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REPO, SPONSORED REPO AND MACRO-PRUDENTIAL REGULATION

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1 Introduction

The repo market played an important role in the 2007-2008 crisis and its aftermath. The "run on repo" started in 2007 when cash lenders withdrew their repo funding due to concerns over securitized mortgages as collateral and haircuts rose dramatically as described in Gorton and Metrick (2012). The combination of very large, unprecedented haircuts with declining asset values, helped fuel the insolvency problems in the banking sector, which would eventually lead to massive bailouts throughout 2008 and the bankruptcy of some major banks.

In the following years, the repo market recovered most of its influence and size, but the Basel III regulations that were imposed to prevent future banking crises and limit leverage would create new frictions in the repo market. The "leverage ratio" in particular has perverse effect on the repo markets. The "leverage ratio" demands that banks hold Tier 1 capital as a percentage of their total assets.

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In the context of repo, banks must report all the repo loans as assets in the balance sheet. This leads to frictions, as there is less incentive for banks to act as intermediaries in the repo market for safe assets. Banks need to report these transactions even if they are compensating their reverse repos with equivalent repos using the same security as collateral, the same cash loan, and the same maturity for both transactions. They cannot net their repo positions. The lack of space on banks' balance sheets for repo was further exacerbated by a macroeconomic climate of low interest rates, which made it difficult for banks to acquire equity and thus expand their tier 1 capital, this connection has been elaborated by Brunnermeier and Koby (2018), who proposed the notion of a "reversal rate" of monetary policy. The ultimate result of these circumstances was reduced liquidity in bond markets, as there is less capital available to finance them.

Crucially, there is one instance where banks can net their positions in repo. If they enter into a repo and an equivalent reverse repo with the same counterparty, then netting is allowed, and these transactions do not increase total assets in the balance sheet. To achieve this outcome Central Clearing Counterparties (CCPs) are used. The CCP intermediates the transactions acting as a buyer to all sellers and seller to all buyers creating a situation where every participant faces the CCP in their transactions. While CCPs are widely used in clearing and netting transactions between dealers in the repo markets, most participants in the market do not have access to it and, therefore, the number of repos that can be netted is limited. To overcome this obstacle the sponsored repo program was created. Through sponsored repo, the dealers, typically large banks, are allowed to sponsor other parties into CCPs. By having a CCP intermediate their transactions with non-dealers, dealer banks become able to net their positions when they act as financial intermediaries. This ultimately increases banks´ capacity to offer repo.

With all these considerations in mind, we aim to create a model capable of introducing both stylized macro-prudential regulations and sponsored repo into a repo market set up that includes both dealers and non-dealers. First we introduce our model and then we add some simplifying assumptions in order to achieve analytical solutions. The characterization of these solutions provides some early insights into the impact of macro-prudential regulation on spreads and volumes and establishes sponsored repo as an effective tool to prevent some of the distortions caused by the leverage ratio.

2 Brief Literature Review

D. Duffie pioneered the use of the equilibrium framework to model the repo markets with his 1996 paper “Special Repo Rates”, his paper focused mostly on explaining repo specialness which is the difference between the general repo rate and the specific repo rate associated with a specific security. Nonetheless, the general framework of his model proves to be useful in a broader context and allows valuable insights into the repo market. In their 2012 paper “Securities market theory: Possession, repo and rehypothecation” Botazzi, Luque and Páscoa develop a repo market model within a stylized general equilibrium framework and introduce a key constraint to the modelling of repo markets called box constraint, this constraint imposes that an agent must borrow a security before being allowed to short sell it. This is the way short selling is done in the markets.The paper provides insights into repo specialness, the building of leverage and re-hypothecation, and the effects of regulation imposed on dealers, among others. A more recent paper, by some of these authors, focused on central clearing. In ”Do Security Prices Rise or Fall when Margins are Raised?”, J.M. Bottazzi and M. Pascoa, now with G. Ramirez, addressed the impact of CCP repo margins on the price of securities. It was observed in that paper that the fact that CCP collects margins from both the cash provider and the cash borrower makes all positions become bounded, contrary to what happened in OTC markets, where positions would be unbounded were it not for the regulatory constraints on dealers. Insights both from work on centrally cleared markets and from work on repo when dealers are present are important to understand how sponsored repo functions. The role of the dealer as an intermediary in the repo market is highlighted by Infante (2019) and he builds a model where the typical cash lenders (Money Market Funds) and cash borrowers (Hedge Funds) are differentiated. Baklanova et al. (2016) reported that haircuts can be negative when the motive behind the trade is to borrow securities and cash is used as collateral. Duffie (2013) discusses the importance of regulatory oversight of CCPs and the positive impact CCPs can have on financial stability as well as the pitfalls of CCP proliferation, which can reduce netting possibilities and lead to competition between CCPs in the form of reduced membership requirements.

