Optimal Policy for Financial Market Tokenization*

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March 19, 2025

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Abstract

Creating more efficient trading platforms can lower costs but also distort trade patterns. We model brokers' tokenization decisions—i.e., whether to represent assets as tradable tokens on a shared, programmable ledger. Brokers with heterogeneous market power compete to attract investors and execute their trades intra-broker or over-the-counter. Moreover, coalitions of brokers can invest in creating a tokenized market with faster, cheaper inter-broker settlement. Due to trade diversion incentives, equilibrium coalition structures feature excessive investment or insufficient unification. Public-private cost-sharing or interoperability mandates fail to achieve first best in isolation, but succeed when implemented jointly. These results withstand incorporating an open-access ledger (e.g., a public blockchain).

Keywords: Tokenization; Intermediation; OTC markets; Coalition formation.
JEL codes: C72, D85, G24, O33.

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1 Introduction

The financial press is abuzz with talk of tokenizing financial assets.[1] Several major brokers, including BlackRock, Goldman Sachs and JP Morgan, have announced tokenization initiatives, as has a coalition of brokers known as the Canton Tokenization Network, and the Boston Consulting Group estimates 16 trillion US dollars of tokenized assets by 2030. While the measurement of tokenization's potential impact is in its infancy, the first estimates indicate that the efficiency gains could be non-negligible, particularly for markets that currently trade over-the-counter (OTC).[2]

Several policy institutions are also taking an active role in the formation of tokenized financial markets, aiming to prevent markets from fragmenting across competing private ledgers. Approaches range from coordinating among brokers and ensuring the interoperability of any privately created ledgers, as is the case in Singapore, to public-private partnerships where the policymaker can take a leading role in the creation and operation of the new market infrastructure, as seen in Brazil, Switzerland, and the multinational Project Agorá.

What are the tradeoffs that policymakers face as they determine whether and to what extent to become involved in the formation of tokenization markets? If fragmentation is the main justification for policy, what are the economic forces driving brokers toward such fragmentation and why is this socially costly? If policy intervention is needed, would regulation, like mandating interoperability, suffice? Or is there a need for the public sector to go further, such as by sharing costs in a public-private partnership to create a tokenized financial market? This paper develops a model to consider these questions and provides the first formal analysis of optimal policy for the formation of tokenized markets.

[1] Tokenization is the creation of assets or representations of assets on a digital ledger that is trusted, shared and programmable. This enables such features as bundled contingent transactions that self-execute when conditions are met and the automation of parts of the issuance, exchange, servicing and redemption of financial assets (Agur et al., 2025; Aldasoro et al., 2023).

[2] In a matched sample of tokenized and conventional bonds, Leung et al. (2023) find that underwriting fees and bid-ask spreads on tokenized bonds are, respectively 25.8 and 5.3 percent lower. Furthermore, for a matched sample of tokenized and traditional asset-backed securities in China, Liu et al. (2023) estimate that tokenization on average lowers yields by 25 basis points. In addition, JP Morgan estimates that the automated redeployment of cash on a tokenized market reduces portfolio management costs by 22 percent.

We model an endowment economy containing six retail investors that need brokers to match them to each other to trade. Investors are initially assigned to one of three brokers and face switching costs if they want to move to a different broker. Broker 1 has one investor as an initial client, Broker 2 has two, Broker 3 has three and, in conjunction with switching costs, this leads to heterogeneity in brokers' market power.[3]

Except for their initial broker assignment, the investors are ex-ante identical. However, after having chosen a broker, a shock sorts the investors into two different groups, of potentially unequal size, that each desire to trade with the other. This sorting represents, for example, a liquidity shock that turns the affected subset of investors into sellers of an asset while the others take the buy side.

Brokers can use up to three trading modalities, which clear sequentially, to match their investors. In the first trading round, each broker clears any feasible within-broker matches of clients with complementary types. In the last trading round, brokers clear outstanding trades on a pre-existing OTC market to which all brokers have access. In between these two rounds, some or all brokers can also settle matches on a tokenized market, if they agreed to form one at the start of the game. Compared to the OTC market, the tokenized market has an advantage in both speed, as it clears earlier, and cost, because OTC transactions come at a variable cost to brokers while the tokenized market does not. However, creating the tokenized market does require participating brokers to incur an initial setup cost.

Brokers earn revenue from transaction fees and can price discriminate between their initial clientele and investors switching from other brokers, in line with the sweeteners that brokers offer new clients in practice. Toward each broker's initial client base, brokers engage in Bertrand competition subject to differentiation in marginal costs (depending on the share of trades that a broker expects to process OTC) and investor matching probabilities (from

[3]This is the simplest structure to analyze trade diversion incentives among heterogeneous brokers: at least three brokers are required for trade diversion to be possible, then at least six investors (distributed unevenly) are required for all brokers to have a different positive number of initial clients.

differentiated access to trading modalities).[4]

At the start of the game, brokers negotiate about forming a tokenized market, foreseeing the implications for their profits through the channels above. The brokers engage in a coalition formation game that results in no coalition, a partial coalition of any two brokers, or the grand coalition of three brokers. An equilibrium is found when none wish to individually or jointly deviate to a different coalition.

Solving for the equilibrium of the game, we find that the grand coalition never forms.[5] When brokers find a tokenized market too costly to set up, no coalition forms. In contrast, when brokers find that the benefits of a tokenized market justify its cost, a partial coalition forms. The underlying force is trade diversion. When one broker is excluded from the tokenized market, the included brokers expect to process a larger share of all investor matches. This outweighs the desire to minimize the cost of the average trade, which is zero when the OTC market is retired under the grand coalition. In equilibrium, the largest broker (Broker 3) and the smallest (Broker 1) band together to divert trade from the third (Broker 2).

A partial coalition is socially suboptimal. Identifying welfare as the sum of investor utility and broker profit, we find that welfare is highest under either the grand coalition or no coalition, depending on the setup cost and efficiency gains of the tokenized market. Intuitively, if the setup cost of the tokenized market is to be incurred, all brokers should be included on the platform to eliminate costly OTC transactions. When partial coalitions form in equilibrium, they instead involve either excess investment or insufficient unification. Excess investment occurs if a tokenized market socially costs more than it is worth but the

[4]Rather than resolving which investors come to trade through heterogeneous asset valuations and bidding, here all investors looking to take a given side of the transaction place the same value on the potential trade. Instead, these investors have heterogeneous access to trading technologies via brokers and this determines their likelihood of a match. This centers our model on the role of endogenous market infrastructure while retaining tractability.

[5]We use a selection criterion to address the multiplicity of equilibria that can arise because each investor's benefits from choosing a given broker depend on how many other investors have chosen it. The criterion selects for minimal investor movement: if the equilibrium where all investors stay at their initial brokers is feasible (i.e., self-confirming if each investor believes that all other investors stay), then it is selected. This criterion provides the strictest test for when policy is needed, since it focuses attention on brokers that need tokenization (rather than client monopolization) to create an efficient market.

private benefit of trade diversion nonetheless leads to its formation through a partial coalition. Insufficient unification results when forming the tokenized market maximizes welfare, but the private benefit of trade diversion leads two brokers to exclude the third from the platform instead of accepting the grand coalition.

We next turn to policy and consider whether an interoperability mandate can attain the social optimum. We incorporate this mandate by giving an excluded broker the option to join the tokenized market. Excess investment is motivated by trade diversion gains to the excluding brokers and the interoperability mandate—by allowing the excluded broker to join nonetheless—eliminates those brokers' socially wasteful desire to form a tokenized market. In contrast, insufficient unification is not so amenable to being solved by interoperability. When the cost of setting up the tokenized market is low enough, all brokers prefer a three-broker tokenized market to the lack of any tokenized market, and so full unification occurs when the preferred option of Brokers 1 and 3 (an exclusive coalition) is precluded by the interoperability mandate. But when the cost of setting up the tokenized market is higher, the least supportive broker vetoes the grand coalition, so no tokenized market forms at all. The attempt to achieve unanimity on a grand coalition thus turns out to be vulnerable to heterogeneous broker incentives and interoperability here leads to underinvestment. Investor externalities are a second force behind such underinvestment, as part of tokenization's efficiency gains accrue to investors through lower fees.

Escaping this underinvestment problem requires a second instrument. In the vein of public-private tokenization initiatives, we let the policymaker tax investors lump-sum and share in the cost of tokenized market formation. When used alone, this tool never improves the equilibrium coalition structure. But we show that the combination of cost sharing and an interoperability mandate *can* achieve first best in all cases.

Motivated by the example of BlackRock offering tokenized securities on open ledgers, including Ethereum, we extend to broker trade on a pre-existing tokenized market that comes without a setup cost but involves positive variable costs (e.g., Ethereum gas fees). We

find that when creating a separate proprietary ledger is not too costly, brokers continue to form partial coalitions to divert trade. Thus, the need for policy remains.

