in the considered domain. In particular:

- $\Delta r(0) = k$;
- $\Delta r(1) = z2a + k$; however, $x = 1$ implies $a = b = 0$. Thus, $\Delta r(1) = k$.

How can we determine the sign of k? As previously shown, $r_j^{b,S^*} - r_j^{b*} > r_i^{b,S^*} - r_i^{b*}$, and, with a little rearranging, we obtain:

$$r_j^{b,S*} - r_j^{b*} > r_i^{b,S*} - r_i^{b*} \Rightarrow r_i^{b*} - r_j^{b*} > r_i^{b,S^*} - r_j^{b,S^*} \Rightarrow$$

$$\frac{1}{3s}(a-b) > \frac{1}{3s}(a-b) + \frac{(1-t_i)}{3t_i}(1-\omega)(1+\bar{r}^l) - \frac{2\omega(1-\sigma)}{3(1-\omega)} \Rightarrow$$

$$0 > \frac{(1-t_i)}{3t_i}(1-\omega)(1+\bar{r}^l) - \frac{2\omega(1-\sigma)}{3(1-\omega)} \equiv k \tag{6.8}$$

Therefore, at the extremes of our domain, the function is negative. Since, as we said before, $\Delta r(x)$ is a convex parabola, the above result implies that the function is negative in the whole interval between 0 and 1. Thus, the optimal yield paid by the bank with the subsidy is always smaller than the one charged by the bank without it. However, although the difference between the two yields is always negative, its size is not monotonic in x, but first increases and then decreases. Indeed, looking at the first derivative of $\Delta r(x)$and studying its sign, we have:

$$\frac{\partial \Delta r(x)}{\partial x} = z(2x + 2a - 1)$$

$$\begin{aligned} &\frac{\partial \Delta r(x)}{\partial x} < 0 \quad \text{for } x \in \left[0, \frac{1}{2} - a\right) \\ &\frac{\partial \Delta r(x)}{\partial x} = 0 \quad \text{for } x = \frac{1}{2} - a \\ &\frac{\partial \Delta r(x)}{\partial x} > 0 \quad \text{for } x \in \left(\frac{1}{2} - a, 1\right] \end{aligned} \tag{6.9}$$

This implies that the difference between the two optimal yields increases (in absolute value) as the distance between the two banks grows from 0 to $\frac{1}{2} - a$. At this point, the difference reaches its maximum level and then it decreases (in absolute value) as x moves towards 1. What does this mean? First of all, we need to look at how the optimal yields move at the change of x, keeping a fixed and moving b. Recalling equations (5.3.7) and (5.3.8):

$$r_i^{b,S*} = (1-\omega)(1+\bar{r}^l)\frac{(2+t_i)}{3t_i} - 1 - \frac{(2h_b + h_a + sub)}{3s}$$

$$r_j^{b,S*} = (1-\omega)(1+\bar{r}^l)\frac{(1+2t_i)}{3t_i} - 1 - \frac{(2h_a + h_b - sub)}{3s}$$

where:

$$h_a = a + \frac{(1-a-b)}{2}$$

$$h_b = b + \frac{(1-a-b)}{2}$$

$$s = \frac{(1-\omega)}{2m(1-a-b)}$$

$$sub = \frac{\omega(1-\sigma)}{2m(1-a-b)}$$

and, therefore:

$$\frac{(2h_b + h_a + sub)}{3s} = \frac{2m(1-b-a)}{3(1-\omega)}\left[\frac{3}{2} + \frac{1}{2}b - \frac{1}{2}a\right] - \frac{\omega(1-\sigma)}{3(1-\omega)}$$

$$\frac{(2h_a + h_b - sub)}{3s} = \frac{2m(1-b-a)}{3(1-\omega)}\left[\frac{3}{2} + a - \frac{1}{2}b\right] + \frac{\omega(1-\sigma)}{3(1-\omega)}$$

We can rewrite (5.3.7) and (5.3.8) as:

$$r_i^{b,S*} = f_i - \frac{2m(1-b-a)}{3(1-\omega)}\left[\frac{3}{2} + \frac{1}{2}b - \frac{1}{2}a\right] \quad (6.10)$$

$$r_j^{b,S*} = f_j - \frac{2m(1-b-a)}{3(1-\omega)}\left[\frac{3}{2} + a - \frac{1}{2}b\right] \quad (6.11)$$

where:

$$f_i = (1-\omega)(1+\bar{r}^l)\frac{(2+t_i)}{3t_i} - 1 - \frac{\omega(1-\sigma)}{3(1-\omega)}$$

$$f_j = (1-\omega)(1+\bar{r}^l)\frac{(1+2t_i)}{3t_i} - 1 + \frac{\omega(1-\sigma)}{3(1-\omega)}$$

Focusing on equation (6.10), the effect of a change in b is not univocal: there is direct effect through b, so that when b increases (the bank's position moves towards the left of the γ-line), the optimal yield of bank i decreases; and an indirect effect through x, so that when b increases (and x decreases), the optimal yield increases as well. Instead, the effect of a change in b on the optimal yield of bank j (equation (6.11)) is positive, both directly and both indirectly through x: if b increases, $r_j^{b,S*}$ does the same.

This behaviour reflects the competition dynamics between the two institutions, which, as shown by the pattern of $\frac{\partial \Delta r(x)}{\partial x}$, are not monotonous in x. When the distance between the two banks is at its maximum ($x = 1$), competition is at its peak: the banks have to compete over all the bond holders, since none of then has a turf of its own. Without loss of generality, let's assume bank j remains at $a = 0$, while bank i starts moving toward the left ($1 - b < 1$). As b increases, bank j increases its optimal yield, because the competitor is getting closer and can potentially attract bank j clients (since the moving cost depends on the distance of a client to a bank, if the latter gets closer, this cost decreases). Bank i, instead, will decrease the offered yield, because, even if it's getting closer to the other bank (so it should have an incentive to raise its yield), now it has a turf of clients, which it has to pay the promised yield. Therefore, as this turf increases (b increases), bank i will lower the optimal yield to contain its costs and $\Delta r(x)$ will increase (in absolute value). However, it will continue to do so until x reaches $\frac{1}{2} - a$ (in our example $\frac{1}{2}$). After this point, the incentive to contain its costs will be overcome by the competition pressure with the other bank, which will push bank i to raise its optimal yield (and $\Delta r(x)$ will start decreasing (in absolute value)), since, once both banks are in the same position, competition will be again at its peak.

The final question we can ask ourselves concerns the bond supply fractions in the subsidy game. We know that the subsidy allows the systemic bank to offer a lower bond yield than its competitor. Does this imply it gets a lower bond supply? In order to answer this question, we need to study the difference between the two optimal demand fractions as a function of x, as we did for the optimal yields. We can write:

$$\begin{aligned} &\left(1 - \bar{\gamma}^{S*}\right) - \bar{\gamma}^{S*} \equiv \Delta\gamma(x) \Rightarrow \\ &\Delta\gamma(x) = \frac{1}{3}\left(x + 2a - 1\right) + 2g \end{aligned} \tag{6.12}$$

where:

$$g = \frac{(1 - t_i)}{3t_i} s(1 - \omega)(1 + \bar{r}^l) + \tfrac{1}{3} sub > 0$$

$\Delta\gamma(x)$ is a line with positive slope, which takes the following values:

- $\Delta\gamma(0) = \frac{1}{3}(2a-1) + 2g$; however, $x = 0$ implies $a = b = \frac{1}{2}$, as given by assumption 2. in paragraph 3.2. Thus, $\Delta\gamma(0) = 2g > 0$.
- $\Delta\gamma(1) = \frac{1}{3}2a + 2g > 0$;

Since $\Delta\gamma(x) > 0$ always in the interval we consider, we can conclude that even though it offers a lower bond yield, bank i's bond supply is higher than bank j's one, $b_i^{*S} > b_j^{*S}$. The State subsidy gives the systemic bank an advantage in its competition with the non-systemic one.

7 Conclusions

The purpose of this paper was developing a theoretical model which could offer some insights on the effects of a systemic subsidy on the competition dynamics among banks. The interaction represented is a simplified one, a static duopoly game in the loans' market and in the bonds' one. Bond holders and their risk perception of the banks (where they place them on the γ-line) determine the intensity of the subsidy's effect (evidence 4). The latter affects banking competition in the following ways:

1. Both banks are more sensitive to changes in the loan market rate. For any given level of $\bar{r}^l$, not only the systemic bank, but also the non-systemic one, seeks profit more aggressively, by offering a higher bond yields than they would if no State aid were allowed.

2. The subsidy increases the offered bond yield for the non-systemic bank, compared to the one it would charge without the subsidy in place. The systemic bank, instead, has the option to set the yield according to the level of risk in the economy and the likelihood of actually being bailed-out.

3. The optimal bond yield charged by the bank with the subsidy is always smaller than the one charged by the bank without it.

4. Since the two banks are sufficiently differentiated in terms of risk profiles for the bond holders (i.e. a,b< $\frac{1}{2}$), bank i's bond supply is higher than bank j's one, $b_i^{*S} > b_j^{*S}$, even though it offers a lower bond yield. The State subsidy gives the systemic bank an advantage in its competition with the non-systemic one.