While there is abundant literature focusing on the repo market, sponsored repo, as a relatively new form of repo, remains relatively unexplored. Some papers do discuss sponsored repo, in particular, its ability to help dealer banks face regulatory constraints by freeing up space in the balance sheet. In their paper "Enhancing Liquidity of the U.S. Treasury Market Under Stress" Liang and Parkinson (2020) propose the expansion of central clearing, with a focus on sponsored repo as one of their four measures to increase the supply of Treasury market liquidity in stress periods. Anbil, Anderson, and Senyuz (2021) found that dealers with more balance sheet constraints charged a higher spread in their intermediation activities in repo. They also found that the expansion of sponsored repo increased the market power of MMFs (Money Market Funds, which is a large segment of the cash lenders in the repo market). Afonso et al. (2020) link the large spike in rates in unsecured and secured funding markets in mid-September 2019 to the sudden withdrawal of funds by MMFs from the sponsored repo program, which temporarily increased intermediation costs for dealers. Furthermore, Spratt (2020) highlighted the role of sponsored repo in providing liquidity to the repo market at year-end in 2019. Barth and Kahn (2020) evidenced the role of hedge funds as the main borrowers in the sponsored repo segment of the repo market and noted their rapid expansion after 2019. Finally, Kahn and Olson (2021) provide data on the participants in the different segments of the cleared repo and note that most entities in the sponsored market do not engage in both borrowing and lending on the same day and, therefore, can be divided into two groups: one that borrows from direct clearing members and another that lends to direct clearing members.

3 Institutional Background

3.1 Repo

Repurchase agreements, “repo” in short, are collateralized short-term loans where a party sells a security and pledges to repurchase it later for a higher price. The difference between the price at which the security is sold and the price at which the security is repurchased is the repo interest rate. The security that is pledged in the repo serves as collateral against the potential default of the seller. Most repo transactions involve government sovereign bonds and are overnight. A reverse repo is merely a repo transaction but from the perspective of the party that lends the cash (borrows the security).

The repo market plays a crucial role in the financial system:

- Parties that possess a lot of securities like hedge funds and banks can borrow money at lower interest rates than in the uncollateralized credit market.
- Parties with excess cash can earn interest with very low risk.
- With naked short-selling being illegal, repo agreements allow the parties who borrow the security (cash lenders) to short-sell the security. This creates a segment in the repo market where the agents are looking to acquire a specific security rather than lending or borrowing cash which merely serves as collateral. In this segment, repo rates can be negative.
- Central banks use repo and reverse repo to conduct monetary policy; the central bank can inject reserves into the financial system by borrowing securities through reverse repo or drain reserves by lending securities through repo.

Many different types of agents and institutions operate in the repo market. We will start by distinguishing between two fundamental types: dealers and non-dealers. Dealers are the key market-makers of the repo market; they are typically banks and may be associated with commercial banks or be stand-alone investment banks. Dealers usually operate in the repo markets with a dual role, they are both significant users of repo and act as intermediaries by running a “matched-book”. “Matched-book” transactions imply that the dealer is borrowing and lending using the same collateral and maturity. Dealers’ incentive to engage in intermediation activities is the spread between the borrowing and the lending rate. Among the non-dealers, the market can be reasonably split into two main groups: cash borrowers and cash lenders. The typical cash lenders are MMFs who find in repo a low-risk, short-term investment that fits their purpose. On the other hand, Hedge Funds are common cash borrowers looking to use the securities in their portfolios to finance their activities at lower interest rates, when compared to the uncollateralized market. Hedge funds might also operate as cash lenders when they are looking to acquire specific securities to cover their short positions. This type of activity, however, is more common in the SC (specific collateral) segment of the market where bilateral repo is predominant, as opposed to the GC (general collateral) segment where different securities are accepted as collateral if they meet certain thresholds of value and quality.

3.2 Capital ratio

In 2010 the CET1 (Common Equity Tier 1) capital requirements were introduced, requiring banks to hold enough CET1 capital to cover 4.5% of their risk-weighted assets (RWAs). CET1 is comprised of common equity and retained earnings. Over the years some additional buffers were progressively added to this ratio, namely a capital conservation buffer of 2.5% and a discretionary countercyclical buffer.

The greatest strength of the Capital ratio is its ability to apply very high risk measures to risky assets, effectively regulating banks portfolios. The downside of this approach is that certain assets can be hard to categorize and is therefore dependent on subjective risk assessments.

3.3 Leverage Ratio

The third Basel Accord, Basel III is a set of international standards designed to increase the solidity and stability of the banking system, that came to be as a response to the financial crisis of 2007-2008. In 2014 the Basel III framework was revised and concerns over banks' ability to fulfill the risk-weighted capital ratios while still building excessive amounts of leverage were raised. As an answer, the leverage ratio was created, stating that banks should hold at least 3% of their total exposure as Tier 1 Capital. Tier 1 Capital encompasses common equity, retained earnings, disclosed reserves, and certain instruments. The total exposure measure includes all on-balance sheet assets, derivative exposures, and securities financing transactions.

The intent behind this ratio is for it to be a transparent and simple measure that serves as a complement to the risk-weighted measure by limiting the banking sector's capability to build up leverage.

This ratio has a particularly pervasive effect on the repo market, as all repo loans enter the total exposure measure, but the collateral that is received does not influence the capital measure. The fact that repo transactions are typically low risk also does not factor in the leverage ratio as assets are not risk-weighted. This results in a situation where repo has a large impact on the balance sheet considering the relatively low returns on repo lending compared to other, riskier, forms of lending. Greenwood et all (2017) find that the leverage ratio is a binding constraint for several large US banks.

3.4 Sponsored Repo

Since 2017, a new form of repo has become increasingly popular: the sponsored repo. Typically, a party must be a member of the CCP to trade with it, with all the inherent costs and obligations. Sponsored repo happens when a dealer sponsors a non-dealer counterparty allowing them to face the CCP in their repo or reverse repo transactions. Sponsored repo yields benefits to both dealers and non-dealers:

- Non-dealers have increased security in their transactions since they are now facing a CCP that protects them from a potential default or fail of their dealer counterparty.