Our paper relates to a budding literature analyzing the implications of tokenization. A programmable ledger enables the simultaneous exchange of a seller's asset and a buyer's payment, and this settlement can occur instantaneously upon agreeing the contract.[6] Lee et al. (2024a,b) highlight a trade-off between the benefits of simultaneous settlement and the potential costs of a liquidity hold-up problem from instantaneous settlement. The latter originates in the requirement for the seller to own the asset at the time of trade, which reveals information that can be exploited by the buyer. These papers analyze the optimal design of a tokenized market in view of this trade-off, where Lee et al. (2024a) center on the joint design of settlement and trading systems and Lee et al. (2024b) on program execution and transaction verifiability. In Chiu and Koeppl (2019), the validation of tokenized market transactions relies on a consensus mechanism that more credibly addresses settlement risk when more miners join, which however depends on rewards that increase as congestion rises and the speed of settlement declines.[7] We contribute to this literature by examining private sector incentives to form tokenized financial markets and providing the first analysis of their implications for policy.

Our paper also intersects two separate strands of literature that investigate the formation of financial market trading structures and the adoption of financial technology. Dugast et al. (2022) are closest to us in the first strand. They model intermediaries of heterogeneous trading capacity that choose between centralized and OTC markets. Small intermediaries

[6]Simultaneity and instantaneity are often grouped together in the term "atomic settlement" but have distinct implications (Lee et al., 2022).

[7]Programmable tokens have also been considered in other contexts than financial asset trade, including means of payment (Kahn and van Oordt, 2022), trade finance (Cong and He, 2019), cross-border payments (Adrian et al., 2023, 2022), credit contract enforcement (Brunnermeier and Payne, 2023), bank runs (Georgiadis-Harris et al., 2024), decentralized finance (Azar et al., 2024), synthetic financial products (Rostek and Yoon, 2024), platform governance (Abadi and Brunnermeier, 2024; Auer et al., 2025; Reuter, 2024; Sockin and Xiong, 2023), monopolistic product market pricing (Brzustowski et al., 2023), truthful disclosure on decentralized markets (Garratt and Monnet, 2023), and the automation of a central planner (Townsend and Zhang, 2023). For a detailed discussion of the features of programmability, see Lavayssière and Zhang (2024).

prefer the OTC market due to the risk sharing that large brokers can profitably provide to them there, while mid-sized intermediaries opt for the centralized market. Our mechanism instead centers on the formation of a coalition to adopt a costly technology that may or may not be socially worthwhile but also facilitates trade diversion.[8] Joint technology adoption by (possibly partial) coalitions also distinguishes us from the second strand that focuses on externalities in financial technology adoption and the role of policy in addressing these (Alvarez et al., 2023; Crouzet et al., 2023; Higgins, 2024; Pagnotta and Philippon, 2018).[9]

The remainder of the paper is organized as follows. The next section presents the setup of the model. Section 3 derives the private sector equilibrium. Section 4 assesses welfare, which Section 5 uses to analyze socially optimal policy. Section 6 summarizes the model extensions and Section 7 concludes. Proofs can be found in the appendices.

2 Model

Our model contains two types of agents: investors and brokers. Investors in the model are retail investors, who cannot trade with each other directly. To trade, they must therefore engage the services of a broker. Investors and brokers are risk neutral and fully informed about the structure of the game that we describe below.

[8]This similarly sets us apart from other papers in this strand, which analyze the emergence of market structure under various conditions, including heterogeneity in investors' asset valuations (Babus and Parlatore, 2022), risk preferences (Malamud and Rostek, 2017), and trading intensity (Farboodi et al., 2023; Sambalaibat, 2022; Üslü, 2019), as well as endogenous market entry of investors (Chen and Duffie, 2021; Duffie et al., 2017; Lee and Wang, 2024; Pagano, 1989) and intermediaries (Atkeson et al., 2015; Biais, 1993; Bolton et al., 2016; Chang and Zhang, 2021; Farboodi, 2023; Farboodi et al., 2019; Miao, 2006; Rust and Hall, 2003; Wang, 2024). More generally, there is an extensive body of research on the comparison between OTC and centralized markets, for which we refer to the literature surveys of Benos et al. (2022), Bessembinder et al. (2020), Duffie (2022), Rostek and Yoon (2025) and Weill (2020).

[9]Much of this strand has recently centered on the adoption of new digital payment systems (Kajol et al., 2022), including the possibility to mandate interoperability among payment providers (Alok et al., 2024; Bianchi and Rhodes, 2024; Bouvard and Casamatta, 2024; Brunnermeier et al., 2023; Chiu and Wong, 2022; Copestake et al., 2025). For a literature survey on interoperability in payments, see Bianchi et al. (2023).

2.1 Investors

Investors are born with a money endowment, η, which they can use for payments, while any unused portion enters the investor's utility linearly (e.g., from consumption paid for with the remaining endowment).

Each investor begins the game attached to a particular broker and we refer to these starting attachments as the initial clientele of a broker. There are three brokers, who start with one, two and three initial investors, respectively. Brokers and investors are numbered according to the initial client base of the broker. Specifically, Broker 1 starts with one investor, Investor 11; Broker 2 starts with two investors, Investor 21 and Investor 22; and Broker 3 starts with three investors, Investor 31, Investor 32 and Investor 33. Written more generally, we denote investors by their initial broker l and a within-initial-broker identifier i, such that $li \in \{11, 21, 22, 31, 32, 33\}$.

We assume that an investor can only be a client of one broker, although this need not be its initial broker. An investor can choose to become a client of a different broker, but this involves a switching cost, τ, which is a non-pecuniary inconvenience cost. Intuitively, τ reflects the substantial time and effort that can be required to transfer assets between brokers (see, for instance, Agur et al., 2025).

Aside from their starting broker attachments, investors are initially homogeneous. At an intermediate stage of the game, investors are exogenously assigned one of two types, a and b, that can each realize a 'gain from trade' by interacting with the other via a broker. These types are a stylized representation of any source of ex-post heterogeneity that generates differences in the valuations of an asset, and hence a desire to trade. For instance, type b could reflect investors hit by a liquidity shock that makes them willing to sell a future income stream to type a investors at a discount to its held-to-maturity value.[10]

On discovering their type $k \in \{a, b\}$, investors enjoy gains from trade, normalized to one,

[10]The combination of ex-ante homogeneity and ex-post heterogeneity of investor types is common in the literature on OTC markets (e.g., Duffie et al., 2005; Hugonnier et al., 2019; Maurin, 2022)

if they are able to interact with the opposing type through their chosen broker. Broker j charges a fee f_{lj} to facilitate this, as discussed further in Section 2.2.2.

We assume for simplicity that investors are equally likely to be assigned to type a as to type b.[11] We denote by P_{kj} the probability that an investor of type k is matched with its opposite type, conditional on choosing to trade through broker j. The expected utility, u^e_{li}, of an investor li choosing broker j is then given by

$$u^e_{li} = \eta + \max\{(1 - f_{lj})\left(\tfrac{1}{2}P_{aj} + \tfrac{1}{2}P_{bj}\right), 0\} - \tau_{lj} \tag{1}$$

where $\tau_{lj} \in \{0, \tau\}$ and $\tau_{lj} = \tau$ if $l \neq j$ (whereas $\tau = 0$ when $l = j$, which means that the investor stays at its initial broker).[12] The max operator reflects that investors will not place a trade with the chosen broker unless the expected net return from doing so is weakly positive.

2.2 Brokers

Brokers earn profits by charging fees to facilitate investors' trades. As noted above, Broker 3 initially has one more investor than Broker 2, who initially has one more investor than Broker 1. This leads to differentiation in market power among them: Broker 3 has the most market power—since it has the most initial or 'home' investors, who face costs to leave—and Broker 1 has the least. Hence, τ parameterizes both the extent of market power toward investors and its differentiation among brokers. For $\tau \to 0$, Broker 3 has no advantage relative to Broker 1, as investors can freely switch. In contrast, for τ large enough brokers become uncontested monopolists with respect to their initial investors, in which case brokers'

[11] This is without loss of generality, since regardless of assignment probabilities, any ex-post set of investor types could materialize. For instance, five type a investors and one type b investor could be drawn. Of course, the probability that this happens would be larger if a were more likely to be assigned, but the model is not quantitative in nature.

[12] For tractability, we do not incorporate remitted broker profits in investor utility. As investors are not atomistic here, incorporating broker profit leads them to weigh how their actions affect broker profits, which is not a mechanism that pairs well with realistic retail investor choices and significantly complicates the model. Note that in Section 4, the policymaker does weigh both investor utility and broker profits.

relative advantages—bestowed by differences in initial clientele—become unassailable.

