Mandatory Central Clearing and Financial Risk Exposure*

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Abstract

I analyze the effect of mandatory counterparty default insurance (central clearing) of over-the-counter (OTC) derivatives on aggregate financial risk exposure. I carefully model the competitive mechanisms in both the OTC derivatives and their insurance market. I show that the introduction of mandatory insurance empowers the for-profit central counterparty (CCP) to raise prices, wherefore only larger clients opt to additionally insure their derivatives (lower credit risk). Smaller clients instead exit the market and remain unhedged (higher market risk). I conclude with a model calibration and counterfactual policy evaluation for the EuroDollar FX derivatives market, showing that mandatory insurance increases aggregate financial risk.

Keywords: OTC derivatives, for-profit CCPs, mandatory central clearing, financial risk

JEL classifications: F38, G28, L5.

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1. Introduction

Central counterparties (CCPs) play an increasingly important role in financial risk mitigation by providing counterparty default insurance (central clearing) for over-the-counter (OTC) derivatives. OTC derivatives are bilateral contracts usually entered between large firms, hedge funds or pension funds (buyers) and banks or broker-dealers (sellers). They are used by buyers to hedge the market risk associated to assets worth more than $8 trillion USD globally (BIS, 2020). Holding these OTC derivatives however exposes buyers to seller default risk, stemming both from the seller's total OTC sales and from other business lines. To ensure payments even in case of seller default, buyers may additionally insure their OTC derivative at a CCP. The CCP consequently takes over the contracted transfer should the seller default.

The benefits of having counterparty default insurance were powerfully illustrated during the Lehman Brothers default in 2008. With $35 trillion of notional outstanding in OTC derivatives, Lehman Brothers defaulted on 5% of all global derivatives contracts at the time. However, only a small share of them were insured at a CCP against the default. And while the claims of buyers with insured derivatives were resolved within three weeks after the default, resolving of non-insured derivatives took several years (Cunliffe, 2018; Fleming and Sarkar, 2014).[1] Influenced by these events, increasing the use of counterparty default insurance became a global regulatory objective. And thus, at the 2009 Pittsburgh summit, the G20 leaders agreed to introduce mandatory counterparty default insurance of standardized OTC derivatives contracts.[2]

This regulatory change, not surprisingly, led to a significant increase in insured OTC derivatives. Further, sellers now post significantly more collateral both for their insured and non-insured OTC derivatives. Empirical evidence thus suggests that mandatory insurance indeed was successful in lowering counterparty default risk exposure in the OTC market (Cominetta et al., 2019). However, buyers exposed to the new regulatory regime report both increased derivatives prices and insurance fees. Additionally, especially smaller buyers experience difficulties in accessing the OTC market altogether. Both the increased prices and limited access have since resulted in former market participants to either lower or cease their hedging activities altogether (BCBS et al., 2018; ESMA, 2019a). Therefore, the benefits of lower credit risk seems to have come at the cost of higher exposure to market risk for at least some buyers.

[1] First payments were made only in 2012, coming at a loss (Cunliffe, 2018; Fleming and Sarkar, 2014).

[2] Mandatory counterparty default insurance was introduced as part of the Dodd Frank Act in the US (U.S. CFTC, 2019) and as part of the EMIR regulation in the EU (European Commission, 2019b); for the equivalent regulations in other countries see (BCBS et al., 2018))

Research Agenda Focusing on the trade-off between credit risk and market risk, this paper analyzes the effect of mandatory counterparty default insurance of OTC derivatives. I start by carefully modeling the competitive mechanism in both the OTC derivatives market and their insurance market, describing how prices and traded quantities are determined. Here, I emphasize how a monopolistic for-profit CCP may also impact the equilibrium outcomes in the derivatives market, both before and after the introduction of mandatory insurance. In this setting, I then examine how the CCP's profit maximizing objective (dis-)aligns with the regulatory objective to mitigate risk exposure. This provides a rationale for why especially smaller market participants suffer from increased market risk exposure. Ultimately, I discuss whether this must be weighted against the decrease in seller credit risk that benefits not only this but also other markets.

For the purpose of providing these insights, I first develop a theoretical model that builds mostly on earlier works by Biais et al. (2012, 2016) and Huang (2019): risk-averse buyers purchase derivatives to hedge their exposure to market risk; risk-neutral derivatives sellers may strategically default; and a monopolistic for-profit CCP offers counterparty default insurance. However, to capture the downstream effects of a regime change more accurately, I relax the standard assumption that buyers only trade with a single (randomly assigned) seller. Instead, I assume that buyers can additionally trade with any other seller upon the payment of switching costs. Further, I assume that buyers are heterogeneous in their size, such that the switching costs have differentiated effects.

This combination of buyer heterogeneity and switching allows me to provide a rich set of new theoretical insights. A core contribution is to study how the for-profit CCP restricts direct access via a two-part tariff system. Here, previous models with homogeneous buyer-seller relationships are limited to assuming that all market participants have equal access to the CCP (Antinolfi et al., 2018; Capponi et al., 2018; Duffie and Zhu, 2011). In reality, only sellers that pay the fixed fee (clearing members) directly access the CCP, providing intermediation for other agents. To the best of my knowledge, this is the first paper to endogenenize the dual role of sellers as derivative counterparties and potential clearing members. This allows me to study how the monopolistic for-profit CCP exploits its two-part tariff system under both voluntary and mandatory insurance to heavily influencing the downstream derivatives market. I am thereby able to understand the heterogeneous effect of the regime shift on both buyers and sellers of different sizes, and their consequent risk exposure.

I complement the theoretical analysis with a calibration exercise to illustrate how these insights can be utilized to understand the effects of mandatory counterparty insurance in a specific derivatives market. For this purpose, I parameterize the model environment to the European EuroDollar FX derivatives market. Simulating the market equilibria under both voluntary and mandatory insurance, I quantify the effect of a regime switch on the CCP's profits, buyers' utilities, and sellers' profits and default probabilities. Given these, I then derive the changes in the average buyer's credit and market risk exposure, and the average seller's default probability. Ultimately, comparing their relative magnitudes under both insurance regimes allows me to perform a counterfactual analysis of aggregate financial risk exposure.

Findings To capture the heterogeneous buyer size in an intuitive way throughout this paper, I will refer to buyers as either being small, medium sized or large. Similarly, I label sellers matched with small, medium sized and large buyers, as small, medium sized and large respectively. The model framework contains three stages: First, the CCP sets its two-part tariff system and sellers decide whether to become clearing members. Secondly, buyers and seller trade the derivative and mandatorily/voluntarily add a counterparty default insurance. In the third stage, the underlying asset uncertainty realizes, sellers may strategically default, and pay-offs are realized. Given this structure, the model is solved through backwards induction. And the consequent sub-game perfect Nash equilibrium (SPNE) characterizes the CCP's entry decision and two-part tariff, sellers' clearing membership choice, derivative and insurance prices, buyers' choice of seller (switching/no switching) and total sales.

I find that under mandatory insurance, the CCP's two-part tariff system introduces a unique size threshold: All smaller buyers and sellers exit the market; and all medium sized and larger sellers become clearing members and sell the bundle of derivative and insurance products. Because insurance is mandatory, the sellers are able to capture the buyers' entire utility gains through the derivatives and insurance price. This implies for one that buyers are actually indifferent between participating in the market or not. It further implies that buyers are captive and never switch, as only realizing reservation utility does not warrant the payment of switching costs.

This is different under voluntary counterparty default insurance. Here, buyers can hold the derivative also without insurance. This strengthens their negotiation stance, resulting in over-all higher utility. Because buyers anticipate utility gains from (at least) the derivative, they also now consider switching to be worthwhile. And while the increased competition reduces derivatives prices (relative to mandatory insurance), this is not entirely bad news for sellers. Being able to offer only the derivative also reduces their pressure to become a clearing member: They are not automatically forced to exit the market, should they choose not to pay the fixed entrance fee. This reduction in CCP market power results in both smaller and medium sized buyers/sellers solely trading the derivative. Larger sellers are also here clearing members and trade the bundle of derivative and insurance. However, as I will show later in the simulation, under certain market characteristics, these sales might be insufficient to incentive CCP entry.

Not surprisingly, I therefore find that a monopolistic for-profit CCP strictly benefits from the increased market power under mandatory counterparty default insurance. Contrary to this, the effect on buyers is unambiguously negative, when their option of holding the derivative alone is removed. The effect on sellers however depends on size. Here, it is easy to see that small sellers strictly suffer under mandatory insurance: Instead of offering only the derivative, they exit the market. Contrary to this, larger sellers strictly benefit: They offer both the derivative and insurance under both regimes, but can charge higher prices under mandatory insurance due to the decreased negotiation stance of buyers. The effect on medium sized sellers is ambiguous and depends on market characteristics: Under mandatory insurance, they face additional costs of becoming clearing members; however, they can potentially off-set this by charging higher prices due to decreased buyer options.

Beside the differentiated expected profits/utilities under the two regimes, the paper also sets out to comment on the overall impact on financial risk exposure. Here, the theoretical analysis highlights three margins of change: buyers' credit risk exposure, buyers' market risk exposure, and a credit risk externality. For the first two, the model matches the originally anticipated effects of higher market risk and lower credit risk exposure: Under mandatory insurance some (smaller) buyers are fully exposed to their market risk, but because all actual sales are insured, their is no credit risk. Under voluntary insurance, only large buyers and sellers insure and thus remove credit risk; small and medium sized buyers hold the derivative alone and are exposed to credit risk but not to market risk. The model also uncovers a third financial risk factor: Having no uninsured and more insured sales under the mandatory regime results in strictly lower seller default probabilities. This will also benefit other financial markets, increasing overall financial stability.

All three channels, and thus also their aggregate effect, crucially depend on the density of small and medium sized relative to larger buyers and sellers. To highlight how regulators can apply these insights to a specific OTC derivatives (sub-)market, I conclude the analysis by calibrating the model environment to the EuroDollar FX derivatives market. Consequently, I perform a counterfactual simulation under both regimes. I show that this market is predominantly used by many, yet relatively small buyers. Simultaneously, the overall impact of this market on seller default risk is little. Thus regulators, correctly, refrain from mandating counterparty default insurance in this market.

Literature With these empirical and theoretical insights, I contribute to a small but growing literature analyzing the role that CCPs play in counterparty risk mitigation and overall financial stability. Led by Biais et al. (2012, 2016), early papers are exclusively theoretical and focus mainly on moral hazard effects of (voluntary) counterparty default insurance.[3] They show that access to central clearing creates disincentives for buyers and sellers of OTC derivatives to enter more secure trades. As Antinolfi et al. (2018) highlight, these adverse effects are compensated when the CCP reveals sufficient private information to counteract moral hazard. Commonly, these papers introduce mutually-owned CCPs funded by the sellers with the objective to mitigate risk via risk-sharing. More recently and especially since the introduction of mandatory insurance, independently owned for-profit CCPs were able to gain importance in the market (Huang, 2019).

Focusing on the impact of especially for-profits CCPs on systemic risk, the theoretical papers by, for example, Amini et al. (2013), Capponi and Cheng (2018) and Huang (2019) have since complemented the earlier research. These papers mostly abstract from moral hazard problems. Instead, they highlight that for-profit CCPs ultimately fail to internalize the risk mitigation object: They set fees and collateral requirements that are too high and low respectively to achieve the highest risk-mitigation possible. I build on these papers by introducing heterogeneity in the buyer size and show that the size of the externality does not affect all agents equally.

Further, I relax the commonly used assumption under which each buyer is randomly matched with exactly one seller, after which the buyer becomes captive (Antinolfi et al., 2018; Huang, 2019; Koeppl et al., 2012). Instead, I allow buyers to switch away from their matched seller, for which they incur a fixed switching cost.[4] This captures the role of established business relationships that rose in importance as the OTC market has become more regulated.[5] I thereby further contribute to the ongoing debate on the price setting mechanism in the OTC market, with early works by Duffie et al. (2005) and Perez Saiz et al. (2012). They study

[3] See also Koeppl et al. (2012); Koeppl (2013)

[4] The impact of switching cost frictions is previously mostly studied in the loan market. Please see Schwert (2018) for a detailed literature review on this.

[5] An important new friction are customer due diligence requirements. When on-boarding to new sellers, buyers are required to provide substantial documentation about their business lines, making it a costly and lengthy process to purchase from a new seller, where there are no established prior business relationships (European Commission, 2019a; ESMA, 2018).

previously dominant market frictions, such as physical distance and sequential search, which have become less important with the introduction of pricing platforms. Combining buyer size heterogeneity with more recent frictions, such as on-boarding cost due to know-your-customer requirements, allows me to provide novel theoretical insights on differential pricing in this market; ultimately bringing me closer to the empirical literature.

Here, my paper most closely relates to the empirical study by Hau et al. (2021), which I also use as a source for data moments. They document derivative price discrimination given a range of buyer characteristics, including buyer size, in the EuroDollar FX OTC derivatives market. As this market is not yet subject to mandatory counterparty default insurance, their paper is limited to reporting the status quo. I provide a theoretical counterpart to their empirical findings. Subsequently calibrating my model and performing a structural exercise, allows me to also discuss the equilibrium outcomes under the counterfactual case of mandatory default insurance. Other, less related empirical studies are the papers by Eisfeldt et al. (2018) and Jager and Zadow (2021), respectively studying the impact of CCP exit and entry on other market participants. Both have in common that they take the voluntary insurance-policy regime as given, and do not comment on the counterfactual case.

Overview The remainder of the paper is organized as follows. Section 2 describes the three-period model environment, populated by risk-averse buyers, risk-neutral sellers and a monopolistic for-profit CCP.The model is solved via backwards induction, such that Section 3 starts with deriving equilibrium outcomes at $t = 1$. Here, Section 3.1 and Section 3.2 describes the market outcome under mandatory and voluntary counterparty default insurance respectively. Then, Section 4 derives the optimal choices of the CCP at $t = 0$. Section 5 contains the empirical exercise for the EuroDollar FX derivatives market. The paper concludes with Section 6, summarizing the main findings and discussing their implications. All proofs are in the Appendix.

2. The Model Environment

First, I briefly outline the general setting, followed by a more detailed description of the agents, the product choices, the competitive setting and the equilibrium notion.

Model Overview There are three dates, $t = 0, 1, 2$, a large set of risk-averse buyers, a large set of risk-neutral sellers, and a monopolistic for-profit CCP. At $t = 0$, every seller (she) is matched with exactly one buyer (he).[6] Buyers are endowed with a heterogeneous number of risky assets.[7] The CCP (it) decides on a two-part tariff system and collateral requirements.[8] Subsequently, sellers may become clearing members by paying the fixed entry fee for access to the CCP.[9] At $t = 1$, all trades take place. Buyers and sellers trade a financial derivative product d used for hedging the asset risk. Here, buyers must pay switching costs when interacting with any other seller besides their initial match. Additionally, clearing members and their product d buyers may mutually agree to purchase product m. Provided by the CCP for a variable fee, product m insures buyers against seller default. At $t = 2$, all uncertainty resolves, payments defined by product d and m are made, and sellers may strategically default.[10] All agents share a common discount factor that is assumed to be 1.

Table 1: Model Timeline

	t = 0	**t = 1**	**t = 2**
CCP	• Sets two-part tariff and collateral • Gets entry fee from clearing members	• Sells prd. m via clearing members • Collects variable fee and collateral	• Pays transfers to insured buyers with defaulting sellers
Sellers	• May become a clearing member	• Sell product d to buyers • Clr. mbs. may agree to product m	• Choose whether to default • Pay transfers if not defaulting
Buyers	• Endowed with a_b risky assets	• Buy product d to hedge assets • Buy product m to insure product d	• Get transfers given asset endowment and product choices

CCP The for-profit CCP is a monopolistic insurer of seller default risk, and providing insurance product m is its only (potential) business line.[11] The structure of product m, described in detail below, is designed by regulators; the CCP's complete profit maximization problem and entry decision are studied in detail in Section 4. For now note that at $t = 0$, the CCP maximizes profit by choosing a two-part tariff system and collateral requirements for product m. I label the sellers, that obtain the right to access the CCP by paying the fixed entrance fee, as clearing members. I assume explicitly that non-clearing members have

[6]This is similar to Antinolfi et al. (2018); Huang (2019); Koeppl et al. (2012)

[7]This is a new model feature assumed explicitly to study the heterogeneous reaction given buyer size.

[8]The monopolistic CCP is modeled similar to Huang (2019); Capponi and Cheng (2018); Amini et al. (2013), but its fee structure is extended to a two-part tariff system with clearing members.

[9]Here, I explicitly assume that buyers cannot access the CCP directly. This is to reflect the reality that regulatory requirements in terms of size and financial due diligence are impossible to meet for buyers. Instead, clearing member sellers may intermediate on their behalf.

[10]The default decision of sellers and how collateral enters is modeled similar to Huang (2019).

[11]A for-profit CCP is prohibited by regulators to have other business lines. In the EU central clearing and CCPs are regulated in the European market infrastructure regulation (EMIR) and in the US by the Dodd Frank Act (European Commission, 2019b; U.S. CFTC, 2019)

no access to the CCP and thus product m.[12] The CCP enters the market, when expecting positive profits from the entry fee, the variable fee and product m sales, and losses exceeding collateral upon clearing member default.[13] Here, it takes into account that other agents expect the CCP to default with probability zero.[14]

Sellers There exists a finite, but large set S of risk-neutral sellers.[15] They are protected by limited liability and thus may strategically default at $t = 2$. Seller default is determined by their (un-)insured sales in this market and the realization of an exogenous income stream L.[16] L is assumed to be an i.i.d draw from a normal distribution with mean $\mu_L > 0$ and variance σ_L^2: $L \sim N(\mu_L, \sigma_L^2)$. Denote the profits of a seller s at time t with Π_s^t and the default probability with $D_s = Pr(\Pi_s^2 \leq 0)$. Then, a seller's total expected profits $\mathbb{E}_0\Pi$ take on the following functional form:[17]

$$\mathbb{E}_0\Pi = \Pi_s^0 + \mathbb{E}_0\Pi_s^1 + (1 - D_s)\mathbb{E}_0\left[\Pi_s^2 \mid \Pi_s > 0\right] + D_s \cdot 0 \tag{1}$$

As sellers are heterogeneous in their matched buyer size (more immediately below), their clearing membership decision is not uniform.[18] I denote the subset of clearing members with M, and their total expected profits with an additional subscript $_M$. Then for all sellers (not) choosing to become a clearing member, it holds that:

$$\forall s \in M: \quad \mathbb{E}_0\Pi_M \geq \mathbb{E}_0\Pi \tag{2}$$

$$\forall s \notin M: \quad \mathbb{E}_0\Pi_M < \mathbb{E}_0\Pi \tag{3}$$

Buyers There exists a large set B of risk-averse buyers with mean variance utility $u(x) = E(x) - \frac{\gamma}{2}Var(x)$, where x are the time-2 pay-offs and $\gamma > 0$ is the degree of risk-aversion.[19] At $t = 0$, each buyer b is endowed with a_b different risky assets. a_b is drawn from a discrete

[12]Note that previous versions of this paper additionally studied the case where non-clearing members could access the CCP via a clearing member that intermediates. However, this was never optimal in equilibrium and would not alter any of the below derived results. It was thus omitted to improve readability.

[13]See Jager and Zadow (2021) for an empirical paper studying the entry decision of CCPs into a market.

[14]Appendix A.3 discusses this assumption in detail and provides a micro-foundation.

[15]By assuming S is large, the presence of a monopolistic seller is ruled out.

[16]The introduction of other business lines is motivated by the fact that Lehman Brothers defaulted, despite having significant positive profits from their OTC business lines (Fleming and Sarkar, 2014).

[17]See Appendix A.2 for a detailed discussion of $\mathbb{E}_0\Pi$ and$\mathbb{E}_0\Pi_M$. Here note that clearing members: at $t = 0$ pay the fixed fee; at $t = 1$ collect prices for product d and m sales at and post collateral, at $t = 2$ either default or collect L, profits from product d sales and receive back collateral. Non-clearing members: at $t = 1$ collect prices for product d, at $t = 2$ either default or collect L and profits from product d sales.

[18]Sellers matched with larger buyers sell higher quantities; allowing them to afford the fixed fee e_m.

[19]See for example Eisfeldt et al. (2020) for a similar approach.

distribution $\mathcal{A}$ over positive integers with minimum value $\underline{a}$ and maximum value $\overline{a}$: $a_b \sim \mathcal{A}\{\underline{a}, \overline{a}\}$. The distribution $\mathcal{A}\{\underline{a}, \overline{a}\}$ is common knowledge, the realization of a_b is however only know to the buyer in question and the sellers.[20] Each of the a_b assets is of unit size and pays a gross return $1+\tilde{r}$ at $t=2$. Here, $1+\tilde{r}$ is an i.i.d. drawn from a normal distribution with mean μ_r and variance σ_r^2: $1+\tilde{r} \sim N(\mu_r, \sigma_r^2)$ with pdf $f(\cdot)$ and cdf $F(\cdot)$.[21] A buyer's per-asset reservation utility, denoted u_r, is thus:

$$u_r = \mu_r - \frac{\gamma}{2}\sigma_r^2 \tag{4}$$

Product d At $t=1$, sellers offer product d to buyers to hedge their asset risk. Sellers can always provide product d at zero marginal cost and charge a price p_d. The product d specifies a transfer τ from seller to buyer paid at $t=2$. τ is a function of the underlying asset's realized return: $\tau = \mu_r - (1+\tilde{r}) \sim N(0, \sigma_r^2)$.[22] When evaluating product d, buyers must however additionally account for the possibility of the seller defaulting on τ: When seller default coincides with $\tau \leq 0$, bankruptcy laws require the buyer to pay τ regardless, leaving the buyer with μ_r; when seller default coincides with $\tau > 0$, the buyer will not receive the transfers and is left with the asset realization $1+\tilde{r} < \mu_r$. Unable to determine a seller's true probability of defaulting on positive transfers, buyers instead form a prediction $\widehat{D}_s$.[23] $\widehat{D}_s$ is endogenously determined in equilibrium, and a function of L and the seller's anticipated equilibrium sales.[24] Denote with u_d a buyer's per-asset utility given $t=2$ pay-offs x_d, emerging from hedging as single risky asset with a product d. Further, denote the pdf associated with the pay-offs x_d with $f_d(x_d)$. Then:[25]

$$u_d = E(x_d) - \frac{\gamma}{2}Var(x_d) \qquad \text{where} \qquad f_d(x_d) = \begin{cases} \widehat{D}_s f(x_d) & x_d \leq \mu_r \\ \widehat{D}_s \left(1 - F(\mu_r)\right) + (1 - \widehat{D}_s) & x_d = \mu_r \\ 0 & x_d > \mu_r \end{cases} \tag{5}$$

[20] Hence, neither the CCP nor other buyers know this. This follows the narrative of OTC trading platforms. Here, buyers post their demand for hedging and sellers post prices. All resulting trades are however private, bilateral contracts. Therefore, parties not directly involved in the competitive bidding or the final deal have no access to the terms of trade, which includes notional size.