- Dealers lessen the burden imposed by repo on their balance sheets. Sponsored repo allows banks to net their positions with the CCP because they are now facing the same counterparty on both sides of the transaction when they intermediate between cash lenders and cash borrowers.

- By eliminating some of the pressure on the dealers' balance sheets, sponsored repo can contribute to the liquidity of the bond market, especially in stress periods when the regulatory constraints might be increasingly binding, and banks might otherwise wish to withdraw funds from repo.

- Higher use of CCPs to intermediate repo transactions contributes to the overall stability of the repo market by concentrating the market and increasing transparency, thus allowing for better risk management and oversight.

Sponsored repo has been expanding rapidly, achieving more than US$600 billion in daily volume in March 2023. Sponsored Repo is not as prevalent in Europe but has also been expanding.

4 A Simple Model of Repo, Leverage Constraints and Sponsored Repo

In this section we develop a simple model with the aim of obtaining analytical solutions and showcasing in a linear setting some of properties of the interaction between repo, the leverage constraint and sponsored repo. Three examples will be provided, each adding additional assumptions over the previous one. In each example equilibrium solutions are found under an assumption of competitive equilibrium.

4.1 Model and Notation

There are three agents divided between two fundamental types: one dealer and two non-dealers. The agents engage in trade over two dates.In the second date there are two states of nature that can be reached with some probability, the states are given by $\sigma \in \Sigma = \{0, 1, 2\}$, where $\sigma = 1$ is a "high" state and $\sigma = 2$ is a "low" state. The agents do not know in advance which state they will face in the second date, but each has his own belief θ_i over the probability of transitioning to each state. In the first date, agents enter into repo and reverse repo, and sell or buy securities. In the second date all securities and repo contracts mature.

Agents have linear utility equivalent to the cash value of their final position in the second date, after all securities and repo contracts mature.

The amount of security l engaged in repo (reverse repo) by agent i is denoted by z_i (w_i). Haircuts $1-h$ are charged by the dealer, such that the amount of money lent by a non-dealer to a dealer i is $(2-h)pw_i$ and the amount of money borrowed by a non-dealer is (hpz_i). Additionally, non-dealers agents can only enter into repo or reverse repo transactions with the dealer and not between themselves.

We define $\rho_w = 1 + r_w$ and $\rho_z = 1 + r_z$, where r_w is the repo rate paid by the dealer to the non-dealer when the dealer is borrowing and r_z is the repo rate paid by the non-dealer when borrowing from the dealer.

There is one security which pays 1 in the "high" state and 0 in the "low" state.

In the first date all agents are endowed with a non-negative amount of the cash and the security.

4.2 Example 1

We will assume the following endowments $e = c_i, l_i, c_i^{\sigma}$ and beliefs for our three agents, as well as a 10% haircut:

- Dealer: $e = (0.5, 1, \zeta)$ and $\theta_d = 0.5$
- Optimist: $e = (1, 1, \zeta)$ and $\theta_o = 0.55$
- Pessimist: $e = (0.5, 1, \zeta)$ and $\theta_p = 0.45$

where ζ is the endowment at the second date and is large enough to ensure that the second date budget constraint inequality is always relaxed.

The equilibrium concept will consist of an equilibrium price for the security and two equilibrium repo rates where both the security market and the repo market clear.

4.2.1 Dealer Problem 1

Under these assumptions the dealer faces the following maximization problem:

$$\max_{c,l,w,z} \quad c + \theta l + \rho_z hpw - \rho_w (2-h) pz \tag{1a}$$

$$\text{s.t.}$$

$$(e^c - c) + (pe^l - pl) + ((2-h)pz - hpw) = 0, \tag{1b}$$

$$c \geq 0, \tag{1c}$$

$$w - z + l \geq 0, \tag{1d}$$

$$z \geq 0, \tag{1e}$$

$$w \geq 0 \tag{1f}$$

Where:

- (1b) is the first date budget constraint.
- (1c) represents the non-negativity of the. cash balance and has λ_1 as the associated multiplier.
- (1d) is the box constraint with the associated multiplier λ_2. We can think of the box constraint as representing physical possession of the underlying security: lending money in repo and receiving the security as collateral increases the amount of security in the "box", while borrowing money decreases it. If agents want to have negative l_i they must borrow the security in reverse repo.
- (1e) and (1f) represent the fact that, since we have split repo transactions into repo lending and repo borrowing, we cannot have negative repo borrowing or lending. They have λ_3 and λ_4 as their associated multipliers, respectively.

