# Informed Intermediaries

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**Abstract**. I develop a theory of intermediation in a market where agents meet bilaterally to trade and buyers cannot commit to payments. Some agents observe the past trading history of traders in the market. These informed agents can secure trades by setting punishments to traders who previously defaulted. The punishing strategy affects equilibrium prices and also determines which trades are hindered by the risk of default. Intermediation is a robust equilibrium feature, generated by asymmetric punishing strategies that yield informed agents either more effective opportunities to trade or the ability to extract more surplus in trades.

## 1. INTRODUCTION

In most decentralized markets, buyer and seller meet and negotiate a price for a good, expecting that the seller will deliver the good and the buyer will pay the agreed price. If either party fails to honor the terms, they face consequences from a legal system. There are markets, however, in which agents cannot rely on an exogenous authority to guarantee that contracts are honored. For obvious reasons, in markets for stolen goods or corruption markets, agents who fail to honor their debts cannot be prosecuted through formal means. Even in markets that are not illegal, legal fees can be prohibitively high or certain contracts may be infeasible to write. In extreme cases, an effective state or justice system may not exist.

In a variety of empirical contexts, such markets have been documented to have a hierarchical trading structure, where some central agents often trade goods not for their own use, but rather to profit from intermediating trades between other market participants. For example, Schneider (2005) interviews 50 "prolific burglars" and finds that their most common method for disposal of burgled or shoplifted goods is by selling them to fences, who then resell the goods to final consumers for a higher price. Della Porta and Vannucci (2016) also document the presence of brokers in corruption networks in Italy, as well as make a case for the importance of mafias as enforcers in the Italian market for corrupt exchange. There are also many papers documenting the hierarchical network structure of trade in different financial markets.[1]

In this paper, I propose a model where agents trade bilaterally and payments are not enforced by an outside authority. Rather, agents honor terms of trade because they wish to maintain

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[1]See, for example, Ashcraft and Duffie (2007), Bech and Atalay (2010) and Afonso and Lagos (2014) for the market for Federal Funds.

a reputation of being trustworthy. In their 1990 paper, Milgrom, North and Weingast write: "A good reputation can be an effective bond for honest behavior in a community of traders if members of the community know how others have behaved in the past – even if any particular pair of traders meets only infrequently." Much in the spirit of the quote, a share of traders in the model are *informed* and observe others' past history of trade. Informed agents emerge as a tacit "police" that secures transactions.

Consistent with empirical observations, I show in the model that a robust feature of equilibria is a hierarchical trade network where informed agents are central and often intermediate trades between other market participants.

The model is a variation of the over-the-counter market in Duffie, Garleanu and Pedersen (DGP, 2005). A mass of agents meet bilaterally and continuously trade due to differences in their valuation for an asset. Unlike in DGP, buyers have no exogenous ability to commit within a meeting: Sellers first transfer the asset and only then do buyers decide whether to make the agreed upon payment. If a buyer does not pay, the seller has no other recourse. Some traders are informed and observe a record of all past meetings. Informed agents can secure trades by refusing to trade with past defaulters.

When a potential seller meets potential buyer, she makes a take-it-or-leave-it price offer to the buyer. Despite this protocol, the seller does not necessarily extract all of the buyer's trade surplus, as she must choose a price that induces the buyer not to default. Aware of the punishment a defaulting buyer is subject to, the seller proposes the highest price that induces no default. For example, if a buyer is punished with a long period of exclusion from trade, then he would not default even if the proposed price is high, and the seller indeed offers a high price. If, otherwise, a buyer is only lightly punished if he defaults, then he can only be trusted to pay a low price. Through this channel, the strategy used by informed agents to punish defaulters shapes the terms of trade in equilibrium.

In Proposition 1, I propose a first class of equilibria that can be sustained if agents are sufficiently patient and there are enough informed agents: All-Trade Equilibria, where the limited commitment friction is completely overcome and no trades are hindered by the risk of default. In All-Trade Equilibria, informed agents who default are punished lightly, but defaulting uninformed agents are punished harshly. As such, informed agents are able to buy assets at a cheaper price and sell them at a higher price than uninformed agents do.

All-Trade Equilibria are efficient, since all trades where the buyer values the asset more highly than the seller take place, despite the limited commitment friction. Moreover, *intermediation* trades also happen: informed agents trade with uninformed agents not for the consumption value of the asset, but rather for its future trade value. Since informed agents buy assets at a cheaper price and sell them at a higher price than uninformed agents, they are able to make a profit by trading and retrading the asset.

Proposition 2 proves existence of the class of Core-Periphery Equilibria. These equilibria are supported by a punishing strategy where uninformed buyers who default against uninformed sellers face no consequence. As such, uninformed traders are peripheral agents who do not

trade with each other, but rather only with informed agents who form the core of the network. Because uninformed agents are constrained by the limited commitment friction, Core-Periphery Equilibria are not efficient.

In Core-Periphery Equilibria, informed agents also act as intermediaries, precisely because they form the core of the trade network and have more trade opportunities than uninformed agents do. As such, uninformed agents sell assets to informed ones at a discount because it would take them longer to find a final buyer on their own, and buy assets for a higher price for a similar motive. This price spread makes intermediation profitable to core traders.