[21] Introducing variable returns that are draw from a continuous distribution is an extension of existing works, such as Biais et al. (2012, 2016); Huang (2019)

[22] To the best of my knowledge this is the first paper that models transfers that fully insure over a continuum of asset realizations, thereby extending the frameworks with discrete asset state-space proposed in Biais et al. (2012, 2016); Perez Saiz et al. (2012); Huang (2019).

[23] A seller's total sales is unknown to buyers, but correctly anticipated in equilibrium.

[24] Note that τ inherits the i.i.d. property from the underlying asset, implying that transfers are uncorrelated within and across buyers, and independent from L.

[25] Please see Appendix A.1 for the closed form expression of (5) in terms of model parameters.

Product m The realized product d sales may subsequently be insured against the seller default through combining it with a product m. Product m is provided by the CCP via a two-part tariff and collateral system, which is set at $t = 0$ subject to several regulatory constraints.[26] For one, the CCP sets a fixed entrance fee e_m that is paid by sellers at $t = 0$ for the right to access the product m. Here, the CCP must set e_m such that there exist at least two clearing members.[27] Further, the CCP charges a non-discriminatory variable fee v_m for every product m. Here regulators require both product d counterparties to simultaneously and separately purchase product m at $t = 1$.[28] Finally, the CCP must set a strictly positive collateral requirement $g_m \geq \underline{g_m}$.[29]

Collateral g_m is collected from clearing members for every product m purchase at $t = 1$, and at $t = 2$ is either returned to non-defaulting clearing members or used to cover defaulting clearing members' transfers. Tying up liquidity in the form of collateral, clearing members face an opportunity cost δ for every unit posted.[30] To compensate for their incurred cost from agreeing to product m, clearing members ask their product d buyers for an additional price p_m, also paid at $t = 1$. Buyers are willing to pay (reasonable) v_m and p_m, as holding product m allows them to eliminate all risk: They expect the CCP to cover transfers, even if those exceed the defaulting clearing member's posted collateral.[31] A buyer's utility u_{dm} from combining a single risky asset with both a products d and m is thus:

$$u_{dm} = \mu_r \tag{6}$$

Switching Costs and Captive Consumers The initial random match between a buyer and a seller represents existing business relationships, and establishing new relationships is costly.[32] Therefore, buyers pay strictly positive switching costs C before trading product d with an unmatched seller.[33] These switching costs thus create incentives for buyers to

[26] These restrictions are specified in the Dodd Frank Act (U.S. CFTC, 2019) and the EMIR regulation in the EU (European Commission, 2019b). For a global overview, please see (BCBS et al., 2018).

[27] With this, regulators rule out a monopoly in the intermediation market. Further, they ensure the CCP is exposed to more than one seller, thereby diversifying the CCP's exposure to seller default risk.

[28] To my knowledge, this is the first paper that carefully incorporates into the analysis that both counterparties of a product d need to agree to the purchase of product m.

[29] Throughout the paper, I perform comparative statics over this parameter and subsequently compare it to the currently required minimum collateral equal to the 5-day 99.5% value-at-risk in the simulation.

[30] This is motivated by an opportunity cost of capital that could else have been invested (Huang, 2019).

[31] Underlying this is the assumption that the CCP is not expected to default, even if collateral is insufficient to cover τ. See Appendix A.3 for more details.

[32] There is a rich empirical banking literature documenting that informational frictions result in costly on-boarding procedures for new clients. See Schwert (2018) for a detailed discussion.

[33] Introducing switching cost is an extension to Biais et al. (2012), where buyers are captive once matched with a good or bad seller.

purchase from their initially matched seller. Contrary to this, the risk aversion γ incentivize buyers to switch to the seller they believe to be the safest. Especially for small buyers' however, the per-asset switching cost C/a_b may exceed their total utility gain from switching for product d and (potentially) m to safer sellers. These buyers are consequently labeled captive consumers.[34]

Quantities, Prices and Competition I assume that a single asset can either be fully hedged and then insured or not at all, but never partially. However, I allow buyers to freely choose whether to purchase products d and m for none, some or all of their assets. The fraction of hedged and subsequently insured assets will depend on prices p_d and p_m. Here, I assume that all sellers compete over prices p_d in a Bertrand fashion. Additionally, clearing members set price p_m in a take-it-or-leave-it fashion: The product d seller makes a single offer without competition; the buyer subsequently chooses whether to accept or refuse.[35] I allow for sellers to price discriminate, such that p_d and p_m may depend on individual buyer characteristics, switching costs, the number of assets hedged/insured, and the buyer incurred portion of CCP fees.[36] Further, p_m is set after product d sales have realized and thus may additionally depend on p_d.

Imperfect Information and The Equilibrium Notion Agents are informed about all model elements unless specifically stated otherwise: The CCP does not observe the realized buyer sizes and the resulting matches, but only the underlying distribution $\mathcal{A}\{\underline{a}, \overline{a}\}$ and market size B.[37] Buyers neither observe the other buyers' realized sizes nor prices offered to them nor their choice of seller.[38] Given this, I apply the notion of sub-game perfect Nash equilibrium (SPNE) with incomplete information; relying on backwards induction to derive all quantities, prices, fees, and collateral requirements.

Parameter Restrictions I assume that the following parameters are strictly positive: asset return mean μ_r and variance σ_r^2, minimum and maximum buyer sizes $\underline{a}$ and $\overline{a}$, mean μ_L and variance σ_L^2 of exogenous profits L, sellers' collateral cost δ, and switching cost C. Further, I assume that underlying agency frictions result in p_d and p_m being weakly positive.[39]

[34] See for example Armstrong and Vickers (2019) for a detailed analysis of captive consumers.

[35] This is because the risk-neutral clearing members must not only agree to the insurance, but can also refuse it, thus giving them the entire bargaining power.

[36] Recall, the CCP's fees and collateral are set in a monopolistic, non-discriminatory fashion.

[37] OTC contracts are private, bilateral trade agreements and therefore modeled as contracts under incomplete information (Acharya and Bisin, 2014; Antinolfi et al., 2018; Eisfeldt et al., 2018).

[38] The latter two are important, as else buyers could infer the size of others from prices and seller choices.

[39] Underlying frictions may for example be that individual broker bonuses that depend on their $t = 1$ profits. Further, regulatory pressure may result financial institutions avoiding speculative losses.

Similarly, I assume that the CCP's entry fee e_m and variable fee v_m are weakly positive.

For the collateral requirements g_m, there exist two model implied thresholds. The first one, labeled g_m^*, denotes the collateral level required for seller default probabilities to strictly decrease in *insured* product d sales. The second one, labeled g_m^{**}, exceeds the first and denotes the collateral level required to induce that seller profits are a strictly increasing function in combined product d and m sales. For the remainder of the main analysis, and confirmed by the calibration exercise later, I assume that the regulatory collateral requirement $\underline{g_m}$ exceeds g_m^{**}. For completeness, Appendix D states the results also for the alternative case.

$$g_m^* = \frac{\mu_L \sigma_r^2}{2\sigma_L^2} \tag{7}$$

$$g_m^{**} = \frac{\mu_L \sigma_r^2}{2\sigma_L^2} + \frac{\sigma_r^2}{2\sigma_L} \tag{8}$$

$$\underline{g_m} > g_m^{**} > g_m^* \tag{9}$$

3. Equilibrium Prices and Quantities at Time 1

This section derives the equilibrium outcomes at $t = 1$, taking the realized results of $t = 0$ as given. Here, Sections 3.1 and 3.2 derive the equilibrium under mandatory and voluntary counterparty default insurance respectively. In Section 4.5, I concluded with a brief comparison of the outcomes under the two regimes.

However, before diving into the analysis, I start with defining the different types of equilibria that may arise at $t = 1$. For this purpose, denote a buyer's aggregate utilities from staying and switching with $U(a_b; stay)$ and $U(a_b; switch)$ respectively; and the total payments in either case with $P(a_b; stay)$ and $P(a_b; switch)$. All four terms are equilibrium objects and depend on: the buyer's asset endowment size, the equilibrium share of hedged and insured assets, the number of switching buyers, and the switching buyers' choice of sellers. More in the following sections. For now note that, characterized by the buyers' choices of product d seller at $t = 1$, three types of equlibria may arise: a no switching equilibrium, a partial switching equilibrium and a fully switching equilibrium.

No Switching Equilibrium A no switching equilibrium is characterized by every buyer purchasing product d exclusively from his matched seller. Or in other words, observing all equilibrium prices and C, for every buyer the utility of staying must exceed the utility from switching. Then, more formally, the no switching equilibrium exists if:

$$U(a_b; stay) - P(a_b; stay) \geq U(a_b; switch) - P(a_b; switch) - C \qquad \forall b \in B \tag{10}$$

Fully Switching Equilibrium In a fully switching equilibrium, all buyers find it optimal to switch for their product d purchase. And thus given all prices and C, for every buyer there exists at least one unmatched seller where the aggregate utility from switching exceeds the utility from staying. This is formalized in condition (11) below:

$$U(a_b; switch) - P(a_b; switch) - C > U(a_b; stay) - P(a_b; stay) \qquad \forall b \in B \tag{11}$$

Partial Switching Equilibrium In a partial switching equilibrium, at least one buyer finds staying optimal and simultaneously at least one buyer prefers to switch sellers for product d. I denote the subsets of staying and switching buyers as $B_{stay} \subset B$ and $B_{switch} = B \setminus B_{stay}$ respectively. Then buyers select into these subsets as follows:

$$U(a_b; stay) - P(a_b; stay) \geq U(a_b; switch) - P(a_b; switch) - C \qquad \forall b \in B_{stay} \tag{12}$$

$$U(a_b; stay) - P(a_b; stay) < U(a_b; switch) - P(a_b; switch) - C \qquad \forall b \in B_{switch} \tag{13}$$

Captive Consumers Recall that buyers vary in size due to their different number of risky assets a_b, yet face the same switching cost C. Especially for smaller buyers, having a high per-asset switching cost, switching may come at a total loss. These buyers are captive consumers, as they never consider switching. Define a buyers total reservation utility with $U_r = a_b u_r$. Then, a buyer is captive if:

$$U(a_b; switch) - C \leq U_r(a_b) \tag{14}$$

3.1. Mandatory Counterparty Default Insurance at Time 1

With these definitions in mind, I now derive the equilibrium outcome under mandatory counterparty default insurance at $t = 1$. Here, product d cannot be held alone, and buyers have two choices: buying the bundle from a clearing member or receiving their reservation utility. I start with analyzing the market outcome, when at least some clearing members offer the product d and m bundle (Section 3.1.1). Subsequently, I comment on the outcome without clearing members or when those never offer the product bundle (Section 3.1.2).

3.1.1. Clearing Members Offering The Bundle

For this sub-section, I explicitly assume that clearing members exist and indeed are willing to offer the bundle of product d and m. I derive the buyers' choices of clearing member, the bought quantities and paid prices through backwards induction: First, I derive p_m, then p_d and the share of assets combined with bundle of product d and m, and finally the buyers' choice of seller.

Product m Prices To derive the price p_m, I assume that product d sales have realized. Then, the product d seller (always a clearing member) can take advantage that buyers cannot hold product d alone: A buyer can only choose between agreeing to the bundle at price p_m or remaining unhedged with reservation utility u_r. Utilizing this, the seller sets p_m such that the buyer is just indifferent between holding the bundle of product d and m or remaining unhedged. As equation (15) illustrates, the sellers account for the buyer paying v_m to the CCP, and p_d to said seller for product d.

$$p_m = u_{dm} - u_r - v_m - p_d \tag{15}$$

Price p_d and No Switching Because p_m is a linear function in p_d, any increase in p_d is compensated by a one-for-one decrease in p_m. Thus individually, p_m and p_d are not uniquely determined. In equilibrium, a seller may set any combination of p_m and p_d, where their sum is equal to the buyer's utility gains from holding both products. The total bundle price thus becomes:

$$p_d + p_m = u_{dm} - u_r - v_m \tag{16}$$

Bundle Quantities & No Switching Equilibrium The bundle price (16) has two implications. First, for any collateral level $g_m \geq \underline{g_m}$, this price results in clearing members' profits strictly increase in bundle sales. And hence, they offers the bundle for all of a buyer's assets. Second, bundle price (17) fails to internalize any switching costs potentially paid for the product d purchases by unmatched buyers. A buyer considering to switch for product d, and anticipating p_m, thus expects a total utility $U_r - C$ — independently of the actually bought bundle quantities upon switching. However, both when staying with his matched seller or not purchasing any product at all, the buyer would instead receive his aggregate reservation utility U_r. Thus, all buyers are captive under mandatory counterparty default insurance and never switch.

***Proposition* 1.** *Under mandatory insurance, all buyers are captive. Hence, the no switching equilirbium is unique and characterized by:*

(i) Buyers, matched with a clearing member, purchasing the product d and m bundle from said seller at a bundle price:

$$p_d + p_m = u_{dm} - u_r - v_m \tag{17}$$

(ii) Buyers, not matched with a clearing member, exiting the market.

3.1.2. A Market Without Clearing Members

The market outcome in the absence of any clearing member follows directly from property *(ii)* in *Proposition 1*: If there is no clearing member offering the bundle, then all buyers exit the market and remain fully exposed to their market risk. And hence, the market experiences failure.

***Corollary* 1.** *Under mandatory insurance, the absence of any clearing member offering the product d and m bundle causes market failure.*

3.2. Voluntary Counter Party Default Insurance at Time 1

In this section, I derive the equilibrium outcome at $t = 1$ under the counterfactual case of voluntary counterparty default insurance. Here, buyers have three options: receive their reservation utility, hold product d as a stand-alone, or additionally add-on a product m. Again, I study two different scenarios: there exist clearing members offering product m (Section 3.2.1), and there exists no clearing member offering product m (Section 3.2.2).

3.2.1. Clearing Members Offering Add-on Product m

Assuming that there exists clearing members that offer product m, I again rely on backwards induction to derive the equilibrium outcomes: First, I assume that that product d sales have realized and derive p_m given p_d. Here, I account for the fact that product d can be held as a stand-alone. Then, I derive the prices p_d , buyers' choice of sellers and share of hedged risky assets. I conclude with comparative statics over switching cost and show how different levels of C impact the equilibrium outcome.

Product m Prices Buyers can always at least purchase product d as a stand-alone. Thus, the product d seller, if a clearing member, can at most charge the utility gains from adding product m on to product d. Setting p_m to capture all buyer surplus, the clearing member accounts for the buyers variable fee v_m paid to the CCP, but not the product d price p_d:

p_d is paid regardless whether a product d combined with a product m or not, consequently entering both sides of the buyer's participation constraint and dropping out. Equation (18) formalizes this:

$$p_m = u_{dm} - u_d - v_m \tag{18}$$

Given the price p_m, buyers extract no further utility surplus from purchasing product m. Additionally, the (sunk) switching cost paid upon product d purchase are not accounted for in p_m. From this, it immediately follows that buyers only compare the utility gains from switching for product d against the associated switching costs, when deciding whether to stay with their matched seller.

Product d Prices Knowing that the subsequent insurance decision does not influence a buyer's seller choice, I can now derive the product d prices. First, it can be shown that buyers always pay $p_d = 0$ upon switching. The market is large, and thus ex ante no unmatched seller has unique characteristics in the eyes of any buyer. Further, product d can be provided at zero marginal cost, yet all sellers' profits strictly increase in any product d sale.[40] Thus, standard Bertrand competition arguments apply and all unmatched sellers offer unrestricted access to product d at:

$$p_d(a_b; switch) = 0 \tag{19}$$

With all unmatched sellers offering product d for zero costs, buyers only consider switching to the clearing members with the highest anticipated product m sales from *other* buyers:[41] Insuring all their product d sales, and experiencing decreasing default rates in their total number of sales, implies them to be safest. I denote the associated utility from switching for product d to the largest clearing members with $u_d(a_b; switch)$. To deter switching, the matched seller must thus be able to set a positive price $p_d(a_b; stay)$ that, given per asset-switching cost C/a_b, makes that the buyer is just indifferent between staying or not. If not possible retain the matched buyer, competition drives down the price $p_d(a_b; stay)$ to zero. Thus, for matched buyers $p_d(a_b; stay)$ is:

$$p_d\left(a_b, stay\right) = \max\left\{C/a_b - \left[u_d\left(a_b; switch\right) - u_d\left(a_b; stay\right)\right],\ 0\right\} \tag{20}$$

[40] Providing uninsured derivatives increases the variance of total seller profits. Protected by limited liability and strategic default however more so for positive than for negative realizations.

[41] Note that the belief over seller default probability $\widehat{D}$ is formed before any product m sale. Hence, the buyer is indifferent whether he himself is additionally offered the add-on. He however cares about the other product m sales given their reduction of seller default risk.

The price (20) applies if the buyer is non-captive and thus the matched seller indeed has to compete for him. For captive buyers, the per-asset switching costs exceeds the utility benefits from switching. With captive buyers never considering to switch, the matched sellers can utilize this by setting $p_d(a_b, captive)$ equal to the utility gains from product d:

$$p_d\left(a_b, stay\right) = \max\left\{C/a_b - \left[u_d\left(a_b; switch\right) - u_d\left(a_b; stay\right)\right],\ 0\right\} \tag{21}$$

***Lemma* 1.** *Under voluntary insurance, sellers always offer product d and additionally, clearing members always offer product m.*

1. *For product d, sellers charge:*
   - *(i) Their unmatched buyers a price:*

$$p_d\left(a_b, switch\right) = 0 \tag{22}$$

   - *(ii) Their non-captive matched buyer a price:*

$$p_d\left(a_b, stay\right) = \max\left\{C/a_b - \left[u_d\left(a_b; switch\right) - u_d\left(a_b; stay\right)\right],\ 0\right\} \tag{23}$$

   - *(iii) Their captive matched buyer a price:*

$$p_d(a_b, captive) = u_d\left(a_b; stay\right) - u_r \tag{24}$$

2. *For product m, clearing members charge a price:*

$$p_m = u_{dm} - u_d - v_m \tag{25}$$

Switching in Equilibrium Following *Lemma 1*, two properties common to all equilibria can be derived. For one, all buyers choose the same seller and product combination for all their a_b assets. Given this, I can simplify the notation and let $U_d(a_b)$ denote the aggregate utility from a buyer's a_b assets. Then:

$$U_d(a_b; switch) = a_b \cdot u_d(a_b; switch) \tag{26}$$

$$U_d(a_b; stay) = a_b \cdot u_d(a_b; stay) \tag{27}$$

Here, it is important to note that $U_d(a_b; switch)$ endogenously depends on the behavior of other buyers in the market: The more *other* buyers switch to a certain clearing member, the lower the clearing member's default probability, the larger the benefits from also switching. From this follows the second equilibrium property that all switching buyers choose the same clearing member. All other buyer choices cannot be sustained, as there is always at least one clearing member with more sales to whom to deviate to.

Whether none, some or all of the buyer switch depends both on C and $U_d(a_b; switch)$, given the (anticipated) behavior of all other buyers in the market. I will start with the level of C under which a no switching equilibrium arises. Quite intuitively, the largest buyers have also the largest gains from switching, as they have the most assets to hedge and insure. Simultaneously, all buyers face the same switching cost. Thus, a no switching equilibrium exists only if C is just equal to or exceeding the largest buyer's benefits from switching, conditional on no other buyer switching. The threshold that induces a no switching equilibrium is labeled with C_{NS}.

***Proposition* 2.** *The no switching equilibrium exists if and only if C exceeds a threshold level C_{NS}. C_{NS} denotes the level of switching cost that makes the largest buyer, i.e. $a_b = \overline{a}$, just indifferent between switching and staying, conditional on nobody else switching:*

$$C_{NS} = U_d(\overline{a}; switch) - U_d(\overline{a}; stay) \tag{28}$$

The no switching equilibrium is contrasted by the fully switching equilibria. In each of them, even the smallest buyers must find switching optimal, conditional on all other buyers switching: The smallest buyers have the lowest aggregate utility gains from switching, but face the same switching costs. This implies that there exist a threshold $\underline{C}$, such that only if $C \leq \underline{C}$, also the smallest buyers switch. Here, all switching buyers choose the same clearing member in equilibrium. However, it does not matter which clearing member exactly they choose. And thus, there exist as many fully switching equilibria as there are clearing members.[42]

***Proposition* 3.** *There exists as many fully switching equilibria as clearing members if and only if C is below a threshold level $\underline{C}$. $\underline{C}$ denotes the level of switching costs where the smallest buyers, i.e. $a_b = \underline{a}$, are just indifferent between staying and switching, conditional on all other buyers switching to the same clearing member:*

$$\underline{C} = U_d(\underline{a}; switch) - U_d(\underline{a}; stay) \tag{29}$$

For any level of C exceeding $\underline{C}$, the cost of switching outweigh the benefits for the smaller buyers. And thus only a fraction relatively larger buyers prefers switching. Here, it can

[42]Recall that $| M | \geq 2$.

be shown that for every level of $C > \underline{C}$, buyers are dividend into the switching and non-switching fraction by a unique size threshold a_{PS}. For all buyers smaller that a_{PS}, the costs of switching outweigh the benefits. All buyers larger than a_{PS} however, switch to the same clearing member. Note here that because now some buyers do not switch, this may result in clearing members with heterogeneous sales. And thus, while there exist multiple partial switching equilibria, there are not necessarily as many as clearing members.

***Proposition* 4.** *For every level of $C > \underline{C}$, there exists a unique buyer size threshold a_{PS} characterizing the partial switching equilibria: buyers of size $a_b \leq a_{PS}$ stay with their matched seller, and all buyers with size $a_b > a_{PS}$ switch to the same clearing member. Here, a_{PS} solves the following equality:*

$$C = U_d\left(a_{PS}; switch\right) - U_d\left(a_{PS}; stay\right) \tag{30}$$

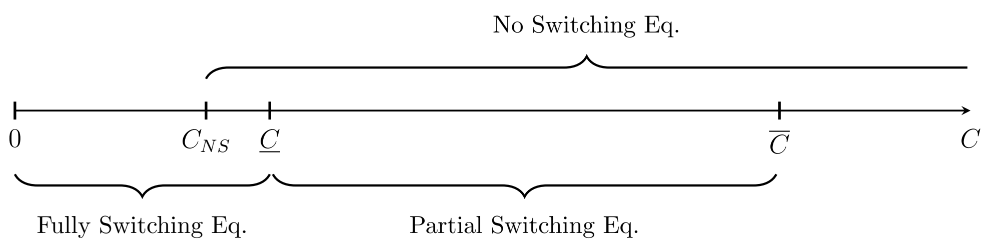
It can be shown that threshold size a_{PS} strictly increases in switching cost C. Thus there exists a threshold $\overline{C}$ for which $a_{PS} = \overline{a}$ and only the largest buyers switch. Any level of C exceeding $\overline{C}$ results in a no switching equilibrium.