2.2.1 Trading modalities

There are up to three types of markets through which brokers can transact to execute trades for their clients. The first type is an intra-broker market. If a given broker's clientele includes some investors of type a and some investors of type b, then the broker can costlessly match pairs of opposing types and execute trades. Up to three such intra-broker markets exist in our model, corresponding to the number of brokers that attract at least two investors. The second type of market is the OTC market, of which just one exists—that connecting all brokers. We assume that this is pre-existing, i.e., it does not need to be set up by the brokers and is always present as an option for trades between any pair of brokers. Unlike intra-broker matching, operating on the OTC market is not costless to brokers: a broker pays γ for every investor that it pairs on the OTC market. The third type of market is a tokenized asset market. No such market exists at the beginning of the game and one is only created if two or more brokers choose to form it. Creating a tokenized market comes with total setup cost s to the involved brokers, and we assume that this cost is evenly split among them.[13] The coalition formation game is described in Section 2.2.4.

The tokenized and OTC markets differ in three ways. First, as described above, the tokenized market costs s to create, while the OTC market has no setup cost. Second, the tokenized market possesses a more cost efficient trading technology, reflecting the advantages described in Section 1. We normalize variable costs of processing a transaction on the tokenized market to zero and therefore γ parameterizes the cost efficiency gap between OTC and tokenized markets. Third, the tokenized market has a speed advantage (e.g., reflecting instantaneous settlement): its trading, clearing and settlement occur before those of the OTC market in the timing of the game shown in Figure 1 and further described in Section 2.3.

[13] In an extension that is currently work-in-progress, we let brokers negotiate about setup cost sharing within coalitions.

Figure 1: Timing and actions

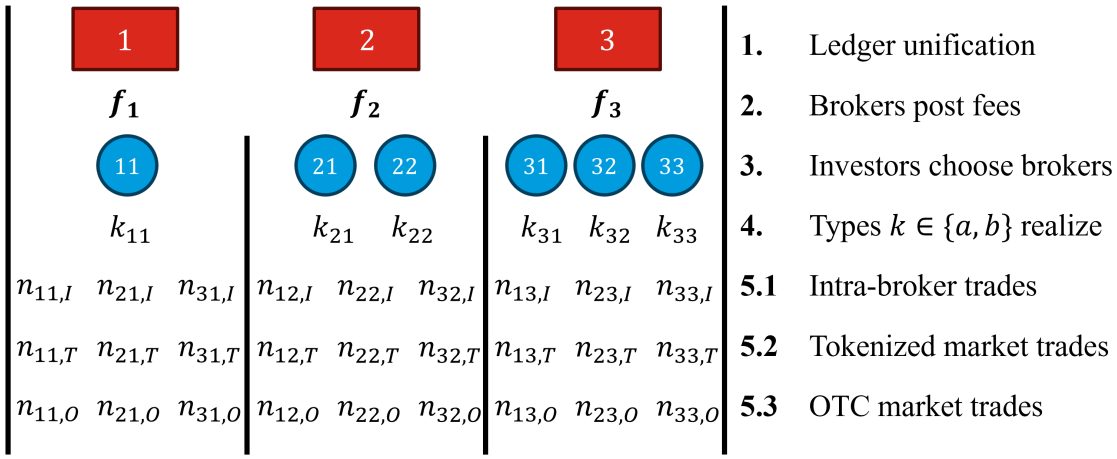
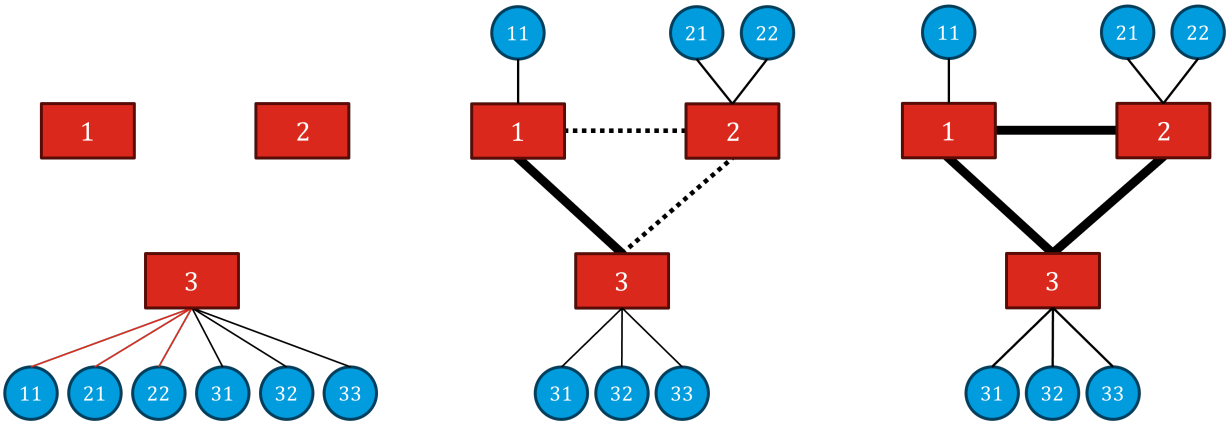


Figure 2: Example outcomes

(a) Broker monopoly (b) Partial unification (c) Full unification



Notes: This figure shows some example permutations of (i) investors' choices of broker, and (ii) brokers' choices regarding tokenized market formation. Blue circles represent investors and red rectangles represent brokers. Intra-broker trading relationships are shown by thin solid lines, with red lines denoting new investor-broker pairs, for which the investor incurs a switching cost. Dotted lines show inter-broker relationships in the pre-existing OTC market, and thick solid lines show inter-broker relationships in a tokenized asset market.

We let intra-broker trade occur before the (tokenized and OTC) inter-broker markets. Brokers first clear trades internally and then, for any remaining unmatched clients, seek an opposing type through trade with another broker. In cases where there are multiple possible investor pairings on a given market, we assume that a random draw determines the allocation of trades. For instance, if on the OTC market there is one type a investor and three type b investors, then each type b investor has a one-third chance of being matched with the type a investor.

Which markets are active depends on investor sorting and the formation of the tokenized market, discussed in Section 2.2.4. To fix ideas, Figure 2 presents three (among the many) possible configurations. Figure 2a considers an example in which all investors choose the same broker, as shown in Figure 2a. All trading relationships are then intra-broker (shown by thin solid lines), with some investors having incurred extra costs to switch broker (shown by red lines). In Figures 2b and 2c, all investors stick with their initial broker. Intra-broker trade can still occur at either Broker 2 or Broker 3. Inter-broker trade may occur too, either through the OTC market (shown by dotted lines) or through the formation of the tokenized market (shown by thick solid lines). Figure 2b shows the case where both types of inter-broker trade coexist, as only Brokers 1 and 3 form a tokenized market. Figure 2c shows the case where instead all brokers join the same tokenized market, so no trade occurs using the pre-existing OTC technology.

2.2.2 Broker fees

Brokers earn revenues from transaction fees f_{lj} on successful matches. These fees represent, e.g., the bid-ask spreads that bond investors incur when trading. We allow brokers full freedom to price discriminate by setting different fees based on an investor's origin l. For example, Broker 1 can set one fee for initial clients, one fee for potential clients switching to it from Broker 2, and one fee for potential clients switching to it from Broker 3. Each broker j thus posts a menu of fees $\boldsymbol{f}_j = (f_{1j};\ f_{2j};\ f_{3j})$ that investors observe before choosing

a broker.[14]

The mode of competition between brokers can be described as Bertrand competition under incumbency, matching, and marginal cost differentiation. The incumbency differentiation comes from positive τ, which provides a broker with market power in setting fees toward its initial clients. The matching differentiation originates in the heterogeneity in initial broker clientele and in inclusion or exclusion from the tokenized market, both of which can in turn produce differences among brokers in the probabilities, P_{kj}, that investors obtain gains from trade.[15] Marginal cost differentiation similarly arises from different probabilities of clearing trade on the three markets. Each trade that a broker facilitates on the OTC market costs it γ, whereas trades on the intra-broker and tokenized markets are costless. The expected marginal cost of facilitating trades can thus differ among brokers, which can affect the fees that they offer investors.