This yields the following first order conditions [1]:

$$p = \frac{\theta + \lambda_2}{1 + \lambda_1} \tag{2}$$

$$\rho_w - 1 = \frac{\lambda_3 - \lambda_2}{(2-h)p} + \lambda_1 \tag{3}$$

$$\rho_z - 1 = \frac{-\lambda_4 - \lambda_2}{hp} + \lambda_1 \tag{4}$$

4.2.2 Non-Dealer Problem 1

The non-dealer agents face the following problem:

$$\max_{c,l,w,z} \quad c + \theta l + \rho_w (2-h) pw - \rho_z hpz \tag{5a}$$

s.t.

$$(e^c - c) + (pe^l - pl) + (hpz - (2-h)pw) = 0, \tag{5b}$$

$$c \geq 0, \tag{5c}$$

$$w - z + l \geq 0, \tag{5d}$$

$$z \geq 0, \tag{5e}$$

$$w \geq 0 \tag{5f}$$

Which yields the following first order conditions for the optimist:

$$p = \frac{\theta_o + \lambda_2}{1 + \lambda_1} \tag{6}$$

$$\rho_z - 1 = \frac{\lambda_3 - \lambda_2}{hp} + \lambda_1 \tag{7}$$

$$\rho_w - 1 = \frac{-\lambda_4 - \lambda_2}{(2-h)p} + \lambda_1 \tag{8}$$

$$c = 0 \tag{9}$$

[1] Only the case relevant for the equilibrium is presented in each example

$$w - z + l = 0 \tag{10}$$

$$w = 0 \tag{11}$$

And the following first order conditions for the pessimist:

$$p = \frac{\theta_p + \lambda_2}{1 + \lambda_1} \tag{12}$$

$$\rho_z - 1 = \frac{\lambda_3 - \lambda_2}{hp} + \lambda_1 \tag{13}$$

$$\rho_w - 1 = \frac{-\lambda_4 - \lambda_2}{(2-h)p} + \lambda_1 \tag{14}$$

$$c = 0 \tag{15}$$

$$w - z + l = 0 \tag{16}$$

$$z = 0 \tag{17}$$

4.2.3 Equilibrium Solution 1

As an equilibrium solution to this first example we have the vector $(p, \rho_z, \rho_w) = (0.5, 1, 1)$.

4.2.4 Equilibrium Summary 1

	Endowments	Positions	Cash and Box	Multipliers	Expected Utility
Notation	e^c, e^l, ζ	l, z, w	$c, (w-z+l)$	$\lambda_1, \lambda_2, \lambda_3, \lambda_4$	$U(c) = c$
Dealer	$0.5, 1, \zeta$	$-7, 20, 30$	$2, 3$	$0, 0, 0, 0$	$\zeta + 1$
Optimist	$1, 1, \zeta$	$30, 30, 0$	$0, 0$	$1, 0.45, 0, 0.1$	$\zeta + 3$
Pessimist	$0.5, 1, \zeta$	$-20, 0, 20$	$0, 0$	$1, 0.55, 0.1, 0$	$\zeta + 2$

4.2.5 Analysis and Discussion 1.1

Despite its simplicity, this first example already provides some interesting insights into the properties of the segments of the repo market where the dealer acts as an intermediary. Here, heterogeneous beliefs are used to segment the market into cash lenders and cash borrowers, as agents who believe the security will perform better(worse) than its price borrow(lend) money in repo to leverage long(short) positions.

The first remark is that the completely unconstrained dealer is unable to create a repo spread in this competitive equilibrium setting. Because the dealer collects haircut on both sides, its positions are unbounded and, therefore, any positive spread will see the dealer attempt to take arbitrarily large positions on (reverse) repo. This excess supply of (reverse) repo from the dealer will push both rates and the spread towards 0, where the dealer is indifferent between entering repo/reverse repo or doing nothing. In this context, the dealer acts purely as a market maker enabling the other agents to achieve their desired positions. What this suggests, briefly stepping outside of the model, is that, in the absence of constraints on the dealer, spreads in the repo market should result from administrative costs inherent to the intermediation activity or from dealer market power.

A second feature of this example is that both the optimist and the pessimist are fully leveraged. This is only possible due to the presence of an intermediary that can take positions both in repo and in the security. Without the dealer the optimist would not have been able to fully lever. The ability to fully lever ensures that the sum of the expected utility of the 3 agents is maximized. The maximum amount of leverage the non-dealer agents can achieve in terms of their absolute final position in the security is given by $max|l_i| = \frac{initialwealth}{haircut \times price}$.

The key multipliers in this example are λ_1 and λ_2, associated with the constraints on the cash(1c) and on the box(1d), respectively. λ_1 can be interpreted, for the non-dealers, as the increase in expected utility that results from fully leveraging an extra unit of available cash and it is equivalent for either the pessimist or the optimist to the utility they would gain if they could have an uncollateralized loan of 1 unit of cash at 0 interest rate. λ_2 is the shadow value of physical possession of the security. Interestingly, the pessimist places a higher value on relaxing the box than the optimist, implying that under symmetrical haircuts and beliefs the shorts should place more value on physical possession of the collateral than the longs. An intuitive interpretation of this multiplier is, for the optimist, the value of obtaining physical possession of 1 unit of the security without having to post cash as collateral and, for the pessimist, the value of being able to perform the naked short selling of exactly one unit of security.

As a final note, it should be mentioned that this example can be generalized, in the sense that for any $0.5 < \theta_o < 1$ and $0 < \theta_p < 0.5$, positions, prices and repo rates remain the same and that for any $\theta_p < \theta_d < \theta_o$ p $=\theta_d$.

4.3 Example 1.2

For the second part of this example lets add the following additional assumptions:

- The dealer constrained by a leverage ratio of $\mu = 0.1$, meaning he must hold equity equal or larger than $\mu(max(pl_d, 0) + hpw_d)$.
- The dealer's equity *eq* is equal to the value of his initial endowments.