The first evidence highlights the distortion in the risk-taking behaviour of both banks, in particular, if for the TBTF bank there might be a situation of moral hazard, for the non systemic institution risk incentives are distorted for the simple reason of remaining in the market. The other results, instead, confirm the competitive advantage given by the subsidy to the systemic bank, which has control over the level of its costs (evidence 2), keeping them lower than the other bank's ones (evidence 3). Moreover, since bond holders perceive the two banks as different in terms of risk profile, giving a value to being systemic (the bank is seen as safer), the TBTF bank can have a higher bond supply than its competitor, despite offering a lower yield (evidence 4). This latter result reflects one of the main "strengths" of the TBTF status: there is no need for any authorities' commitment, as long as the markets believes an institution will be bailed out, they will give it "special treatment". As Stern and Feldman (2004) wrote:

"Indeed, creditors can develop expectations of government protection even when policymakers have in the past committed to no-bailout policies. The problem is that such pledges are not time consistent. ... policymakers discount or ignore long-term concerns and focus exclusively on the perceived short-term benefits of their actions... As a result they violate they earlier commitment... Creditors recognise that policymakers will encounter this same set of short-term benefits, costs and incentives each time a potential failure forces them to contemplate bailout."

For this reason, the introduction of bail-in systems alone is not enough to stop this perception effect. Governments need to be credible in their commitment towards not bailing out institutions anymore, without making exceptions. The latter condition, of course, requires an effective and efficient resolution system in place and one might argue that the one we have in Europe at the moment is not that. This is why it is important to keep studying and understanding the distortions of systemic institutions and use this knowledge to continue improving our current regulations. In particular, given the above results, we should probably give more consideration to adopting an antitrust approach in banking regulations, especially when dealing with systemic banks and not just during resolutions. We are moving towards a more concentrated banking sector, encouraging bank mergers which will create bigger players, likely to be systemic. While there are evident advantages to this choice, we should carefully consider whether they surpass the disadvantages and, more importantly, have in place the right frameworks to deal with the related issues. Now it's the time.

8 Appendix I - Partial Asymmetric case

In this scenario, there is no subsidy; nevertheless, the bond holders perceive the banks has having two different risk profiles, placing them in two different positions over the γ line. Without loss of generality, we assume bank i is towards the right end of the line, while bank j is towards the left end. As for the asymmetric case described before, the first thing to find is the position on the line of the indifferent bond holder, $\bar{\gamma}$; afterwards, the optimal reaction functions from the banks' maximisation problem are derived; finally, substituting the $\bar{\gamma}$ initially computed in these function, we find the equilibrium bond yields and optimal $\bar{\gamma}$.

Finding $\bar{\gamma}$

We solve the following equation:

$$E[W_i] = E[W_j]$$

$$(1-\omega)\left\{r_i^b - m\left[\gamma - (1-b)\right]^2\right\} + \omega\left\{(-1 - m\left[\gamma - (1-b)\right]^2)\right\} =$$

$$(1-\omega)\left[r_j^b - m(\gamma - a)^2\right] + \omega\left[-1 - m(\gamma - a)^2\right] \Rightarrow$$

$$\bar{\gamma} = a + \tfrac{(1-a-b)}{2} + \tfrac{(1-\omega)}{2m(1-a-b)}(r_j^b - r_i^b) = h_a + s(r_j^b - r_i^b)$$

$$1 - \bar{\gamma} = a + \tfrac{(1-a-b)}{2} + \tfrac{(1-\omega)}{2m(1-a-b)}(r_i^b - r_j^b) = h_a + s(r_j^b - r_i^b)$$

Where:

$$h_a = a + \tfrac{(1-a-b)}{2}$$

$$s = \tfrac{(1-\omega)}{2m(1-a-b)}$$

The banks' maximisation problem

$$\text{Bank } i\text{:} \max_{r_i^b} (1-\omega)\left[(1-\bar{\gamma})B(1+\bar{r}^l) - (1-\bar{\gamma})B(1+r_i^b)\right] +$$

$$+\omega\left\{\left[-(1-\bar{\gamma})B(1+r_i^b)\right]\right\} \Rightarrow$$

$$\max_{r_i^b} (1-\omega)(1-\bar{\gamma})B(1+\bar{r}^l) - (1-\bar{\gamma})B(1+r_i^b)$$

$$\text{Bank } j\text{:} \max_{r_j^b} (1-\omega)\left[\bar{\gamma}B(1+\bar{r}^l) - \bar{\gamma}B(1+r_j^b)\right] + \omega\left[-\bar{\gamma}B(1+r_j^b)\right] \Rightarrow$$

$$\max_{r_j^b} (1-\omega)\bar{\gamma}B(1+\bar{r}^l) - \bar{\gamma}B(1+r_j^b)$$

Reaction functions and optimal yields

$$\begin{cases} r_i^b = \dfrac{1}{2}r_j^b + \dfrac{(1-\omega)(1+\bar{r}^l)}{2} - \dfrac{(s+h_b)}{2s} \\ \\ r_j^b = \dfrac{1}{2}r_i^b + \dfrac{(1-\omega)(1+\bar{r}^l)}{2} - \dfrac{(s+h_a)}{2s} \end{cases}$$

$$\begin{cases} r_i^{b*} = (1-\omega)(1+\bar{r}^l) - 1 - \dfrac{(2h_b+h_a)}{3s} \\ \\ r_j^{b*} = (1-\omega)(1+\bar{r}^l) - 1 - \dfrac{(2h_a+h_b)}{3s} \end{cases}$$

Optimal $\bar{\gamma}$

$$r_i^{b*} - r_j^{b,*} = \tfrac{1}{3s}(a-b)$$

$$\bar{\gamma}^* = \tfrac{1}{2} + \tfrac{a-b}{6}$$

$$1 - \bar{\gamma}^* = \tfrac{1}{2} + \tfrac{b-a}{6}$$

9 References

Acharya, V. V., Anginer, D., and Warburton, A. J. (2016). The end of market discipline? investor expectations of implicit government guarantees.

Allen, F., Carletti, E., Goldstein, I., et al. (2017). Government guarantees and financial stability.

Arnoud, B., Thakor, A. V., and Udell, G. F. (1987). Competition, risk neutrality and loan commitments. *Journal of Banking and Finance*, 11:449–471.

Balasubramnian, B. and Cyree, K. B. (2011). Market discipline of banks: Why are yield spreads on bank-issued subordinated notes and debentures not sensitive to bank risks? *Journal of Banking & Finance*, 35(1):21–35.

Barros, P. P. (1999). Multimarket competition in banking, with an example from the portuguese market. *International Journal of Industrial Organization*, 17(3):335–352.

Benoit, J.-P. and Krishna, V. (1987). Dynamic duopoly: Prices and quantities. *The review of economic studies*, 54(1):23–35.

Benston, G. J., Hunter, W. C., and Wall, L. D. (1995). Motivations for bank mergers and acquisitions: Enhancing the deposit insurance put option versus earnings diversification. *Journal of money, credit and banking*, 27(3):777–788.

Berger, A. N. and Hannan, T. H. (1989). The price-concentration relationship in banking. *The Review of Economics and Statistics*, pages 291–299.

Bertsch, C., Calcagno, C., and Le Quement, M. (2015). Systematic bailout guarantees and tacit coordination. *The BE Journal of Economic Analysis & Policy*, 15(1):1–36.

Besanko, D. and Thakor, A. (1993). Relationship banking. *Deposit Insurance and Bank Portfolio.*

Besley, T. and Seabright, P. (1999). The effects and policy implications of state aids to industry: an economic analysis. *Economic policy*, 14(28):14–53.

Black, L., Correa, R., Huang, X., and Zhou, H. (2016). The systemic risk of european banks during the financial and sovereign debt crises. *Journal of Banking & Finance*, 63:107–125.

Block, C. D. (2012). A continuum approach to systemic risk and too-big-to-fail. *Brooklyn Journal of Corporate, Financial & Commercial Law*, 6(2):1.

Bonaldi, P., Hortaçsu, A., and Kastl, J. (2015). An empirical analysis of funding costs spillovers in the euro-zone with application to systemic risk. Technical report, National Bureau of Economic Research.

Boyd, J. H. and De Nicolo, G. (2005). The theory of bank risk taking and competition revisited. *The Journal of finance*, 60(3):1329–1343.

Brewer, E. and Jagtiani, J. (2013). How much did banks pay to become too-big-to-fail and to become systemically important? *Journal of Financial Services Research*, 43(1):1–35.

Brown, C. O. and Dinç, I. S. (2011). Too many to fail? evidence of regulatory forbearance when the banking sector is weak. *The Review of Financial Studies*, 24(4):1378–1405.

Burda, M. C. and Dluhosch, B. (2002). Cost competition, fragmentation, and globalization. *Review of International Economics*, 10(3):424–441.

Collie, D. R. (2000). State aid in the european union: the prohibition of subsidies in an integrated market. *International Journal of Industrial Organization*, 18(6):867–884.