***Corollary* 2.** *The set of switching sellers decreases with C, such that there exists a switching cost level $\overline{C}$ for which only the largest buyers of size $\overline{a}$ switch. For any higher level of $C > \overline{C}$, the no switching equilibrium is unique.*

Co-Existence of Equilibria Summarizing the results, there are three important thresholds on switching cost C that determine when the different types of equilibria (co-)exist: $\underline{C}$, $\overline{C}$, and C_{NS}. The thresholds $\underline{C}$ and $\overline{C}$ are exogenous to the market. They determine the existence of the fully and partial switching equilibria, which never co-exist. The threshold C_{NS} is endogenously determined at time 0 and is increasing in g_m.[43] At this stage, C_{NS} is taken as given and may be below, equal to or above $\underline{C}$, but is always below $\overline{C}$. Thus, when C_{NS} is lower than $\underline{C}$ the no switching equilibria may co-exist both with the fully and partial switching equilibria. When C_{NS} exceeds $\underline{C}$, only the no and partial equilibria may coexists. The existence and multiplicity of equilibria as a function of C are summarized in Figure 1 below.[44]

[43] Higher collateral makes switching more profitable, implying a higher C to deter also the largest buyers.
[44] For a formal discussion, please see Appendix B.2.

Figure 1: Existence of Equilibria When Product m is Traded



3.2.2. A Market Without Product m Sales

A market without any product m sales may arise for three reasons: the CCP chooses not to enter, there are no clearing members, clearing members exist but never offer product m. The equilibrium outcome is however, not too different from above. For one, all sellers offer the stand-alone product d to all buyers for all their assets. And again, the market is large such that no unmatched seller is unique in the eyes of a single buyer. Hence, unmatched buyers charge $p_d(a_b; switch) = 0$. Further, sellers again charge their captive consumers their entire utility gains from product d.

The main difference is that now the utility from switching strictly decreases in the unmatched seller's total sales: a seller's default probability strictly increases in the volume of uninsured product d sales. Given this, a matched seller deters switching by setting a price such that her buyer is just indifferent between staying or switching to the seller with the lowest total sales. Put differently, the matched seller is able to charge a premium above per-asset switching cost equivalent to the utility losses experienced from switching to other sellers. Ultimately, this leads to an equilibrium with no switching, where the unmatched sellers with the lowest default probabilities are those matched with a buyer of size $\underline{a}$. Let $u_d(a_b; switch)$ denote the utility from switching to one of those sellers.

***Proposition* 5.** *Under voluntary insurance and in the absence of clearing members, the no switching equilibrium is unique. Here, sellers always offer product d and charge:*

(i) Their unmatched buyers a price:

$$p_d\,(a_b, switch) = 0 \tag{31}$$

(ii) Their non-captive matched buyer a price:

$$p_d\,(a_b, stay) = C/n_b + u_d\,(a_b; stay) - u_d\,(a_b; switch) > 0 \tag{32}$$

(iii) Their captive matched buyer a price:

$$p_d(a_b, captive) = u_d\,(a_b; stay) - u_r \tag{33}$$

4. The CCP's Profit Maximization Problem at Time 0

In this section, I derive the SPNE by analyzing the optimal $t = 0$ choices, given the (anticipated) $t = 1$ market outcomes and the consequent realizations at $t = 2$. The equilibrium choices of agents at $t = 0$ realize in two stages: First, the CCP simultaneously chooses the fixed entry fee e_m, the variable fee v_m, and the collateral requirements g_m. Then, observing the CCP's choices and anticipating sales, sellers decide whether to become a clearing member.

In this context, please note that closed form solutions of optimal fees and collateral are complex and depend on the relative size of model parameters. I therefore present only general results here; and provide a full set of numerical solutions for a carefully calibrated set of parameters in Section 5. Given this, the Section is organized as follows: Section 4.1 described in detail the CCP's profit-maximization problem. This is followed by the analysis of the SPNE under mandatory (Section 4.2) and voluntary counterparty default insurance (Section 4.3). Finally, Section 4.4 concludes the theoretical analysis by comparing the outcomes under the two regimes and commenting on the financial risk trade-off.

4.1. The CCP's Profit Maximization Problem

Recall that the realizations of a_b are unknown to the CCP. It thus forms (rational) expectations $\mathbb{E}_0$ over the buyer-seller matches and consequent market outcomes at $t = 0$, $t = 1$ and $t = 2$. Denote the associated CCP profits at time t with Π_C^t. Further, recall that I assume that the CCP is never expected to default. This assumption is discussed in detail in Appendix A.3, where I provide a micro-foundation. Here it is important to note that CCP default does not enter the its maximization problem. Thus, the CCP chooses v_m, e_m, and g_m simultaneously to maximize the following constrained problem:

$$\mathbb{E}_0\Pi_C = \max_{e_m, v_m, g_m} \; \mathbb{E}_0\Pi_C^0\Big(e_m\Big) + \mathbb{E}_0[\Pi_C^1(v_m, g_m) \mid M] \; + \; \mathbb{E}_0[\Pi_C^2(\tau, L, g_m) \mid M; Q_{dm}] \tag{34}$$

$$s.t.$$

$$|M(e_m)| \geq 2 \tag{35}$$

$$g_m \geq \underline{g_m} \tag{36}$$

As indicated in equation (34), time zero profits Π_C^0 directly depend on the choice of e_m dictating the number of clearing members. Here, constraint (35) applies stating that there must be at least two clearing members, i.e. the set M has a cardinality weakly greater than two. At $t = 1$, v_m and g_m determine total product m sales and thus profits Π_C^1. Here, sales are conditional on the sellers' clearing membership choice and further constraint (36) applies: the collateral g_m requirement must be at least equal to the regulatory minimum $\underline{g_m}$. At $t = 2$, the CCP may experience losses from covering the transfers τ of defaulting clearing member with insufficient collateral. Given the total sales Q_{dm} and clearing membership, these default losses thus depend on expected transfers τ, collateral g_m and exogenous profits L.

4.2. Mandatory Counterparty Default Insurance

When insurance is mandatory, both sellers and the CCP anticipate the no switching equilibrium to arise at $t = 1$. Recall here, that all in equilibrium clearing members sell the bundle of product d and m for all their matched buyers' asset and only for those assets. Given this, I first describe the sellers' total expected profits as a function of membership status and matched buyer size and then the SPNE's general characteristics.

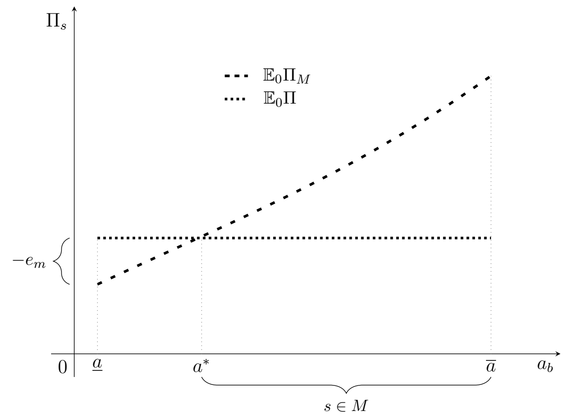
Sellers' Expected Profits Under mandatory insurance, the sellers compare profits from exiting the market ($\mathbb{E}_0\Pi$) to becoming a clearing member that only trades with her matched buyer ($\mathbb{E}_0\Pi_M$). Below, equations (37) and (38) state their respective functional forms, and Figure 2 plots them over the range of matched buyer size a_b. There, note that the profits from market exit are independent of matched buyer size and $\mathbb{E}_0\Pi$ is thus, a flat line over all a_b. Instead, $\mathbb{E}_0\Pi_M$ is a strictly increasing, convex function in matched buyer size.

$$\mathbb{E}_0\Pi = (1-D_s)\mathbb{E}_0[L \mid L > 0] \tag{37}$$

$$\mathbb{E}_0\Pi_M = -e_m + a_b\left(p_d + p_m - v_m - (1+\delta)\, g_m\right) + (1-D_M)\mathbb{E}_0\left[L + a_b(g_m - \tau) \mid L + a_b(g_m - \tau) > 0\right] \tag{38}$$

The CCP can influence the degree of convexity, as well as the intersection with the y-axis, by setting different values for g_m, v_m and e_m. Here, both increases in g_m and v_m reduce the degree of convexity. Further, setting $e_m = 0$ implies that $\mathbb{E}_0\Pi_M(\underline{a})$ approximates $\mathbb{E}_0\Pi(\underline{a})$, while increase in e_m shifts the expected clearing member profits $\mathbb{E}_0\Pi_M$ downwards.

Figure 2: The SPNE Under Mandatory Counterparty Default Insurance



The No Switching SPNE Given the properties of $\mathbb{E}_0\Pi$ and $\mathbb{E}_0\Pi_M$, Figure 2 quite intuitively illustrates that there exists a unique size threshold a^* that divides sellers into clearing members and non-clearing members: For sellers with matched buyers smaller than a^*, leaving the market is profit maximizing. For sellers with matched buyers weakly larger than a^* becoming a clearing member and offering the product bundle is profit maximizing. Threshold a^* thus, allows me to characterize the SPNE under mandatory insurance.

***Proposition* 6.** *Under mandatory counterparty default insurance, the SPNE with no switching at $t = 1$ is unique and characterized by size threshold $a^*(g_m, v_m, e_m)$, where:*

(i) Every seller matched with a buyer weakly larger than a^* becomes a clearing member.

(ii) Every seller matched with a buyer smaller than a^* exits the market.

4.3. Voluntary Counterparty Default Insurance

In this sub-section, I derive the SPNE, when product m is voluntary and agents anticipate a no, fully or partial switching equilibrium respectively. Sellers decide again whether to become clearing members, but are now able to sell an uninsured product d.

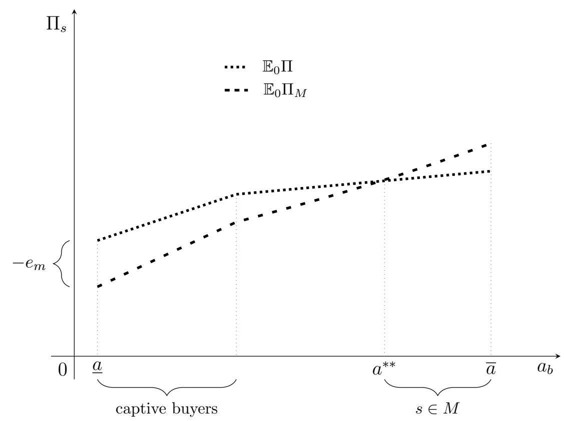
The No Switching SPNE In the no switching equilibrium all buyers stay with their matched seller and buy the product combination they are offered. The resulting profits of (non-)clearing members are stated in equations (39) and (40) and Figure 3 (below) illustrates both.

$$\mathbb{E}_0\Pi = a_b p_d + (1 - D)\mathbb{E}[L - a_b\tau \mid L - a_b\tau > 0] \tag{39}$$

$$\mathbb{E}_0\Pi_M = - e_m + a_b(p_d + p_m - v_m - (1 + \delta)g_m)) + (1 - D_M)\mathbb{E}[L + a_b(g_m - \tau) \mid L + a_b(g_m - \tau) > 0] \tag{40}$$

Non-clearing members can (and will) always sell product d to their matched buyer, and thus $\mathbb{E}_0\Pi$ is now strictly increasing in a_b. Similarly to before, clearing members always additionally sell product m. Thus $\mathbb{E}_0\Pi_M$ is strictly increasing in a_b, however, not globally convex anymore. Instead, both functions experience a kink, where buyers move from being captive to non-captive.

Figure 3: The SPNE Under Voluntary Counterparty Default Insurance



Again, the CCP can decrease the slope and intercept of $\mathbb{E}_0\Pi_M$ by increasing g_m/v_m and e_m respectively. However, local convexity in the part for captive and non-captive consumers is always preserved. Thus again, there exists a unique size threshold a^{**}, where only the sellers matched with larger buyers become clearing members.

***Proposition* 7.** *Under voluntary insurance, the SPNE with a CCP and no switching at $t = 1$ is characterized by a unique size threshold $a^{**}(g_m, v_m, e_m)$, where:*

- *(i) Every sellers matched with a buyer larger than a^{**} becomes clearing members to offer also product m.*
- *(ii) Every seller matched with a buyer smaller than a^{**} offers only product d as non-clearing members.*

No Fully Switching SPNE In any fully switching equilibrium, all buyers switch to the same clearing member, which subsequently posts collateral for every sale. Because B is large, such levels of collateral result in a (predicted) default probability of zero. Therefore, this seller cannot extract any profits from her product m sales: u_d equals u_{dm} for $D_M = 0$. It immediately follows that $p_m = 0$. Additionally, the seller charges $p_d(a_b; switch) = 0$, resulting in overall zero price charges from the product d and m sales. Yet, the seller would still have to pay collateral cost δ. This results in strictly negative expected profits of a clearing member (see equation (41)). If instead the seller exits the market, she would still realize the strictly positive profits from only receiving profits L (see equation (42)).

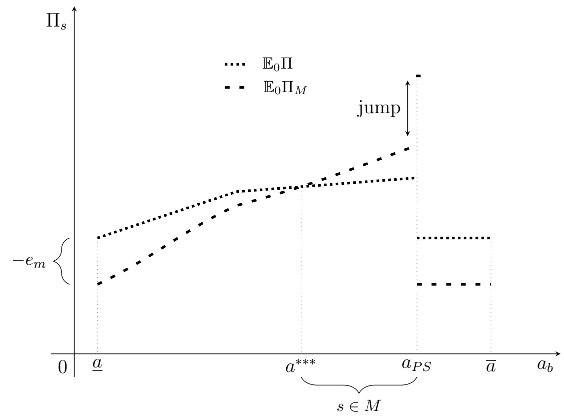
$$\mathbb{E}_0\Pi_M = -e_m - Q_{dm}(v_m + \delta g_m) < 0 \qquad \forall e_m, v_v \geq 0 \tag{41}$$
$$\mathbb{E}_0\Pi = (1-D)\mathbb{E}_0[L \mid L > 0] > 0 \tag{42}$$

And thus, the positive profits from exiting the market exceed the strictly negative profits from becoming a clearing member. To incentivize sellers to become clearing members regardless, the CCP would need to charge negative fees, which is ruled out by assumption. However, even if allowing for this, it can be shown that this would lead to negative CCP profits. And a for-profit CCP would thus rather exit than serving the market. Because the CCP does not serve the market, there exist no clearing members and seller offers product m. Hence, there does not exists any SPNE with fully switching under voluntary insurance. Instead, the no switching equilibrium without clearing members as the arises as the SPNE.

***Proposition* 8.** *Under voluntary insurance, and whenever anticipating all buyers to switch at $t = 1$, the CCP prefers to exit the market and the SPNE without clearing members and no switching arises.*

The Partial Switching SPNE Recall that any partial switching equilibrium is characterized by an exogenous size threshold a_{PS}, where all larger buyers switch and all weakly smaller buyers stay. Given this, profits and thus choices of sellers with matched buyers strictly smaller than a_{PS} are identical to the no switching equilibrium described above. Instead, the sellers matched with buyers of size strictly larger than a_{PS} cannot retain their buyers. And thus, their profits equal those realized from market exit. The most interesting happens exactly at the threshold a_{PS}. Because $\mathbb{E}_0\Pi_M$ is strictly increasing, those seller must be clearing members (assuming a market has any). It follows trivially that, those sellers are also the clearing members with the highest anticipated sales. Therefore, all switching buyers only consider switching to them and their expected profits experience a jump. This is illustrated in Figure 4 below.

Figure 4: The Partial Switching SPNE Under Voluntary Insurance



Summarizing the SPNE with partial switching, there exists thus a first threshold a^{***} that divides sellers into non-clearing and clearing members. Similarly to the other thresholds, a^{***}increases in v_m, g_m and e_m. However, this holds only until cut-off a_{PS}, determining the largest clearing members. It is to those clearing members, all larger buyers consider switching to (explaining the jump in expected profits). And hence, there exists as many partial switching equilibria as buyers of size a_{PS}. Finally, all larger buyers exit the market as non-clearing members.

***Proposition* 9.** *Under voluntary insurance there exists as many partial switching SPNE as sellers of size a_{PS}. They all share a unique size-thresholds $a^{***}(g_m, v_m, e_m)$, where:*

(i) Sellers matched with buyers strictly smaller than a^{***} offer product d as non-clearing members.

(ii) Sellers matched with buyers between a^{***} and a_{PS} become clearing members and offer product d and m.

(iii) Sellers matched with buyers strictly larger than a_{PS} exits the market.

4.4. Comparing Voluntary and Mandatory Counterparty Default Insurance

Before comparing the results under mandatory and voluntary insurance, I will briefly summarize them. Under mandatory insurance the no switching equilibrium is unique and the CCP sets fees such that large buyers hold the product bundle, while small buyers and their sellers exit. Under the voluntary insurance, the CCP only operates when at least a portion of buyers do not switch. Then larger buyers hold the bundle, while smaller buyers only hold product d.

4.5. The Effect on Agents

The Effect on the CCP Not surprisingly, the CCP is strictly better off under the mandatory insurance regime. Under mandatory insurance, the seller's only alternative to clearing membership is to exit the market. Under voluntary insurance however, the sellers can sell product d as a stand-alone, and thus realize strictly increasing profits also without offering product m. Further, larger buyers are non-captive under voluntary insurance resulting in lower profits for clearing members. Therefore, even when just setting the same fees and collateral, the CCP would benefit from a regime switch: the lower outside option for both buyers and sellers under mandatory insurance results in more clearing members and higher total sales. Additionally, the CCP is of course able to adjust fees and collateral as it sees fit, potentially extracting more surplus.

The Effect on Sellers The effect of mandatory insurance on sellers' profits is not uniform. It depends both on matched buyer size and the SPNE under voluntary insurance. Loosing their ability to sell uninsured derivatives and instead exiting the market, it is quite intuitive that smaller buyers are strictly worse off. Contrary to this, large sellers strictly benefit. Their buyers have the lowest per-asset switching cost, resulting in lower prices and even switching away in the partial switching SPNE. Under mandatory insurance however, all buyers become captive, allowing the large sellers to always retain their matched buyers and to charge significantly higher prices. The effect of a regime switching on medium sized sellers is however ambiguous. Under voluntary insurance, they sell only product d, while mandatory insurances forces them into clearing membership at price e_m not previously paid. However, their buyers now become captive, allowing them to extract more utility via $p_d + p_m$. How much so however, depends on the variable fee v_m set by the CCP. Thus, depending on model parameters dictating CCP choices, they may overall benefit or suffer.

The Effect on Buyers Recall that under mandatory insurance, buyers are always left with their reservation utility: buyers matched with clearing members are captive and buyers not matched with clearing members exit the market. Under voluntary insurance however, only small buyers are captive and left with their reservation utility. The smaller buyers are just indifferent between the two regimes. All non-captive (larger) buyers however, always at least receive additionally utility from their hedging with product d under voluntary insurance. These are thus strictly worse off, when product m is mandatory.

***Corollary* 3.** *Regime change from voluntary to mandatory counterparty default insurances:*

(i) Makes the CCP strictly strictly better off.
(ii) Makes smaller sellers strictly, worse off, has ambiguous effects on medium-sized sellers, and makes large sellers strictly better off.
(iii) Has no effect on smaller buyers, but makes larger buyers strictly worse off.

4.6. Financial Risk Analysis

The above *Corollary* concludes the micro-structure analysis of this market. Recall however, that this paper was originally set out to understand how a regime shift between mandatory and voluntary insurance impacts the overall financial risk exposure. In this section, I discuss how the above derived equilibrium results can be utilized to understand in particular the trade-off between credit risk-exposure and market-risk exposure common to this market. Here I also argue, how the model highlights a third risk-channel: the credit risk externality. As sellers become safer, their clients in other markets benefits and overall financial stability is improved.

Credit Risk Exposure The policy objective of mandatory counterparty default insurance is the reduction of buyer exposure to seller default (credit) risk. As the theoretical results highlight, this is indeed the case. Mandatory insurance eliminates all uninsured product d sales. However, while medium sized seller become clearing member and now offer insured sales to their buyers, smaller buyers and sellers exit the market.

Market Risk Exposure These smaller buyers consequently remain fully exposed to their asset risk. Depending on the size of the underlying asset variance σ_r^2, this might leave buyers with quite a substantial risk, they are unable to hedge under mandatory insurance.

Seller Default Risk This however also means that their matched sellers do not take on this on their balance sheet. This decreases their default probabilities. Similarly, the medium sized sellers, now clearing members, post collateral at the CCP for every OTC trade. As highlighted above, for sufficiently large $g_m > g_m^*$, this also reduces their default probabilities. If the combined reduction of smaller and medium sized sellers is substantial enough, it may warrant buyers' on average higher exposure to market risk.

Overall Financial Risk Summarizing the three points above, the overall shift in financial risk in a given OTC market depends on: [1] the relative density of small and medium sized buyers, [2] the size of σ_r^2. and [3] the improvement of seller default risk from both market access and clearing membership. A model calibration over these parameters is able to provide a quantitative assessment of the aggregate effect.

5. Calibration and Counterfactual Policy Evaluation

This section illustrates how the above described model insights can be utilized for a counterfactual analysis of mandatory and voluntary counterparty default insurance for a specific OTC derivatives market. For this purpose, I parameterize the model environment to the European EuroDollar FX derivatives market. In this, I build on the analysis by Hau et al. (2021), who provide some data moments for parameterization. They also show that during this period, the average OTC FX derivative contract had a duration of 69 days, almost exactly one quarter. Therefore, I assume that the above described model reflects one quarter ahead trade choices. I normalize all variables to be denoted in millions of euros.

5.1. *Parameterization*

To parameterize the model, I normalize all values to €mn. To calibrate the size distribution, I rely on data moments provided by Hau et al. (2021) for the period between April 1st, 2016 and March 31st, 2017. For this purpose, I relax the assumption that now assume that the buyer size distribution $\mathcal{A}\{\underline{a}, \overline{a}\}$ is discrete, bounded above and below. Instead, I assume that $\mathcal{A}[\underline{a}, +\infty)$ is continuous and only bounded below but not above. This allows me to estimate the functional form using simulated method of moments. All other model parameters are calibrated using data from 2014Q1 to 2016Q1 to reflect that financial market participants traditionally use (public) historic data to inform their decision making. The model parameterization and methods are summarized in Table 2 and subsequently described in detail. If not interested in such, the reader may move directly to the counterfactual evaluation in Section 5.2.