Given the equilibrium multiplicity, Section 5 proposes a refinement: I look for equilibria that maximize informed agents' values. Since all equilibria rely on informed agents coordinating on punishing strategies to ensure trade, it is reasonable to expect informed agents' preferred equilibria. The main results are that it can benefit informed agents to use punishing strategies that yield better terms of trade to themselves (Proposition 5), and that create a core-periphery trade network by preventing trade between uninformed agents (Proposition 4).

Both of these channels that benefit informed agents also generate motives for equilibrium intermediation, so that we can conclude that intermediation is to be expected in decentralized markets with limited commitment. Moreover, a consequence of Proposition 4 is that inefficient equilibria such as Core-Periphery Equilibria yield higher value to informed agents than efficient All-Trade Equilibria.

1.1. **Related Literature.** This paper is related to a recent literature on intermediation in over-the-counter markets. Initial models feature exogenously given middlemen who facilitate trade (e.g., Duffie, Garleanu and Pedersen, 2005 and Lagos and Rocheteau, 2009). Many papers have since tackled the question of the endogenous emergence of some agents as intermediaries. The papers that are closest to mine are Farboodi, Jarosch and Shimer (2020) and Farboodi, Jarosch, Menzio and Wiriadinata (2019).[2] The former finds that agents with faster meeting rates, and hence more opportunities to trade, become intermediaries; while the latter shows that intermediation arises purely due to differences in bargaining power across agents. I propose an alternative theory, which relies on agents' limited commitment to future payments. This new theory can be seen as a microfoundation for the two previous explanations, as the punishing strategies used by informed agents in my model lead to some agents endogenously having better trade opportunities or surplus extraction.

Babus and Hu (2017) study a repeated game played in a network and also show a link between intermediation and trade when agents cannot commit to payments.[3] In their model, without intermediation, trade fails as the number of agents becomes large; and with intermediation, trade can be sustained regardless of the size of the market. The first main difference between their model and mine is that I study the limit case where there is a continuum of agents. Secondly, intermediation emerges dynamically in my model, when agents trade for future

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[2]See also Afonso and Lagos (2015), Chang and Zhang (2019) and Bethune, Sultanum and Trachter (2020).
[3]Fainmasser (2019) is another paper that considers the link between intermediation and cooperation in repeated games in networks.

resale purposes. In their framework, this is not possible, as assets are not carried between periods. Finally, my paper highlights the effect of punishing strategies on equilibrium features.

My paper also relates to the sizable literature on limited commitment in search-theoretic models of liquidity. Generally, the main difference between those models and mine is that the assets agents trade in my environment are long-lived and might be traded for speculative motives, rather than a commodity that is consumed before the end of each period. This distinction is key for linking the limited commitment friction to intermediation.[4]

Finally, I contribute to the literature linking intermediation and trade efficiency. Previous work has found intermediation to facilitate trade by minimizing transaction costs (Townsend, 1978), minimizing search frictions (Rubinstein and Wolinsky, 1987; Duffie, Garleanu and Pedersen, 2005), or reducing monitoring costs (Diamond, 1984). In terms of the monitoring motivation for intermediation, my paper is closely related to Diamond (1984) and the subsequent literature. In Diamond's model, intermediation increases efficiency by lowering the total cost of monitoring. In my model, intermediation can be welfare-improving by providing incentives for informed agents to join the market, and then monitor trades.

## 2. MODEL

I study an economy where time is continuous and the horizon infinite, and future utility flows are discounted by all agents at rate $r > 0$. A unit measure of agents bilaterally meet to trade an indivisible asset with supply fixed at $1/2$. In these meetings, a numeraire good is used as medium of exchange.

**Preferences.** At any time, each agent in the market either holds an asset or does not. They cannot accumulate assets or sell assets they do not yet have. An agent with idiosyncratic valuation $v \in \{L, H\}$ receives flow value $\delta_v$ when holding an asset, where $\delta_H > \delta_L \geqslant 0$.

Asset holdings are subject to shocks: At a Poisson rate $\eta > 0$, an agent that is holding an asset loses it and, at that same rate, an agent that is not holding an asset receives one. The difference in flow payoffs between high and low valuation agents, as well as the asset holding shocks, imply that agents wish to continuously trade and retrade the assets.[5]

**Bilateral Trade and Limited Commitment.** At rate $\lambda > 0$, an agent meets another randomly selected agent. If one of the agents in the meeting has an asset and the other does not, they have an opportunity to trade.

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[4]My paper is close to Cavalcanti and Wallace (1999), where agents are either monitored, having all their previous trades being recorded, or not monitored. Monitored agents can commit to future payments since they can be punished for defaults. In my paper, agents are heterogeneous in their access to a public record rather than in their being recorded or not. Other related papers are Carapella and Williamson (2015) and Bethume, Hu and Rocheteau (2018).

[5]In most of the literature stemming from Duffie, Garleanu and Pedersen (2005), this trading motive is achieved through shocks in agents' valuations for the asset, rather than to the asset holdings as in my model. In the absence of limited commitment, these modeling choices are equivalent.

The agent that holds an asset (the potential seller) makes a take-it-or-leave-it price offer, in terms of the numeraire good, to the agent who does not have an asset (the potential buyer).If this potential buyer accepts the offer, the asset is transferred from seller to buyer. After this transfer takes place, the buyer chooses to pay the agreed upon price or to default. [6]

Despite the seller making a take-it-or-leave-it price offer, sellers do not necessarily extract all of the buyers' surpluses, since they must also make sure that the buyers choose not to default. In fact, the seller-optimal price offer is such that the buyer is made exactly indifferent between defaulting and not defaulting.