Cunnigham, L. A. (2006). Too big to fail: moral hazard in auditing and the need to restructure the industry before it unravels. *Colum. L. Rev.*, 106:1698.

Dann, L. Y. and James, C. M. (1982). An analysis of the impact of deposit rate ceilings on the market values of thrift institutions. *The Journal of Finance*, 37(5):1259–1275.

Degryse, H. and Ongena, S. (2005). Distance, lending relationships, and competition. *The Journal of Finance*, 60(1):231–266.

Degryse, H. and Ongena, S. (2008). Competition and regulation in the banking sector: A review of the empirical evidence on the sources of bank rents. *Handbook of financial intermediation and banking*, 2008:483–554.

Demirgüç-Kunt, A. and Detragiache, E. (2002). Does deposit insurance increase banking system stability? an empirical investigation. *Journal of monetary economics*, 49(7):1373–1406.

Demirgüç-Kunt, A. and Huizinga, H. (2013). Are banks too big to fail or too big to save? international evidence from equity prices and cds spreads. *Journal of Banking & Finance*, 37(3):875–894.

Demirguc-Kunt, A., Laeven, L., and Levine, R. (2003). Regulations, market structure, institutions, and the cost of financial intermediation. Technical report, National Bureau of Economic Research.

Deneckere, R. J. and Kovenock, D. (1996). Bertrand-edgeworth duopoly with unit cost asymmetry. *Economic Theory*, 8(1):1–25.

Diamond, D. W. and Dybvig, P. H. (1983). Bank runs, deposit insurance, and liquidity. *Journal of political economy*, 91(3):401–419.

Flannery, M. J. and Sorescu, S. M. (1996). Evidence of bank market discipline in subordinated debenture yields: 1983–1991. *The Journal of Finance*, 51(4):1347–1377.

Foster, S. E. (2010). Too big to fail-too small to compete: Systemic risk should be addressed through antitrust law but such a solution will only work if it is applied on an international basis. *Fla. J. Int'l L.*, 22:31.

Freixas, X. and Rochet, J.-C. (2008). *Microeconomics of banking*. MIT press.

Goldstein, I. and Pauzner, A. (2005). Demand–deposit contracts and the probability of bank runs. *the Journal of Finance*, 60(3):1293–1327.

Hellmann, T. F., Murdock, K. C., and Stiglitz, J. E. (2000). Liberalization, moral hazard in banking, and prudential regulation: Are capital requirements enough? *American economic review*, 90(1):147–165.

Hotelling, H. (1929). Stability in competition. *EconomicJournal*, (39):41–57.

Huang, X., Zhou, H., and Zhu, H. (2012). Assessing the systemic risk of a heterogeneous portfolio of banks during the recent financial crisis. *Journal of Financial Stability*, 8(3):193–205.

Hughes, J. P. and Mester, L. J. (1993). A quality and risk-adjusted cost function for banks: Evidence on the "too-big-to-fail" doctrine. *Journal of productivity analysis*, 4(3):293–315.

Hughes, J. P. and Mester, L. J. (2013). Who said large banks don't experience scale economies? evidence from a risk-return-driven cost function. *Journal of Financial Intermediation*, 22(4):559–585.

Hull, J., Predescu, M., and White, A. (2004). The relationship between credit default swap spreads, bond yields, and credit rating announcements. *Journal of Banking & Finance*, 28(11):2789–2811.

Jacklin, C. J. and Bhattacharya, S. (1988). Distinguishing panics and information-based bank runs: Welfare and policy implications. *Journal of Political Economy*, 96(3):568–592.

James, C. (1977). A theory of risk-averse bank behaviour.

James, C. (1983). An analysis of intra-industry differences in the effect of regulation: The case of deposit rate ceilings. *Journal of Monetary Economics*, 12(3):417–432.

Jiménez, G., Lopez, J. A., and Saurina, J. (2013). How does competition affect bank risk-taking? *Journal of Financial stability*, 9(2):185–195.

Keeley, M. C. (1990). Deposit insurance, risk, and market power in banking. *The American economic review*, pages 1183–1200.

Kleinow, J., Nell, T., Rogler, S., and Horsch, A. (2014). The value of being systemically important: event study on regulatory announcements for banks. *Applied Financial Economics*, 24(24):1585–1604.

Kloeck, A. (2014). Implicit subsidies in the eu banking sector. *An Intermediary Report which is Part of the Forthcoming Study:"Banking Structural Reforms: A Green Perspective", Study commissioned by the Greens/EFA group in the European parliament.*

Koehn, M. and Santomero, A. M. (1980). Regulation of bank capital and portfolio risk. *The journal of finance*, 35(5):1235–1244.

Martinez-Miera, D. and Repullo, R. (2010). Does competition reduce the risk of bank failure? *The Review of Financial Studies*, 23(10):3638–3664.

Martinez Peria, M. S. and Schmukler, S. L. (2001). Do depositors punish banks for bad behavior? market discipline, deposit insurance, and banking crises. *The journal of finance*, 56(3):1029–1051.

Morgan, D. P. and Stiroh, K. J. (2005). Too big to fail after all these years.

Neven, D. (1985). Two stage (perfect) equilibrium in hotelling's model. *The Journal of Industrial Economics*, pages 317–325.

Nieto Parra, S. (2005). The macroeconomic implications of the new banking capital regulation in emerging markets: A duopoly model adapted to risk-averse banks.

Nishiyama, Y. (2007). Are banks risk-averse? *Eastern Economic Journal*, 33(4):471–490.

Northcott, C. A. et al. (2004). *Competition in banking: A review of the literature*. Bank of Canada Working Paper.

O'hara, M. and Shaw, W. (1990). Deposit insurance and wealth effects: the value of being "too big to fail". *The Journal of Finance*, 45(5):1587–1600.

Osborne, M. J. and Pitchik, C. (1987). Equilibrium in hotelling's model of spatial competition. *Econometrica: Journal of the Econometric Society*, pages 911–922.

Penas, M. F. and Unal, H. (2004). Gains in bank mergers: Evidence from the bond markets. *Journal of Financial Economics*, 74(1):149–179.

Petersen, M. A. and Rajan, R. G. (1995). The effect of credit market competition on lending relationships. *The Quarterly Journal of Economics*, 110(2):407–443.

Postlewaite, A. and Vives, X. (1987). Bank runs as an equilibrium phenomenon. *Journal of political Economy*, 95(3):485–491.

Ratnovski, L. (2013). *Competition policy for modern banks*. Number 13-126. International Monetary Fund.

Rime, B. (2005). Do too-big-to-fail expectations boost large banks issuer ratings. *Swiss National Banks, Systemic Stability Section: Working Paper (May 9).*

Russell, E. (2009). The case for constructive ambiguity in a regulated system: Canadian banks and the'too big to fail'problem.

Santomero, A. M. (1984). Modeling the banking firm: A survey. *Journal of money, credit and banking*, 16(4):576–602.

Santos, J. A. (2014). Evidence from the bond market on banks"too-big-to-fail'subsidy.

Sironi, A. (2003). Testing for market discipline in the european banking industry: evidence from subordinated debt issues. *Journal of Money, Credit and Banking*, pages 443–472.

Stahl, D. O. (1988). Bertrand competition for inputs and walrasian outcomes. *The American Economic Review*, pages 189–201.

Stern, G. H. and Feldman, R. J. (2004). *Too big to fail: The hazards of bank bailouts.* Brookings Institution Press.

Ueda, K. and Di Mauro, B. W. (2013). Quantifying structural subsidy values for systemically important financial institutions. *Journal of Banking & Finance*, 37(10):3830–3842.

Unal, H. (1989). Impact of deposit-rate ceiling changes on bank stock returns. *Journal of Money, Credit and Banking*, 21(2):206–220.

VanHoose, D. (2007). Theories of bank behavior under capital regulation. *Journal of Banking & Finance*, 31(12):3680–3697.

White, L. J. (2014). Antitrust and the financial sector-with special attention to'too big to fail'.

Zardkoohi, A., Kang, E., Fraser, D., and Cannella, A. A. (2018). Managerial risk-taking behavior: A too-big-to-fail story. *Journal of Business Ethics*, 149(1):221–233.

Zhou, C. (2009). Are banks too big to fail? measuring systemic importance of financial institutions.

II Response Time under Gains and Losses

with S. Angino

Abstract

Response time is a cheap proxy for the cognitive effort exerted by individuals in order to reach a decision. In this paper we analyse whether the domain of choice affects response times. We find that, in both individual and social contexts, subjects are around 25% faster under gains than under losses. The result is surprisingly stable across different tasks and the context of choice (i.e., whether the decision affects another person besides oneself).

Keywords: Loss, risk attitude, social preferences.

1 Introduction

Most experiments conducted in behavioural economics restrict themselves to analyse people's choices and how they vary according to circumstances. However, for no cost, researchers can keep track of another variable linked to the decisional process of individuals: response time.