Table 2: Model Parameterization Normalized to €mn

Parameter	Notation	Value	Method	Data Source
Buyer size	$a_b \sim Weibull(\lambda, k)$	$\lambda = 0.686,\ k = 0.689$	SMM	Hau et al. (2021)
Asset Return	$(1+\tilde{r}) \sim N(\mu_r, \sigma_r^2)$	$\mu_r = 1.012,\ \sigma_r = 0.095$	return of US corp. bonds and exchange rate volatility	St. Louis Fed (2021) Bundesbank (2021)
Risk Aversion	γ	$\gamma = 4.37$	-	Eisfeldt et al. (2020)
Seller profits	$L \sim N(\mu_L, \sigma_L)$	$\mu_L = 199.846,\ \sigma_L = 115.169$	avg., std.	S&P Global (2021)
Collateral Cost	δ	$\delta = 0.000636$	avg. EURIBOR	Bundesbank (2021)
Switching Costs	C	$C \in \{\underline{C},\ \overline{C},\ 2\overline{C}\}$	parameter implied	-

Buyer Asset Size Distribution I estimate the buyer size distribution using a two-step simulated method of moments (SMM) estimation with 1000 Montecarlo draws in each step[45]. Here, I assume that buyer-size is drawn from a Weibull distribution with parameters λ and κ, as it is bounded below at zero and relatively free in shape.[46] As moments, I use the 10th, 25th, 50th and 75th percentile of notional outstanding of Euro/Dollar FX derivatives clients as stated in Hau et al. (2021).[47] I chose percentiles as moments, rather than mean or standard deviation, to ensure a good match at the lower and middle part of the size distribution. This is motivated by the theoretical analysis highlighting that results are driven mainly by changes in the market outcomes for small and medium sized buyers and their matched sellers. The estimation results are summarized in Table 3 below. Table 4 states the size-grid over which the simulation is ultimately performed, where

[45]See for example Evans (2018) for a description

[46]For robustness, I additionally tested the Pareto and exponential distribution, but both performed significantly worse in matching the data moments.

[47]Note that their percentiles are stated annually, wherefore I divide the total notional outstanding by four to proxy quarterly notional outstanding.

I set the maximum size $\overline{a}$ to the 99th percentile. Figure 5 plots the resulting Weibull densities.

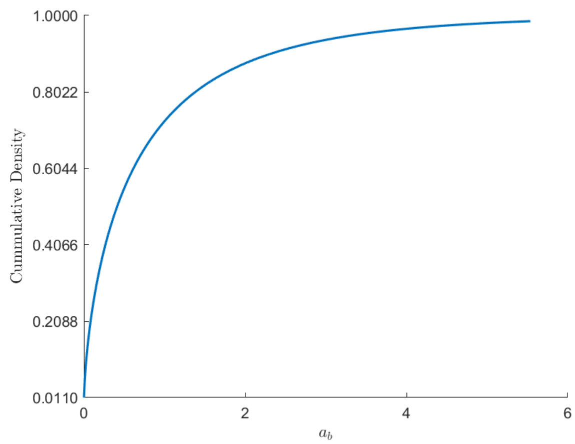
Table 3: Notional Outstanding (in €mn)

	p10	p25	p50	p75
Data Moments (Hau et al., 2021)	0.025	0.100	0.450	2.850
Simulated Moments (SMM) $a_b \sim Wbl(\lambda = 0.686, k = 0.689)$	0.020	0.091	0.357	0.989

Table 4: Buyer Size Grid for Simulation

	$\underline{a}$	$\overline{a}$	Steps
$a_b \in$	0.001	5.536	500

Figure 5: Simulated Buyer Size CDF



Buyer Asset Return In the Euro/Dollar FX derivatives market, the asset volatility (for a given notional outstanding) is determined by the exchange rate. Assume that a buyer has invested 1€ in a U.S. $ denominated corporate bond with return r. Denote the EuroDollar exchange rate today and a quarter ahead with ξ_t and ξ_{t+q} respectively. Then this investment realizes the following risky return $\tilde{r}$:

$$(1 + \tilde{r}) = (1 + r)\frac{\xi_t}{\xi_{t+q}} \tag{43}$$

To calculate r, I use the daily Moody's Seasoned Triple-A Rated Corporate Bond Yield (DAAA) time series for the period Q12014-Q12016 (St. Louis Fed, 2021). From those, I first calculate the mean daily return, which I then transform into quarterly returns. For simplicity, I assume away all return volatility in r. Then, the volatility of $\tilde{r}$ is determined solely by the exchange rate volatility and can be fully hedged away. I obtain the realized EuroDollar exchange rates ξ_t and ξ_{t+q} from the Bundesbank's statistical warehouse (Bundesbank, 2021). Then, I calculate $(1 + \tilde{r})$ for the period 2014Q1 to including 2016Q1, setting $q = 63$.[48] I lose 14 quarterly-returns to public holidays. The calibrated parameters are summarized in Table 5 below.

Seller Profits To obtain the the mean and volatility of seller profits, I use financial balance sheet and income statement data from S&P Global Market Intelligence from 2014Q1 to including 2016Q1. I limit the sample to those EU financial institutions that most commonly offer OTC derivatives: commercial banks, investment banks, brokers and capital markets service providers.[49]

[48] There are 63 days in a trading quarter.

[49] I include the EU's small state affiliates Andorra, Faeroe Islands, Greenland, Gibraltar, Vatican, which are also subject to the EMIR. I however exclude Norway, Iceland and Liechtenstein, who only joined the EMIR agreement in July, 2017.

I exclude all entities with non-operating parent companies, missing net-income, and missing or negative common equity.[50] Further, I trim at the 1st and 99th percentile to exclude outliers due to extreme loss or profit shifting purely driven by accounting practices. I am thus left with 121 individual sellers and 776 observations.[51] Subsequently, I calculate the mean and variance of the net income variable. Finally, to obtain μ_L and σ_L, I add the sample-average of common equity to the mean.[52]. This is, because in reality financial institutions do not default when profits are negative, but when equity capital is not-sufficient to capture losses.

Figure 6: Seller Profits (Data and Fitted)

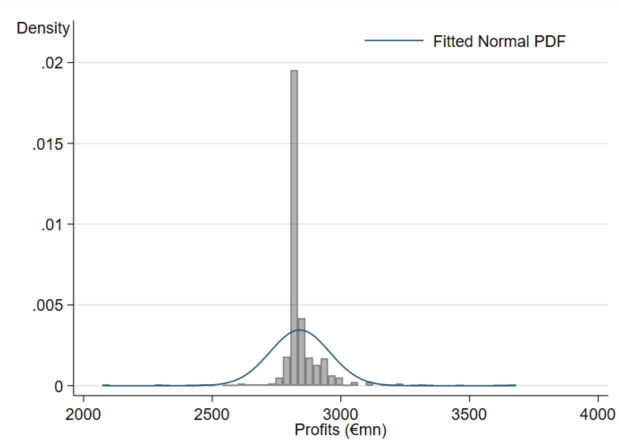


Table 5: Calibrated Asset Return

	Obs.	μ_r	σ_r
$1+\tilde{r}$	649	1.012	0.09492

Table 6: Calibrated Seller Profits

	Obs.	μ_L	σ_L
L	776	199.846	115.169

Collateral Cost For every insured OTC sale, the seller must post cash collateral. This money could have been invested elsewhere, obtaining market returns. Given the quarterly time-frame of the model, I use the EURIBOR three-month funds rate (daily quotations) as a relevant comparative investment opportunity.[53] Again, I compute the average quarterly return for the periods 2014Q1 to 2016Q1. This results in a δ equal to 0.000636.

Switching Cost The two switching cost thresholds $\underline{C}$ and $\overline{C}$, that determine the existence and uniqueness of different SPNE, are implied by the model parameters. Table 7 states their values and an additional level of C used for the analysis. The threshold C_{NS} is additionally determined by the CCP choice of g_m. However, as I will show below, it plays no role in the further analysis. Therefore, it is omitted here.

[50]Ideally, one would use common equity tier 1 levels. Unfortunately, this variable is only available for the largest 44 entities and would reduce the sample by an significant amount. Therefore, I rely on the more general common equity measure as the second best.

[51]Note that this is slightly less than the 204 FX derivatives dealers reported in Hau et al. (2021).

[52]Equity capital is by definition not normally distributed. Thus to preserve the normality of the net income variable, I add the mean equity only ex post.

[53]The time-series is obtained via the Bundesbank statistical warehouse and carries the serial number BBK01.ST0316.

Table 7: Schwitching Costs Thresholds (in €mn)

$\underline{C}$	$\overline{C}$	$2\overline{C}$
0.000002	0.010891	0.021782

5.2. *Calibrated Equilibrium Outcomes*

This subsection describes the simulated SPNE, given the calibrated market parameters. First, I briefly describe the simulation algorithm, after which I derive the SPNE under voluntary and mandatory counterparty default insurance. These SPNE are composed of: a CCP entry decision and the resulting fees; the sellers' membership choice, default probabilities prices and expected profits, and the buyers' expected utilities.

The Solution Algorithm I perform the following computational exercise: First, I take CCP entry as given. Then, I numerically solve for the equilibrium outcomes, including expected CCP profit, for a wide range of possible e_m, v_m and g_m combinations (see Table 8). Here, I rely on the functional forms derived in the theoretical analysis. Subsequently, I check whether there exist combinations for which CCP entry leads to positive CCP profits. If not, I conclude that there is no CCP entry and derive the SPNE equilibrium absent of a CCP. If yes, I identify the CCP-profit maximizing combination of v_m, e_m and g_m, and, given these, derive the remaining equilibrium outcomes.

Table 8: Grid Space For Optimization

Grid	lowest value	highest value	steps
e_m	0	$\overline{a}\frac{\gamma}{2}\sigma_r^2$	200
v_m	0	$\frac{\gamma}{2}\sigma_r^2$	200
g_m	$\underline{g_m} = \sqrt{5/63} \cdot 2.576\sigma_r$	$10\sigma_r$	200

Table 9: Collateral Thresholds

$\underline{g_m}$	g_m^*	g_m^{**}
0.006538	0.000068	0.000107

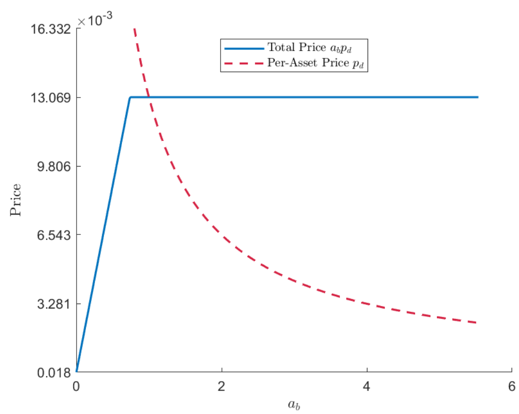
Here note that I have applied the EMIR regulatory minimum collateral requirement of 99.5% five-day value at risk (European Commission, 2012; ESMA, 2021). As shown in Table 9 above, $\underline{g_m}$ is thus above both model implied collateral thresholds g_m^* and g_M^{**}. Thus, the initial assumption is validated and the above theoretical results accurately match the European regulatory framework.

Market Outcome Under Voluntary Insurance In the analyzed years, no CCP was willing to provide counterparty default insurance for the European OTC EuroDollar FX derivatives market (ESMA, 2019b). I confirm that my model is able to replicate this by checking that a CCP does not find entry profitable. This is because the size of the market risk underlying the exchange rate derivative (σ_r) is very small relative to the variance in seller profits (σ_L). Thus, OTC trades only marginally contribute to the seller credit risk and counterparty default insurance provides little additional value for buyers. Capturing only limited utility, but gaining exposure to potentially high costs upon seller default, the CCP thus expects negative profits and decides not to enter. Here *Lemma 1* shows that price p_m is independent of the size C, such that this result holds for any level of $C > 0$. For illustrative purposes, I below show the SPNE outcome for $C = 2 \cdot \overline{C}$.

Recall from *Proposition 5* that, in the absence of a CCP and assuming $C > 0$, the SPNE with no switching is unique. And further that the SPNE is characterized by all smaller (captive) buyers paying a total price p_d equal to their the total utility surplus of buying product d. All larger (non-captive) buyers pay the switching cost plus a premium equal to their utility loss upon switching. Below, Figure 7a plots the buyers' total and per-asset price as a function of their size a_b. Figure 7b plots the resulting per-asset utility as a function of their size a_b, accounting for the paid price. In both graphs you can see a kink, at the size where buyers stop being captive.

Figure 7: Buyer Prices and Utilities (no CCP, $C = 2\overline{C}$)

(a) Total and Per-Unit Prices



(b) Buyers' Per-Asset Utility Post Payment

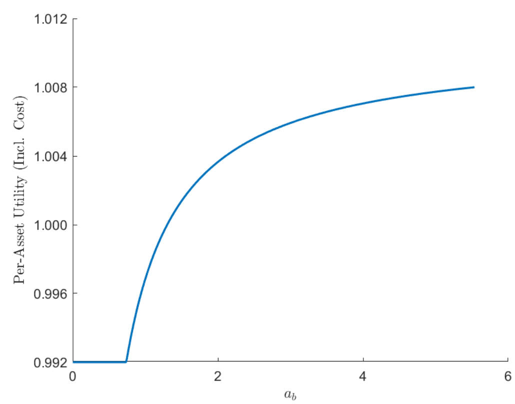
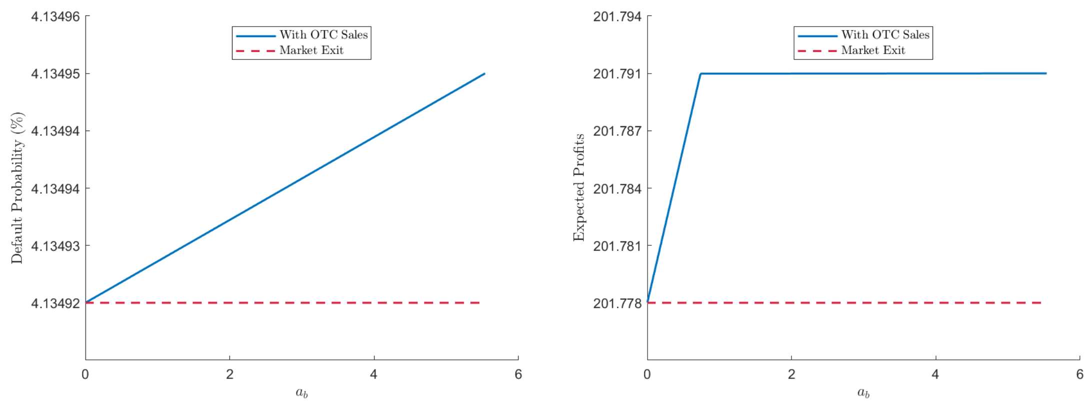


Figure 8 (below) plots the SPNE outcomes regarding sellers. Here, Figure 8a plots the sellers' default probabilities as a function of matched buyer size. As all hedges are uninsured, not surprisingly, the sellers' default probabilities increase with the matched buyer's size and thus sales. However, due to the small size of the EuroDollar FX OTC market, the effect is minute and around 0.005 basis points. For the same reason, the sellers' total profits also only marginally increase when serving the OTC market (Figure 8b). Notice here that, as discussion in Section 4.3, the profit function displays the kink, where buyers become non-captive.

Figure 8: Seller Default and Profits (no CCP, $C = 2\overline{C}$)

(a) Seller Default (b) Seller Profits



Market Outcome Under Mandatory Insurance The *Corollary 3* concludes that the CCP strictly benefits from mandatory counterparty default insurance, as it can capture a higher surplus from buyers and sellers. My model simulation predicts that, would mandatory insurance be introduced in this market, this surplus is sufficient to incentive CCP entry (see Figure 9).[54] And hence, I can exclude market failure. The CCP's profit maximizing choices of e_m, v_m and g_m are summarized in Table 10.

Figure 9: CCP Profits (Simulated)

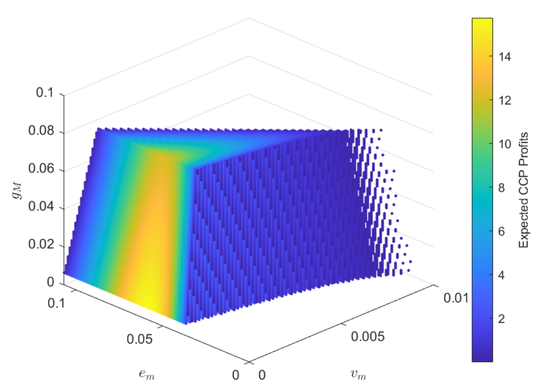


Table 10: Equilibrium Product m Prices

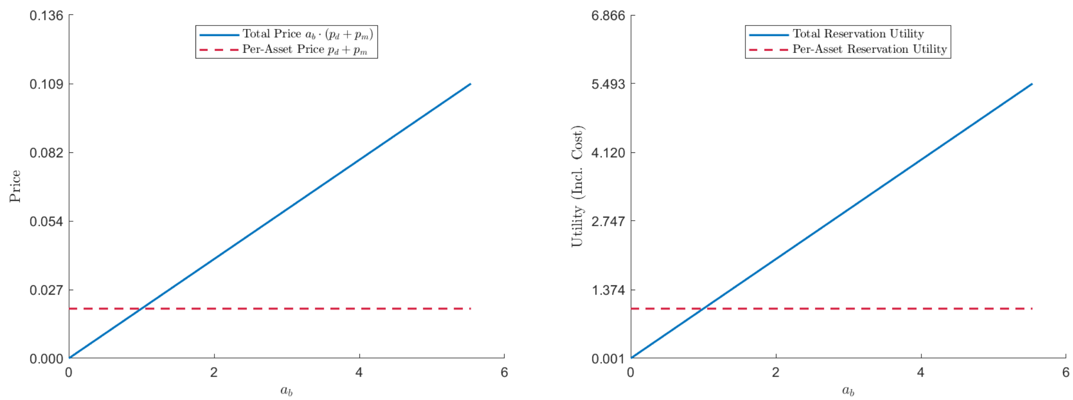
	Value
e_m	0.05944
v_m	0
g_m	0.006538
CCP Profits	15.72
Clearing Membership Rate (%)	7.215

From *Lemma 3* it is then known that in a market with a CCP, buyers either leave the market or are charged their entire utility surplus from product d and m. In either case, they are always left with their reservation utility (see Figure 10).

[54]This is not an unlikely scenario. As the policy debate more recently moved to including more markets in mandatory insurance regime, a CCP has indeed already secured the (monopoly) right to serve the EuroDollar FX market. It has however not yet offered any actual insurance, while insurance is still voluntary ESMA (2019b).

Figure 10: Buyer Prices and Utilities under Mandatory Insurance

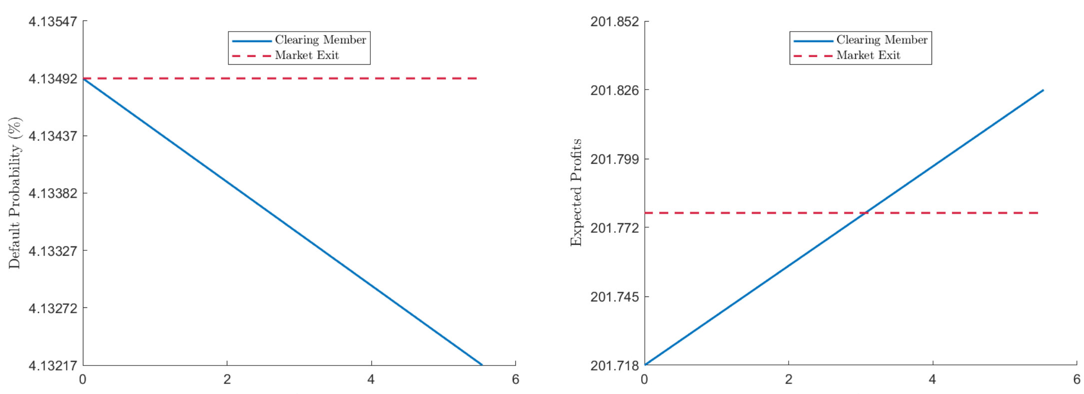
(a) Total and Per-Unit Prices (b) Buyers' Total Utility



And following this, as *Proposition 1* states, the no switching equilibrium is unique and all buyers are captive. However, given the CCP fees, the sellers ability to extract the matched buyer's entire utility is not sufficient for all sellers to find it optimal to become clearing members. By *Proposition 6*, only larger sellers find it optimal to become clearing members, while smaller sellers exit. Figure 11b shows that this is indeed also the case for the here simulated EuroDollar FX derivatives market.

Figure 11: Seller Default and Profits Under Mandatory Insurance

(a) Seller Default (b) Seller Profits



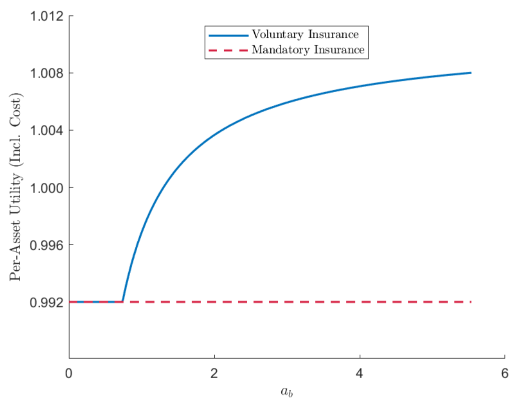
5.3. Counterfactual Comparison

Having derived the equilibrium outcomes under both regimes, I now turn to the counterfactual comparison. Mirroring the theoretical analysis, I considers first the effects on agents' and then on the overall financial risk, given the increase in buyers' marker risk-exposure, the decrease in buyers' credit-risk exposure and the credit risk-externality.

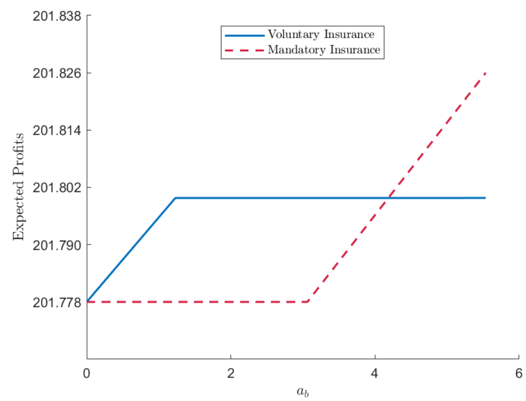
The Impact On Market Participants The impact on the CCP has already been briefly discussed above: under voluntary insurance it would not enter, while expecting a positive profit under mandatory insurance. Figure 12 (below) further confirms and quantifies that captive buyers are indifferent while non-captive buyers are strictly worse off under mandatory insurance. Thus the model calibration matches the theoretical result presented in *Corollary 3* with respect to the CCP and buyers.