The buyers' decision to default or not depends on who learns about their default and how they react to that information. Of course, the seller who is defaulted on knows about it. However, this seller cannot use this information to punish the defaulter, since the population of agents is very large and the defaulting buyer will never meet this particular seller again. In turn, a seller who anticipates that a buyer would default chooses not to sell their asset. This means that, for trade to take place in this environment with limited commitment, information about past defaults must spread beyond each meeting. This is formally argued in Kandori (1992).

**Information and Trigger Punishing Strategies** A measure $\phi$ of agents is *informed* ($I$) and, upon meeting a potential trading partner, observe their past trading history – the identity of past trading partners and whether they defaulted or not. The other $1 - \phi$ agents are *uninformed* ($U$) and do not observe said history. Agents' information types are independent of their valuation.

Informed agents use their knowledge of past trading history to punish defaulting agents. To that end, they use *trigger punishing strategies*: when a buyer defaults, a punishment regime is triggered with some probability. In that case, the buyer is forever excluded from trade with informed agents.[7] All informed agents use the same trigger strategy and there is anonymity, i.e., an informed agent who meets two agents with the same trading history chooses the same action in both meetings.

Formally, the set of trading histories plus the realization of a public randomization device is partitioned in two: elements which induce informed agents to *trade* and elements that induce informed agents *not to trade*. I denote these elements *unflagged histories* and *flagged histories*, respectively.

To fully describe the punishing strategy, I also need to assign punishments to informed agents who fail to punish when called upon to do so, i.e., informed agents who trade with flagged agents. It is enough to impose that informed agents who trade with flagged agents become flagged. If a flagged agent wants to buy from an informed agent, she has no incentive to repay, and hence the informed agent will not engage in this sale. If a flagged agent wants to sell to an

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[6]The buyer has limited commitment and can choose to default, but the model could seamlessly be flipped to the case where the buyer first pays and then the seller chooses whether to transfer the good or not.

[7]There are other, non-trigger, strategies which also support the equilibria I find and there are parameter values for which other strategies might support equilibria which are not supported by the trigger class. However, the harshest trigger strategy, whereby a buyer is punished with probability 1 after default, is also the harshest punishment informed agents can inflict on defaulters across all the possible, even non-trigger, strategies.

informed agent, the informed agent will already get punished from engaging in this trade and will hence have no incentive to pay. Anticipating that, the flagged agent does not sell.

## 3. Equilibrium Definition

Let $V_{va}^i$ be the value to an unflagged agent of information type $i \in \{I, U\}$, valuation $v \in \{H, L\}$ and asset holding $a \in \{0, 1\}$. Accordingly, let $\tilde{V}_{va}^i$ be the value of that same agent when he is in the flagged regime. There are 16 potential trades between unflagged agents and $(i_s, v_s, i_b, v_b)$ denotes a trade between a seller of type $(i_s, v_s) \in \{I, U\} \times \{H, L\}$ and a buyer of type $(i_b, v_b) \in \{I, U\} \times \{H, L\}$. The surplus in this meeting is given by $V_{v_s0}^{i_s} - V_{v_s1}^{i_s} + V_{v_b1}^{i_b} - V_{v_b0}^{i_b}$, the value to the buyer of acquiring an asset minus the value to the seller of losing an asset.

**Punishing Strategy and Price Determination.** Define the trigger punishing strategy $\tau : (\{I, U\} \times \{H, L\})^2 \to [0, 1]$ where $\tau(i_s, v_s, i_b, v_b)$ is the probability that the buyer becomes flagged after defaulting on trade $(i_s, v_s, i_b, v_b)$. In meeting $(i_s, v_s, i_b, v_b)$, the buyer will choose to pay the seller if the seller's price offer $p$ satisfies:

$$(1) \qquad V_{v_b1}^{i_b} - p \geqslant (1 - \tau(i_s, v_s, i_b, v_b)) V_{v_b1}^{i_b} + \tau(i_s, v_s, i_b, v_b)\tilde{V}_{v_b1}^{i_b}$$

On the left-hand side of condition (1) is the value to the buyer of paying the price $p$ requested by the seller: the buyer leaves the meeting with the asset and without triggering any punishment, but incurs in payment $p$. On the right-hand side, is the value of defaulting: with probability $(1 - \tau(i_s, v_s, i_b, v_b))$, the buyer leaves the meeting with the asset and does not trigger punishment, and with probability $\tau(i_s, v_s, i_b, v_b)$, the buyer leaves the meeting with the asset, but triggers the punishment regime.

When set to equality, condition (1) determines the highest price the seller can charge while guaranteeing that the buyer will not default. Thus, the seller's optimal take-it-or-leave-it price offer in meeting $(i_s, v_s, i_b, v_b)$ is

$$(2) \qquad p(i_s, v_s, i_b, v_b) = \tau(i_s, v_s, i_b, v_b)(V_{v_b1}^{i_b} - \tilde{V}_{v_b1}^{i_b})$$

If participating in the market is valuable, then $V_{v_b1}^{i_b}$ is larger than $\tilde{V}_{v_b1}^{i_b}$ and the seller can charge a positive price and guarantee that the buyer does not default. Equation (2) shows that a harsher punishment to default (larger $\tau$) raises the maximum price the seller can charge, because it decreases the buyer's deviation value. In the other limit, if there is no punishment to default ($\tau = 0$), the price is zero.