2.2.3 Broker profits

Let $n_{lj,p}$ denote the number of trades facilitated by broker j for investors from origin l on market $p \in \{I, T, O\}$, representing the intra-broker, tokenized and OTC markets respectively. Furthermore, $n_{lj} = \sum_p n_{lj,p}$ denotes the total number of trades, across all three markets, facilitated by broker j for investors from origin l. We stack these totals from all three origins in the vector $\mathbf{n}_j = (n_{1j}; n_{2j}; n_{3j})$. Lastly, $n_{j,O} = \sum_l n_{lj,O}$ denotes the total number of trades facilitated by broker j on the OTC market, across investors from all three origins. The broker's total profit is then:

$$\pi_j = \boldsymbol{f}_j' \mathbf{n}_j - \gamma \cdot n_{j,O} - s_j \tag{2}$$

where

$$s_j = \mu_j \frac{s}{m} \tag{3}$$

[14]We specify that fees f_{lj} are always non-negative, reflecting that in well-functioning markets negative bid-ask spreads would be quickly arbitraged away if they arose.

[15]A broker that services more investors has a greater chance of matching its investors intra-broker. And a broker that is part of the tokenized market has an additional probability of matching investors, compared to a broker whose only access to other brokers is through the OTC market.

is the potential cost to broker j of forming a tokenized market, where m is the number of brokers participating and μ_j is a dummy taking value one if broker j is involved in forming such a market and zero otherwise.

2.2.4 Tokenized market formation

The game begins with an opportunity for a coalition of brokers to form a tokenized market. We allow for an arbitrarily long period of negotiation, and simply require that, for a coalition structure that emerges to be an equilibrium, no broker or coalition of brokers would strictly prefer to deviate from their existing coalition.

Formally, denote by $J = \{1, 2, 3\}$ the set of brokers in the market and denote by $\mathcal{P}$ the set of all possible coalition structures, i.e., all partitions of J.[16] Each coalition structure $\mathcal{C} \in \mathcal{P}$ is associated with a single vector $\boldsymbol{\pi}^e(\mathcal{C}, s, \gamma) \in \mathbb{R}^3$ of expected payoffs $\pi_j^e(\mathcal{C}, s, \gamma)$ for each broker j, given observed cost parameters s and γ, where expectations are formed over the distribution of investor types at a subsequent stage. A coalition structure $\mathcal{C}$ is then an equilibrium if there does not exist any alternative coalition structure $\mathcal{C}'$ containing a new coalition $C' \notin \mathcal{C}$ such that $\pi_j^e(\mathcal{C}', s, \gamma) > \pi_j^e(\mathcal{C}, s, \gamma)\ \forall\ j \in C'$.[17] A tokenized market is formed when an equilibrium contains a coalition of more than one broker. For convenience, we attach the terms 'No Coalition' and 'Grand Coalition' to, respectively, the coalition structures $\{\{1\}, \{2\}, \{3\}\}$ and $\{1, 2, 3\}$.

We note that brokers' coalition formation choices involve externalities on each other due to trade diversion and the shifts in market power it implies, as well as on investors if coalition formation affects equilibrium fees.

[16] Intuitively, each coalition structure is a set of non-empty coalitions such that each broker is included in exactly one coalition. For our three-broker case, there are five such coalition structures, so we have: $\mathcal{P} = \{\{\{1\}, \{2\}, \{3\}\},\ \{\{1, 2\}, \{3\}\},\ \{\{1, 3\}, \{2\}\},\ \{\{1\}, \{2, 3\}\},\ \{\{1, 2, 3\}\}\}$. The first of these is the case where no tokenized market forms, the second to fourth structures represent the partial coalitions of two brokers, and the last structure is the three-broker coalition.

[17] For instance, the structure containing the three-broker coalition ($\mathcal{C} = \{\{1, 2, 3\}\}$) is an equilibrium if: (i) no individual broker would strictly prefer to use only the OTC market for inter-broker trade, and (ii) no pair of brokers would both strictly prefer to form their own tokenized market that excludes the third broker.

2.3 Timing

The timing of agents' actions and the realization of events is shown in Figure 1. The game takes place over the following five stages. In Stage 1, a coalition of brokers (possibly) forms a tokenized market. In Stage 2, brokers post their menus of fees to investors. In Stage 3, investors choose their brokers. In Stage 4, investors' types realize. Finally, in Stage 5, brokers execute trades—first intra-broker, then on the tokenized market (if it exists), and lastly on the OTC market.

Only the first three stages of this game are decision stages. In the first two stages, brokers choose coalitions in the tokenized market formation game and then set their fees $\boldsymbol{f}_j$. In the third stage, investors choose which broker to sign up with. The fourth and fifth stages are realization stages. When types are realized at Stage 4, this reveals potential trades. The set of trades that actually occurs then results from brokers' sequential execution of trades in Stage 5—first clearing intra-broker matches, then matches in the tokenized market, and finally in the OTC market, with random draws breaking any ties within these three sub-stages, as described above.

2.4 Optimization problems

To prepare for solving the game by backward induction, we present the agent optimization problems in the reverse order of the decision stages. At Stage 3, each investor li chooses its broker j_{li} to maximize the expected value of its payoff u_{li}, taking into account the (observed) coalition structure $\mathcal{C}$ and the (observed) vector of all fees $\boldsymbol{f} = (\boldsymbol{f}_1; \boldsymbol{f}_2; \boldsymbol{f}_3)$ charged by every broker:

$$\max_{j_{li}} \{u^e_{li}(\mathcal{C}, \boldsymbol{f})\}\,. \tag{4}$$

At Stage 2, each broker j sets its menu of fees $\boldsymbol{f}_j$ to maximize its expected profits. It takes into account the (observed) coalition structure $\mathcal{C}$ from Stage 1 and foresees how its

fees will subsequently affect investors' choices of broker at Stage 3, and hence the broker's expected number of trades at Stage 5:

$$\max_{\boldsymbol{f}_j}\{\pi_j^e(\mathcal{C}) = \boldsymbol{f}_j'\mathbf{n}_j^e(\mathcal{C},\boldsymbol{f}) - \gamma\cdot n_{j,O}^e(\mathcal{C},\boldsymbol{f}) - s_j\} \tag{5}$$

where the expectations operator on $\mathbf{n}_j^e$ and $n_{j,O}^e$ reflects that at Stage 2 investor types—which will be drawn at Stage 4—affect matching at Stage 5.

Finally, in Stage 1 brokers bargain over coalition structures $\mathcal{C}$ in an attempt to maximize their expected profits $\pi_j^e(\mathcal{C})$, as described in Section 2.2.4 above. When doing so, they backward induce all subsequent stages of the game.

2.5 Equilibrium selection criterion

We work toward solving for the Subgame Perfect Nash Equilibrium (SPNE) of this game by backward induction. The Stage 3 subgame that determines investors' selection of brokers lends itself to multiple equilibria, however. The reason is that investors impose externalities on each other. The more investors pool on one broker, the more attractive that broker is to other investors, given that brokers give priority to (costless) intra-broker trades. For example, for a given parameterization the following equilibria could co-exist: first, an equilibrium where each investor acts from the prior that all other investors will stay at their initial brokers and this prior is confirmed by each investors' decision to stay, as in Figures 2b and 2c; second, an equilibrium where each investor expects all other investors to move to (or stay at) Broker 3 and, given this prior, all investors indeed aggregate at Broker 3, as in Figure 2a.

For parameterizations that give rise to multiple equilibria at Stage 3, we utilize an equilibrium selection criterion. Specifically, among the set of feasible (i.e., self-confirming priors) subgame equilibria, we select the equilibrium with the least investor switching. For instance, if one equilibrium involves all investors remaining with their initial broker, and another in-

volves all investors pooling on one broker, we select the former. This reflects both the rise of passive investing, where investors' choice of broker can be sticky (e.g., maintaining the same index-tracking fund for many years), and the far larger number of retail investors than brokers, such that coordinating all investors to pool on one broker is difficult. Importantly, this 'minimal movement' criterion also encourages private sector tokenization initiatives *without* public intervention. The less likely investors are to pool on one broker, the more brokers have to gain from coordinating to form a unified ledger, rather than each trying to attract all investors onto their own ledger. Given our aim of evaluating whether public policy to unify tokenized asset markets could improve on the private sector outcome, this criterion thus creates an especially stringent test.[18]

2.6 Parameter restrictions

To let our model speak effectively to broker coalition formation incentives, we let

$$\frac{1}{3} \leq \tau \leq \frac{2}{3} \tag{6}$$

When switching costs are sufficiently large, brokers become uncontested monopolists toward their investor bases. Brokers then set fees at investors' gains from trade, regardless of coalition structure. With uncontested monopolies, fees therefore no longer endogenously respond to coalition structures, depriving the model of an important margin of broker optimization and adjustment to coalitions. The constraint $\tau \leq \frac{2}{3}$ suffices to exclude such monopolies.