4.3.1 Dealer Problem 2

The dealer now faces the following maximization problem:

$$\max_{c,l,w,z} \quad c+\theta l+\rho_z hpw-\rho_w(2-h)pz \tag{18a}$$

s.t.

$$(e^c-c)+(pe^l-pl)+((2-h)pz-hpw)=0, \tag{18b}$$

$$c\geq 0, \tag{18c}$$

$$w-z+l\geq 0, \tag{18d}$$

$$z\geq 0, \tag{18e}$$

$$w\geq 0, \tag{18f}$$

$$eq-\mu(max(pl_d,0)+hpw_d)\geq 0 \tag{18g}$$

Which yields the following first order conditions:

$$p=\frac{\theta+\lambda_2}{1+\lambda_1+\delta\mu\lambda_5} \tag{19}$$

$$\rho_w-1=\frac{\lambda_3-\lambda_2}{(2-h)p}+\lambda_1 \tag{20}$$

$$\rho_z-1=\frac{-\lambda_4-\lambda_2}{hp}+\lambda_1+\mu\lambda_5 \tag{21}$$

$$eq-\mu(max(pl_d,0)+hpw_d)=0 \tag{22}$$

4.3.2 Non-Dealer Problem 2

The non-dealers face the same problem as before and will have the following first order conditions:

For the optimist:

$$p=\frac{\theta_o+\lambda_2}{1+\lambda_1} \tag{23}$$

$$\rho_z-1=\frac{\lambda_3-\lambda_2}{hp}+\lambda_1 \tag{24}$$

$$\rho_w - 1 = \frac{-\lambda_4 - \lambda_2}{(2-h)p} + \lambda_1 \tag{25}$$

$$c = 0 \tag{26}$$

$$w = 0 \tag{27}$$

And for the pessimist:

$$p = \frac{\theta_p + \lambda_2}{1 + \lambda_1} \tag{28}$$

$$\rho_z - 1 = \frac{\lambda_3 - \lambda_2}{hp} + \lambda_1 \tag{29}$$

$$\rho_w - 1 = \frac{-\lambda_4 - \lambda_2}{(2-h)p} + \lambda_1 \tag{30}$$

$$w - z + l = 0 \tag{31}$$

$$z = 0 \tag{32}$$

4.3.3 Equilibrium Solution 2

As the equilibrium solution to this example we have the vector $(p, \rho_z, \rho_w) = (0.5, 1.1, 1)$.

4.3.4 Equilibrium Summary 2

	Endowments	Positions	Cash and Box	Multipliers	Expected Utility
Notation	e^c, e^l, ζ	l, z, w	$c, (w-z+l)$	$\lambda_1, \lambda_2, \lambda_3, \lambda_4, (\lambda_5)$	$U(c) = c$
Dealer	$0.5, 1, \zeta$	$0, 20, 22$	$2, 2$	$0, 0, 0, 0, 1$	$\zeta + 2$
Optimist	$1, 1, \zeta$	$23, 22, 0$	$0, 1$	$0.1, 0, 0, 0.045$	$\zeta + 1.65$
Pessimist	$0.5, 1, \zeta$	$-20, 0, 20$	$0, 0$	$1, 0.55, 0.1, 0$	$\zeta + 2$

4.3.5 Analysis and Discussion 1.2

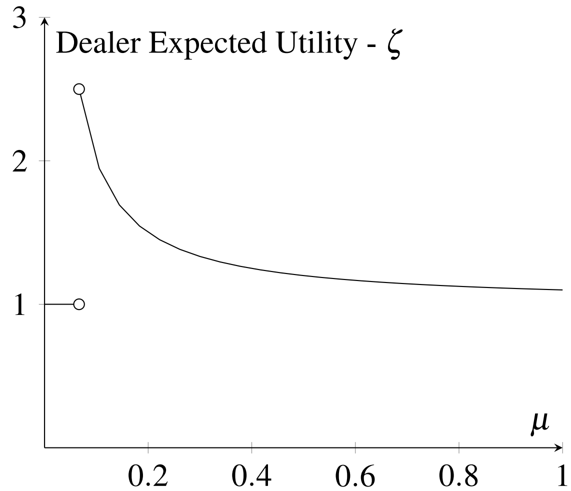
The first thing to notice in this second example is that the repo rate r_z is no longer 0. The leverage constraint binds the dealers and a repo rate of 0 would now lead to excess supply of repo from the optimist. The equilibrium rates $(\rho_z, \rho_w) = (1.1, 1)$, now make the optimist indifferent to leveraging, because the interest he must pay compensates exactly the expected gain from investing in the security. The leverage ratio ensures that the dealers supply of repo is always bounded. The ratio μ is an essential part of this equilibrium. For any $\mu \geq \frac{1}{15}$ we would revert back to the first equilibrium as the leverage ratio would be less binding for the dealer than the haircut is for the non-dealers.

An important note is that equity is exogenous to this model. No action the agents can take in the first date changes their equity. This explains the absence of equity in all the conditions except (22).

The new multiplier λ_5 is directly present in both the pricing equation and the equation for the rate at which the dealer lends. A higher λ_5 has a negative effect on price as having a position in the security enlarges the dealer's balance sheet. In the specific context of this example the price remains the same because the dealer chooses l_d optimally to be 0, not putting any pressure on the prices. On the other hand the increase in ρ_z is quite evident and it appears in condition (21). The economic intuition for the increase in rho_z is simple, a contracting balance sheet availability decreases the supply of reverse repo by the dealer and, therefore, raises the cost of of repo financing.