It is convenient to define the buyer and seller surplus shares in each meeting.

Let $\beta : (\{I, U\} \times \{H, L\})^2 \to \mathbb{R}$, where $\beta(i_s, v_s, i_b, v_b)$ is the proportion of the surplus that remains with the seller in meeting $(i_s, v_s, i_b, v_b)$.

$$(3) \qquad \beta(i_s, v_s, i_b, v_b) = \frac{V_{v_s0}^{i_s} - V_{v_s1}^{i_s} + p(i_s, v_s, i_b, v_b)}{V_{v_s0}^{i_s} - V_{v_s1}^{i_s} + V_{v_b1}^{i_b} - V_{v_b0}^{i_b}}$$

**Equilibrium Trades.** Let $\mathcal{I} : (\{I, U\} \times \{H, L\})^2 \to \{0, 1\}$ be such that $\mathcal{I}(i_s, v_s, i_b, v_b) = 1$ indicates that trade $(i_s, v_s, i_b, v_b)$ takes place in equilibrium and $\mathcal{I}(i_s, v_s, i_b, v_b) = 0$ that it does not. A trade is mutually beneficial if both seller and buyer retain a positive surplus. In equilibrium, only mutually beneficial trades take place. Additionally, all strictly beneficial trades must take place.

$$(4) \qquad \mathcal{I}(i_s, v_s, i_b, v_b) = 1 \Rightarrow \beta(i_s, v_s, i_b, v_b) \in [0, 1] \text{ and } V_{v_s0}^{i_s} - V_{v_s1}^{i_s} + V_{v_b1}^{i_b} - V_{v_b0}^{i_b} \geqslant 0$$

$$(5) \qquad \beta(i_s, v_s, i_b, v_b) \in (0, 1) \text{ and } V_{v_s0}^{i_s} - V_{v_s1}^{i_s} + V_{v_b1}^{i_b} - V_{v_b0}^{i_b} > 0 \Rightarrow \mathcal{I}(i_s, v_s, i_b, v_b) = 1$$

**Value Functions.** Given the surplus sharing rules defined above, we can write the unflagged and flagged agents' value functions. To that end, also let $\{\mu_{va}^i\}$ denote the stationary distribution of unflagged agents across valuations and asset holdings. I focus on stationary equilibria with no default on path, and so I refrain from adding notation for the stationary measure of flagged agents, which must be zero.

Value functions for unflagged and flagged agents, respectively, are shown below. They are composed by the flow value received if holding an asset, the value due to asset holding shocks and flows from trade.

(6)
$$rV_{v0}^i = \eta \left(V_{v1}^i - V_{v0}^i\right) + \lambda \sum_{v_s \in \{L, H\}} \mu_{v_s1}^I \, \mathcal{I}(I, v_s, i, v) \left(1 - \beta(I, v_s, i, v)\right) \left(V_{v1}^i - V_{v0}^i + V_{v_s0}^I - V_{v_s1}^I\right)$$
$$+ \lambda \sum_{v_s \in \{L, H\}} \mu_{v_s1}^U \, \mathcal{I}(U, v_s, i, v) \left(1 - \beta(U, v_s, i, v)\right) \left(V_{v1}^i - V_{v0}^i + V_{v_s0}^U - V_{v_s1}^U\right)$$

(7)
$$rV_{v1}^i = \delta_v + \eta \left(V_{v0}^i - V_{v1}^i\right) + \lambda \sum_{v_b \in \{L, H\}} \mu_{v_b0}^I \, \mathcal{I}(i, v, I, v_b) \, \beta(i, v, I, v_b) \left(V_{v_b1}^I - V_{v_b0}^I + V_{v0}^i - V_{v1}^i\right)$$
$$+ \lambda \sum_{v_b \in \{L, H\}} \mu_{v_b0}^U \, \mathcal{I}(i, v, U, v_b) \, \beta(i, v, U, v_b) \left(V_{v_b1}^U - V_{v_b0}^U + V_{v0}^i - V_{v1}^i\right)$$

(8)
$$r\tilde{V}_{v0}^i = \eta(\tilde{V}_{v1}^i - \tilde{V}_{v0}^i) + \lambda \sum_{v_s \in \{L, H\}} \mu_{v_s1}^U \, \mathcal{I}(U, v_s, i, v)(\tilde{V}_{v1}^i - \tilde{V}_{v0}^i)$$

(9)
$$r\tilde{V}_{v1}^i = \delta_v + \eta(\tilde{V}_{v0}^i - \tilde{V}_{v1}^i) + \lambda \sum_{v_b \in \{L, H\}} \mu_{v_b0}^U \, \mathcal{I}(i, v, U, v_b) \, \beta(i, v, U, v_b)(V_{v_b1}^U - V_{v_b0}^U + \tilde{V}_{v0}^i - \tilde{V}_{v1}^i)$$

The value experienced by agents in the flagged regime differs from these above in that flagged agents do not trade with informed agents, thus (8) and (9) do not account for value of meeting with informed agents. Flagged agents can still trade with uninformed agents, who are not able to observe their past defaults. Moreover, since the flagged agent is already in the punishment regime and cannot be punished further, flagged buyers always default, which is also accounted

for in (8). Since I work with equilibria with no default on path, these trades never take place. However, they still affect the value of the deviation.