We aim to spotlight cases where the market for brokerage is somewhat contestable, but not so contestable that brokers' incentives shift away from coalition formation toward intra-broker unification. This is essentially another form of monopolization, this time by attracting

[18] Additionally, to avoid discontinuities on indifference thresholds, we introduce tie-breaking assumptions in favor of (larger) tokenized market formation when brokers are exactly indifferent between coalitions. When brokers are indifferent between a coalition of three and another option (either a smaller coalition or No Coalition), then they choose the coalition of three. When two brokers are indifferent between forming a coalition of two and No Coalition then they form the coalition of two. These tie-breaking assumptions are without loss of generality—none of our results would be overturned by reversing them.

all investors to the same broker (as in Figure 2a, for example). The lower bound of $\tau \geq \frac{1}{3}$ ensures that the equilibrium wherein all investors stay at their initial brokers is always feasible.

Moreover, to facilitate the derivation of analytical solutions for optimal broker fees, the condition in (7) constrains the cost of clearing OTC transactions to be no more than one-sixth of an investor's gains from trade.[19]

$$0 < \gamma \leq \frac{1}{6} \tag{7}$$

Lastly, to ensure that investors have enough endowment to cover fees (and also to always retain positive utility if they incur non-pecuniary cost τ), we let

$$\eta \geq 2\,. \tag{8}$$

3 Equilibrium

This section presents the equilibrium of the game described in Section 2, which Lemma 1 shows depends on the tokenized market setup cost s and the OTC market trading cost γ.[20]

Lemma 1 (Baseline equilibrium) *If $s > \frac{1}{8} + \frac{7}{8}\gamma$, no tokenized market forms in equilibrium. If $s \leq \frac{1}{8} + \frac{7}{8}\gamma$, Brokers 1 and 3 form a tokenized market.*

Proof of Lemma 1. See Appendix A.1 (p. 36). ■

[19] Although our model is not quantitative in nature, OTC transaction costs that comprise no more than $\frac{1}{6}$ of an investor's gains from trade could be considered realistic, since bid-ask spreads on OTC markets, while much larger than on centralized exchanges, are usually not too large relative to the price of the asset being purchased. The technical reason for this condition is as follows: While poaching investors from another broker allows the gaining broker to utilize intra-broker clearance on more trades, it can also lead to more OTC transactions for this broker, depending on how many investors remain at other brokers. When OTC transactions become too costly, this aspect complicates the determination of fee equilibria. We note that setting $\gamma \leq \frac{1}{6}$ incurs no qualitative loss of generality, as seen in Section 4 where all relevant policy zones are represented.

[20] The other two exogenous parameters—the endowment η and the switching cost τ—do not influence equilibrium outcomes, subject to the constraints discussed in Section 2.6.

Figure 3 depicts these regions. Above the blue line, no multi-broker coalition forms (i.e., no tokenized market is created) because the setup cost is too high relative to the potential benefits. On and below the blue line, the outcome reflects two forces. First, tokenized markets in general are more attractive, because the setup cost is lower relative to the cost of the OTC alternative (i.e., γ). Second, forming a partial coalition with two brokers diverts trade from the excluded broker toward the participating brokers. To see this, note that the 1 & 3 Coalition forms even as γ approaches zero, as long as s is not too high. Here, forming a tokenized market offers no reduction in costs—since all trades are already costless—but it still provides a benefit to participating brokers in the form of preferential access to the other's investors, due to the faster execution of tokenized market trades in Stage 5. This raises the matching probabilities offered by the participating brokers (at the expense of the excluded broker), in turn allowing them to charge higher fees.

Among the three feasible partial coalitions (1 & 2, 1 & 3, 2 & 3), why does the 1 & 3 Coalition form? Brokers 2 and 3 are each other's fiercest competitors: their larger initial clienteles than Broker 1 mean that, ceteris paribus, they offer better matching odds than Broker 1, due to intra-broker clearing. Thus, in the competition for Broker 2's initial clients, Broker 3 binds how high Broker 2 can set its fees given switching costs and, similarly, Broker 2 binds Broker 3's fees. Forming a partial coalition with Broker 1, gives each the opportunity to weaken the other's position, since an excluded broker offers a worse matching probability to investors. Hence, when either Broker 2 or 3 joins a partial coalition with Broker 1, it expects to process more trades and at higher equilibrium fees. Broker 1 also benefits from trade diversion and this benefit is largest when forming a partial coalition with Broker 3, because this gives it the best chance to match its investor on the tokenized market.

Figure 3: Baseline equilibrium

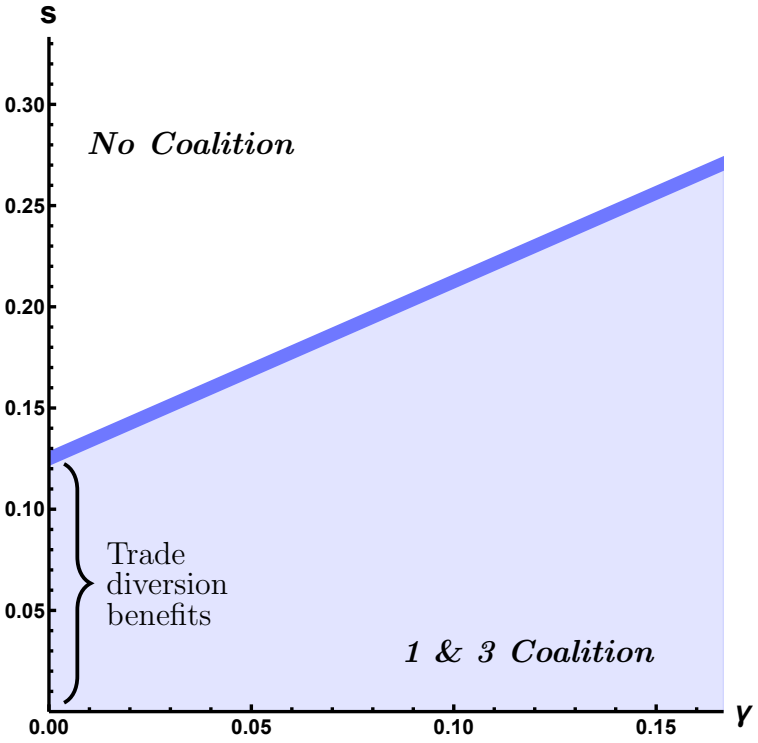
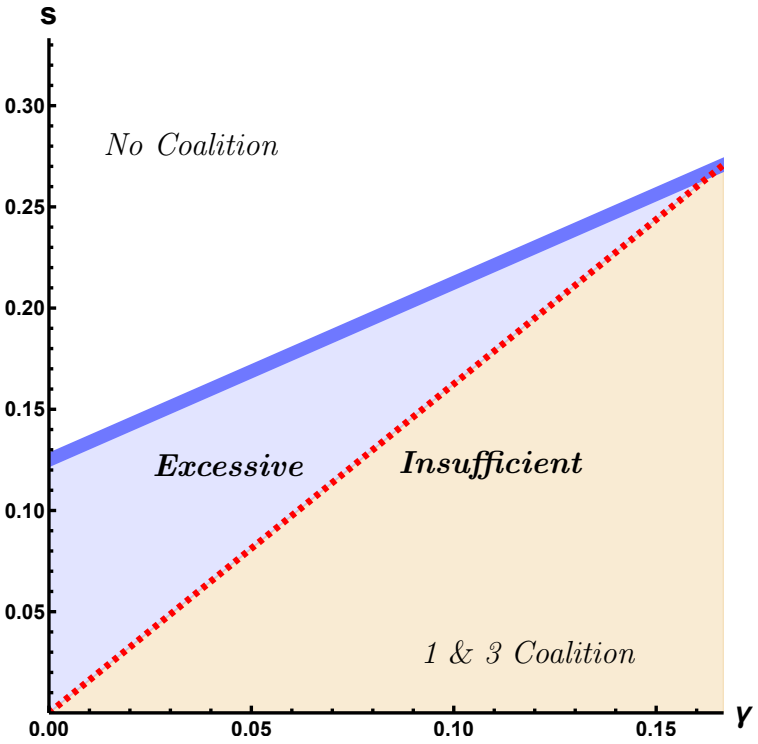


Figure 4: Excessive and insufficient coalition formation



4 Welfare

Denote the total expected profit of the brokerage sector by $\Pi^e = \sum_{j=1}^{3} \pi_j^e$, and the total expected utility of the investors by $U^e = \sum_{li} u_{li}^e$. Total expected welfare is then given by $W^e = \Pi^e + U^e$. For convenience, we let 'welfare' to refer to total *expected* welfare.