More interestingly, the multiplier λ_5 is inversely proportional to the leverage ratio μ indicating, perhaps counter-intuitively, that the value of obtaining additional equity increases as the leverage ratio decreases. This is indeed true if we consider the repo rates to be fixed: the ability to enlarge the balance sheet from an extra unit of equity increases as the leverage ratio decreases and so does the expected utility. This is not, however, taking into account the wider general equilibrium effects: as a dealer expands its balance sheet, it exerts downward pressure on the spread it charges and a smaller spread will decrease the value of additional equity. These two contrasting effects make it unclear how changes in the leverage

Figure 1: Leverage ratio and Utility



ratio should affect the value of equity and even the dealers expected utility, posing a potentially interesting empirical question. Figure 1 illustrates the relationship between the leverage ratio and the expected utility in the context of this example. The discontinuity in the function represents the movement from one corner solution to another when $\mu = \frac{1}{15}$.

4.4 Example 1.3

In the last part of the example we add the following assumptions:

- All repo transactions between the 3 agents will now go through a CCP
- The CCP charges margins $m = 0.05$ to all participants, for every transaction and returns them in the second date
- The leverage constraint now operates on the net position of the dealer rather than the total position, becoming $eq - \mu(max(pl_d, 0) + max(hp\phi, 0) \geq 0$ where $\phi = w_d - z_d$
- Margins paid on netted transactions are netted as well

- CCP reinvests the money collected as margin by lending it to the dealer at ρ_w
- since the dealer is now less exposed and able to net his positions we will assume the haircut is reduced to 0.05.

4.4.1 Dealer Problem 3

The dealer now faces the following maximization problem:

$$\max_{c,l,w,z} \quad c+\theta l+\rho_z hpw-\rho_w(2-h)pz+\rho_w mp\,|z-w| \tag{33a}$$

s.t.

$$(e^c-c)+(pe^l-pl)+((2-h)pz-hpw)-mp\,|z-w|)=0, \tag{33b}$$

$$c\geq 0, \tag{33c}$$

$$w-z+l\geq 0, \tag{33d}$$

$$z\geq 0, \tag{33e}$$

$$w\geq 0, \tag{33f}$$

$$eq-\mu(max(pl_d,0)+max(hp(w-z),0))\geq 0 \tag{33g}$$

4.4.2 Non-Dealer Problem 3

The non-dealer agents now face the following problem:

$$\max_{c,l,w,z} \quad c+\theta l+\rho_w(2-h)pw-\rho_z hpz+mp(z+w) \tag{34a}$$

s.t.

$$(e^c-c)+(pe^l-pl)+(hpz-(2-h)pw)-mp(z+w)=0, \tag{34b}$$

$$c\geq 0, \tag{34c}$$

$$w-z+l\geq 0, \tag{34d}$$

$$z\geq 0, \tag{34e}$$

$$w\geq 0 \tag{34f}$$

Which yields the following first order conditions for the optimist:

$$p=\frac{\theta_o+\lambda_2}{1+\lambda_1} \tag{35}$$

$$\rho_z-1=\frac{\lambda_3-\lambda_2+(hp-mp)\lambda_1}{hp} \tag{36}$$

$$\rho_w-1=\frac{-\lambda_4-\lambda_2+((2-h)p+mp)\lambda_1}{(2-h)p} \tag{37}$$

$$c=0 \tag{38}$$

$$w-z+l=0 \tag{39}$$

$$w=0 \tag{40}$$

And the following first order conditions for the pessimist:

$$p=\frac{\theta_p+\lambda_2}{1+\lambda_1} \tag{41}$$

$$\rho_z-1=\frac{\lambda_3-\lambda_2+(hp-mp)\lambda_1}{hp} \tag{42}$$

$$\rho_w-1=\frac{-\lambda_4-\lambda_2+((2-h)p+mp)\lambda_1}{(2-h)p} \tag{43}$$

$$c=0 \tag{44}$$

$$w-z+l=0 \tag{45}$$

$$z=0 \tag{46}$$

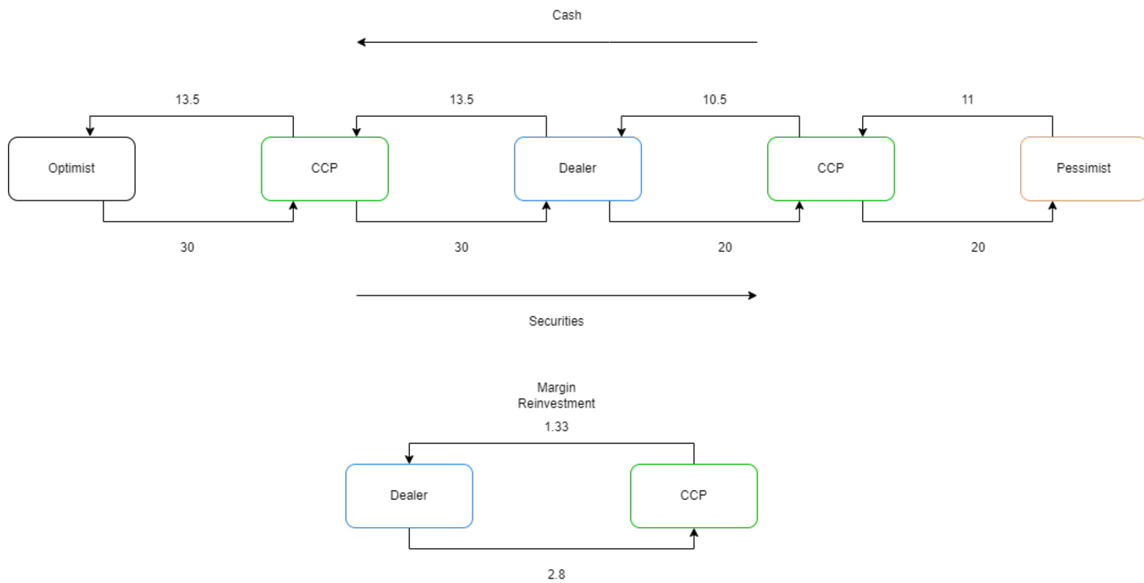


Figure 2: Sponsored Repo Equilibrium

4.4.3 Equilibrium Solution 3

As an equilibrium solution to the third example we have the vector $(p, \rho_z, \rho_w) = (0.5, 1, 1)$.