**Stationary Distribution** The distribution of agents across types must satisfy the adding up constraints given below.

$$(10) \qquad \sum_{v\in\{H,L\}} \sum_{a\in\{0,1\}} \mu_{va}^I = \phi$$

$$(11) \qquad \sum_{v\in\{H,L\}} \sum_{a\in\{0,1\}} \mu_{va}^U = 1 - \phi$$

$$(12) \qquad \sum_{i\in\{I,U\}} \sum_{v\in\{H,L\}} \mu_{v1}^i = \frac{1}{2}$$

Finally, in any stationary equilibrium, the stationary distribution must be so that the inflow into each state is equal to the outflow. For any $v \in H, L$ and $i \in \{I, U\}$, the following must hold:

$$(13) \quad \mu_{v1}^i \left[ \eta + \sum_{v_b\in\{H,L\}} \sum_{i_b\in\{I,U\}} \mu_{v_b0}^{i_b} \mathcal{I}(i,v,i_b,v_b) \right] = \mu_{v0}^i \left[ \eta + \sum_{v_s\in\{H,L\}} \sum_{i_s\in\{I,U\}} \mu_{v_s1}^{i_s} \mathcal{I}(i_s,v_s,i,v) \right]$$

**Symmetry.** I focus on symmetric equilibria, where an agent's equilibrium trading behavior only depends on her information type and on whether their asset holdings are well-aligned with their valuation.[8] An agent's portfolio is misaligned if they have high valuation but no asset, or if they hold an asset but have low valuation. Their portfolio is well-aligned otherwise. Symmetry requires a misaligned seller to have a trading pattern that mirrors that of a misaligned buyer of the same information type. Formally:

$$(14) \qquad \mathcal{I}(i_s, v_s, i_b, v_b) = \mathcal{I}(i_b, \sim v_b, i_s, \sim v_s)$$

$$(15) \qquad \beta(i_s, v_s, i_b, v_b) = 1 - \beta(i_b, \sim v_b, i_s, \sim v_s)$$

**Equilibrium Definition.** A stationary equilibrium with no default is a set of unflagged value functions $\{V_{va}^i\}$, flagged value functions $\{\tilde{V}_{va}^i\}$, trade indicator $\mathcal{I}$, seller surplus shares $\beta$ and punishment strategy $\tau$ and stationary distribution $\{\mu_{va}^i\}$ such that (3)-(15) are satisfied.

## 4. ALL-TRADE AND CORE-PERIPHERY EQUILIBRIA

I propose two classes of equilibria. In the first class, All-Trade Equilibria, the limited commitment friction is completely overcome, and no positive surplus trades are hindered by the threat of default. In the second class, Core-Periphery Equilibria, the threat of default prevents uninformed agents from directly trading with each other. In these equilibria, uninformed agents

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[8]Farboodi, Jarosch and Shimer (2020) similarly restrict attention to the set of symmetric equilibria in their model.

are *peripheral* traders, only trading with the informed *core* traders. The informed core traders trade amongst themselves and also with the peripheral traders.

In the language of Italian markets for corrupt exchange, as in Della Porta and Vanucci (2016), "the mafia" can be seen as the group of informed agents who have detailed knowledge of the behavior of individuals in a community. In All-Trade Equilibria, the mafia punishes any individual who fails to honor their debt to someone, regardless of whether the cheated creditor is himself in the mafia or not. In Core-Periphery Equilibria, the mafia turns a blind eye to individuals who default on creditors who are not mafia participants, but punish anyone who cheats on a mafia participant.

The two classes of equilibria illustrate that there are two different manners types of punishing strategy asymmetries that generate intermediation: surplus-sharing asymmetries (present in both All-Trade and Core-Periphery Equilibria) and asymmetries in effective trade opportunities (present in Core-Periphery Equilibria). In Section 5, I show that both these channels can be used by informed agents to maximize their equilibrium values.

4.1. **All-Trade Equilibria.** We saw in equations (2) - (5) that there is a mapping between the punishing strategy $\tau$ and the surplus sharing rule $\beta$ and trade indicator $\mathcal{I}$. Throughout the paper, instead of starting with a punishing strategy $\tau$ and finding the equilibrium that it supports, I take the reverse approach. First, I conjecture potential equilibrium trade indicator $\mathcal{I}$ and surplus sharing rule $\beta$ and then search for a punishing strategy $\tau$ which supports the conjectures.

To build the class of All-Trade Equilibria, I start with the conjecture that all positive surplus trades take place. Formally, $\mathcal{I}$ is such that:

$$(16) \qquad V_{v_s0}^{i_s} - V_{v_s1}^{i_s} + V_{v_b1}^{i_b} - V_{v_b0}^{i_b} > 0 \Rightarrow \mathcal{I}(i_s, v_s, i_b, v_b) = 1$$

Moreover, I conjecture a surplus sharing rule where, when informed and uninformed agents trade, the informed agent keeps at least half of the surplus.[9] In all other trades, the surplus is split equally between buyer and seller. Formally, for some $\beta^I \in [.5, 1)$, $\beta$ is given by:

$$(17) \qquad \beta(I, v_s, U, v_b) = \beta^I \geqslant \frac{1}{2} \qquad \beta(U, v_s, I, v_b) = 1 - \beta^I \leqslant \frac{1}{2}$$

$$\beta(I, v_s, I, v_b) = \frac{1}{2} \qquad \beta(U, v_s, U, v_b) = \frac{1}{2}$$

Notice again that the seller makes take-it-or-leave-it price offers in all meetings, but he is subject to the limited commitment constraint and must make a price offer that induces the

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[9]The reverse equilibria, where the uninformed agents keep at least half of the surplus, also exist and are discussed further later in the paper.

buyer not to default. It is thus possible to build equilibria where the seller does not keep all the surplus, as I conjecture above.