Lemma 2 (Optimal outcomes) *If $s > \frac{13}{8}\gamma$, welfare is maximized when no tokenized market exists. If $s < \frac{13}{8}\gamma$, welfare is maximized by a tokenized market that includes all brokers. If $s = \frac{13}{8}\gamma$, welfare is equal under both outcomes.*

Proof of Lemma 2. See Appendix A.2 (p. 36). ■

Proposition 1 (Excessive and insufficient coalition formation) *The private equilibrium can feature excessive or insufficient coalition formation. Coalition formation is excessive if $\frac{13}{8}\gamma \leq s \leq \frac{1}{8} + \frac{7}{8}\gamma$. Coalition formation is insufficient if $s \leq \frac{13}{8}\gamma$.*

Proof of Proposition 1. The result follows immediately from comparing the regions defined in Lemmas 1 and 2. ■

Figure 4 visualizes Proposition 1. Below the red dashed line, identified by Lemma 2, the Grand Coalition is socially optimal because the efficiency benefits of tokenization outweigh the costs and the gap between these benefits and costs is largest in the Grand Coalition where costly OTC trade is fully eliminated. Above this line, setup costs are too high and No Coalition is socially optimal.[21] We also note that investor utility makes the red dashed line run higher than if only broker profits entered welfare, because part of the efficiency gains of tokenization endogenously pass on to investors in the form of lower equilibrium fees.

[21] Note that the red dashed line passes through the origin: without efficiency gains any setup cost is too high, and without a setup cost any efficiency gains justify creating the Grand Coalition. We further note that the parameter η also affects welfare (which trivially increases for a higher η) but does not affect broker behavior. A higher τ does not affect aggregate welfare because in equilibrium all brokers retain their initial investors and τ is not incurred. Higher τ does however affect the distribution of welfare between investors and brokers, since a higher switching cost allows brokers to extract higher fees from their initial investors.

No Coalition is socially optimal in Figure 4's white and blue regions, but in the latter brokers form the 1 & 3 Coalition. Trade diversion benefits create private incentives that result in excessive coalition formation: s is incurred to set up a tokenized market, but welfare would be higher if instead brokers relied only on the OTC market. In contrast, in the yellow region it is socially optimal to incur s and set up a tokenized market, but the coalition that forms privately is too narrow: Brokers 1 & 3 divert some trades from Broker 2 but remaining trades with that broker occur at the (socially wasteful) higher OTC cost γ.

5 Policy analysis

It is immediately apparent that a policymaker endowed with heavy-handed tools, such as the ability to both forbid and force tokenized market formation, can always attain first best by forbidding tokenization above the red line in Figure 4 and mandating the Grand Coalition below it. But political economy often precludes such heavy-handed approaches. This section considers whether a policymaker can attain first best through less intrusive means. In particular, we center attention on the two types of policies seen in the initiatives discussed on p.1: an interoperability mandate and a public-private partnership to form a tokenized market. Among these two, the interoperability mandate is arguably the lighter-touch policy because it merely requires that brokers keep the door open to each other when creating a new ledger, while a public-private partnership involves fiscal resources to help create and possibly operate the ledger. We therefore start our policy discussion from the interoperability mandate and then ask whether and when it should be supplemented by (the minimum necessary) public cost-sharing.

We incorporate the interoperability mandate—introduced prior to Stage 1—as a requirement that any coalition of two brokers deciding to form a tokenized market must offer the third broker the opportunity to join at no cost. We break Stage 1 into three sub-stages. At Stage 1.1, each broker j sets a budget limit of s_j^{max} that it is willing to invest in tokenization

projects. At Stage 1.2, coalitions of brokers can form tokenized markets by each investing $s_j \leq s_j^{max}$, as described in Section 2.2. Finally, if a coalition C of two brokers formed at Stage 1.2, Stage 1.3 occurs, in which the excluded broker $k \notin C$ is offered the opportunity to join C at no cost (i.e., $s_k = 0$).[22] With this setup we derive the following results:

Lemma 3 (Interoperability mandate and excessive coalition formation) *An interoperability mandate prevents the excess coalition formation that occurs in equilibrium when* $\frac{13}{8}\gamma \leq s \leq \frac{1}{8} + \frac{7}{8}\gamma$.

Proof of Lemma 3. See Appendix A.3 (p. 36). ■

The interoperability mandate counteracts trade diversion: partial coalitions are no longer sustained in equilibrium because the participating brokers pay $\frac{s}{2}$ to form a coalition that the excluded broker subsequently decides to join for free. Brokers thus come to choose between No Coalition or the Grand Coalition.[23] In the blue region in Figure 5 at least one broker is never willing to form the Grand Coalition, so No Coalition results. The blue zone is where coalition formation is excessive in the private equilibrium (as in Figure 4) and therefore the interoperability mandate here leads to the socially optimal outcome of No Coalition.

Lemma 4 (Interoperability mandate and insufficient coalition formation #1) *An interoperability mandate prevents the insufficient coalition formation that results in equilibrium when* $s \leq \frac{27}{20}\gamma$.

Proof of Lemma 4. See Appendix A.4 (p. 36). ■

[22] We include Stage 1.1 to avoid a free-rider problem that can otherwise emerge in Stage 1.2. In the absence of upper limits on s_j, each broker has an incentive to block the Grand Coalition in the hope of forcing the other brokers to bear the full cost of setting up a tokenized market that the excluded broker will ultimately be able to join for free in Stage 1.3. Since all brokers reason the same, this strategy is never successful, but it can also preclude any equilibrium from forming. Stage 1.1 arguably speaks to real-world possibilities to commit, since brokers could credibly convey a limit on how much they are willing to invest in tokenization (i.e., $s_j^{max} \leq s/3$ in our case). Note that this Stage 1.1 is without loss of generality versus the baseline, since a model featuring Stages 1.1 and 1.2 alone (without the interoperability mandate introduced at Stage 1.3) results in identical coalition structures to the simpler combined Stage 1 described in Section 2.3.

[23] In this section, we use 'Grand Coalition' to refer only to the 'Egalitarian Grand Coalition' that is formed when all brokers contribute $\frac{s}{3}$—i.e., this label excludes a tokenized market encompassing three brokers but paid for by only two.

Figure 5: Equilibrium with an interoperability mandate

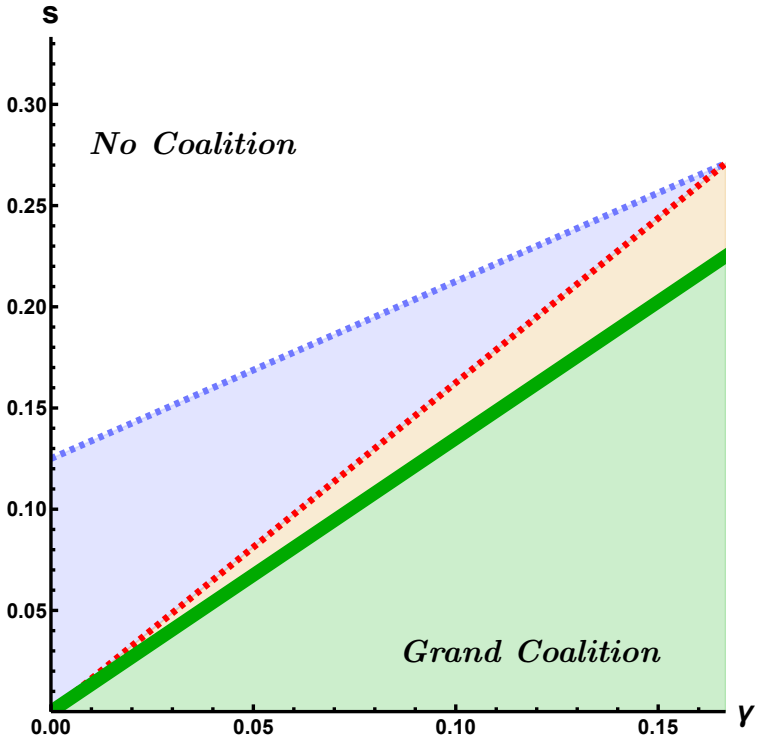
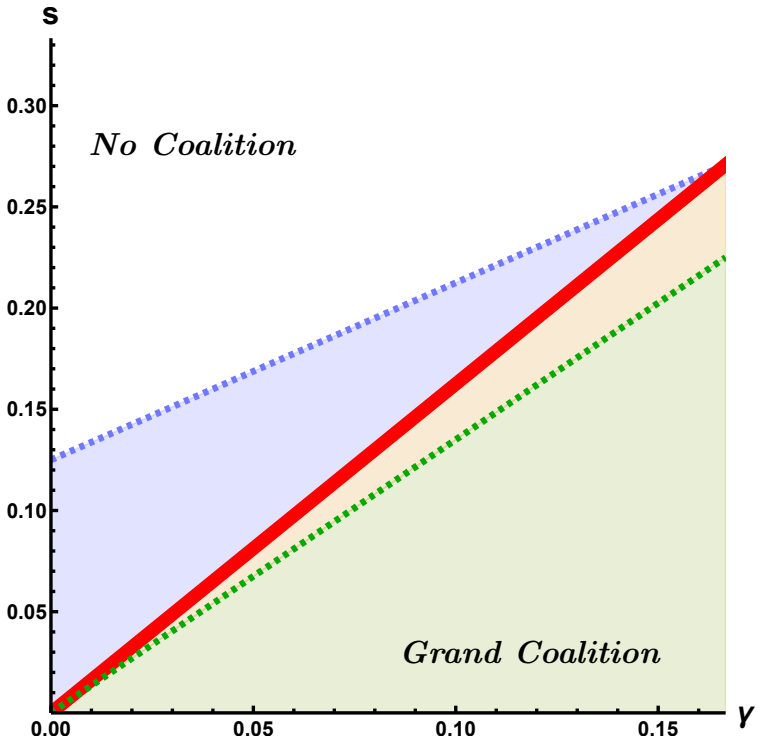


Figure 6: Equilibrium with an interoperability mandate and tokenization subsidy



This result relates to the green region in Figure 5, where coalition formation is insufficient in the private equilibrium (Figure 4). The green line shows the boundary below which all brokers prefer the Grand Coalition to No Coalition.