Response time is a cheap[10] proxy for the cognitive effort exerted by individuals in order to reach a decision (Rubinstein, 2007). It contains information which the mere choice - e.g. how much to contribute in a dictator game, which of two alternatives is selected, etc. – does not. For example, choice outcomes are often discrete, while response times are continuous. As such, they can shed additional light on the underlying preferences of the decision maker, which is the ultimate goal of many microeconomics fields. As Spiliopoulos and Ortmann (2018) put it, response time analysis "*holds considerable potential for experimental economics, deserves greater attention as a methodological tool, and promises important insights on strategic decision making in naturally occurring*".

However, to the best of our knowledge, the impact of the domain in which the decision problem is framed on response times has not yet been investigated thoroughly. Prospect theory sees individuals' choices possibly changing across domain, and there is plenty of evidence backing this prediction, but there appears to be no research yet on response times under gains and losses. This paper attempts to close such gap.

The main question we try to answer is: which domain demands a higher cognitive effort, and how large is the difference?

[10] In other fields, functional magnetic resonance imaging (fMRI) is often used to monitor brain activity during subjects' decision-making process. However, this is an expensive type of research.

We expect decisions in the domain of losses to require higher cognitive effort. The argument works as follows: according to prospect theory, the disutility associated to a loss is greater than the utility attached to a gain of equal size. Also, decisions involving larger stakes (and thus higher levels of utility) require more cognitive effort than decisions involving smaller stakes (Moffatt (2005)). Hence, when facing stakes of the same size in the two different domains, given that in absolute terms the utility of the loss is higher than the utility of the gain, we expect to see a faster response in the domain of gains.

We reanalyse data from the experiment described in Angino (2017), which presents the "loss after earned endowment" methodology as a way to effectively implement losses in a laboratory environment: subjects assigned to the loss treatment earn their endowment after the completion of a simple task that is meant to be perceived as useful for the experimenter. In this way, subjects feel rightfully endowed to their compensation and will not consider it as manna from heaven during the main phase of the experiment.

We find that decisions taken under losses require a significantly higher amount of time with respect to those made under gains. For dictator games the difference is around 19%, while for binary decisions it goes up to 28%. Also, we find that, the more the subjects are risk-seeking, the longer they think before taking a decision.

Section 2 reviews the literature on cognitive effort and response times. Section 3 describes the experiment in detail. Section 4 introduces the determinants of response times, with the main focus on the domain of choice. Section 5 discusses main findings and concludes.

2 Literature Review

First of all, we need to clarify the difference between "response time" and "decision time". The former is the amount of time between the moment the screen with the alternatives is shown to the participant and the moment in which he or she actually inputs the choice in the system (usually by clicking a button). The decision elapses from the moment the individual start sampling information from the scenario at stake to the moment in which he or she "mentally" reaches a decision (Stone, 1960(?)). As such, decision time is a component of response time.

The economic literature does not usually distinguish between the two, as the actual difference is often negligible for its purposes. It is relevant in other fields instead, for example in neuroscience. In the following, we will therefore use only the term "response time", in line with most of economics literature.

Research on response time, as a way to better understand human preferences, probably starts in 1868, with Dutch ophthalmologist Franciscus Cornelis Donders (Sternberg (1969)). Set aside the psychological literature, there are two ways response time enters behavioural economics.

One strand of research analyses the effect of constraining response time on choices: in these experiments, the time available to take a decision is reduced, or delayed, or a minimum threshold of seconds is imposed before the subject can implement the decision. These experiments, which are usually referred to as exogenous time experiments, are especially interesting to study the impact of emotions on decision making. For example, to cope with time pressure, subjects are found to rely more on heuristics.

The second strand of literature deals with endogenous time. In this setting, subjects are free to devote the amount of time they prefer to each task or decision. This freedom is exploited to gather additional information about the decision maker's cognitive process or preferences, explain the determinants of the effort applied to a task and, in some cases, try to find connections between response times and choices.

Moffatt (2005)frames the interest for cognitive effort in terms of the "capital-labour-production" model. In this view, capital is the knowledge and expertise subjects brings into the laboratory, and is assumed to be constant over the course of the experiment. Labour is the cognitive effort subjects *decide to* allocate to the task, and is seen as fully adjustable depending on the incentives at work. The output of capital and labour is the subjects' performance in the task.

In line with this model, Chabris et al. (2009) focus on inter-temporal choices and find that response time increases with the similarity in the expected value of the binary choices. The differences in discounted value is found to account for 54.1% of the variance of the average response time. Similarly, in Moffatt (2005) and Konovalov and Krajbich (2017b), subjects make slower decision as they approach indifference. Intuitively, when decisions largely differ in value, and one dominates (not in a game-theory sense) the other, the choice will be made in a short time relative to a scenario in which the two alternatives are similar.

Some works classify decision-makers into types according to their response times (instinctive versus deliberative, for example), as it is found that such classifications can me more effective in predicting people's choices than those based on, say, risk aversion (Rubinstein (2016)).

Research in response times intersects the one on social preferences, in the attempt to find out whether human beings are instinctively fair or selfish. Piovesan and Wengström (2009) find that selfish decisions are linked to faster responses, as such choices "rationally" require to consider only one's own payoff and pick the option with the highest utility. Opposite results have also emerged [11], but differences in experimental design and methodology could explain this divergence[12]. For an extensive review of response time analysis, including the one encompassing social preferences, we refer to Spiliopoulos and Ortmann (2018).

How does the loss domain enter in this literature? In order to find mention of the loss domain we have to look beyond the fence, into exogenous time experiments. Kocher et al. (2013) studied the effect of time pressure on risk attitudes, finding that risk seeking in the loss domain turns into risk aversion, while risk aversion in gain prospects stays unchanged.

[11] Rubinstein (2007)and Rand et al. (2012) for strategic situations found that altruism and cooperation manifest in a fast, instinctive response.

[12] Tinghög et al. (2013)

The reason why response time experiments in the loss domain are scarce, to say the least, possibly lies in the difficulty to implement losses in a laboratory environment in a convincing way. Simply providing subjects with money without a proper reason may lead them to consider their endowment as house money; consequently, the recorded choices and response times would not be those the experimenter is interested in. Next section explains the methodology beyond the implementation of losses. With such basis, we are going to analyse the differences in endogenous response time for decisions in gain and loss prospects.

3 Experiment

We analyse data from the experiment already examined in Angino (2017). We include below an extensive description of the experiment. For further information, please refer to the above-mentioned paper.

The experiment was held in CESARE lab at LUISS Guido Carli university. The sample consists of 101 students with a background in economics, political science and law. Instruction were provided in Italian to minimise misunderstanding due to language, and on paper sheets. Instructions were read aloud and questions were answered privately. The experiment was programmed and conducted in Z-Tree (Fischbacher (2007)).

To identify the effect of the domain on risk attitudes, a between-subject design was used: each participant was assigned either to the gain or to the loss treatment.

Data were collected using the "loss after endowment" method: in the loss treatment, subjects were first asked to complete a task. In particular, they had to fill up a dataset with answers to an unrelated survey, previously completed by other students. Subjects were informed that such data were to be used in other independent studies, so it was important to insert answers carefully. Only the ID of the responder and her answers (in letters from A to E) appeared on the answer sheets, in order to avoid any influence on subsequent choices. The task was designed in a way to enhance the endowment effect: it was meant to be perceived as useful and, at the same time, it had to be within everyone's mean in order to keep the number of subjects constant during the experiment[13].

At the completion of the task, each subject knew that she had earned 20 euro[14]. From this point on, subjects in the gain and in the loss treatment faced the same kind of choices, only framed in different domains. Participants in the gain (loss) treatment received the first (second) set of instructions with information about the payment system, then started the "real" experiment.
The tasks are explained in the next two subsections. For payment purposes, one period was randomly selected for everyone and the corresponding scenarios were considered, as described in more detail below.

[13] The examination of inserted answers reveals that subjects were performing the task with care, making only a plausible number of mistakes.

[14] Due to the laboratory's policy, it was not possible to materially deliver the money before the end of the experiment.

After all subjects had completed the tasks, they were shown the amount earned in the experiment and were asked to complete a questionnaire with socio-demographic information and perceived clarity of the instructions. Finally, they were paid in private and allowed to leave. The sample includes 51 subjects in the gain treatment and 50 in the loss one.

3.1 Binary choices

The games that the subjects face in the experiment are of two types: binary choices and dictator games. It is important, at this point, to start establishing the terminology. We use the term *domain* to refer to the way the choice is framed, i.e., in terms of gains and losses. We use the term *context* to distinguish between decisions that do and do not involve other subjects' payoffs. Indeed, subjects face binary choices in the *social* and in the *individual* context, respectively. Dictator games, of course, will only be played in a social context.

The structure of the experiment goes as follows: first, subjects face a set of binary choices in the social context, then they deal with two dictator games, finally they face again binary choices, in an individual context this time.

In spite of the order in the experiment, we start by describing binary choices in isolation.

3.1.1 Individual context

Participants face 13 scenarios in which neither the subject's payoff is affected by other participants' decisions, nor the subject's decision impacts other's payoffs.