Figure 12: Counterfactual Market Outcomes ($C = 2\overline{C}$)

(a) Buyers' Per-Asset Utility



(b) Sellers' Profits

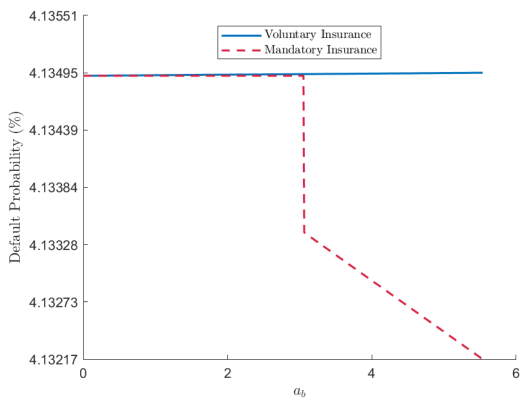


Corollary 3 also highlights that especially for medium sized sellers it depends on model parameters whether the ability to set higher prices under mandatory insurance offsets the cost of becoming clearing members. In this particular market, the underlying currency uncertainty σ_r^2 is relatively small, implying a high reservation utility and only low utility gains from insurance. Unable to set significantly higher prices, medium sized sellers therefore suffer from the introduction of mandatory counterparty default insurance (see Figure 12a).[55]

Credit Risk Externality This negative impact on buyers, and small and medium sized sellers may be an acceptable cost to pay given a significant improvement in seller default risk. However, comparing the impact of the regime switch on seller default probabilities, this effect is negligible. Figure 13 plots the simulated default risk under both regimes, depending on the size of the seller's matched buyer. And the improvement in seller default probabilities is always less than 0.1 basis points. Accounting for the relatively higher density of small clients, the difference in average default probabilities under voluntary (D^V) and mandatory (D^M) insurance is even smaller (see equations (44) through (46)). Mandatory counterparty default insurance for EuroDollar FX derivatives would therefore only marginally impact the stability of the financial market as a whole.

[55] Simulations confirm that, given the parameter space, this result holds for all levels of C.

Figure 13: The Impact On Seller Default Risk



$$D^V = \int_{\underline{a}}^{\overline{a}} D_s^V w(a_b) da_b = 4.02808\ \% \tag{44}$$

$$D^M = \int_{\underline{a}}^{\overline{a_b}} D_s^M w(a_b) da_b = 4.02769\ \% \tag{45}$$

$$\Delta D = D^M - D^V = -0.00039\ \% \tag{46}$$

Buyers' Credit Risk Exposure These default probabilities, while not negligible, are still insufficient to result in any meaningful credit risk exposure under voluntary insurance— even though all buyers are exposed to credit risk, i.e. fully hedged but not insured (see *Proposition 5*). Equation (47) describes the average buyer's credit risk exposure under voluntary insurance, denoted with CR^V. Under mandatory insurance, buyers either exit the market or purchase the bundle of both the derivative and the insurance (see *Proposition 1*). Hence, no buyer is exposed to seller credit risk and the average credit risk CR^M is equal to zero. Given this, the decrease in exposure due to a potential regime shift from voluntary to mandatory insurance, denoted ΔCR, is also below.

$$CR^V = \int_{\underline{a}}^{\overline{a}} D_s^V a_b \sigma_r w(a_b) \mathrm{d}a_b = 0.00324 \tag{47}$$

$$CR^M = 0 \tag{48}$$

$$\Delta CR = CR^M - CR^V = -0.00324 \tag{49}$$

Buyers' Market Risk Exposure The simulation confirms *Lemma 1*: Under voluntary insurance all buyers hedge their asset with a product d. And thus, their exposure to market risk MR^V is zero (see Equation (50)). Under mandatory insurance however, all buyers' matched with a non-clearing members exit the OTC market and remain fully exposed to market risk (see *Proposition 6*). Recall further that the size-threshold for clearing membership was denoted with a^*. Then equation (51) below states the average buyer's market risk exposure under mandatory counterparty default insurance MR^M. Having no exposure to market risk under voluntary, and some exposure under mandatory insurance, implies that the difference in marker risk exposure ΔMR is increasing with a potential regime shift.

$$MR^V = 0 \tag{50}$$

$$MR^M = \int_{\underline{a}}^{a^*} a_b \sigma_r w(a_b) \mathrm{d}a_b = 0.05570 \qquad \text{where} \quad a^* = 3.062 \tag{51}$$

$$\Delta MR = MR^M - MR^V = 0.05570 \tag{52}$$

Average Value-at-Risk The above described market risk and credit measures are the two components of the average buyer's 95th percentile value-at-risk, denoted 95% VAR (see equation 53). Relying on the values of MR and CR under both regimes, allows me to derive the relative change in the average buyer's 95% VAR following a shift to mandatory insurance. Denoted with $\%\Delta VAR$, this change in the average buyer risk-exposure is substantial with 1744.31 %. As equation highlights (54), this is independent of the actually percentile VAR considered, as the multiplying factor enters both nominator and denominator and thus cancels out.

$$95\%\ VAR = 1.96 \cdot [MR + CR] \tag{53}$$

$$\%\Delta VAR = 100 \frac{\Delta MR + \Delta CR}{MR^V + CR^V} = 1744.31\ \% \tag{54}$$

Summarizing Table 11 (below) summarizes the overall impact that the introduction of mandatory counterparty default insurance would have on the three risk measures. Accounting for the relative increase in market risk and the decrease in credit risk, the average buyers total risk exposure increases by 1744.31 %. Simultaneously, the improvement in credit risk, benefiting other financial market segments, is negligible. Therefore, introducing mandatory counterparty insurance for EuroDollar FX OTC derivatives would go against the regulatory objective to decrease financial risk and thereby enhancing financial stability. And thus European supervisors have rightly so refrained from introducing it in this market.

Table 11: The Effect of Mandatory Counterparty Default Insurance

Credit Risk Exposure	Market Risk Exposure	Change in VAR (%)[56]	Credit Risk Externality
$\Delta CR = -0.00324$	$\Delta MR = 0.05570$	$\%\Delta VAR = 1744.31\ \%$	$\Delta D = -0.00039\ \%$

[56]This is calculated by $100 \cdot (\Delta MR + \Delta CR)/(MR^V + CR^V)$.

6. Conclusion

In this paper, I set out to understand the effect of a policy shift from voluntary to mandatory insurance of OTC derivatives on both the market equilibrium and the associated financial risk. For this purpose, I first carefully model the competitive environment in the markets of OTC derivatives and their insurance. Here, I analyze the SPNE under both regimes and derive which buyer purchases which products at which price from which seller. I pay special attention to how a for-profit CCP may influence not only the purchase of counterparty default insurance, but also to which extend buyers purchase the derivative at all. Subsequently, I compare the SPNE outcomes under both regimes and derive buyers' average exposure to both market risk and credit risk.

This ultimately allows me to evaluate the theoretically predicted effects of a regime switch against the policy objective of overall financial risk reduction under mandatory counterparty default insurance. Here, I highlight in particular that the effectiveness of mandatory insurance in reducing risk exposure is determined by the trade-off between smaller buyers exiting and medium sized buyers additionally purchasing the insurance product. The overall effect depends on the relative density of smaller and medium sized buyers. I further uncover an additionally risk component to be consider: the potential spillover effect into other markets via overall reduced seller default risk. To highlight how these insights can be used for a concrete OTC derivatives class, I quantify these trade-offs through a calibration and simulation of the EuroDollar FX derivatives market.

The core limitation of the above analysis is the assumption that the market is served by a (monopolistic) for-profit CCP. And indeed, the largest derivatives markets are served by mostly monopolistic for-profit CCPs. However, for some smaller derivatives classes, the market sellers instead jointly found a mutualized CCP.[57] Participating in a mutually owned CCP exposes them directly to the default risk of other sellers, and thus the CCP might be able to internalize the risk mitigation objective of the regulation. However, new membership in such mutualized CCPs requires the approval of existing clearing members. Thus, original members may use the introduction of mandatory insurance to drive out market competitors. Ultimately, this might also lead to high market exit rates and again, significant increases in market risk exposure rates for buyers. A natural next steps would thus be to look into how the markets react (differently) to mandatory counterparty insurance, when served by a mutualized CCP. This might also provide insights why some markets are insured by for-profit CCPs and others by mutualized CCPs.

[57]See Huang (2019) Appendix C for a list of for-profit and mutualized CCPs and ESMA (2019b) for an up-to-date overview over CCP licenses in the EU.

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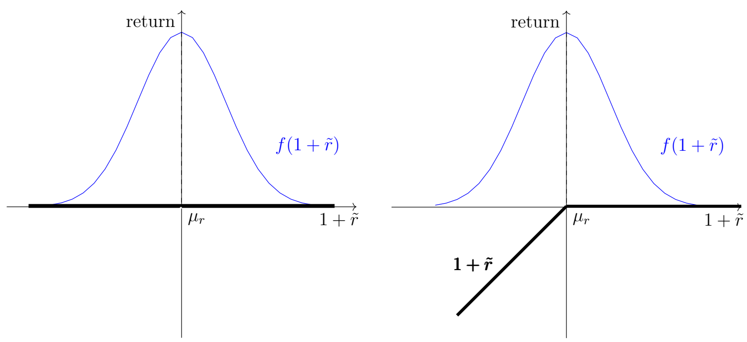
Appendix A. Agent Specifications

A.1. Buyers' Utility Function

Utility from product d In $t = 1$ a buyer B can purchase product d from a seller s, which specifies transfers $\tau = \mu_r - (1 + \tilde{r})$. s has an estimated default probability of $\hat{D}_s$. In the case of no seller default, a buyer of product d left with $1 + \tilde{r} + \tau = \mu_r$ (see Figure 14a). In the case of seller default, it is important to distinguish whether the buyer is in the money or out of the money. When the seller defaults, while being in the money bankruptcy laws require the buyer to honor his commitments. Thus, the buyer is still left with μ_r whenever default occurs for $1 + \tilde{r} > \mu_r$. In the case of seller defaulting out-of-the-money (where $1+\tilde{r} \leq \mu_r$), a buyer does not receive the promised positive transfers. The buyer is therefore left with the asset realization $1 + \tilde{r}$ (see Figure 14b).

Figure 14: Asset Return with product d

(a) No seller default: 1-$\widehat{D}_s$ (b) Seller default: $\widehat{D}_s$



The resulting pay-offs have the following probability density function:

$$f(\tau) = \begin{cases} \widehat{D}_s f(1+\tilde{r}) & 1+\tilde{r} \leq \mu_r \\ \widehat{D}_s(1 - F(\mu_r)) + (1 - \widehat{D}_s) & x = \mu_r \\ 0 & x > 0 \end{cases} \tag{55}$$

Given this, I can compute the expected return from purchasing product d:

$$\mathbb{E}[x] = F(\mu_r)\widehat{D}_s\mathbb{E}[x \mid x \leq \mu_r] + \mu_r \left[\widehat{D}_s(1 - F(\mu_r)) + (1 - \widehat{D}_s)\right] \tag{56}$$

$$\mathbb{E}[x] = \mu_r - \frac{\widehat{D}_s}{2}\sigma_r\frac{\sqrt{2}}{\sqrt{\pi}} \tag{57}$$

Similarly, the variance is:

$$\mathbb{E}[x]^2 = \mu_r^2 - \widehat{D}_s \mu_r \sigma_r \frac{\sqrt{2}}{\sqrt{\pi}} + \frac{\widehat{D}_s^2}{4}\sigma_r^2 \frac{2}{\pi} \tag{58}$$

$$\mathbb{E}[x^2] = F(\mu_r)\widehat{D}_s \mathbb{E}[x^2 \mid x \leq \mu_r] + \mu^2 \left[\widehat{D}_s(1 - F(\mu_r)) + 1 - \widehat{D}_s)\right] \tag{59}$$

$$\mathbb{E}[x^2 \mid x \leq \mu_r] = \mathbb{VAR}[x \mid x \leq \mu_r] + E[x \mid x \leq \mu_r]^2 \tag{60}$$

$$= \sigma_r^2(1 - \frac{2}{\pi}) + \mu_r^2 - 2\mu_r\sigma_r \frac{\sqrt{2}}{\sqrt{\pi}} + \sigma_r^2 \frac{2}{\pi} \tag{61}$$

$$= \mu_r^2 + \sigma_r^2 - 2\mu_r \sigma_r \frac{\sqrt{2}}{\sqrt{\pi}} \tag{62}$$

$$\mathbb{E}[x^2] = 0.5\widehat{D}_s\sigma_r^2 - \widehat{D}_s\mu_r\sigma_r\frac{\sqrt{2}}{\sqrt{\pi}} + \mu_r^2 \tag{63}$$

$$\mathbb{VAR}[x] = \frac{\widehat{D}_s}{2}\sigma_r^2(1 - \frac{\widehat{D}_s}{2}\frac{2}{\pi}) \tag{64}$$

$$\mathbb{VAR}[x] = \mathbb{E}[x^2] - \mathbb{E}[x]^2 = \frac{\widehat{D}_s}{2}\sigma_r^2(1 - \frac{\widehat{D}_s}{\pi}) \tag{65}$$

And thus, the for single asset from seller as is:

$$u_d = \mu_r - \frac{\widehat{D}_s}{2}\sigma_r \frac{\sqrt{2}}{\sqrt{\pi}} - \frac{\gamma}{2}\frac{\widehat{D}_s}{2}\sigma_r^2(1 - \frac{\widehat{D}_s}{\pi}) \tag{66}$$

Utility from product m Conditional on having purchased product d , buyers may purchase product m from one of the clearing members. Product d and product m are not required to be bought from the same seller. Due to a combination of CCP structure and regulations, the CCP has an expected default probability of zero (see section 4.1 for more details). The utility from product d purchased from seller s with product m bought from seller s' is thus: $u_{dm} = \mu_r$.

A.2. Sellers' Profit Function

Recall that a seller's total product d sales are denoted Q_d. Additionally, denote Q_{dm} as the portion of product d sales that are additionally combined with a product m, where necessarily $Q_{dm} \leq Q_d$. Further, denote a clearing member's total quantity of product m sales without involvement in the underlying product d as Q_m.[58] Then the sellers' total expected profits are:

[58] Note that theoretically a seller $s \in M$ also has the option to only sell product d and the buyer buys product m from another seller $s' \in M$. Again product m must also be bought by seller $s \in M$ for v_m and collateral g_m must be posted. This is however never optimal as shown in Lemma **??**. For simplicity, I

$$\forall s \notin M: \qquad \mathbb{E}_0\Pi = \quad 0 \quad + \mathbb{E}[\Pi_s^1] + (1-D_s)\,\mathbb{E}\left[\Pi_s^2 \mid \Pi_s^2 > 0\right] \tag{67}$$

where

$$\Pi_s^1 = Q_d P_d \tag{68}$$

$$\Pi_s^2 = L - T \quad \sim N(\mu_L, Q_d\sigma_r^2 + \sigma_r^2) \tag{69}$$

$$D_s = D(Q_d) = Pr(\Pi_s^2 \leq 0) \tag{70}$$

$$\forall s \in M: \qquad \mathbb{E}_0\Pi_M = -\,e_m + \mathbb{E}[\Pi_s^1] + (1-D_s)\,\mathbb{E}\left[\Pi_s^2 \mid \Pi_s^2 > 0\right] \tag{71}$$

where

$$\Pi_s^1 = Q_d P_d + Q_{dm}\left[P_c + P_m - f - (1+\delta)g_m\right] + Q_m P_m \tag{72}$$

$$\Pi_s^2 = Q_{dm}g_m + L - T \quad \sim N(Q_{dm}g_m, Q_d\sigma_r^2 + \sigma_r^2) \tag{73}$$

$$D_s = D(Q_d, Q_{dm}) = Pr(\Pi_s^2 \leq 0) \tag{74}$$

Here, I would like to highlight that p_m enters negatively in the profit function of non-clearing members (see equation (**??**)) and positively in the profit function of clearing members (see (**??**)). This is because a non-clearing member must pay for intermediation services for each of her insured product d sales. Clearing members instead provide intermediation services both for their own product d sales (entering in Q_{dm}) and for other sellers' product d sales (entering in Q_m).

The profit functions for $t = 0$ and $t = 1$ are straight forward and more elaboration is thus omitted here. Below a derivation of the expected $t = 2$ profits $(1 - D_s)\,\mathbb{E}\left[\Pi_s^2 \mid \Pi_s^2 > 0\right]$ and a few properties. To derive the expected time two profits, I define a few variables.

Define: $t = 2$ profits as $Y \sim N(\mu_Y, \sigma_Y^2)$
Define: $Y = \sigma_Y Z + \mu_Y$ where $Z \sim (0, 1)$
Denote: $\varphi(.)$ and $\Phi(.)$ the pdf and cdf of the standard normal distribution $N(0, 1)$.
Define: X as the strategic default threshold, such that $x = \frac{X-\mu_Y}{\sigma_Y}$

1. Expected profits at $t = 2$ are: $(1 - D_s)\mathbb{E}_0\left[\Pi_2|\Pi_2 > 0\right] = \big(1 - F(X)\big)\,\mu_Y + \sigma_Y^2 f(X)$

$$D_s = F(0) \tag{75}$$

$$\mathbb{E}_0\left[\Pi_2|\Pi_2 > 0\right] = \mu_Y + \sigma_Y \frac{\sigma_Y f(0)}{1 - F(0)} \tag{76}$$

$$(1 - D_s)\mathbb{E}_0\left[\Pi_2|\Pi_2 > 0\right] = \big(1 - F(0)\big)\,\mu_Y + \sigma_Y^2 f(0) \tag{77}$$

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omitted this in equation (**??**). I however account for this possibility in the following analysis. For a detailed description of all possible product d and m combinations, please see Appendix **??**

2. Define $\mu_Y(z)$ as a function of an equilibrium object z. Then:

$$\frac{\partial(1-D_s)\mathbb{E}_0\left[\Pi_2|\Pi_2>0\right]}{\partial z} = \frac{\partial\left(1-F\left(0\right)\right)\mu_Y(z)+\sigma_Y^2 f(0)}{\partial z} \tag{78}$$

$$= \frac{\partial\mu_Y(z)}{\partial z}\left(1-F(0)\right) \tag{79}$$

$\frac{\partial(1-D_s)\mathbb{E}_0[\Pi_2|\Pi_2>0]}{\partial z} = \frac{\partial\mu_Y(z)}{\partial z}\left(1-F(0)\right)$.

$$\frac{\partial\left(1-F\left(X\right)\right)\mu_Y(z)+\sigma_Y^2 f(X)}{\partial z} = \frac{\partial\left(1-F\left(X\right)\right)}{\partial z}\mu_Y(z)+\left(1-F\left(X\right)\right)\frac{\partial\mu_Y(z)}{\partial(z)}+\sigma_Y^2\frac{\partial f(X)}{\partial z} \tag{80}$$

$$\frac{\partial F(X)}{\partial z} = \frac{\partial\frac{1}{2}\left[1+erf\left(\frac{X-\mu_Y(z)}{\sigma_Y\sqrt{2}}\right)\right]}{\partial\mu_Y(z)} \tag{81}$$

$$\rightarrow \quad erf(-x) = -erf(x) \tag{82}$$

$$\frac{\partial F(X)}{\partial z} = \frac{\partial\frac{1}{2}\left[1-erf\left(\frac{\mu_Y(z)-X}{\sigma_Y\sqrt{2}}\right)\right]}{\partial z} \tag{83}$$

$$= -\frac{1}{2}\frac{\partial erf\left(\frac{\mu_Y(z)-X}{\sigma_Y\sqrt{2}}\right)}{\partial z} \tag{84}$$

$$= -\frac{\partial\mu_Y(z)}{\partial z}\frac{1}{2}\frac{1}{\sqrt{2}\sigma_Y}\frac{2}{\sqrt{\pi}}e^{\frac{-(\mu_Y(z)-x)^2}{2\sigma_Y^2}} \tag{85}$$

$$= -\frac{\partial\mu_Y(z)}{\partial z}f(X) \tag{86}$$

$$\frac{\partial\left(1-F\left(X\right)\right)}{\partial\mu_Y(z)}\mu_Y(z) = \frac{\partial\mu_Y(z)}{\partial z}f(X)\mu_Y(z) \tag{87}$$

$$\sigma_Y^2\frac{\partial f(X)}{\partial z} = \frac{\partial\mu_Y(z)}{\partial z}\sigma_Y^2\frac{2(X-\mu_Y(z))}{\sigma_Y^2 2}\frac{1}{\sqrt{2\sigma_Y^2\pi}}e^{\frac{-(X-\mu_Y(z))^2}{\sigma_Y^2 2}} \tag{88}$$

$$= \frac{\partial\mu_Y(z)}{\partial z}(X-\mu_Y(z))\frac{1}{\sqrt{2\sigma_Y^2\pi}}e^{\frac{-(X-\mu_Y(z))^2}{\sigma_Y^2 2}} \tag{89}$$

$$= \frac{\partial\mu_Y(z)}{\partial z}(X-\mu_Y(z))f(X) \tag{90}$$

$$\frac{\partial\left(1-F\left(X\right)\right)\mathbb{E}\left[Y|Y>X\right]}{\partial\partial z} = \frac{\partial\mu_Y(z)}{\partial z}\left[f(X)\mu_Y(z)+\left(1-F\left(X\right)\right)+(X-\mu_Y(z))f(X)\right] \tag{91}$$

$$= \frac{\partial\mu_Y(z)}{\partial z}\left[Xf(X)+\left(1-F\left(X\right)\right)\right] \tag{92}$$

$$\rightarrow \quad X = 0 \tag{93}$$

$$\frac{\partial\left(1-F\left(X\right)\right)\mathbb{E}\left[Y|Y>X\right]}{\partial z} = \frac{\partial\mu_Y(z)}{\partial z}\left(1-F(0)\right) \tag{94}$$

3. Define $\mu_Y(z)$ and $\sigma_Y(z)$ as a function of an equilibrium object z. Then:

$$\frac{\partial(1-D_s)\mathbb{E}_0\left[\Pi_2|\Pi_2>0\right]}{\partial z} = \frac{\partial\left(1-F(0)\right)\mu_Y(z)+\sigma_Y(z)^2 f(0)}{\partial z} \tag{95}$$

$$= f(0)\sigma_Y(z)\frac{\partial\sigma_Y(z)}{\partial z} + \left(1-F(0)\right)\frac{\partial\mu_Y(z)}{\partial z} \tag{96}$$