The conjecture that informed agents keep a larger share of the surplus when meeting with uninformed agents is supported by a punishing strategy $\tau$ which punishes uninformed defaulters very harshly, with a high trigger probability of exclusion from the market. Knowing that the punishment for default is harsh, the informed seller can make a high take-it-or-leave-it price offer and extract a large share of the surplus. On the other hand, informed defaulters are punished lightly, with a small probability of triggering exclusion from the market. The uninformed seller thus knows he must demand a low price from the informed buyer in order to avoid default. As such, the informed buyer keeps a large share of the surplus of the trade to himself.

In Proposition 1, I show that if the measure of informed agents is large enough and agents are sufficiently patient, then there is a punishing strategy $\tau$ that supports an equilibrium consistent with the conjectures in (16) and (17).

**Proposition 1.** *For each $\beta^I \in [.5, 1)$, an All-Trade Equilibrium satisfying (16) and (17) exists if $\phi$ is sufficiently large ($\phi \to 1$) and $r$ sufficiently small ($r \to 0$).*

*Conversely, for each $r, \phi \in (0, 1)$, there exists a $\bar{\beta} \in (.5, 1)$ such that, if $\beta^I > \bar{\beta}$, then an All-Trade Equilibrium does not exist.*

*All-Trade Equilibria are efficient and feature intermediation by informed agents.*

The Proof of Proposition 1, which I now describe, is in the Appendix, where I also characterize the unflagged and flagged values, and the stationary distribution in the All-Trade Equilibria.

**Equilibrium Values and Trades.** I start out by substituting the $\mathcal{I}$ and $\beta$ conjectures in (14), (16) and (17) into the equations defining agents' value functions both in the unflagged and flagged regimes, and the stationary distribution in (6) - (13).

The first observation is that the implied stationary distribution is symmetric: The measure of uninformed (informed, respectively) agents with high valuation but without an asset is equal to that of uninformed (informed) agents with low valuation and holding an asset. I define $\mu^U \equiv \mu^U_{H0} = \mu^U_{L1}$ and $\mu^I \equiv \mu^I_{H0} = \mu^I_{L1}$, the measures of agents with misaligned portfolios.

Now define $S^i_v$ to be the value of holding an asset to agent of information type $i$ and valuation type $v$, so that $S^i_v \equiv V^i_{v1} - V^i_{v0}$. With some algebra, I show that the starting conjectures imply

$$S^i_H = \left[\frac{1}{2(r+2\eta)}\right](\delta_H + \delta_L) + \alpha^i(\delta_H - \delta_L) \qquad S^i_L = \left[\frac{1}{2(r+2\eta)}\right](\delta_H + \delta_L) - \alpha^i(\delta_H - \delta_L)$$

$$(18) \qquad\qquad \text{where } \alpha^I = \frac{1}{2(r + 2\eta + \lambda(2\mu^U \beta^I + \mu^I))}$$
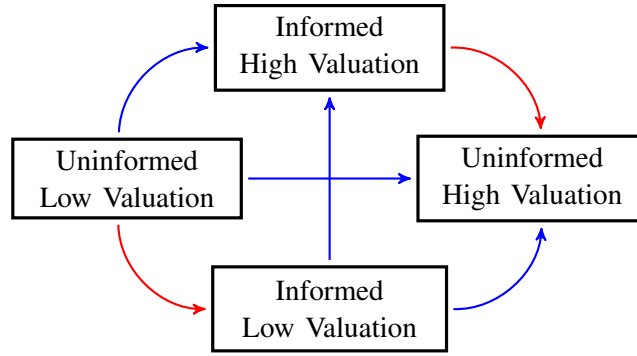
FIGURE 1. Trade pattern supported in the All-Trade Equilibria. Blue arrows indicate portfolio balancing trades. Red arrows indicate intermediation trades.

$$(19) \qquad \text{and } \alpha^U = \left[ \frac{r + 2\eta + \lambda\beta^I(2\mu^U + \mu^I) + \lambda(1 - \beta^I)(\phi/2 - \mu^I)}{r + 2\eta + \lambda(\mu^U + \phi/2(1 - \beta^I))} \right] \alpha^I$$

Since $\beta^I \geqslant .5$, it is easy to check that the term multiplying $\alpha^I$ in equation (19) is weakly larger than 1, so that $\alpha^U \geqslant \alpha^I$. This means that agents' values are ordered $S_H^U \geqslant S_H^I > S_L^I \geqslant S_L^U$, with all inequalities being strict if $\beta^I$ is strictly larger than .5.

The constants $\alpha^I$ and $\alpha^U$ are effective discount rates which determines the size of the wedge between $S_H^i$ and $S_L^i$. This wedge stems from the difference in the flow value of holding an asset for agents with high or low valuation. If $\alpha^i$ is higher, this difference is bigger. Note that $\alpha^i$ is higher whenever agents get less opportunities to trade due to more frictions (lower $\lambda$). The intuition is that when an agent with high valuation gets few opportunities to trade, it is important for them to hold onto an asset. If, on the other hand, opportunities to trade are abundant, the value of having an asset in hand is not as large, as the opportunity to buy one presents itself often.