A *scenario* is made up two alternatives, a sure amount on the one side, a lottery on the other. Subjects must decide between them. The prizes of the lottery are always 20 and 0 euro under gains, -20 and 0 euro under losses. The sure amount and the probability of winning the lottery - hence the expected value associated with it - change in each scenario and are the parameters that identify them. Indeed, scenarios can be described using the pair $(D\, vs\, EV)$: (D)eterministic outcome versus (E)xpected (V)alue of the lottery *after the initial endowment has been taken into account.* This means that, in the domain of losses, the 20 euro gained by completing the task must be added to each outcome. Doing so eases comparison between domains.

Scenarios that follow the same structure in the definition of the alternatives are grouped for ease of discussion in *scenario types.* The first scenario type is summarised in 3.1.1 figure below.

Figure 3.1.1: 10 vs EV scenario

GAIN

$$10 \text{ vs } \begin{array}{l} \xrightarrow{p} 20 \\ \xrightarrow[1-p]{} 0 \end{array}$$

LOSS

$$-10 \text{ vs } \begin{array}{l} \xrightarrow{p} 0 \\ \xrightarrow[1-p]{} -20 \end{array}$$

In this type of scenario, the deterministic amount to be compared with the lottery is always 10 euro - or minus 10 euro, under losses -, while the probability to win the lottery assumes one value in the possible set, from 20% to 80% in 10% increments.

As you can see in the figure above, in both domains p is assigned to the highest outcome: 20 euro under gains, 0 under losses. After we take into account the initial endowment of 20 euro for decisions in the domain of losses, we can describe this type of scenario under both domains as $(10\, vs\, EV)$, where the expected value of the lottery ranges from 4 to 16.

Let's clarify this further with an example. Take the pair (10 vs 4): it describes two scenarios:

- Under gains, a choice between 10 euro and a lottery with a 20% probability to win 20 euro, which has an expected value equal to 4.
- Under losses, a choice between a loss of 10 euro (which, given the initial endowment, leaves the subject with 20-10=10 euro) and a lottery with a 20% probability to lose nothing, hence to bring home the initial endowment untouched. This lottery has again an expected value equal to 4.

Figure 3.1.2 below illustrates this example. In the parenthesis we have the amount the subject gets under each alternative after the initial endowment is considered. It is easy to see that the scenarios are equivalent.

Figure 3.1.2: 10 vs EV scenario - an example

GAIN

$$10\ (10) \text{ vs } \begin{array}{l} \xrightarrow{0.2} 20\ (10) \\ \xrightarrow[0.8]{} 0\ (0) \end{array}$$

LOSS

$$-10\ (10) \text{ vs } \begin{array}{l} \xrightarrow{0.2} 20\ (10) \\ \xrightarrow[0.8]{} 0\ (0) \end{array}$$

The second type of scenario is summarised by $(D\, vs\, 10)$, as shown in Figure 3.1.3. Thus, the expected value of the lottery is fixed at 10, being the probability to win always 50%, while the deterministic amount ranges from 4 to 16 in 2 euro increments.

Figure 3.1.3: D vs 10 scenario

GAIN

$$20p \text{ vs } \begin{array}{l} \xrightarrow{0.5} 20 \\ \xrightarrow[0.5]{} 0 \end{array}$$

LOSS

$$-20(1-p) \text{ vs } \begin{array}{l} \xrightarrow{0.5} 0 \\ \xrightarrow[0.5]{} -20 \end{array}$$

The intersection of the two types is scenario ($10\,vs\,10$). We will consider this as a special case.

If either of these scenarios are selected for payment, every subjects see his or her decision implemented:

- If, in the scenario that has been selected, the subject has chosen the deterministic allocation, this is what he or she gets.

- If the subject has chosen the lottery, a random drawn with the relevant parameters decides the outcome[15].

3.1.2 Social context

As anticipated, the 13 scenarios described above are also played in social context. In each period, the subjects are paired with a different anonymous participant. Again, we have two types of scenarios (with a bit of overlapping for the ($10\,vs\,10$) scenario). In the figures below, the second number in the parenthesis refers to the payoff of the second subject.

In scenarios of type ($10\,vs\,EV$), the deterministic allocation is fair: both subjects receive or pay the same share. The lottery instead results into maximum inequality, as ultimately one wins and the other loses. Probabilities to win differ across scenarios, hence so do the expected values of the lottery. Except for the 50-50 scenario, expected payoffs are thus unequal for the two subjects.

Figure 3.1.4: 10 vs EV scenario

GAIN

$$(10,10) \text{ vs } \begin{array}{l} \xrightarrow{p} (20,0) \\ \xrightarrow[1-p]{} (0,20) \end{array}$$

LOSS

$$(-10,-10) \text{ vs } \begin{array}{l} \xrightarrow{p} (0,-20) \\ \xrightarrow[1-p]{} (-20,0) \end{array}$$

[15]For example, assume the subject selects a lottery in which he or she wins with 60% probability. The computer extracts a number from 0 to 100; if the number is below 60, the subjects wins.

In scenarios of type ($D\,vs\,10$), the chances to win the lottery are the same for the two subjects, but the deterministic allocation is not.

Figure 3.1.5: D vs 10 scenario

GAIN	LOSS
$(20p,20(1-p))$ vs $\xrightarrow{0.5}$ (20,0) / $\xrightarrow[0.5]{}$ (0,20)	$(-20(1-p),-20p)$ vs $\xrightarrow{0.5}$ (0,-20) / $\xrightarrow[0.5]{}$ (-20,0)

Differently from the order in which we presented the two types of scenarios, subjects first face choices in social context, then in the individual one. We have a total of 26 choices for each individual.

If a social context scenario is selected for payment, a random draw with equal probabilities determines which player is the decision maker, that is, the one who will see his or her own her decision implemented:

- If the decision maker has chosen the deterministic allocation, each subject receives the relative amount.
- If the decision maker has preferred the risky alternative, a random drawn with the relevant probabilities decides the outcome.

3.2 Dictator games

Subjects play two types of dictator games. One is the traditional, deterministic version, in which the decision maker has to share a given amount between oneself and the anonymous subjects he or she is paired with. In the gain domain this amount is equal to 20 euro. In the loss domain, the "amount" is in reality a loss of 20 euro: if the decision maker allocates, say, -14 euro to the other subject, the latter will have to give away 14 euro in case this scenario is selected for payment, and the decision maker pays the remaining 6 euro.

We call this game "Deterministic Dictator Game" (DDG). If the DDG is selected for payment, a random draw with equal probabilities would select the decision maker, the one whose decision is implemented.

The second version we use was proposed first by Krawczyk and Le Lec (2010). In this case, the decision maker must allocate chances rather than deterministic quantities. In particular, in the gain domain, subjects decide how to share the probability to win 20 euro, with such probability being represented by a number of tokens from 0 to 100. Giving the other 10 tokens, for example, means giving him or her 10% probability to win 20 euro and keeping the remaining 90% for oneself.

Similarly, in the loss domain, the decision maker allocates chances to lose 20 euro and end up with nothing.

This version is called "Probabilistic Dictator Game" (PDG). If the PDG is selected for payments, a first random draw with equal probabilities select the decision maker. A second draw, with parameters given by the decision maker's choice, decides who wins and who loses.

The DDG is used to analyse subjects' preferences for outcome-based fairness, while the PDG looks instead at at procedural fairness. Machina (1989) offers a simple and compelling example of the importance of procedural fairness beyond simple outcome allocation: a mother wants to assign a non-divisible treat (say, a ticket) to one of her two kids. She is indifferent as to which child gets the ticket, but she strictly prefers to assign it based on a random coin flip rather than choosing one of the two kids. Anyone can recognise this as a fair procedure, as both kids get the same chance to win; yet, the final outcome will not be fair as only one kid gets the ticket.

As for binary choices, we report all amounts and probabilities in terms of final outcomes for ease of comparison. Again, the main changes concern losses. For example, a decision maker deciding to pay 6 euro out of 20 is reported as having decided to keep 14 euro. Similarly, a decision makers which keeps a 10% probability to lose 20 euro is reported as having kept 90% probability to win 20 euro, for an expected amount of 18 euro.

4 Results

In this section, we present the analysis of response times, with a particular emphasis on the role of the domain.

4.1 Results for binary choices

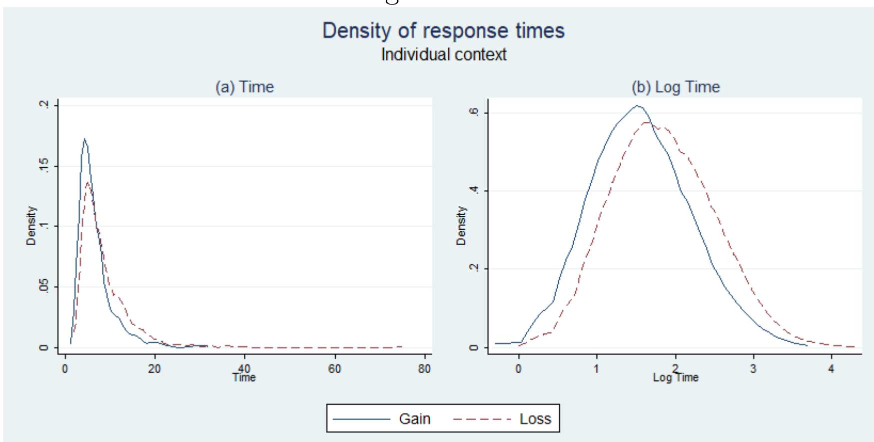
4.1.1 Individual context

In isolation, the average response time is 6.7 seconds under gains and 8.6 under losses. A simple t-test rejects the null hypothesis that they are equal at virtually any level of significance.