Figure 2 showcases the flows of cash and securities in equilibrium

4.4.4 Equilibrium Summary 3

	Endowments	Positions	Cash and Box	Multipliers	Expected Utility
Notation	e^c, e^l, ζ	l, z, w	$c, (w-z+l)$	$\lambda_1, \lambda_2, \lambda_3, \lambda_4, (\lambda_5)$	$U(c) = c$
Dealer	$0.5, 1, \zeta$	$-7, 22.8, 30$	$2, 0.2$	$0, 0, 0, 0, 0$	$\zeta + 1$
Optimist	$1, 1, \zeta$	$30, 30, 0$	$0, 0$	$1, 0.45, 0, 0.1$	$\zeta + 3$
Pessimist	$0.5, 1, \zeta$	$-20, 0, 20$	$0, 0$	$1, 0.55, 0.1, 0$	$\zeta + 2$

4.4.5 Analysis and Discussion 1.3

In this final example, the possibility to net its positions allows the dealer to take unbounded positions in repo as long as he matches them with an equivalent reverse repo. This pushes the repo rates towards 0 once more, as the leverage ratio no longer binds.

Another crucial aspect of this last example is the addition of the margin m, which constrains the positions of the non-dealers, acting in the same way as the haircut. In fact, this analysis hinges on the choices of margins, haircuts and the leverage ratio. If the margin is set too high then sponsored repo could potentially decrease the sum of the expected utility of the agents when compared to the second example. On the other hand a higher leverage ratio would cause a reduction in the expected utility of the second case, while having much less impact when sponsored repo is allowed.

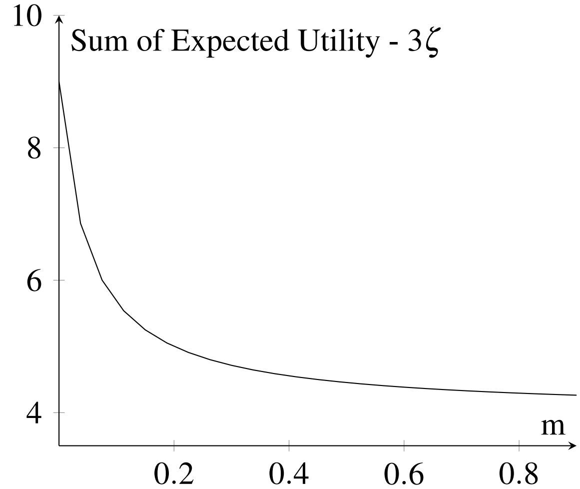
The differences in the dealers positions and box between the case with sponsored repo and the first example comes from the fact that the CCP reinvests the margins by lending in the repo market. This reinvestment is illustrated in Figure 2. While in this example the dealer possesses enough securities in his box to collateralize the CCP's margin investments, under different conditions it could happen that the added supply of reverse repo by the CCP is large enough to change the equilibrium repo rates or prices.

5 The impact of capital and leverage ratios on the repo market: a general model

In this section we propose the starting point for a generalized model capable of incorporating more aspects of the repo market and macro-prudential regulation and providing further insight into some of the ideas developed in the previous section.

We retain two types of agents: dealers and non-dealers. Dealers are denoted by $d \in D = \{1,2,...,n\}$ and non-dealers by $i \in I = \{1,2,...,m\}$. Like in the simple model the agents engage in trade over two dates. In the first date there is only

Figure 3: Margins and Utility



one state of nature, while in the second date there are two states of nature that can be reached with some probability, the states are given by $\sigma \in \Sigma = \{0,1,2\}$. The agents do not know in advance which state they will face in the second date, but they have a belief over the probability of transitioning to each state. Both dealers and non-dealers maximize their respective utility functions $U_d(c_d^\sigma)$ or $U_i(c_i^\sigma)$, where c_i^σ is the final cash balance in the second date and $\frac{dU}{dc} > 0$ and $\frac{d^2U}{dc} \leq 0$.

5.1 The Securities

There are two securities: A ”safe” security, which pays in cash in the second date and always delivers its promise, denoted by l^s; and a ”risky” security which pays its promise in one of the states of nature and an amount below its promise in the other state, denoted by l^r. The agents know in advance the amount the risky security will pay in each state. The prices in the first date are denoted by p^s and p^l, in the second date both securities mature.