Lemma 5 (Interoperability mandate and insufficient coalition formation #2) *An interoperability mandate does not prevent the insufficient coalition formation that results in equilibrium when* $\frac{27}{20}\gamma < s \leq \frac{13}{8}\gamma$.

Proof of Lemma 5. See Appendix A.5 (p. 36). ■

This result, which relates to the yellow region in Figure 5, has the same intuition as Lemma 3, but occurs in a region where the private equilibrium produces insufficient rather than excessive coalition formation in Figure 4. Like in Lemma 3, at least one broker vetoes the Grand Coalition so that No Coalition ensues.[24]

Lemma 5 highlights a deeper tension: the social planner favors the Grand Coalition more than does the broker who is least keen to join it. The social planner weighs aggregate broker profits, as well as investor utility. Instead, the private equilibrium only produces the Grand Coalition when the *least amenable* broker prefers it to No Coalition. The resulting 'underinvestment problem' can only be solved by policy that changes the least amenable broker's valuation of the Grand Coalition outcome.

We therefore next turn to a combination of the interoperability mandate with public cost sharing, which we introduce in the form of a tokenization subsidy. This subsidy $\sigma > 0$ is announced before Stage 1 and reduces the setup cost from s to $s - \sigma$. The subsidy is funded with a lump-sum tax on investor endowments. By itself (without interoperability) such a

[24]Interestingly, in the yellow region the veto is always cast by Broker 2—the very broker that is excluded from the tokenized market without the interoperability mandate. Broker 2 prefers the Grand Coalition to the 1 & 3 Coalition. But after interoperability removes the latter as a feasible equilibrium, Broker 2 is the least inclined toward the Grand Coalition in comparison to No Coalition. Broker 3 can spread the setup cost of the Grand Coalition over the largest number of expected transactions. Per expected transaction, however, Broker 1 sees the largest cost reductions from joining the Grand Coalition because without tokenization it processes all transactions OTC. For Broker 2, these expected cost reductions per transaction are smaller, while it also has fewer expected transactions over which to spread the setup cost than Broker 3.

subsidy is not a useful policy. This can be seen from Figure 4, where the outcome at each point (γ, s) in the chart is replaced by $(\gamma, s - \sigma)$ vertically below. Below the blue line, this never changes the coalition structure—regardless of the size of σ—since the 1 & 3 Coalition always forms. Above the blue line, the equilibrium is already socially optimal and there is nothing for the subsidy to improve upon. Thus, no simple tokenization subsidy can achieve first best when used alone.[25]

Combining an interoperability mandate with a tokenization subsidy instead allows the policymaker to sufficiently incentivize the marginal broker to join the Grand Coalition in the yellow region of Figure 5. We derive the following result:

Lemma 6 (Interoperability mandate plus tokenization subsidy) *An interoperability mandate combined with a tokenization subsidy $\sigma \geq \frac{11}{40}\gamma$ prevents the insufficient coalition formation that results in equilibrium when $\frac{27}{20}\gamma < s \leq \frac{13}{8}\gamma$.*

Proof of Lemma 6. See Appendix A.6 (p. 36). ■

In Figure 5, all points in the yellow region are directly above a point in the green region where the interoperability mandate produces the Grand Coalition. Hence, in all such cases a sufficiently large subsidy produces the Grand Coalition by moving the equilibrium point from (γ, s) to $(\gamma, s - \sigma)$. In combination with Lemmas 3 and 4 above, we thus have:

Proposition 2 (Optimal policy) *A policymaker with the ability to impose an interoperability mandate and subsidize the creation of tokenized markets can always achieve the first best outcome. Specifically, it can achieve this by:*

1. *Taking no action (laissez-faire) if $s > \frac{1}{8} + \frac{7}{8}\gamma$,*

2. *Imposing an interoperability mandate if $s \leq \frac{1}{8} + \frac{7}{8}\gamma$, and*

[25] A sufficiently large tax ($\sigma < 0$, representing, e.g., stringent regulatory or licensing requirements) could prevent excessive coalition formation (blue zone of Figure 4) by offsetting the gains from trade diversion that otherwise motivate Brokers 1 and 3 to form a tokenized market. However, such a tax cannot resolve insufficient coalition formation, as there is no point in Figure 4—across any s—at which brokers form the Grand Coalition.

3. *Subsidizing the formation of tokenized markets if* $\frac{27}{20}\gamma < s \leq \frac{13}{8}\gamma$*, where the minimum needed size of the subsidy is* $\sigma^{min} = \frac{11}{40}\gamma$.

Proof of Proposition 2. When $s > \frac{1}{8} + \frac{7}{8}\gamma$, No Coalition maximizes welfare (Proposition 1) and laissez-faire is optimal. Policies 2 and 3 result from combining Lemmas 3, 4, and 6. ■

Equilibrium outcomes under this policy package are shown in Figure 6. In the white region, No Coalition is both the private equilibrium and optimal, so the policymaker takes no action. In the blue region, the private equilibrium leads to excessive investment, but the interoperability mandate produces No Coalition, the optimal outcome. Below the red line, the Grand Coalition is optimal, and this is achieved by the interoperability mandate alone (in the green region) or in combination with a sufficiently large subsidy (in the yellow region).

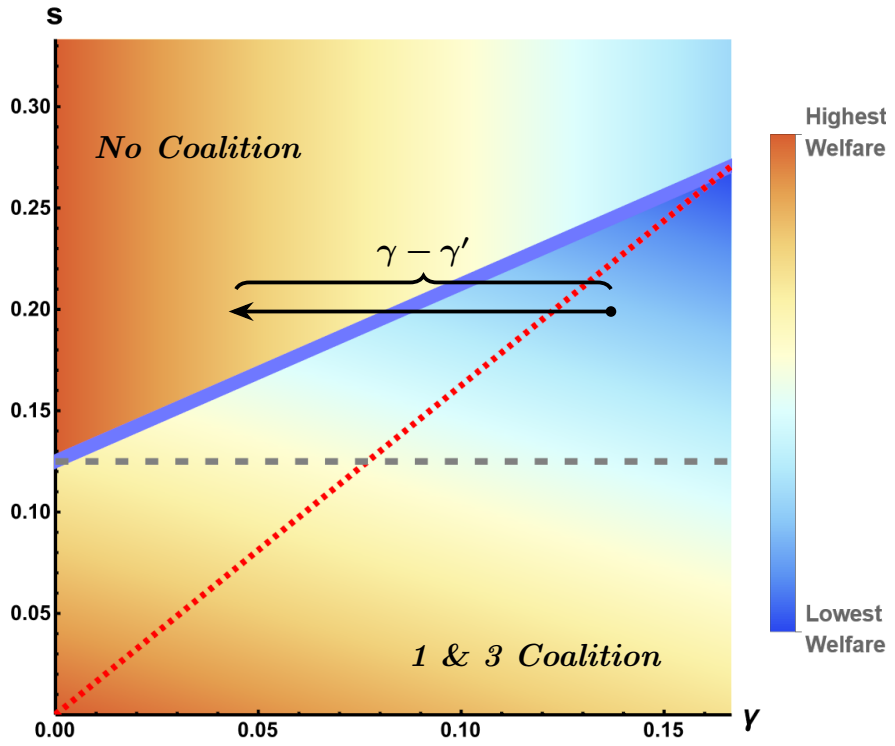
6 Extension to an independent ledger infrastructure

The baseline model assumes that brokers invest s to establish a tokenized market on a proprietary ledger. An alternative is to use a pre-existing public blockchain, such as the Ethereum ledger, which can support trade in tokenized assets.[26] We therefore extend the model to include the existence of an independent ledger infrastructure (ILI) that any broker can freely join and that offers an inter-broker trading cost, $\gamma' \in (0, \gamma)$. The reason that the ILI clears trades at positive cost, unlike brokers' proprietary ledger, is that transaction validation on a public blockchain is not costless (e.g., Ethereum gas fees). We assume that each broker decides whether to join the platform at the beginning of the game, before Stage 1, and that trades on the ILI clear after the proprietary tokenized market but before the OTC market.[27] We derive the following results:

[26] For example, this is the case for the BlackRock USD Institutional Digital Liquidity Fund, whose public-blockchain tokens earn US Treasury yields (with access currently limited to investments above $5 million).