With these values at hand, we can establish the set of trades with positive surplus in this conjectured equilibrium. These trades are pictured in Figure 1. The first type are *portfolio balancing trades*, where assets move from sellers with low valuation to buyers with high valuation. The surplus in these trades is positive, given by $S_H^{i_b} - S_L^{i_s} > 0$, where $i_b$ and $i_s$ are the information types of buyer and seller respectively. These trades are portfolio-balancing because both agents enter the meeting with misaligned portfolios and leave it with aligned portfolios.

The second type of positive surplus trades are *intermediation trades*, where buyer and seller have the same valuation type. When an informed buyer with low valuation meets an uninformed seller with low valuation, this trade has positive surplus given by $S_L^U - S_L^I \geqslant 0$. Similarly, when an uninformed buyer with high valuation meets an informed seller with high valuation, this trade also has positive surplus, given by $S_H^H - S_H^U \geqslant 0$.

These are trades where informed agents act as intermediaries: they trade not for the consumption value of the asset, but rather for its future trade value. Since informed agents keep more

than half of the surplus in all trades with uninformed agents, they buy assets at a lower price than they expect to sell them for in a future encounter. As such, they wish to buy assets even if they have low valuation. Conversely, they sell assets even in the high valuation state, since they charge a higher price than they expect to buy a new asset for in a future trade.

Note that the ability to extract more than half of the surplus is not inherent to informed agents, but rather an endogenous feature of the conjectured equilibrium.

**All-Trade Equilibrium with $\beta^I = .5$.** When $\beta^I = .5$, surplus is shared evenly between buyer and seller in all meetings, even between informed and uninformed agents. In that case, we have $S_H^U = S_H^I > S_L^I = S_L^U$, and the surplus of intermediation trades is equal to $0$, so that agents are indifferent between trading and not trading in intermediation meetings. This illustrates that, in the All-Trade Equilibria, the motive for intermediation stems from the asymmetry in surplus sharing between informed and uninformed agents.

**Verifying Equilibrium Existence.** So far, I assumed that some punishing strategy $\tau$ supports the All-Trade Equilibrium conjectures. With the equilibrium values calculated above, I can now verify when such a $\tau$ exists. Effectively, I need to verify that, for some $\tau$, the seller's optimal take-it-or-leave-it price offer in each positive surplus meeting exactly implements the conjectured surplus sharing rule in (17).

For each meeting positive surplus meeting $(i_s, v_s, i_b, v_b)$, there must be some $\tau(i_s, v_s, i_b, v_b) \in [0, 1]$ such that:

$$(20) \qquad p(i_s, v_s, i_b, v_b) = \tau(i_s, v_s, i_b, v_b)(V_{v_b1}^{i_b} - \tilde{V}_{v_b1}^{i_b})$$

where $p(i_s, v_s, i_b, v_b) = V_{v_s1}^{i_s} - V_{v_s0}^{i_s} + \beta(i_s, v_s, i_b, v_b)\left[(V_{v_s1}^{i_s} - V_{v_s0}^{i_s}) - (V_{v_b1}^{i_b} - V_{v_sb}^{i_b})\right]$

To build such a punishing strategy, all I need to verify is that the loss in value from being excluded from the market, is larger than the price in each meeting: $V_{v_b1}^{i_b} - \tilde{V}_{v_b1}^{i_b} \geqslant p(i_s, v_s, i_b, v_b)$. If that is the case, then there is some $\tau(i_s, v_s, i_b, v_b) \in [0, 1]$ for which (20) is exactly satisfied.

In the Appendix, I show that, for each value of $\beta^I \in [.5, 1)$, if $r$ is sufficiently small and $\phi$ sufficiently large, then the loss in value from being excluded from trade with informed agents is large enough that this condition holds.

Moreover, I show that for any given values of $r$ and $\phi$, there is some $\bar{\beta}$ strictly below $1$ such that the all trade equilibrium cannot be sustained if $\beta^I > \bar{\beta}$. This upper bound exists because, if $\beta^I$ is too large, then the value to uninformed agents from trading with informed agents is very low. In that case, losing access to those trades is not a sufficiently strong punishment to ensure that uninformed buyers do not default.