Further:

$$\frac{\partial f(X)}{\partial z} = -\frac{1}{\sigma(z)}\frac{\partial\sigma(z)}{\partial z}f(0) + f(0)\left(\frac{-\mu_Y(z)}{\sigma_Y(z)^2}\right)\left[\frac{\partial\mu_Y(z)}{\partial z} - \frac{\mu_Y}{\sigma_Y(z)}\frac{\partial\sigma_Y(z)}{\partial z}\right] \tag{97}$$

$$\frac{\partial F(0)}{\partial z} = -f(0)\left[\frac{\partial\mu_Y(z)}{\partial z} + \frac{(-\mu_Y)}{\sigma_Y(z)}\frac{\partial\sigma_Y(z)}{\partial z}\right] \tag{98}$$

4. Define $\sigma_Y(z)$ as a function of an equilibrium object z. Then:

$$\frac{\partial F(0)}{\partial z} = -f(0)\left[\frac{(-\mu_Y)}{\sigma_Y(z)}\frac{\partial\sigma_Y(z)}{\partial z}\right] \tag{99}$$

A Parameter Restriction on Collateral It is reasonable to assume that regulatory authorities require the collateral to be large enough such that seller default probability actually decreases in insured sales. Such that insuring the OTC market makes sellers actually less likely to default. Here, using the just derived properties this implies:

$$\frac{\partial D_m}{\partial Q_{dm}} = -d_m\left[g_m - \frac{(g_m Q_{dm}+\mu_L)\sigma_r^2}{2(Q_{dm}\sigma_r^2+\sigma_L^2)}\right] < 0 \tag{100}$$

$$\longrightarrow$$

$$g_m - \frac{(g_m Q_{dm}+\mu_L)\sigma_r^2}{2(Q_{dm}\sigma_r^2+\sigma_L^2)} > 0 \qquad \forall Q_{dm}\geq 0 \tag{101}$$

$$g_m > \frac{\mu_L\sigma_r^2}{2\sigma_L^2} \tag{102}$$

Notice that this automatically implies that d_M is decreasing in insured sales:

$$\frac{\partial d_m}{\partial Q_{dm}} = -\frac{\sigma_r^2}{2(Q_{dm}\sigma_r^2+\sigma_L^2)}d_M - d_M\frac{(Q_{dm}g_m+\mu_L)}{Q_{dm}\sigma_r^2+\sigma_L^2}\underbrace{\left[g_m - \frac{(g_m Q_{dm}+\mu_L)\sigma_r^2}{2(Q_{dm}\sigma_r^2+\sigma_L^2)}\right]}_{+} < 0 \tag{103}$$

A.3. The CCP

CCP Profits In the main-text, I presented following maximization problem:

$$\mathbb{E}_0\Pi_C = \max_{e_m,v_m,g_m} \quad \mathbb{E}_0\Pi_C^0\Big(e_m\Big)+\mathbb{E}_0\Pi_C^1\Big(v_m, g_m;\ e_m\Big) + \mathbb{E}_0\Pi_C^2\Big(L, \tau;\ e_m, v_m, g_m\Big) \tag{104}$$

$$s.t.$$

$$|M(e_m)| > 1 \tag{105}$$

$$g_m > 0 \tag{106}$$

To fully characterize the different profit elements, I denote an additional set of notations. Denote as $\bar{M}$ the expected number of clearing members: $\mathbb{E}[|\ M\ |]$. Further, denote with $\bar{Q}_{dm}$ the expected bundle sales of a clearing member. Finally, let $\mathbf{1}$ denote an indicator function that takes on the value one, when $\mathbb{E}_0\Pi_m$ exceeds $\mathbb{E}_0\Pi$ for a seller with a matched buyer of size a_b. Then:

$$\bar{M} = S\sum_{a_b=\underline{a}}^{\bar{a}} \mathbf{1}_{\Pi_m>\Pi}a(a_b) \tag{107}$$

$$\bar{Q}_{dm} = \mathbb{E}[Q_{dm} \mid s \in M] \tag{108}$$

$$\mathbb{E}_0\Pi_C^0\Big(e_m\Big) = \bar{M}e_m \tag{109}$$

$$\mathbb{E}_0\Pi_C^1\Big(v_m, g_m;\ e_m\Big) = \bar{M}\bar{Q}_{dm}2v_m \tag{110}$$

$$\mathbb{E}_0\Pi_C^2\Big(L, \tau;\ e_m, v_m, g_m\Big) = \bar{M}Pr(\bar{Q}_{dm}(-\tau+g_m)+L\leq 0)\mathbb{E}[\bar{Q}_{dm}(-\tau+g_m) \mid \bar{Q}_{dm}(-\tau+g_m)\leq 0 \ \&\ \bar{Q}_{dm}(-\tau+g_m)+L\leq 0] \tag{111}$$

$$\text{where} \qquad \bar{Q}_{dm}(-\tau+g_m) \sim N(\bar{Q}_{dm}gm, \bar{Q}_{dm}\sigma_r^2) \quad \text{and} \quad L\sim N(\mu_L,\sigma_L^2) \tag{112}$$

Note that given the nature of the underlying normal distributions, no further closed form can be obtained for time-2 losses. However, they can be numerically computed using the following double integral:

$$Pr(\bar{Q}_{dm}(-\tau+g_m)\leq 0 \ \&\ \bar{Q}_{dm}(-\tau+g_m)+L\leq 0) = \int_{-\infty}^{0} f_{\bar{Q}_{dm}(-\tau+g_m)}(x)\int_{-\infty}^{-x} f_L(y)\mathrm{d}y\mathrm{d}x \tag{113}$$

$$\mathbb{E}[\bar{Q}_{dm}(-\tau+g_m) \mid \bar{Q}_{dm}(-\tau+g_m)\leq 0 \ \&\ \bar{Q}_{dm}(-\tau+g_m)+L\leq 0]$$

$$= \frac{1}{Pr(\bar{Q}_{dm}(-\tau+g_m)\leq 0 \ \&\ \bar{Q}_{dm}(-\tau+g_m)+L\leq 0)}\int_{-\infty}^{0} xf_{\bar{Q}_{dm}(-\tau+g_m)}(x)\int_{-\infty}^{-x} f_L(y)\mathrm{d}y\mathrm{d}x \tag{114}$$

CCP Default Mechanism Notice that the just described maximization problem is a simplified version of reality, as it assumes that the CCP is expected to never defaults. As a for-profit entity, the CCP may also strategically default at $t = 2$. Due to its central role in the market, default would have significant consequences for all parties involved. For the buyers with defaulting sellers, a defaulting CCP would mean that their product m carries little to no value. Additionally, a defaulting CCP is not able to (fully) repay initially non-defaulting sellers their collateral. This may cause cascading seller defaults.

To limit the default risk of the CCP, regulators impose several restrictions. I have previously discussed two of them: the CCP must collect collateral from sellers;[59] and must have more than one clearing member. Both ensure that the CCP is less exposed to any individual seller's default. Two additional measures are minimum CCP capital requirements K and a clearly defined default mechanism.[60] The latter minimizes organizational frictions by determining in which order resource are used to cover a defaulting seller's transfers (see Figure 15).

Figure 15: The CCP's Default Mechanism

1. The defaulting seller's positive transfers.

2. The collateral of the defaulting seller only.

3. Its own capital K (set by regulators).

\- default threshold

4. Collateral of the non-defaulting sellers.

From Figure 15 it can quite intuitively be induced that cascading defaults are only avoided when K is sufficient to cover all defaulting sellers' losses exceeding collateral. Given the nature of normal distributions, a very bad realization may always happen such that cascading defaults are triggered. However, they can be ruled out in expectations:

Lemma 2. *Depending on the capital level K the CCP is exptected to default either with probability zero or one.*

Sketch of proof:

[59] I abstract from the possibility that the CCP asks sellers to additionally provide an lump-sum collateral payment ex ante. This is without loss of generality, because the true size of a clearing member is unknown to the CCP. Therefore, charging a lump sum independent os size is in expectations equivalent to setting a higher a higher g_m for the average sales of a clearing member.

[60] The here presented default mechanisms is a simplification of the real world and taken from Huang (2019). For a detailed theoretical analysis of CCPs default waterfalls, please see Duffie and Zhu (2011).

1. Capital K would be posted at $t = 0$. At $t = 2$, the owner(s) of the CCP get the proportion of capital K returned that is not paid to buyers upon seller default. When the payment to buyers exceeds the capital K, then the CCP finds it optimal to strategically default:

2. Ex ante, the CCP is expected to strategically default at $t = 2$, whenever:

$$\mathbb{E}[\Pi_C^2] \leq K \tag{115}$$

3. Note from expressions (113) and (114) that the expected loss from a single clearing member is a finite number. Further note that defaults are uncorrelated across banks. Therefore, the CCP's expected losses conditional on default from all banks is the sum of each bank's individual expected losses. Finally, in expectation the $\bar{M}$ clearing members have the same size. Therefore the sum reduces to an average clearing members expected losses times $\bar{M}$: also a finite number.

4. Consequently, for any given $\{e_m, v_m, g_m\}$, the regulator can set K such that equation (115) holds true with probability one or zero.

5. All agents are rational and aware of the buyer size distribution $\mathcal{A}$. Thus, they expect the CCP to default either with probability zero or one.

6. Assuming that the CCP does not default (in expectations) is thus equivalent to assuming that the regulatory authority requires the CCP to be sufficiently capitalized.

Given the regulators overall objective to minimizing financial risk and the fact that we do observe for-profit CCPs in reality, this assumption seems reasonable. The alternative would be to assume that ex ante, the CCP is insufficiently capitalized and expected to default with probability one. Then insuring in the CCP would de facto be equivalent to insuring in a mutualized CCP. In Section 6, I conclude with a brief discussion implications for the market on this.

Appendix B. Proofs Section 3

B.1. Proofs Section 3.1 Mandatory Counterparty Default Insurance

For this section, note that product d and m must be sold as a bundle. Thus buyers only consider to purchase from sellers that form the subset M. All remaining sellers exit the market per definition.

Sketch of Proof for *Proposition 1*:

1. The proof starts by deriving price p_m.

1.1. To derive p_m, recall that it is set in a take-it-or-leave-it-fashion: the buyer agrees or declines the offer. Thus, p_m is set such that the buyer's participation constraint is just binding.

1.2. Further recall that product d cannot be held alone, as product m is mandatory. Then, a realized product d seller sets p_m such that the buyer is just indifferent between holding the product d and m bundle or nothing at all:

$$u_{dm} - p_d - p_m - v_m = u_r \tag{116}$$

$$p_m = u_{dm} - p_d - v_m - u_r \tag{117}$$

2. From this, it can be shown that no buyer switches.

2.1. The buyer is left with his reservation utility:

$$u_{dm} - p_d - p_m - v_m = u_{dm} - p_d - v_m - (u_{dm} - p_d - v_m - u_r) = u_r \tag{118}$$

2.2. Note that p_m never accounts for the switching cost paid for the product d purchase. Then a buyer not switching is left with total utility U_r. This is the case when: the seller offers the bundle for some assets only, the seller offers the bundle for all asset, or the matched seller never offers any product. A switching buyer will however always expect a total utility $U_r - C$. Thus buyer's never switch.

2.3. It follows immediately that buyers matched with non-clearing members exit the market together with them.

3. Anticipating a bit the order of the main text, note that *Corollary 1* immediately follows from point 5. If all sellers exit, so do all buyers. And hence, we have market failure.

4. Given the price (117), then p_d can be derived. Looking at equation 117, it becomes clear that any increase in p_d translates into a one-for-one decrease in p_m and thus the seller is indifferent between either. She simply sells the bundle of both products at prices $p_d + p_m = u_{dm} - u_r - f - \frac{C}{a_b}$.

5. Now that I have derived the bundle price, I can derive the properties of clearing member profits

$Pi^1_M + \mathbb{E}_0\Pi^2_m$ as a function of bundle quantities Q_{dm}: $Q_{dm} \in [0, a_b]$.

5.1.The clearing members' profits $\mathbb{E}_1\Pi_m$ are sum of two functions: a linear and a non-linear component:

$$\mathbb{E}_1\Pi_M = \underbrace{-e_m}_{\text{intercept}} + \underbrace{Q_{dm}\left(p_d + p_m(1+\delta)g_m\right)}_{\text{linear in } Q_{dm}} + \underbrace{(1-D_M)(g_mQ_{dm} + \mu_L) + d_M(Q_{dm}\sigma_r^2 + \sigma_L^2)}_{\text{non-linear in } Q_{dm}} \quad (119)$$

This is easily confirmed, when looking at the FOC wrt. Q_{dm}:

$$\frac{\partial \Pi_M}{\partial Q_{dm}} = \underbrace{p_d + p_m - v_m - (1+\delta)g_m}_{\text{constant}} + \underbrace{(1-D_m)g_m + d_m\frac{\sigma_r^2}{2}}_{\text{dependent on } a_b} \quad (120)$$

5.2. The the slope-value linear component falls into three categories:

5.2.1. $p_d + p_m - v_m - \delta g_m > 0$.
5.2.2. $p_d + p_m - v_m - \delta g_m = 0$
5.2.3. $p_d + p_m - v_m - \delta g_m < 0$

5.3. The non-linear component of $\mathbb{E}_1\Pi_M$ is strictly increasing in Q_{dm}. Depending on g_m however, it is either strictly convex or locally concave/convex, but never strictly concave.

5.3.1.The non-linear component has a strictly positive slope:
- $(1 - D_M)$ denotes the probability of non-default and is naturally between zero and one,
- I have assumed $g_m > \frac{\mu_L^2\sigma_r^2}{2\sigma_L^2}$, which are all positive parameters,
- d_m denotes the pdf at point of default and is thus by definition positive, as is σ_r^2.

5.3.2.1. Using properties derived in Section A.2, I can show that the second derivative is:

$$\frac{\partial(1-D_M)g_m + \frac{\sigma_r^2}{2}d_m}{\partial Q_{dm}} = d_m\left[g_m - \frac{\sigma_r^2}{2}\frac{g_mQ_{dm} + \mu_L}{Q_{dm}\sigma_r^2 + \sigma_L}\right]^2 - d_m\frac{\sigma_r^4}{4(Q_{dm}\sigma_r + \sigma_L)} \quad (121)$$

For this to be strictly increasing, we must have:

$$d_m\left[g_m - \frac{\sigma_r^2}{2}\frac{g_mQ_{dm} + \mu_L}{Q_{dm}\sigma_r^2 + \sigma_L}\right]^2 - d_m\frac{\sigma_r^4}{4(Q_{dm}\sigma_r + \sigma_L)} > 0 \quad (122)$$

$$g_m > \frac{\sigma_r^2\sqrt{Q_{dm}\sigma_r^2Q_{dm} + \sigma_L^2}}{Q_{dm}\sigma_r^2 + 2\sigma_L^2} + \frac{\mu_L\sigma_r^2}{Q_{dm}\sigma_r^2 + 2\sigma_L^2} \quad (123)$$

Both terms on the right-hand-side decrease in a_b, such that a necessary level of g_m to ensure convexity it:

$$g_m > \frac{\sigma_r^2}{2\sigma_L} + \frac{\mu_L \sigma_r^2}{2\sigma_L^2} > g_m^{**} \tag{124}$$

5.3.2.2.2. Contrary, to be a strictly concave function, it must be that:

$$g_m < \frac{\sigma_r^2 \sqrt{Q_{dm}\sigma_r^2 a_b + \sigma_L^2}}{Q_{dm}\sigma_r^2 + 2\sigma_L^2} + \frac{\mu_L \sigma_r^2}{Q_{dm}\sigma_r^2 + 2\sigma_L^2} \tag{125}$$

Given that again the right-hand-side is decreasing in Q_{dm}, it must hold for very large Q_{dm}:

$$g_m < \lim_{Q_{dm}\to\infty} \frac{\sigma_r^2 \sqrt{Q_{dm}\sigma_r^2 Q_{dm} + \sigma_L^2}}{Q_{dm}\sigma_r^2 + 2\sigma_L^2} + \lim_{Q_{dm}\to\infty} \frac{\mu_L \sigma_r^2}{Q_{dm}\sigma_r^2 + 2\sigma_L^2} = 0 \tag{126}$$

However, I have assumed that $g_m > \frac{\mu_L \sigma_r^2}{2\sigma_L} = g_m^*$. Thus strict concavity of the non-linear part can be ruled out.

5.3.2.4. By logic of completion it must thus be that for levels of $g_m \in (\frac{\mu_L \sigma_r^2}{2\sigma_L}, \frac{\sigma_r^2}{2\sigma_L} + \frac{\mu_L \sigma_r^2}{2\sigma_L^2}] = [g_m^*, g_m^{**}]$, the non-linear part is concave for low Q_{dm} but convex for large Q_{dm}; yet in any case strictly increasing.

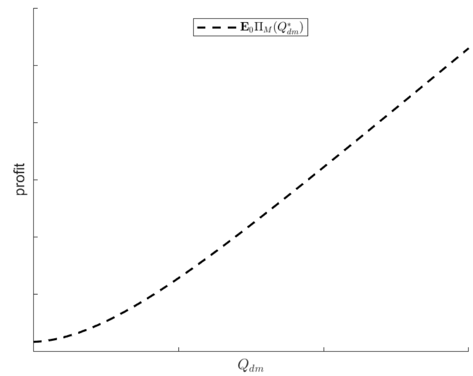
5.3.3. Note that approaching large Q_{dm}, the slope becomes linear and approximates g_m:

$$\begin{aligned} \lim_{Q_{dm}\to\infty} \left[(1 - D_m)\, g_m + \frac{\sigma_r^2}{2} d_m \right] &= g_m \left(1 - \lim_{Q_{dm}\to\infty} D_m \right) + \frac{\sigma_r^2}{2} \lim_{Q_{dm}\to\infty} d_m && (127) \\ &= g_m (1 - 0) + 0 = g_m && (128) \\ & && (129) \end{aligned}$$

5.4. Recall that, I have assumed that $g_m \geq \underline{g_m} > g_m^{**}$. And thus, $\mathbb{E}_1 \Pi_m$ is a strictly convex function. The contrary case is analyzed in the next Section.

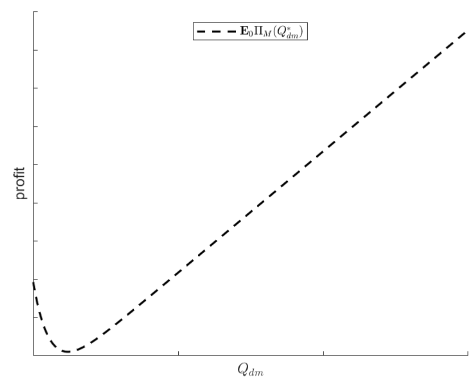
5.5.I then turn to combining the different cases from 3. and 4. and describe all the possibly functional forms of $\mathbb{E}_1 \Pi_m$. I conclude that, allowing for partial insurance, that conditional on being a CM, a seller always offers the insurance.

5.5.1. Assume that the linear part has a (weakly) positive slope. Then, the sum of strictly increasing convex function (non-linear part) and strictly/weakly increasing quasi-convex function (linear part) results in a strictly increasing, convex function ($\mathbb{E}_1 \Pi_m$).



5.5.2. Assume that linear part has a strictly decreasing slope.

5.5.3.1. Here, if $g_m > -p_d - p_m - v_m + (1+\delta)g_m$, $\mathbb{E}_0\Pi_m$ is decreasing for low Q_{dm} but is ultimately strictly increasing and positive. For large Q_{dm}, $\mathbb{E}_1\Pi_M$ asymptotically approaches a slope of $p_d + p_m - v_m - \delta g_m > 0$.



Because $\mathbb{E}_0\Pi_m$ is strictly decreasing in Q_{dm}, this would imply for CMs matched with buyers of low a_b, that those do not offer any bundle, yet become clearing members. This is ruled out by assumption of this section. Having assumed that CM indeed offer product bundle d and m. To not reach any contradiction it remains to verify that this is indeed the case in the $time1$ section.

5.5.3.2. If $g_m < -p_d - p_m - v_m + (1+\delta)g_m$, then the $\mathbb{E}_1\Pi_m$ is always strictly decreasing (figure trivial, therefore omitted)

6. Recall that under mandatory insurance, the no switching equilibrium is unique. Thus, thus combining the just derived results. For $g_m > g_m^**$, and conditional on being a clearing member, buyers hedge and insure all of a buyers assets. All non-clearing members exit the market together

with their buyers. Recall, that it remains to be verified that, expecting not to hedge and insure any assets, the seller does not become a CM (point 5.3.1.).

This concludes the proofs for Section 3.1. For proof of the Corollary, please see point 3. in *Proposition 1.*

B.2. Proofs Section 3.2 Voluntary Counter Party Default Insurance

Under voluntary insurance, the product d can be held also without bundling it with a product m. Given this, I start by deriving p_m as stated in Lemma 1.

Sketch of proof for Lemma 1

1. Take a buyer that has bought product d from $s \in M$ at price p_d with the intention to buy product m.

2. Again, the seller can set a take it or leave it offer, [61] The difference to mandatory insurance however is, that the buyer now may choose to forego the insurance and hold product d as a stand-alone. Thus, the seller can only capture all utility up until $u_d - p_d$. Accounting for the buyer's other expenses associated with product m this implies:

$$u_{dm} - p_d - p_m - v_m = u_d - p_d \tag{130}$$

$$p_m = u_{dm} - u_d - v_m \tag{131}$$

3. Note for completeness that seller s will never allow the buyer to access the CCP via another clearing member. For that the buyer would additionally incur switching cost. Entering the buyer's participation constraint for product mThese will lower find profit maximizing to allow b to use another seller for intermediation.

4. Then it remains to be shown that clearing members always offer product m to all their product d buyers regardless of size.

4.1. For this, assume buyers have consistent beliefs $\hat{D}$, such that in equilibrium $\hat{D}_s$ is correctly anticipated and shared by all buyers (confirmed later).

4.2. Assume that Q_d sales have realized. Then, any variation in expected profits solely depend on changes in Q_{dm}.

[61] The veto powers comes from regulators requiring that product m is bought by both counterparties, or it won't come into effect at all.