[27] This reflects that the new infrastructure is faster than the legacy OTC infrastructure, but also that brokers choosing to set up their own tokenized market could (and would) still choose to favor those trades on their private tokenized market over those on the public ILI.

Figure 7: Equilibrium with independent ledger infrastructure



Proposition 3 (Independent ledger infrastructure) *The availability of a sufficiently efficient independent ledger infrastructure leads the private equilibrium to produce the first-best outcome if and only if tokenized market setup costs are high. Specifically:*

1. *When $s > \frac{1}{8}$, there always exists an (ILI versus OTC) efficiency gain $\gamma - \gamma'$ that leads the private equilibrium to produce the first-best outcome.*

2. *When $s \leq \frac{1}{8}$, there is no efficiency gain $\gamma - \gamma'$ that leads the private equilibrium to produce the first-best outcome.*

Proof of Proposition 3. See Appendix A.7 (p. 37). ■

Since the ILI comes with lower transaction costs than the OTC market and is costless to join, all brokers do so. The OTC market is therefore displaced: brokers clear on the ILI any trades remaining after the intra-broker and proprietary tokenized markets have settled.

Figure 7 compares the outcome of this extension to the baseline. For any given initial

point (γ, s) representing the baseline equilibrium, the presence of the ILI moves the market to a new point (γ', s) that has lower 'residual-market' (i.e., ILI or OTC) trading costs. For any point in Figure 7, such a leftward shift necessarily raises aggregate welfare by reducing trading costs. However, the potential for such a shift to achieve the first best outcome depends on the initial level of s. When s is high (above the grey dashed line) any point where the 1 & 3 Coalition forms in the baseline model can become a point in the No Coalition zone, for a large enough ILI-driven cost reduction $\gamma - \gamma'$. The arrow in Figure 7 shows one example. Forming a proprietary tokenized market is sufficiently costly relative to the potential gains from trade diversion that Broker 1 and Broker 3 are amenable to abandoning their private coalition and conducting all their inter-broker trades on the ILI. However, when s is low, forming a proprietary tokenized market—with the concomitant gains from trade diversion—is so cheap that even an ILI with a trading cost of $\gamma' \to 0$ does not induce Brokers 1 and 3 to forego forming their own exclusive market.

When the presence of the ILI fails to move the private equilibrium to the social optimum, optimal policy remains as in Proposition 2:

Corollary 1 (Policy implications of independent ledger infrastructure) *When* $s \leq \frac{1}{8} + \frac{7}{8}\gamma'$ *(i.e. where the 1 & 3 Coalition results in Figure 7), the optimal combination of an interoperability mandate and public-private cost-sharing achieves the social optimum. This is not always attainable when either policy instrument is used in isolation.*

Proof of Corollary 1. See Appendix A.8 (p. 37). ■

7 Conclusion

As more brokers explore the tokenization of financial assets, policymakers seek to reap the potential benefits that this technology offers while mitigating the risk of market fragmentation. This paper assesses why such fragmentation could arise, when policy intervention to prevent it is needed, and how such policy should be designed.

Our model introduces endogenous joint technology adoption by brokers into a model of OTC trade. Brokers with heterogeneous market power compete to attract investors and execute their trades. Coalitions of brokers can invest in creating a tokenized market that enables faster and cheaper settlement between them. Trade diversion incentives can result in equilibrium coalition structures that feature excessive investment or insufficient unification.

Turning to interventions currently being explored by policy institutions, our model finds that neither an interoperability mandate nor public cost-sharing always achieve first best when implemented in isolation. An interoperability mandate reduces the private return to forming a tokenized market, since the inability to exclude other brokers precludes trade diversion. This disincentive addresses excessive investment. However, when insufficient unification is the problem, the disincentive from interoperability can be too strong and instead cause an underinvestment problem. In contrast, public cost-sharing can stimulate investment by reducing the burden falling on brokers, but does not affect the trade diversion incentives that produce exclusive coalitions. In combination, the two policies give the policymaker both a 'carrot' and a 'stick' to achieve the optimal degree of unification in all cases.

Public cost-sharing also speaks to indirect subsidization through the provision of a central bank-issued means of payment for tokenized financial markets. Tokenized money is needed to enable trading on a market with tokenized assets. Brokers could issue such tokens themselves through so-called 'tokenized deposits', which are essentially stablecoins issued by financial institutions. This comes with costs, however, including from the liquidity locked up to provide a credible backing for these tokens. Several policy initiatives (e.g., Brazil, Switzerland) currently contemplate the provision of a Central Bank Digital Currency (CBDC) as a means to settle transactions on a tokenized market, which could reduce the barriers for the private sector to tokenize.

Future work could build on our framework to incorporate microfoundations for means of payment choice on a tokenized market or for the benefits of tokenized assets' programmability that we have modeled in simplified form. Future work could also consider alternative

broker strategies, such as the monetization of data generated on the tokenized market, or selling access to such a market if a broker can gain a first-mover advantage in tokenization. The interaction between brokers' incentives to tokenize and information asymmetries (either among brokers or between investors and brokers) could also be explored.

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Appendix

A Proofs

This appendix will contain proofs omitted from the main text. All calculations are performed in a *Mathematica* file that is available on request.

A.1 Proof of Lemma 1

Overview. We derive the equilibria of the baseline model in two stages. First, we solve Stages 3 and 2 by backward induction to derive the expected payoff vector $\boldsymbol{\pi}^{\boldsymbol{e}}(\mathcal{C}, s, \gamma)$ associated with each coalition structure $\mathcal{C}$ for given values of the tokenized market setup cost s and the OTC market trading cost γ. At Stage 3, investors choose brokers based on observed fees and expected match probabilities. At Stage 2, each broker therefore sets the highest fee for its home investors that is consistent with retaining them. We confirm that, for every coalition structure, such a unique fulfilled-expectations 'Stay Equilibrium' exists: there is always a single set of fees $\boldsymbol{f}$ such that (i) all brokers maximize expected profits, and (ii) all investors maximize expected utility by choosing to stay, under the prior that all other investors will stay. Given our 'minimal movement' selection criterion, the existence of a unique Stay Equilibrium (which, by definition, minimizes movement) in turn implies that it is the unique equilibrium that results in Stages 2 and 3 (for each $\mathcal{C}$, s and γ). Second, we compare the expected payoffs $\pi_j^e(\mathcal{C}, s, \gamma)$ of each broker across coalition structures to identify the coalition structure that results in Stage 1, for each combination of s and γ.

Detailed proof. To be written. [See Mathematica file 'Private sector baseline.nb'.]

A.2 Proof of Lemma 2

To be written. [See Mathematica file 'Optimal policy and model extensions.nb'.]

A.3 Proof of Lemma 3

To be written. [See Mathematica file 'Optimal policy and model extensions.nb'.]

A.4 Proof of Lemma 4

To be written. [See Mathematica file 'Optimal policy and model extensions.nb'.]

A.5 Proof of Lemma 5

To be written. [See Mathematica file 'Optimal policy and model extensions.nb'.]

A.6 Proof of Lemma 6

To be written. [See Mathematica file 'Optimal policy and model extensions.nb'.]

A.7 Proof of Proposition 3

To be written. [See Mathematica file 'Optimal policy and model extensions.nb'.]

A.8 Proof of Corollary 1

We provide a visual proof. Within Figure 7, for any arbitrarily efficient ILI (defined by $0 < \gamma' < \gamma$), one can define a maximum level of the setup cost $s' > 0$ such that the rectangle R between the origin and the point (γ', s') is identical to the corresponding rectangle in Figure 4. Within R, both excessive and insufficient coalition formation must occur in equilibrium—as can be seen by considering any rectangle of positive side length whose bottom-left corner is at the origin in Figure 4. Thus all three policy zones in Figure 6 are also contained within R, so the same analysis as in Proposition 2 applies; when used alone neither an interoperability mandate nor public-private cost-sharing can always achieve first best, but a combination of the two can.