Figure 4.1.1(a), which shows the kernel density estimates of response times for the two domains, also points in the direction of a difference between them. The dashed line, representing the density under losses, is on the right compared to the solid line, representing the gain domain.

Figure 4.1.1(a) also makes evident that there are outliers, in forms of very slow decisions, in both domains. To moderate the effect of such observations, we also plot the densities of the logarithm of decision times. In Figure 4.1.1(b), we can see even more clearly that the distribution of decision times under losses is distinctly shifted towards the right.

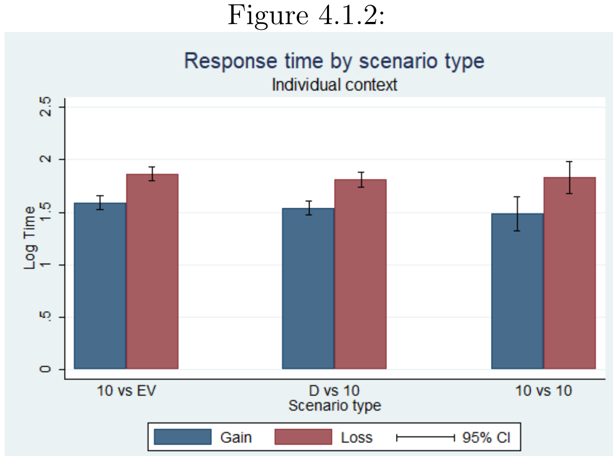
Figure 4.1.1:



Column (a) of Table 4.1.1 reports the result of a random-effect regression of the logarithm of response time on a dummy variable indicating the domain in which the choice was framed. This confirms the presence of a significant different across domains. Decisions framed in terms of gains are 27.7% faster than those framed in terms of losses.

As explained previously, subjects face two types of scenarios - which make three if we consider the (10 vs 10) one separately. It could be that our results are driven only by one type of scenario. Figure 4.1.2 suggests than this is not the case, and Column (b) of Table 4.1.1 confirms this econometrically. We include in the previous model two dummies, one for the (D vs 10) and one for the (10 vs 10) type of scenario, the baseline being the (10 vs EV) one. In each type of scenario, the difference in response times between domains has roughly the same size. Also, the type of scenario does not impact the average response time under gains.

Figure 4.1.2:



The domain of choice, of course, is not the only factor that affects cognitive effort. Consider

Figure 4.1.3, where we plot the evolution of the average of log response times for both domains. The graph shows that subjects gain experience as the experiment proceeds: there is a pronounced decrease in response times after the first few periods, followed by a somewhat stable level throughout the remaining ones. Intuitively, as subjects get familiar with the format of the task, they need less time to make their choice. Column (c) of Table 4.1.1, which includes the number of scenarios faced up to that moment, shows that response times decrease by approximately 2.6% at every period.

Figure 4.1.3:

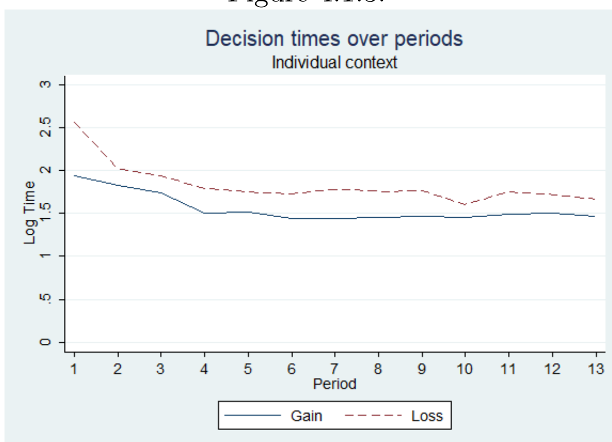


Figure 4.1.3 also shows that the difference between response times under gains and under losses remains present for the whole duration of the game. In the first few periods the difference is large: the format of the task under losses appears particularly hard to digest at first sight, but the learning curve of the subjects is steep and the response time gap between the two domain stabilises afterwards. Column (d) of Table 4.1.1 shows that the interaction between the number of scenarios faced and the loss domain is not statistically significant: subjects deciding under gains and losses experience a similar decrease in response times as they face more and more scenarios. Also, the results of the regression tell us that, at the very beginning of the experiment, choices under loss require between 35 and 43% longer than those under gain depending on the type of scenario.

Table 4.1.1 - Results, individual context				
	(a)	(b)	(c)	(d)
Loss	0.277***	0.275***	0.272***	0.350***
	(0.000)	(0.000)	(0.000)	(0.000)
(D vs 10)		-0.0472	-0.0385	-0.0400
		(0.226)	(0.317)	(0.296)
(10 vs 10)		-0.104	-0.0970	-0.0982
		(0.205)	(0.240)	(0.231)
Loss × (D vs 10)		-0.00805	-0.00310	0.000870
		(0.889)	(0.955)	(0.987)
Loss × (10 vs 10)		0.0699	0.0790	0.0830
		(0.520)	(0.467)	(0.445)
Period-1			-0.0377***	-0.0311***
			(0.000)	(0.000)
Loss × (Period-1)				-0.0133
				(0.090)
Constant	1.558***	1.588***	1.810***	1.771***
	(0.000)	(0.000)	(0.000)	(0.000)
Observations	1313	1313	1313	1313

p-values in parentheses

Random-effect, clustered standard errors.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In line with Moffatt (2005), we also add to the model the difference in the utility of the two alternatives, subjective difference. Intuitively, when alternatives are close in terms of utility, in order to refine one's own valuation, the subject must think longer.

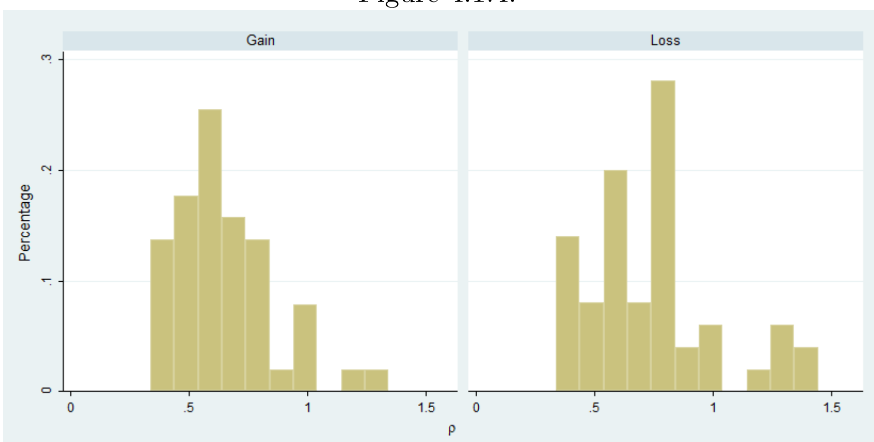
In order include this variable in the model, we first need to assume a functional form for the utility. We chose a simple CRRA function:

$$u_i(x) = x^{\rho_i}$$

with $\rho_i > 0$. Then we estimate the parameter ρ for each of the 101 individuals based on their 13 decisions.

The distribution of the parameter for both domains is plotted in Figure 4.1.4. The vast majority of individuals in both domains are risk averse, with $\rho < 1$. Only 4% of subjects (2 out of 51) in the gain treatment are risk seeking, while this number increases to 12% (6 out of 50) for the loss treatment. Also, we find that the average ρ is 0.64 for individuals playing with gains and 0.73 for those playing with losses; a t-test confirms that the average parameter under losses is higher than the one under gains ($p - value = 0.039$). This result in line with previous evidence that individuals tend to risk more when the choice is framed in terms of losses.

Figure 4.1.4:



The vast majority of individuals in both domains are risk averse, with $\rho < 1$. Only 4% of subjects (2 out of 51) in the gain treatment are risk seeking, while this number increases to 12% (6 out of 50) for the loss treatment. Also, we find that the average ρ is 0.64 for individuals playing with gains and 0.73 for those playing with losses; a t-test confirms that the average parameter under losses is higher than the one under gains ($p - value = 0.039$). This finding in line with previous evidence that individuals tend to risk more when the choice is framed in terms of losses.

Using our estimates $\hat{\rho}_i$ we are able to estimate $u_i(x)$ and thus the absolute subjective difference, defined as the difference of the utility of each alternative for a given individual in a given scenario ($D\ vs\ EV$).

$$|\Delta_i^u| = |\ u_i(D) - pu_i(20)\ |$$

We also include the objective difference, subtracting the expected value of the lottery from the deterministic alternative:

$$|\Delta_i^o| = |\ D - 20p\ |$$

In Table 4.1.2, we see that that the coefficient on loss slightly changes to 29%. We confirm that, when the difference between the utility of the alternatives increases, response times decrease. Instead, we do not find any significant effect for the objective difference.