5. Using results from Appendix A.2, the slope of seller profits as a function of Q_{dm} for a given Q_d is:

$$\frac{\partial \Pi_s^1 + (1 - D_s)\mathbb{E}_1[\Pi_s^2 \mid \Pi_s^2 > 0]}{\partial Q_{dm}} = p_m - v_m - (1+\delta)g_m + g_m(1 - D_M) \tag{132}$$

$$= u_{dm} - u_d - 2v_m - (\delta + D_M)g_m \tag{133}$$

6. Here it is important to note that any marginal change in Q_{dm} is not observable to buyers, such that the seller takes $\hat{D}$ as given for this FOC.

6.1. Consequently, $u_{d-} - u_d - v_m - \delta g_m$ remain unchanged.[62]

6.2.Further, D_M is strictly decreasing in Q_{dm} when holding Q_d constant. This is because the seller posts additional collateral for every product m sale while at the same time keeping risk-exposure constant.

7. Given this, we can have three cases.

7.1. If $u_{dm} - u_d - v_m - \delta g_M < 0$, then the CM never offers product m to any buyer.

7.2. If $u_{dm} - u_d - v_m - \delta g_m - D_M(Q_{dm} = 0) > 0$. Then, the CM offers product m to any buyer, indenpendent of size.

7.3. If $u_{dm} - u_d - v_m - \delta g_m - D_M(Q_{dm} = 0) > 0$, but ultimately $u_{dm} - u_d - v_m - \delta g_m$, then the expected profits first decrease in total sales but are ultimately strictly increasing. Then, a seller insures all product ds, conditional on having amassed sufficient sales. In this case, it is independent whether these sales come from one or several buyers,

8. Summarizing points 7.1.-7.2., a clearing member either offers the product m to all or none of her product d sales. And thus, clearing members do not discriminate between buyers regarding product m.

9. I follows immediately from p_m that buyers choose sellers only based on the utility from product d:

9.1. The utility from holding product d alone is: $u_d - p_d$.

9.2. Recall that $p_m = u_{dm} - u_d - v_m$. Then utility minus prices from holding the bundle is:

[62] Nevertheless, to be verified that this (take-as-given) $\hat{D}$ is consistent ex ante from a buyer's point of view. This is formally addressed in *Remark 2*.

$u_{dm} - p_m - p_d - v_m = u_d - p_d$

9.3. Following this, all buyers' choice of seller solely depends on the utility u_d relative to the price p_d and per asset switching cost C/a_b.

10. This allows me to derive the price p_d and buyers choice of seller. Before doing so, please note the following about buyer's beliefs $\widehat{D}_s$ about seller default.

10.1. First recall, that I have assumed that S is large and sellers compete in prices over product d.

10.2. Second, it can be shown that sellers find it strictly profit maximizing to sell product d for any $p_d \geq 0$ and always offer product d for all of a buyers assets.

10.2.1. This follows directly from the sellers' right to strategically default on negative profits at $t = 2$. Using properties of the sellers' profit functions as derived in section A.2, it can be shown that the expected profits are strictly increasing in the number of units of product d sold:

$$\frac{\partial \mathbb{E}_0 \Pi^s}{\partial Q_d} = p_d + \frac{\sigma_r^2}{2} f(0) > 0 \quad \forall p_d \geq 0 \tag{134}$$

10.2.2. Note here, that the seller takes the buyers' beliefs about their default probability as given. I.e. given an associated buyer belief of their default probability, sellers find it always profitable to sell additional derivatives. It is later to check that these buyer beliefs are ex ante correct.

10.3. Any equilibrium, where a buyer wants to insure only a fraction of the assets cannot be sustained in Bertrand competition. 10.3.1. To sustain such an equilibrium, p_d must be strictly above zero. Denote the fraction of hedged assets with x

$$\begin{aligned}
x &\in [0,1) && (135)\\
x a_b(u_d - p_d) + (1-x) a_b u_r - \mathbf{1}C &> a_b(u_d - p_d) - \mathbf{1}C && (136)\\
x(u_d - p_d) + (1-x) u_r &> u_d - p_d && (137)\\
(1-x)p_d + (1-x)u_r &> (1-x)ud && (138)\\
p_d &> u_d - u_r > 0 && (139)\\
p_d &> 0 && (140)
\end{aligned}$$

10.3. This shows that sellers have an incentive to deviate from any price $p_d > 0$, if this implies they gain new buyers. This is because they make strictly positive profits at $p_d = 0$. Hence any equilibrium, where a buyer insures only a fraction of assets after observing p_d cannot be sustained. Because there is always at least one seller charging $p_d = 0$.

11. Given this, it follows almost directly that all unmatched sellers charge a $p_d(a_b; switch) = 0$ to their non-matched buyers to incentivize them to switch.

11.1. Here recall that a large market implies no unmatched seller is ex ante unique in the eyes of buyers: there exist at least one other seller with the same sized matched buyers.

11.2. Recall that offering product d at $p_d = 0$ is still strictly profit maximizing.

11.3. Thus standard Bertrand competition arguments apply and all unmatched sellers charge $p_d(a_b, switch) = 0$.

12. Then, note that all buyers consider switching to the same seller and derive a per-asset utility $u_d(a_b, switch)$ from that.

12.1 Recall that I have assumed that there exist clearing members that are selling product m. Further, conditional on that, I have shown that they insure all their product d buyers asset.

12.2. Further, recall that their default probability reduces in total product m sales.

12.3. A risk-averse buyer therefore prefers switching to the clearing member(s) they expect to have highest product m sales to other buyers.

12.4. All buyers have the same information set and preference. Any SPNE is thus characterized by the buyers' anticipating (correctly) the clearing members with the most product m sales. I denote this anticipated utility from switching with $u_d(a_b, switch)$.

13. Contrary to this, the utility from staying is denoted with $u_d(a_b; stay)$. Then, recall any other buyer charges $p_d(a_b, switch) = 0$. Then, the matched buyer charges a price $p_d(a_b; stay)$ that just makes the buyer indifferent between switching or not:

$$u_d(a_b; stay) - p_d(a_b; stay) = u_d(a_b, switch) - C/a_b \tag{141}$$

$$p_d(a_b; stay) = C/a_b - \left[u_d(a_b, switch) - u_d(a_b; stay)\right] \tag{142}$$

Any higher price for sure makes the buyer switch and cannot be profit maximizing for the matched seller. Recall that even for $p_d = 0$ selling product d is profitable. For any lower price however, the seller would leave profits on the table.

14. This price is not sufficient to deter switching if the gains from switching exceed the switching costs. In that case $p_d(a_b, stay)$ would be negative violating the assumptional restriction. Then the matched buyer would charge $p_d(a_b, stay) = 0$ such that:

$$p_d(a_b; stay) = \max\{C/a_b - \left[u_d(a_b, switch) - u_d(a_b; stay)\right]\ ;\ 0\} \tag{143}$$

15. Similarly, it may also be that the gains from switching are not enough to ever entice switching. Recall that this is the case when;

$$u_d(a_b; switch) - C < u_r \tag{144}$$

In that case, the matched seller is a de-facto monopolist can can charge:

$$p_d(a_b; stay) = u_d(a_b; stay) - u_r \tag{145}$$

Given the above results, I can now derive some general properties of the equlibria:

1. All buyers purchase the same combination of assets from the same seller.

1.1. From the Lemma above, we know that buyers are always offered product d at a competitive price that induces either their staying with their matched buyer or switching.

1.2. We further know that, when purchasing product d from a clearing member, the buyer is either offered product m for all or none of his assets. He accepts this in either case, as p_m is such that the buyer is always indifferent between holding the product or not.

1.3. And hence, buyers always hegde all assets, and insure either all or none of them.

2. Then note that set of sellers to which buyers consider to switch to can be restricted to the set of clearing members M.

2.1. Before we know that once a seller is a clearing member, the seller always finds it optimal to sell the counterparty default insurance to all its buyers (or none).

2.2. For the same amount of buyers switching to a clearing member relative to a non-clearing member, they have a lower default probability due to $g_m \geq g_m^*$. Therefore, the buyers considering switching anticipates, that the clearing member will post collateral g_m for at all of her other buyers.

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3. Further, all buyers switch to the same clearing member. Proof by contradiction:

3.1 Assume not, such that majority share of the switching buyers has switched to sellers s^* and the remaining buyers have switched to s^{**}, where $s^*, s^{**} \in M$. Every buyer that found it profitable to switch to s^{**} finds it even more profitable to switch to s^*.

3.2 This is because switching costs are the same for every buyer whether they switch to s^* or s^{**}. However, the gains of trade from insurance increase the more buyers purchase from the same seller as ${}^{\partial \widehat{D}}/_{\partial Q_{dm}} > 0$.
Using results from section A.2:

$$\frac{\partial F\left(0, \mu\left(\#\text{ of insurance sales}\right), \sigma^2\right)}{\partial \#\text{ of insurance sales}} = -g_m f(0) < 0 \quad for \quad g_m > 0 \tag{146}$$

3.3 Hence, all buyers switching to the smaller clearing member have an incentive to switch to the bigger clearing member instead. Only if all buyers switch to the same clearing member do they not haven an incentive to deviate.

4. Thus, it just remains to be shown whether given C none, some or all buyers switch.

I will start with the fully switching equilibrium. Sketch of proof for ***Proposition*** *3* :

1. In a fully switching equilibrium, it must be that a matched seller s will not be able to hold its matched buyer b even for a price $p_d(a_b, stay) = 0$. As the switching cost frictions are not large enough to deter switching, standard price competition arguments apply and all sellers charge $p_d(a_b; switch) = 0$.

2. Then, we know from Corollary **??** that in any fully switching SPNE all buyers switch to the same clearing member.

3. Further, a buyer b is offered derivative product d at price $p_d(a_b; scwitch) = 0$ from that seller s^* (and all other sellers). Consequently,

4. conditions (11) and (12) can be rewritten, such that for every b switching to $s^* \in M$ is optimal

[63] The buyer can anticipate that they will also be offered the default insurance from any clearing member. However, recall that this seller will capture all utility gains from the insurance. The buyer considering to switch is thus only considering which seller offers the highest utility gains, when purchasing the derivative *without* insurance.

if:

$$u_d(a_b; stay) \leq u_d(a_b; switch) - \frac{C}{a_b} \quad \forall a_b \tag{147}$$

$$C \leq a_b \left[u_d(a_b; switch) - u_d(a_b; stay)\right] \quad \forall a_b \tag{148}$$

5. Then note that in a fully switching equilibrium, all buyers switch to the same clearing member. This clearing member posts collateral for every sale. Having assumed that $g_m > g_m^*$ implies that this clearing members default probability decreases with every sale. Further, having assumed the market to be large, implies $u_d(a_b; switch)$ is equal to $u_{dm} = \mu_r$. This is because for the large sales volume, D_M asymptotically approximates zero.

6. It can be shown that the right hand side of inequality (148) is strictly increasing in a_b.

$$\frac{\partial a_b \left[u_d(a_b; switch) - u_d(a_b; stay)\right]}{\partial a_b} = \frac{\partial a_b \left[u_{dm} - u_d(a_b; stay)\right]}{\partial a_b} \tag{149}$$

$$= \underbrace{u_{dm} - u_d(a_b; stay)}_{+} - a_b \underbrace{\frac{\partial u_d(a_b; stay)}{\partial a_b}}_{-} \tag{150}$$

6.1. the first time in the FOC is positive, as for a risk-averse buyer the utility in the absence of default risk exceeds the utility from buying product d from a risky seller with a positive probability of default.

6.2. The second term is overall positive. $u_d(a_b; stay)$ is decreasing in the number of assets a buyer has, because it is formed before the seller would insure the assets at the CCP. And any uninsured product d sales increases the variance of seller profits, but not the mean. And thus ultimately increases default probability. Multiplied however, by a minus one implies it enters overall positively in the slope.

7. It is thus both necessary and sufficient to show that condition 150 holds for the smallest buyer in the market. This is because the smallest buyer has the lowest utility gains from switching relative to the switching cost C. Nevertheless, switching must still be optimal for this buyer.

7. Applying the law of large numbers, the smallest buyer in the market is of size $\underline{a}$. Thus, for fully equilibrium to exists, it is both necessary and sufficient that:

$$C \leq \underline{a} \left[u_d(\underline{a}; switch) - u_d(\underline{a}; stay)\right] \tag{151}$$

$$\leq U_d(\underline{a}; switch) - U_d(\underline{a}; stay) \tag{152}$$

8. Then finally recall that the set of clearing members M contains at least two sellers. Ex ante, buyers are indifferent to which clearing member to switch to. Therefore, there exist $\mid M \mid$ fully switching equilibria.

The fully switching equilibrium is contrasted by the no switching equilibrium, where all buyers stay with their matched seller. Sketch of proof for ***Proposition 2*** :

1. Assuming the number of buyers is large results in the expected value of the sample maximum converging to the distribution maximum: $\mathbb{E}[\max a_b] \to a_b$.

2. Recall that I have shown/assumed above that: clearing members offer product m, those clearing members with the most sales are safest, these are never monopolists and always charge p_d, and thus buyers only consider switching to them. Finallym the utility from switching to the safest clearing member is denoted with $u_d(a_b, switch)$,

3. Then the no switching equilibrium exists if, each seller can set a price $p_d(a_b; stay) \geq 0$ and still deter switching.

$$C \geq a_b \left[u_d(a_b; switch) - u_d(a_b; stay)\right] \qquad \forall a_b \tag{153}$$

4. Here note again that the right-hand side is increasing in a_b:

$$\frac{\partial a_b \left[u_d(a_b; switch) - u_d(a_b; stay)\right]}{\partial a_b} = \underbrace{u_d(a_b; switch) - u_d(a_b; stay)}_{+} + a_b \underbrace{\left[\frac{\partial u_d(a_b; switch)}{\partial a_b} - \frac{\partial u_d(a_b; stay)}{\partial a_b}\right]}_{+} \tag{154}$$

4.1. The first term above is quite trivially positive. The clearing member, anticipating her buyer not to switch and offering product m to that buyer, is safer. Thus a risk-averse buyer has a higher utility from purchasing product d upon switching.

4.2. The second term is not so straight forward and math is omitted here due to complexity. But it can be shown that: 4.2.1. Both $u_d(a_b; switch)$ and $u_d(a_b; switch)$ decrease in a_b, as the default probability increases in uninsured sales. 4.2.2. $u_d(a_b; switch)$ decreases by less than $u_d(a_b; stay)$. This follows from the fact that the clearing member has a higher mean from the collateralized product m sales. Using expression (99)), therefore CMs default probability increases less. Therefore, the risk-averse buyer's utility decreases less. 4.2.3. Then both decreasing, but $u_d(a_b; stay)$ decreasing more implies that the difference between the two derivatives is positive.

4.3. Thus, a positive plus a positive term is positive. And the right-hand-side strictly increases in a_b

5. Therefore it is both necessary and sufficient for the no switching equilibrium to exists, when even the largest buyers of size $\overline{a}$ do not switch, conditional on nobody else switching. Thus the above condition reduces to:

$$C \geq U_d(\overline{a}; switch) - U_d(\overline{a}; stay) \tag{155}$$

6. The no-switching equilibrium is the unique equilibrium if there does not exists any other belief system under which switching is the best response.

6.1. In the most extreme belief system, a buyer of size $\overline{a}$, expects all other buyers to switch to the same clearing member: This buyer as the lowest per asset switching costs; the lowest utility from staying with his matched buyer (due to the high volume of uninsured sales) and would expect a perfectly safe clearing member in a large market.

6.2. Hence, even in the most extreme belief system, switching is never optimal if:

$$C \geq U_{dm}(\overline{a}; switch) - U_d(\overline{a}; stay) \tag{156}$$

6.3. I label the threshold for which the equation just holds with $\overline{C}$.

Then, I can show that for every $C \in [\underline{C}, \overline{C}]$ a fraction of smaller buyers stay and a fraction of larger buyers switches. This defines a partial switching equilibrium.

Sketch of Proof for *Proposition 4*

1. The partial equilibria can ever only be characterized by a continuum of buyers below a threshold n_c not switching and a continuum of buyers above the threshold n_C switching. The proof follows through exclusion.

1.1. An alternative candidate equilibrium is, where some smaller and some larger buyers switch, but there is a discontinuity in-between. However, this equilibrium cannot be sustained. In point 4. for the proof of Proposition 2, I have shown that for a given number of switching buyers, the benefits of switching strictly increase in size. Thus, if the larger and the smaller buyers find switching optimal, so would the medium sized buyers in the middle. This would violate the assumption that (correctly anticipated), there is a break in the switching buyers' size. Thus, this candidate equilibrium can be ruled out.

1.2. Following a similar logic (omitted as identical to the above point), any partial equilibrium, where some smaller buyers switch and some larger buyers not, can be ruled out.

1.3. Thus, any partial equilibrium must have a unique threshold, where all larger buyers switch to the same seller and all smaller buyers stay with their matched seller.

2. Then, the size threshold n_C is thus the buyer, who is just indifferent between switching or not, anticipating all larger buyers to switch:

$$C = U_d(a_c; switch) - U_d(a_c; stay) \tag{157}$$

3. Here, notice that the subset of switching buyers endogenously adjusts.

No Sellers Offering Product m This paragraph completes the analysis of voluntary insurance by derive the equilibrium, when no sellers offer product m.

1. First note, that no seller offers product m and hence, no seller posts collateral. Therefore, any additional product d increases the seller's default probability: a product d only increases the variance of seller profits, but the mean remains constant at $\mu_L > 0$ (see equation 99).

2. Second note that given this, buyer's utility from switching decreases in the total product d sales from the unmatched seller. Therefore, b buyer's consider to switch only to the sellers with the lowest total sales.

3. Then it can be shown that the no switching equilibrium exists.

3.1. Again, similar arguments as above apply and all none-matched buyers charge $p_d(a_b; switch) = 0$.

3.2. Then, in the no switching equilibrium, the seller with the lowest sales is the one matched with a buyer of size $\underline{a}$. The associated utility from switching to that seller is $u_d(a_b; switch)$.

3.3. Anticipating (correctly) that no other buyer switches to a matched buyer's seller, he expects a utility $u_d(a_b; stay) > u_d(a_b; switch)$. This is because the matched seller has totally less sales, than if the buyer would switch.

3.4. Given this $p_d(a_b; switch) = 0$ and C, it can be shown that the matched buyer can always charge a price $p_d(a_b; stay) > 0$ that deters switching:

$$u_d(a_b; stay) - p_d(a_b; stay) = u_d(a_b; switch) - C/a_b \tag{158}$$

$$p_d(a_b; stay) = \underbrace{C/a_b}_{+} + \underbrace{u_d(a_b; stay) - u_d(a_b; switch)}_{+} > 0 \tag{159}$$

3.5. Then recall from earlier, that for any $p_d(a_b; stay) \geq 0$, the seller will offer the product d and find it profitable.

3.6. Thus, neither buyers nor sellers have an incentive to deviate and the no switching equilibrium exists.

3.7. Note for completeness, that in case a buyer is captive, he is still charged $p_d(a_b; stay) = u_d(a_b; stay) - u_r$.

4. Further, it can be shown that this no switching equilibrium exists.

4.1 First, I exclude any equilibrium where two or more buyers purchase from the same seller. Two or more buyers purchasing from the same seller implies both that: at least one seller has zero sales and at least one buyer pays switching costs C. Then, the buyer, who has to pay switching costs C has an incentive to deviate to the seller without sales. He would have to pay C in either case. However, the utility from purchasing product d from a seller without any other sales strictly exceeds the one from staying with the seller with additional buyers. Hence, he has an incentive to deviate.

4.2. There could however exists a different equilibrium, where at least some buyers switch, but all buyers end up with an individual seller.

4.2.1. First, note that the equilibrium follows in two stages: first sellers set prices; then given these prices, buyers play their best response regarding switch versus staying. Here, as always, they stay if:

$$u_d(a_b; stay) - p_d(a_b; stay) \geq u_d(a_b; switch) - p_d(a_b; switch) - C/a_b \tag{160}$$

4.2.2. Then to introduce such equilibrium, the sellers charge unmatched buyers again $p_d(a_b; switch) = 0$. This is as always, because ex ante no unmatched seller is unique: all are expected to have no other sale in equilibrium. To their matched buyers however, the sellers must also charge their a price:

$$p_d(a_b; stay) > C/a_b + u_d(a_b; stay) - u_d(a_b; switch) \tag{161}$$

This is to ensure, buyers indeed switch to another seller.

4.2.3. Recall that the sellers have an incentive to sell product d even for $p_d = 0$. Thus, such equilibrium can be sustained only if:

$$0 > C/a_b + u_d(a_b; stay) - u_d(a_b; switch) \quad \forall b \in B_{switch} \tag{162}$$

In any other case, the matched seller has an incentive to deviate and charge $p_d(a_b; stay) \geq 0$ to retain the matched seller, when anticipating to also attracting the unmatched seller.

Summarizing The Voluntary Insurance Results Unlike under mandatory insurance, there exists a multiplicity of equilibria under voluntary insurance. Remark formally summarizes them.

Remark 1.
If M and $S_{dm} \cup M_{dm}$ are non-empty subsets and $C_{NS} \leq \underline{C}$, then for:

(i) $C \in [0, C_{NS})$ only the fully switching equilibria exist,
(ii) $C \in [C_{NS}, \underline{C}]$ the fully switching equilibria and the no switching equilibrium coexist,
(iii) $C \in (\underline{C}, \overline{C}]$ the partial switching equilibria and no switching equilibrium coexist ,
(iv) And $C > \overline{C}$ the no switching equilibrium is unique.

If M and $S_{dm} \cup M_{dm}$ are non-empty subsets and $C_{NS} > \underline{C}$, then for:

(v) $C \in [0, \underline{C}]$ only the fully switching equilibria exist,
(vi) $C \in (\underline{C}, C_{NS})$ only partial switching equilibria exist,
(vii) $C \in [C_{NS}, \overline{C}]$ the partial switching equilibria and no switching equilibrium coexist,
(viii) And $C > \overline{C}$ the no switching equilibrium is unique.

Appendix C. Proofs Section 4: Time 0 Outcomes

C.1. Proofs for Section 4.2: Mandatory Insurance

Under mandatory insurance, and relying on results from Section 3, the sellers compare the following two expected profits, when deciding whether to become a CM $t = 0$:

$$\mathbb{E}_0\Pi = (1-D)\mathbb{E}_0[L \mid L > 0] = (1-D)\mu_l + d(a_b\sigma_r^2 + \sigma_L^2) \tag{163}$$

$$\mathbb{E}_0\Pi_M = -e_m + a_b \cdot (p_d + p_m - (1+\delta)g_m) + (1-D_M)(a_b g_m + \mu_L) + d_M(a_b\sigma_r^2 + \sigma_L^2) \tag{164}$$

Given these, one can show that the SPNE is a unique no switching equilibrium with large sellers becoming clearing members and small sellers exiting (together with their buyers).