5.2 Repo and Reverse Repo

The amount of security l^s engaged in repo (reverse repo) by agent i is denoted by z_i^s (w_i^s). Haircuts $1-h$ are charged by the dealer, such that the amount of money lent (borrowed) by agent i is $(2-h^s)p^s w_i^s$ ($h^s p^s z_i^s$). Additionally, non-dealers agents can only enter into repo or reverse repo transactions with dealer agents and not between themselves and an analogous restriction applies to dealers. We define $\rho_w^s = 1 + r_w^s$ and $\rho_z^s = 1 + r_z^s$, where r_w^s is the repo rate paid by the dealer to the non-dealer when the dealer is borrowing and r_z^s is the repo rate paid by the non-dealer when borrowing from the dealer using the safe security as collateral. The notation follows analogously for when the risky security is posted as collateral. The spreads earned by the dealers are given by $\rho_z^s - \rho_w^s$ and $\rho_z^r - \rho_w^r$.

5.3 Stylised macro-prudential regulations

Two stylised macro-prudential regulations are designed with the purpose of emulating the pressures imposed on dealers(banks) balance sheets by the capital ratio and the leverage ratio. In the context of this model the assets of a dealer are their cash balance c_d, their conceded loans $h^s p^s w_d$ and their non-negative position in each security $max(p^s l_d^s, 0) + max(p^s l_d^r, 0)$. The stylised leverage ratio forces dealers to have equity larger or equal than $\mu[h^s p^s w_d^s + h^r p^r w_d^r + max(p^s l_d^s, 0) + max(p^s l_d^r, 0)]$, where $0 \leq \mu \leq 1$ is the leverage ratio. The stylised capital ratio forces dealers to have equity greater or equal than $CR[\alpha p^s w_d^s + \beta p^r w_d^r + \alpha max(p^s l_d^s, 0) + \beta max(p^r l_d^r)]$, where $0 \leq CR \leq 1$ is the capital ratio and α and β are the risk weights.

5.4 Endowments

In the first date all agents are exogenously endowed with non-negative amounts of cash, security l^s and security l^r. In the second date agents are once again endowed with a non-negative amount of cash, which they know in advance. Endowments are denoted by $e_i = (e_i^1, e_i^s, e_i^r; e_i^\sigma)$.

5.5 Constraints

In the first date non dealers face the following budget constraint:

$$e_i^1 + (p^s e_i^s - p^s l_i^s) + (p^r e_i^r - p^r l_i^r) + (h^s p^s z_i^s - (2-h^s) p^s w_i^s) + (h^r p^r z_i^r - (2-h^r) p^r w_i^r) = c_i^1 \tag{47}$$

While the dealers face:

$$e_d^1 + (p^s e_d^s - p^s l_d^s) + (p^r e_d^r - p^r l_d^r) + ((2-h^s) p^s z_d^s - h^s p^s w_d^s) + ((2-h^r) p^r z_d^r - h^r p^r w_d^r) = c_d^1 \tag{48}$$

Additionally, all agents face the following two box constraints:

$$w_i^s - z_i^s + l_i^s \geq 0 \tag{49}$$

and

$$w_i^r - z_i^r + l_i^r \geq 0 \tag{50}$$

Finally, for all agents, $c_i^1 \geq 0, z_i \geq 0$ and $w_i \geq 0$.

In the second date non-dealers face the following budget constraints:

$$\begin{aligned} &(e_i^\sigma + c_i^1) + l_i^s + l_i^{r,\sigma} + \\ &\quad (\rho_w^s p^s (2-h^s) w_i^s - \rho_z^s p^s h^s z_i^s) + (\rho_w^r p^r (2-h^r) p^r w_i^r - \rho_z^r p^r h^r z_i^r) = c_i^\sigma \end{aligned} \tag{51}$$

While dealers face:

$$\begin{aligned} &(e_d^\sigma + c_d^1) + l_d^s + l_d^{r,\sigma} + \\ &\quad (\rho_z^s p^s h^s w_d^s - \rho_w^s p^s (2-h^s) z_d^s) + (\rho_z^r p^r h^r w_d^r - \rho_w^r p^r (2-h^r) z_d^r) = c_d^\sigma \end{aligned} \tag{52}$$

6 Concluding Remarks and Future Research

The following are the more relevant conclusions that can be drawn from the model in section 4:

- In the absence of constraints on the dealer, spreads in the repo market should result from administrative costs inherent to the intermediation activity or from dealer market power.

- Under symmetric beliefs and haircuts the shorts should place more value on collateral possession than the longs.

- An increase in an already binding leverage ratio can increase spreads and will decrease the volume of transactions in the repo market. The overall welfare impact of this distortion is always negative, but the effect on the dealer is undetermined.

- Direct effects make additional equity less valuable under higher leverage ratios, general equilibrium effects might, however, make additional equity more valuable under higher leverage ratios.

- Sponsored Repo can be an effective tool in countering market distortions generated by macro-prudential regulation such as the leverage constraint. The overall cost of participating, in particular in terms of margins, is the crucial element in determining the amount of value sponsored repo can generate.

- Further investigation is needed with regards to potential distortions in the market from having the CCP collect margin and reinvesting it in repo.

Several avenues of research remain open with regard to the particular set up discussed in sections 4 and 5. On one hand it is possible to keep expanding the linear utility model of section 4 by including an additional security and the capital ratio. An example with analytical solutions of such model would be harder but perhaps still possible. On the other hand an example using the non-linear and more rigorous framework outlined in section 4 could provide the most valuable insights but will likely require numerical solutions. Another question of interest would be to compare the impact of all these regulations under different accounting standards, namely what would happen if short sales were treated as negative assets rather than liabilities and would, therefore, appear in the asset side of the balance sheet with a negative sign.

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