Table 4.1.2 - Results, CRRA utility	
Loss	0.290***
	(0.000)
Period-1	-0.0377***
	(0.000)
D vs 10	-0.0415
	(0.129)
10 vs 10	-0.0592
	(0.384)
Subjective difference	-0.0154*
	(0.031)
Objective difference	0.00397
	(0.690)
Constant	1.820***
	(0.000)
Observations	1313

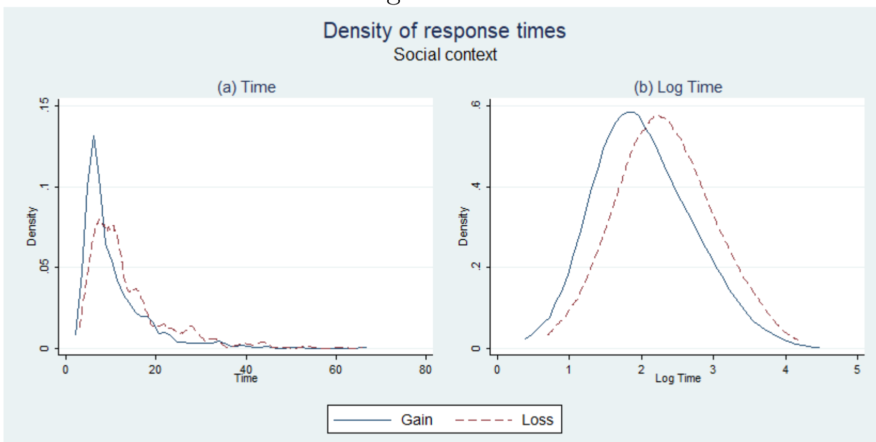
p-values in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

4.1.2 Social context

We repeat the analysis for decisions that involve the payoff of another participant. Once again we find that subjects are slower under losses. The average response time for the gain treatment is 10.4 seconds, while it reaches 13.5 second for the loss one. The random-effect model in Column (a) of Table 4.1.3 shows that the difference amounts to 29.5%, remarkably similar to the one we found in the individual context. The kernel densities in Figure 4.1.5, and especially Panel (b), suggest that the shift is particularly sizeable around the centre of the distribution.

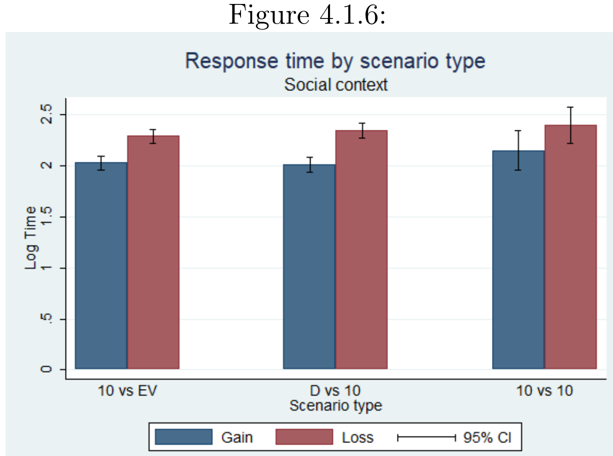
Figure 4.1.5:



Then we look at each type of scenario separately. The (D vs 10) and (10 vs EV) scenario types respect the pattern identified so far: decisions made under losses are slower, and the size of the difference remains high, just above 30%. For the (10 vs 10) scenario type however, the difference lowers to 18.7%, and the 95% confidence interval on the loss coefficient goes from -4.3% to 40.7%: we cannot exclude that there is no difference between domains, but we cannot even exclude that such difference is as big as in the other two scenario types (see Figure 4.1.6).

Consider the last two columns of the graph below. Compared to the other pairs, not only the difference between domains is smaller, driven by a higher response time in the gain domain, but also standard errors are larger. Remember that for this scenario we only observe the subjects once, hence we have only less observations than for other scenario types.

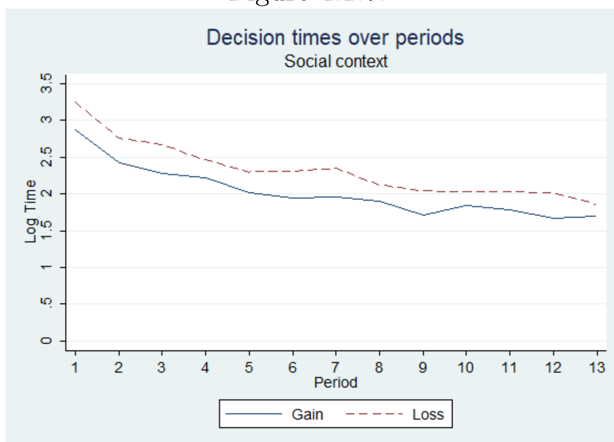
Figure 4.1.6:



When the plot the evolution of the average response times in logs, we see that the difference between domains remains constant (Figure 4.1.7). Also, compared to the individual context, the decline in response times for both domain continues steadily over the course of the experiment.

Indeed, in the social context, response times decrease each period by approximately 8% regardless of the domain of choice (see Columns (c) and (d) in 4.1.3).

Figure 4.1.7:



This effect is more than twice the one estimated for the individual context, which was 3.8%. Why is this the case? Recall that subjects face scenarios in the social context first and then, after a break, they play in the individual context. Hence, the steep learning curve occurs in the social context phase.

Table 4.1.3 - Results, social context				
	(a)	(b)	(c)	(d)
Loss	0.295***	0.260***	0.303***	0.364***
	(0.000)	(0.000)	(0.000)	(0.000)
(D vs 10)		-0.0173	0.0330	0.0300
		(0.681)	(0.325)	(0.372)
(10 vs 10)		0.123	0.191*	0.187*
		(0.201)	(0.011)	(0.014)
Loss × (D vs 10)		0.0764	0.00261	0.00419
		(0.223)	(0.957)	(0.932)
Loss × (10 vs 10)		-0.0120	-0.121	-0.119
		(0.922)	(0.206)	(0.214)
Period-1			-0.0860***	-0.0809***
			(0.000)	(0.000)
Loss × (Period-1)				-0.0103
				(0.182)
Constant	2.027***	2.025***	2.513***	2.484***
	(0.000)	(0.000)	(0.000)	(0.000)
Observations	1313	1313	1313	1313

p-values in parentheses

Random-effect, clustered standard errors.

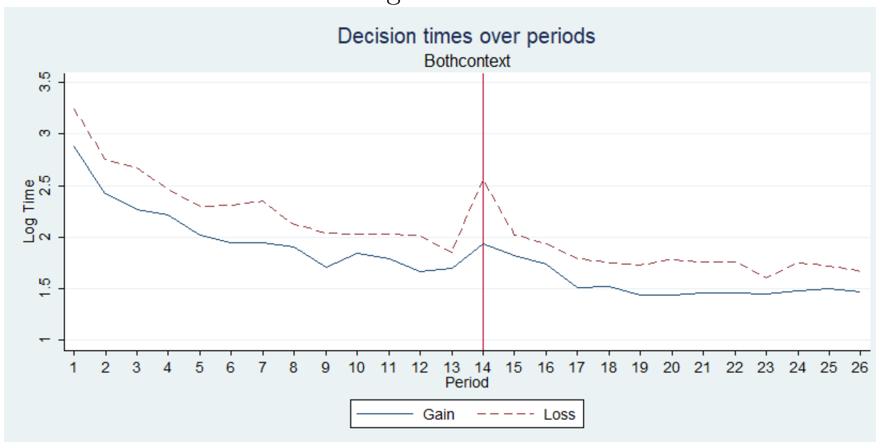
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

It is useful at this point to plot the average response time over the whole experiment consecutively (Figure 4.1.8). The red vertical line separates the two parts: on the left-hand side we have choices in social context, on the right-hand side the ones in isolation.

The two lines follow a similar pattern. They experience a continuous decrease over the first half, a jump when the new part starts, finally a new, milder decline until they get nearly flat around the 20th period.

As for the difference between domains, we see that it does not not fade away over the course of the survey. Even with more experience, the cognitive effort required by the loss domain remains higher.