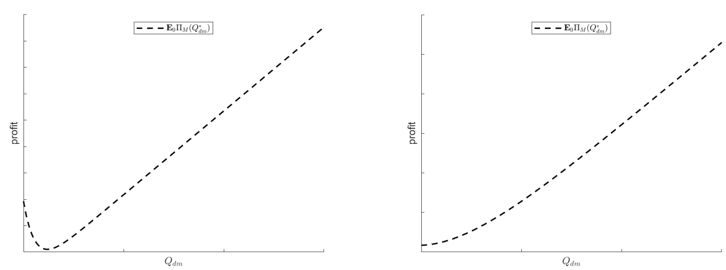
Sketch of proof for *Proposition 6*:

1. Note that $\mathbb{E}_0\Pi$ is a constant function at $D(Q_d = 0)\mu_L + d(Q_d = 0)\sigma_L^2$.

2. Note that for $Q_{dm} = Q_d = 0$, $\mathbb{E}_0\Pi_M$ is equal to $\mathbb{E}_0\Pi - e_m$, i.e., it intersects the y-axis e_m units below.

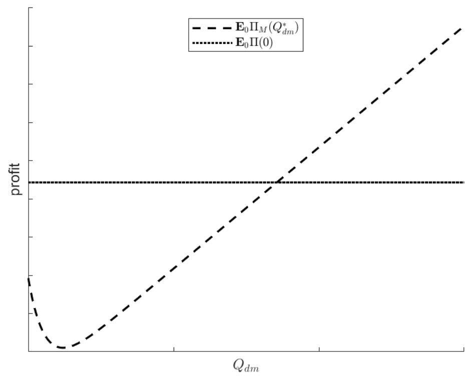
3. Further, recall the functional forms of of $\mathbb{E}_0\Pi_M$:

Figure 16: Different Shapes of Expected Clearing Member Profits when $g_m > g_m^{**}$



4. It becomes immediately clear that intersecting the y-axis (weakly below) $\mathbb{E}_0\Pi$, the clearing member profits cross the profits from exiting at most once.

5. Pivoting back to the proof of *Proposition 1*, here I now consider the case where $\mathbb{E}_0\Pi_m$ has a local minimum in Q_{dm} before increasing and ultimately becoming positive. In that case it can easily be seen that $\mathbb{E}_0\Pi$ crosses the expected clearing member profits only once. And more importantly in the upward sloping part. Consequently, conditional on being a CM, a seller offer the bundle to all assets of a buyer. This concludes the proofs under mandatory counterparty default insurance.



C.2. *Proofs for Section 4.3: Time 0 Equilibrium under Voluntary Insurance*

In this sub-section I derive the SPNE under voluntary insurance anticipating the different outcomes at $t = 1$.

No Switching Equilibrium I start with all agents anticipating a no switching equilibrium at $t = 1$. The resulting expected profits of (non-) clearing members are thus:

$$\mathbb{E}_0\Pi_M = -e_m + a_b(p_d + p_m - v_m(1+\delta)g_m) + (1 - D_M)(a_b g_m + \mu_L) + d_M(a_b\sigma_r^2 + \sigma_L^2) \tag{165}$$

$$\mathbb{E}_0\Pi = a_b p_d + (1 - D) \cdot \mu_L + d(a_b\sigma_r^2 + \sigma_L^2) \tag{166}$$

Where:

$$p_m = u_{dm} - u_d(a_b; stay) - v_m \tag{167}$$

$$\text{captive buyers:} \quad p_d = u_d(a_b; stay) - u_r \tag{168}$$

$$\text{non-captive buyers:} \quad p_d = C/a_b - \big[u_d(a_b; switch) - u_d(a_b; stay)\big] \tag{169}$$

Sketch of proof for *Proposition 7*

1. Recall from earlier that profits $\mathbb{E}_0\Pi_0$ are always strictly increasing in total buyer size and thus sellers always offer at least product d. However, these profits depend on whether buyers are captive or not:

1.1. for captive buyers, $\mathbb{E}_0\Pi_0$ has the following slope in Q_d:

$$\frac{\partial \mathbb{E}\Pi}{\partial Q_d} = u_d(a_b; stay) + a_b - u_r \tag{170}$$

1.2. For non captive buyers, the slope is:

$$\frac{\partial \mathbb{E}\Pi}{\partial Q_d} = C + u_d(a_b; stay) - u_d(a_b; switch) \tag{171}$$

1.3. Recall that buyers are captive as long as: $u_d(a_b; switch) - C/a_b < 0$. These sellers thus extract the enture consumer surplus.

1.4. This is not longer possible, once buyers move from being captive to non-captive, sellers experience a kink in their profit function.

2. Now, I will turn to clearing member profits.

2.1. The clearing members matched with captive consumers can realize the same functional prices as under voluntary insurance. Even though CCP fees might vary under the two regimes, the general properties of the function remain the same.

2.2. For sellers matched with non-captive consumers, profits are still a strictly convex function:

$$\frac{\partial \mathbb{E}_0\Pi_m}{\partial Q_{dm}(Q_d)} = \underbrace{u_{dm} - u_d(a_b; switch) - v_m - (1+\delta)g_m + (1-D_m)g_M}_{linearpart} + \underbrace{(1-D_m)g_m + \frac{\sigma_r^2}{2}d_m}_{convexpart} \tag{172}$$

$$\tag{173}$$

2.3. However, the overall slope is lower, as:

$$u_{dm} - u_d(a_b; switch) < u_{dm} - u_r \tag{174}$$

$$u_r < u_d(a_b; switch) \tag{175}$$

Thus, while maintaining local convexity, $\mathbb{E}_0\Pi_M$ also experience as kink at the local threshold.

3. Note that assuming reasonable values of v_m and g_m, this local convexity is sufficient to ensure a single crossing and unique solution for the threshold.

Fully Switching Equilibrium Instead for low C, the fully switching equilibria are anticipated at $t = 1$. Sketch of proof for*Proposition 8*:

1. Recall that I have assumed that there exists a clearing member indeed offering the product d

plus m to all buyers. Then, it can be shown that $u_{dm} = u_d$.

1.1. For B large, $\widehat{D} = 0$ as $\frac{\partial D}{\partial Q_{dm}} < 0$ for $g_m > g_m^*$.

1.2. Because $\widehat{D}_M = D_M = 0$, we have $u_{dm} = u_d = \mu_r$.

2. Then, assuming $p_m \geq 0$, and $u_{dm} = u_d$, it must be that $v_m = 0$. For any higher $v_m > 0$, the buyer would not agree to product m as: $u_{dm} - u_d - v_m = -v_m < 0$.

3. Given this, it naturally follows that $p_m = 0$. Further, recall from *Proposition 3* that $p_d(a_b; switch) = 0$.

4. Assume that a seller expects to be the one clearing member. Then, offering product d and m results in strictly negative profits for for $\delta > 0$. Denote the average buyer's expected size with $\hat{a}$. Then:

$$\mathbb{E}_0\Pi_M = B\hat{a}[p_d + p_m - (1+\delta)g_m] + (1-0)B\hat{n}g_m + 0 \cdot (B\hat{a}\sigma_r^2 + \sigma_L^2) \tag{176}$$
$$= - B\hat{a}\delta g_m < 0 \tag{177}$$

Expected not to be that clearing member, the seller expects the profits from exiting the market.

$$\mathbb{E}_0\Pi = (1 - D(0))\mu_L + \sigma_l^2 d(0) \tag{178}$$

5. The probability of becoming the CM with all sales is one over the number of CMs: $\frac{1}{|M|}$. Then, comparing the pay-offs of being a clearing member and not are:

$$-\frac{1}{\mid M \mid}B\hat{n}\delta g_m + \frac{1}{\mid M \mid}[(1 - D(0))\mu_L + \sigma_l^2 d(0)] < \tag{179}$$
$$-B\hat{n}\delta g_m < (\mid M \mid -1)(1 - D(0))\mu_L + \sigma_L^2 d(0) \tag{180}$$

6. As the expected profits of becoming a clearing member are always below the expected profits from exiting the market, the subsets M is empty.

7. Unable to capture any clearing members, the CCP refrains from entering.

8. Note that sellers can always sell product d uninsured, even as a CM. However, they may additonal agree to offer product m. The additional profits from product m sales are:

The Partial Switching Equilibrium Sketch of proof for *Proposition 9*:

1. The properties of the profit functions for all sellers with non-switching buyers are identical as the ones under the no switching equilibrium:

1.1. $\mathbb{E}_0\Pi$ intersects the y-achsis above $\mathbb{E}_0\Pi_M$, but increases less in matched buyer size. Ultimately, they cross-upon which all larger sellers become clearing members.

1.2. The sellers with switching buyers cannot generate any sales. And thus, their profits are equal to market exit (minus e_m if exiting as a clearing member.

2. A reason they cannot generate any sales is due to all buyers switching to the seller with the largest non-switching buyers of size a_{PS}.

2.2. These sellers are clearing members, and thus insures her buyer's product m sales.

3. Any other equilibrium cannot be sustained.

3.1. Assume that only large sellers with non-switching buyers become clearing members. Then, one of them would attract all switching buyers and make a positive profit.
However, then a seller of with a buyer of size $a_P S$ has an incentive to deviate by becoming a clearing member. This way, she will for sure attract all buyers of size larger a_{PS}, because including her matched buyer, she has more total sales. And given the convex nature of $\mathbb{E}_0\Pi_M$, we know that offering additional the product bundles is optimal.

3.2. Assume only sellers, with matched buyers that are smaller than a_{PS} become clearing members cannot be optimal. If those find it optimal to pay e_m to sell the bundle to their matched buyer and potentially other (switching) buyers, then any larger seller also finds it optimal. This argument can be continued until a_{PS} is reached.

3.3 Thus, only equilibrium, where sellers matched with buyers of size a_{PS} become clearing members can be sustained. With equal probabilities, one of those sellers consequently attract all switching buyers at $t = 1$. In expectations, these sellers thus experience a jump in their profit function.

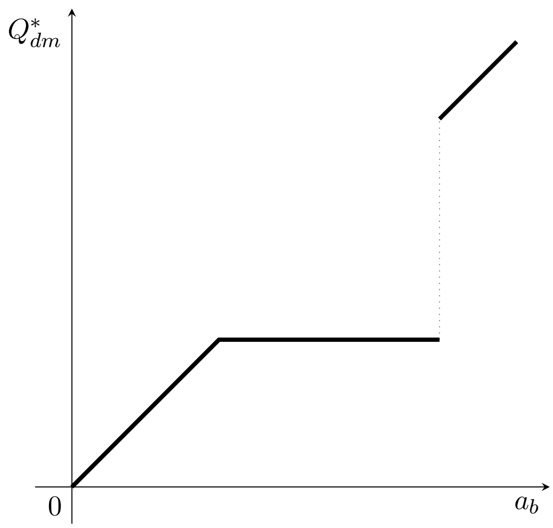
Appendix D. The SPNE When $g_m \leq g_{**}$

The main analysis focuses on the SPNE for the case where $\underline{g_m} > g_m^{**}$, which automatically also restricts the CCP's collateral choice g_m to that range. While this restriction is justified by the calibration exercise, this section nevertheless provides the theoretical results under the alternative: when the CCP sets $g_m \leq g_m^{**}$, supported by $\underline{g_m} \leq g_m^{**}$. Here, I maintain the assumption that $\underline{g_m} \geq g_m^{*}$, i.e. the regulator ensures that *insured* OTC derivatives increase the instability of the financial market.

D.1. Time 1 Outcomes

Mandatory Insurance The functional form of prices p_m and p_d are unaffected by the level of collateral. Hence, buyers are still indifferent between holding the bundle or exiting the market. Further, the no switching equilibrium is still unique. However, for g_m weakly smaller than g_m^{**}, clearing member profits non-monotonically increase in bundle sales: for small and large buyers, the clearing member profits strictly increase in bundle quantities; medium sized buyers will only be offered to insure a share of their a_b assets.

Figure 17: Equilibrium Bundle Quantities Q_{dm}^* when $g_m \in (g_m^*,\ g_m^{**}]$



$$g_m^* = \frac{\mu_L \sigma_r^2}{2\sigma_L^2} \tag{181}$$

$$g_m^{**} = \frac{\mu_L \sigma_r^2}{2\sigma_L^2} + \frac{\sigma_r^2}{2\sigma_L} > g_m^* \tag{182}$$

***Proposition* 10.** *Under mandatory insurance, the no switching equilirbium is unique and characterized by a bunlde price $p_d + p_m = u_{dm} - u_r - v_m$. However, for $g_m \in [g_m^*, g_m^{**}]$, only small and large clearing members offer the bundle for all their matched buyer's assets, while medium sized buyers offer to hedge and insure only a fraction. Buyers not matched with a clearing member exit the market.*

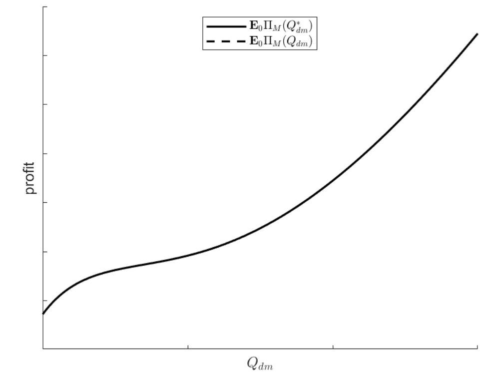
Sketch of proof:

1. The proof for bundle pries $p_d + p_m$ is omitted due to repetition. Please see Section B above for derivation.

2. Recall that $\mathbb{E}_1\Pi_M$ has two parts: a linear part in Q_{dm} and a non-linear part in Q_{dm}. Here, assuming $g_m \in (g_m^*, g_m^{**}]$ implies that the non-linear part is strictly increasing but concave for lower and convex only for higher Q_{dm}.

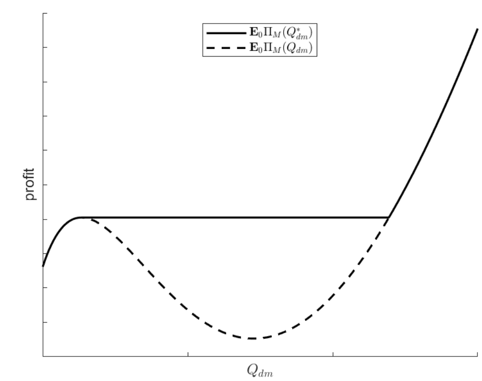
3. Given the properties og these two components, $\mathbb{E}_1\Pi_M$ can take on these functional forms:

3.1. Assume that the linear part has a positive slope. Then $\mathbb{E}_1\Pi_M$ is strictly increasing, but preserves its concavity for low Q_{dm}.



3.2.Assume that the liner part has a negative slope.

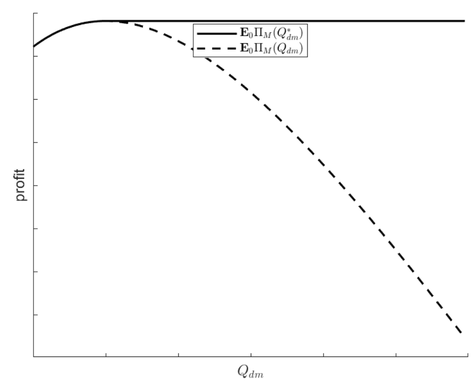
3.2. Here, for $g_m > -p_d - p_m - v_m + (1+\delta)g_m$, $\mathbb{E}_1\Pi_m$ is increasing for low Q_{dm} until a local maximum, then decreasing for intermediate Q_{dm} until a local minimum, but ultimately strictly positive and for large Q_{dm} asymptotically approaches a slope of $p_d + p_m - v_m - \delta g_m > 0$. See the dashed line in Figure **??** below.



However clearing members are free to insure only a fraction $Q^*_{dm} \leq Q_{dm}$ of the possible sales available to them. And thus, given the no switching equilibrium, sellers matched with intermediate the realized profits have a flat line for intermediate sales.

Here notice that any increase in v_m increases the flat line both to the left and right side: it lowers the linear part, while leaving the non-linear part unaffected. Hence, the overall slope is decreased at all Q_{dm} And hence, if v_m is sufficiently low me move into case 5.4.1. below. The reverse however also holds true such that if v_m is low enough, the linear part has a positive slope and we move to case 5.1.

3.2.2. For $g_m < -p_d - p_m + v_m + (1+\delta)g_m$, the function $\mathbb{E}_1\Pi_m$ may increasing for low Q_{dm} until a local maximum is reached (almost immediately after 0), but consequently strictly decreases until it approximates a slope $p_d + p_m - v_m - \delta g_m < 0$. See dashed line in Figure **??** below.



However again, the CM may offer to only partially hedge and insure their buyers' assets. And thus, the optimal number of sales Q_{dm} becomes a flat line after the maximum.

3.2.3. For $g_m << -p_d - p_m + v_m + (1+\delta)g_m$, the function $\mathbb{E}_1\Pi_m$ is strictly decreasing, even for low Q_{dm}. Figure omitted as trivial.

Voluntary Insurance The time-1 outcomes under voluntary insurance do not depend whether g_m exceed g_m^{**} or not. For a more detailed analysis of this, please see the Section above For here just note that this is for the following reasons:

1. All sellers offer at least product d. Further, the buyers are however indifferent whether they are offered product m.

2. The beliefs of switching buyers are formed before any actual sales realize and also shared: all buyers switch to the same seller.

3. For a given belief set, any CM either clears all or none of her product d sales.

4. These beliefs must be ex ante correct. And thus, any equilibrium with switching must have a

clearing member insuring all product d sales.

D.2. Time 0 Outcomes

Mandatory Insurance Recall from the time 1 outcomes that, for small $g_m \leq g_m^{**}$, medium sized clearing members may insure only a fraction of the buyers' assets. This is because a clearing member's total expected profits are non-monotonically increasing: $\mathbb{E}_0\Pi_M$ has a flat part with zero slope for intermediate values of a_b. Given this, it can easily be seen that Proposition 6 still holds here: there exists a unique size threshold a^* determining clearing membership.

Figure 18: Different Shapes of Expected Clearing Member Profits when $g_m \in [g_m^*, g_m^{**}]$

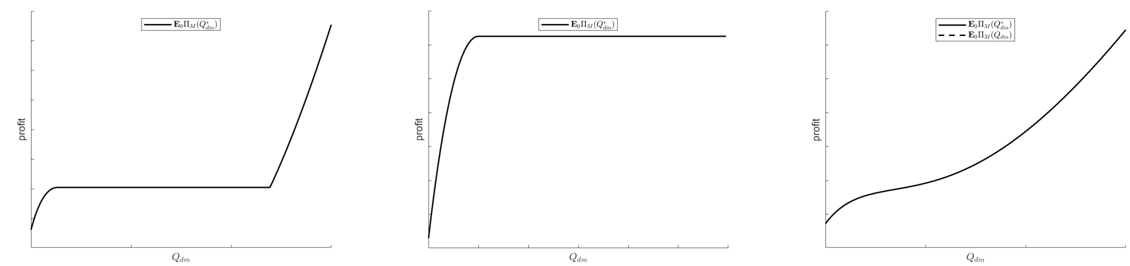
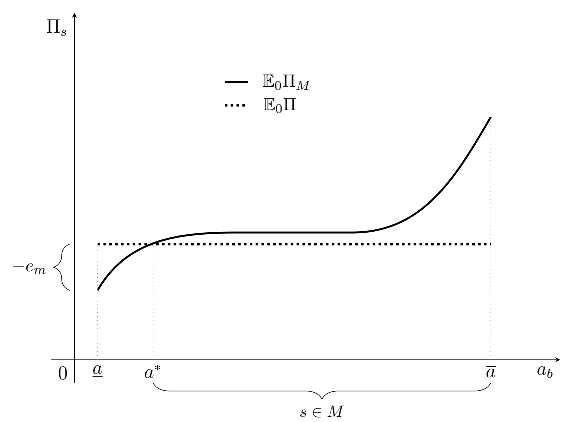
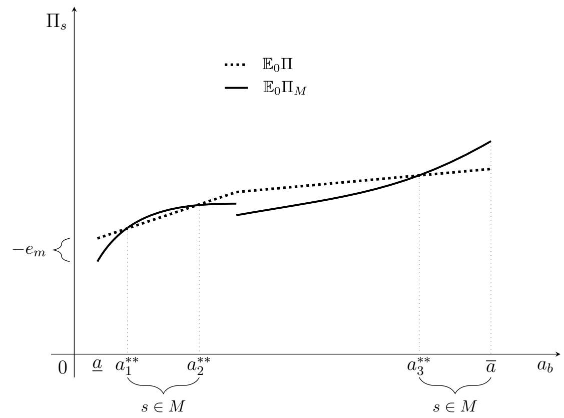


Figure 19: The SPNE Under Mandatory Insurance When $g_m \leq g_M^{**}$



Voluntary Insurance & No Switching If $g_m \in (g_m^*, g_m^{**}]$, the functional form of $\mathbb{E}_0\Pi_M$ becomes quite complex.

Figure 20: The SPNE Under Voluntary Insurance When $g_m \in (g_m^*, g_m^{**}]$



Thus, under voluntary insurance, the 7 does not apply any more.

***Proposition* 11.** *Under voluntary insurance, the SPNE with a CCP, no switching at $t = 1$ and a collateral leve $g_m \in (g_m^*, g_m^{**}]$, then multiple size thresholds define clearing membership and smaller clearing members may exist.*

Voluntary Insurance & Fully Switching The results under fully switching are identical to the ones in the main text.

Voluntary Insurance & Partial Switching Given the above described functional forms for $\mathbb{E}_0\Pi_M$ when $g_m \leq g_m^{**}$

Figure 21: The SPNE Under Voluntary Insurance When $g_m \in (g_m^*, g_m^{**}]$

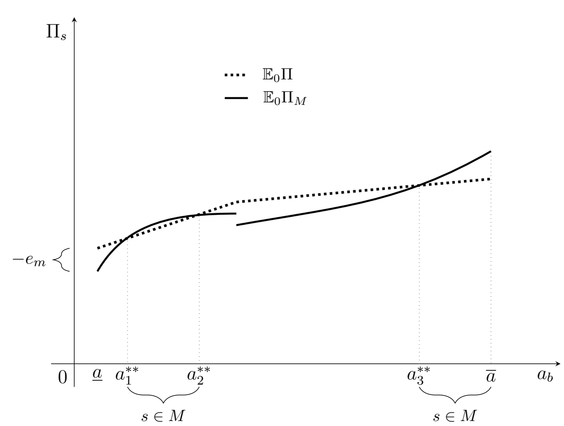


Figure 22: The SPNE Under Voluntary Insurance When $g_m \in (g_m^*, g_m^{**}]$