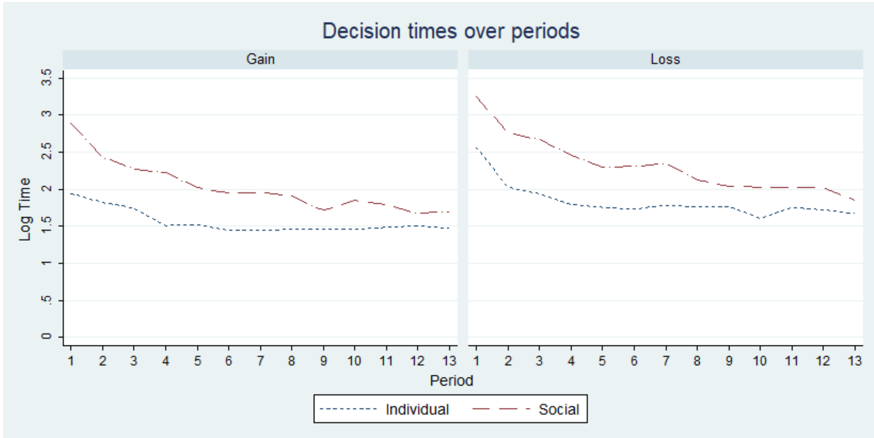
Figure 4.1.8:



At this point, one may be tempted to compare response times in the two parts of the experiment. Descriptive statistics and visual evidence show that decisions in the social context take longer than those in isolation. If people are not rational agents, who only care about their own payoff - regardless of whether subjects are altruistic, inequality averse or seeking, - it makes sense that they consider the other's payoff for their decision and this requires additional time. But do our figures actually mean that, when the payoff of other subjects is involved, more cognitive effort is spent on the decision? Or is this linked to the fact the subjects face the social context first? Under this second hypothesis, the difference between the two parts is due to experience, not to the context itself.

The structure of the experiment does not allow us to provide a definitive answer, since we have no treatment in which subjects first face the individual context and later the social one. Yet, we can cautiously go deeper in to this issue and test the water. In 4.1.9 we plot the evolution of response times over the course of the experiment by domain. Average response times in the social context remain above the ones for the individual context in all periods, but the two differences are decreasing over time. Hence, we cannot exclude that the difference between context is driven by experience rather than by social preferences entering the stage. Further research is needed to identify the importance of these two factors.

Figure 4.1.9:



4.2 Results for dictator games

We have found that the loss domain requires a much higher cognitive effort compared to the gain one. Does the difference in response times carry on to a different type of game? To answer this question, we consider a deterministic dictator game (DDG) and a probabilistic dictator game (PDG).

In the DDG, the average response time under gains is 21.7 second, while under losses it reaches 26.7. Table 4.2.1 shows that the difference in the logarithm of response time is significant. The effect of the domain is again rather large, around 21%.

Here, the average response time for the domain of gains is 19.2 seconds, for the domain of losses is 22.3. The difference, 17.9%, is inferior but still similar to the one found for the DDG.

Results in these two social games confirm those of the previous section: individuals exert higher cognitive effort under losses, with a difference in response times around 20%.

Table 4.2.1 - Results, dictator games

	DDG	PDG
Loss	0.212**	0.179*
	(0.006)	(0.046)
Constant	3.005***	2.845***
	(0.000)	(0.000)
Observations	101	101

p-values in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure 4.2.1:

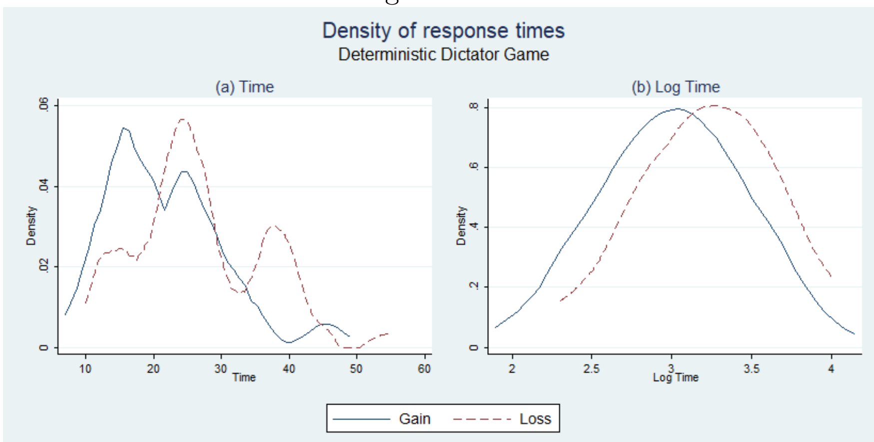
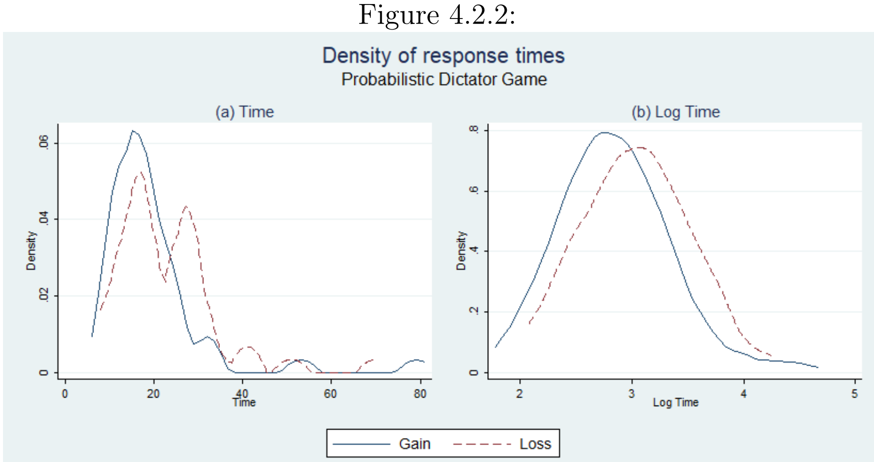


Figure 4.2.2:



5 Conclusions

This paper has investigated cognitive effort exercised by subjects in a variety of games - binary and continuous choices, in both the individual context and in the social one - taking response times as a proxy. Our main focus has been the difference in the level of cognitive effort between the loss and the gain domain.

We have shown that individuals consistently exercise a higher cognitive effort when they face alternatives framed in terms of losses. Also, such increase is sizeable and rather stable across games. It goes from 20% in the dictator games to 30% in the binary choices. According to prospect theory, losses loom larger than gains. Previous research shows that the higher the incentives, the higher is cognitive effort. Hence, when playing with the same absolute values, decisions under losses require more time. For every minute spent on the experiment's scenarios in the gain treatment, around fifteen additional seconds are necessary under losses.

We have also confirmed the importance of experience. Every period decreases response time from 4% to 8%; whether this depends on the subjects acting in the social context or on the order of the games requires further investigation, as well as the higher level of cognitive effort we find when subjects face binary choices in the social context. Similarly, in line with previous literature, we found that closeness to indifference is linked with higher response times.

6 References

Angino, S. (2017). *The importance of being clustered - Sharing or gambling over The importance of being clustered - Sharing or gambling over losses.* PhD thesis, LUISS Guido Carli.

Camerer, C. F. and Hogarth, R. M. (1999). The effects of financial incentives in experiments: A review and capital-labor-production framework. *Journal of risk and uncertainty*, 19(1-3):7–42.

Chabris, C. F., Morris, C. L., Taubinsky, D., Laibson, D., and Schuldt, J. P. (2009). The allocation of time in decision-making. *Journal of the European Economic Association*, 7(2-3):628–637.

Fischbacher, U. (2007). z-tree: Zurich toolbox for ready-made economic experiments. *Experimental economics*, 10(2):171–178.

Kocher, M. G., Pahlke, J., and Trautmann, S. T. (2013). Tempus fugit: time pressure in risky decisions. *Management Science*, 59(10):2380–2391.

Konovalov, A. and Krajbich, I. (2017a). On the strategic use of response times.

Konovalov, A. and Krajbich, I. (2017b). Revealed indifference: Using response times to infer preferences.

Krawczyk, M. and Le Lec, F. (2010). 'give me a chance!'an experiment in social decision under risk. *Experimental economics*, 13(4):500–511.

Machina, M. J. (1989). Dynamic consistency and non-expected utility models of choice under uncertainty. *Journal of Economic Literature*, 27(4):1622–1668.

Moffatt, P. G. (2005). Stochastic choice and the allocation of cognitive effort. *Experimental Economics*, 8(4):369–388.

Piovesan, M. and Wengström, E. (2009). Fast or fair? a study of response times. *Economics Letters*, 105(2):193–196.

Rand, D. G., Greene, J. D., and Nowak, M. A. (2012). Spontaneous giving and calculated greed. *Nature*, 489(7416):427.

Rubinstein, A. (2007). Instinctive and cognitive reasoning: A study of response times. *The Economic Journal*, 117(523):1243–1259.

Rubinstein, A. (2016). A typology of players: Between instinctive and contemplative. *The Quarterly Journal of Economics*, 131(2):859–890.

Spiliopoulos, L. and Ortmann, A. (2018). The bcd of response time analysis in experimental economics. *Experimental economics*, 21(2):383–433.

Sternberg, S. (1969). Memory-scanning: Mental processes revealed by reaction-time experiments. *American scientist*, 57(4):421–457.

Stone, M. (1960). Models for choice-reaction time. *Psychometrika*, 25(3):251–260.

Tinghög, G., Andersson, D., Bonn, C., Böttiger, H., Josephson, C., Lundgren, G., Västfjäll, D., Kirchler, M., and Johannesson, M. (2013). Intuition and cooperation reconsidered. *Nature*, 498(7452):E1.