In Figure 2, I display parameter regions where the proposed equilibrium holds. In the top-left panel, I fix $\beta^I = .7$ and plot out the region in the $(\phi, r)$ space. In the bottom-left panel, I fix $\phi = .7$ and show that, for higher $\beta^I$ values, agents need to be more patient in order for the All-Trade Equilibrium to be sustained.
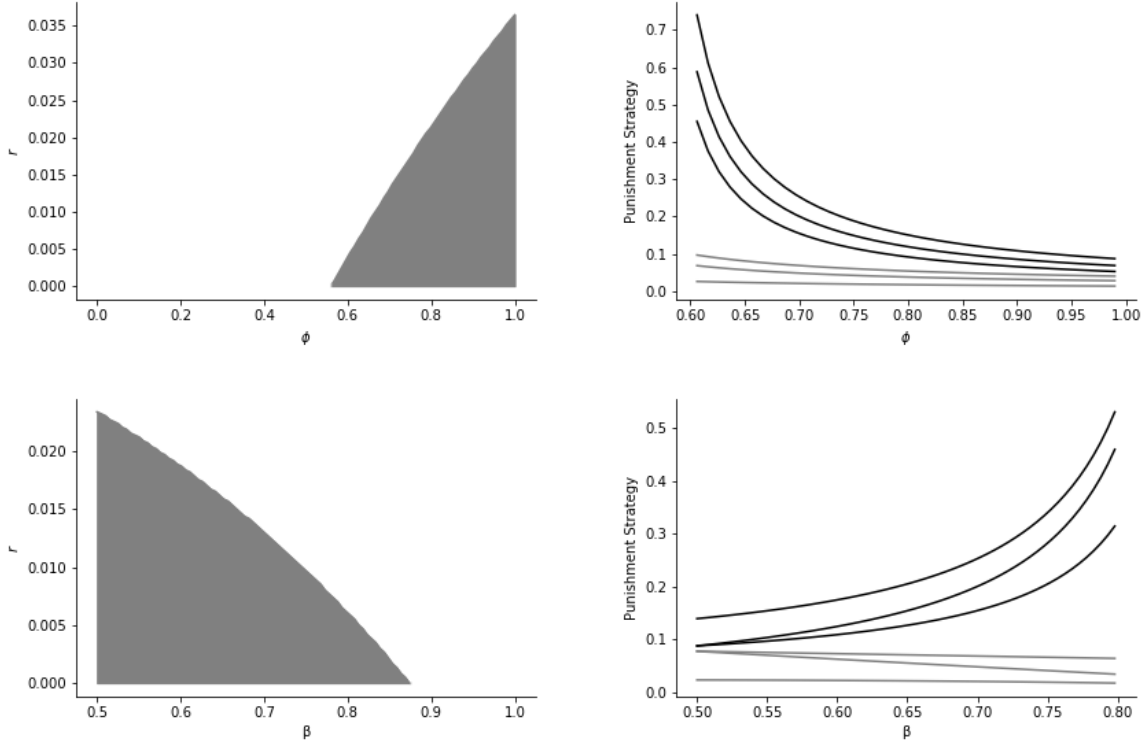
FIGURE 2. In the left panels, the shaded gray area represents the parameter region where the All-Trade Equilibrium exists. Other parameters are fixed at $\lambda = 2$, $\eta = .2$, $\delta_H = 1$, $\delta_L = 0$. For the top-left panel, $\beta^I = .7$ and for the bottom-left, $\phi = .7$. In the top-right panel, I fix the discount factor $r = .003$ and $\beta^I = .7$ and show, for each $\phi$, the punishment strategy $\tau$. The $\tau$ values in black correspond to punishment in trades in which uninformed agents are buyers subject to the punishment and the $\tau$ values in gray to punishments to informed buyers. Accordingly, the bottom-right panel displays $\tau$ as a function of $\beta^I$ when $r = .003$ and $\phi = .7$.

In the top and bottom right panels of Figure 2, I fix the value of $r$ and display the punishing strategy $\tau$ as a function of $\phi$ and $\beta^I$. In black are the probabilities of becoming flagged when uninformed buyers default and the gray lines correspond to the probability of flagging informed buyers that default in each of the three trades where informed agents are buyers. Notice that uninformed agents are always punished more harshly for defaults – the black lines are always above the gray ones. This is consistent with uninformed agents being charged higher prices in trades and retaining a lower share of surplus.

**Efficiency.** A measure of efficiency is the proportion of misaligned agents in the economy in the stationary distribution, i.e. $\mu^I + \mu^U$. If there are no misaligned agents, then all assets are successfully allocated to high valuation agents and the overall flow payoff generated is maximal. In All-Trade Equilibria, constrained efficiency is met: the measure of misaligned agents is minimized, subject to the meeting technology and the asset holding shocks. This is so because every portfolio balancing meetings result in trade, so that assets efficiently flow from low to high valuation agents.

The total measure of misaligned agents is

$$(\mu^U + \mu^I) = \left[ -\frac{\eta}{\lambda} + \sqrt{\left(\frac{\eta}{\lambda}\right)^2 + \frac{1}{2}\frac{\eta}{\lambda}} \right]$$

If meeting frictions vanish, i.e. $\lambda \to +\infty$, the proportion of misaligned agents goes to 0. On the other hand, when $\eta$ is much bigger than $\lambda$, $\mu^U + \mu^I$ converges to $1/4$, which is equivalent to the asset being randomly assigned across agents in the market.

4.2. **Core-Periphery Equilibria.** I now build a class of equilibria in which uninformed agents do not trade with each other, called Core-Periphery Equilibria. In Core-Periphery Equilibria, trades between uninformed agents are hindered by the risk of default, because informed agents do not punish uninformed buyers who default on uninformed sellers.

As before, I start with a conjecture of trade indicator $\mathcal{I}$ and surplus sharing rule $\beta$. Positive surplus trades take place if and only if involving at least one informed agent:

$$(21) \qquad \mathcal{I}(i_s, v_s, i_b, v_b) = 1 \Leftrightarrow (i_s, i_b) \neq (U, U) \text{ and } V^{i_s}_{v_s 0} - V^{i_s}_{v_s 1} + V^{i_b}_{v_b 1} - V^{i_b}_{v_b 0} > 0$$

Moreover, surplus sharing is such that informed agents keep at least half of the surplus when trading with uninformed agents: for some $\beta^I \in [.5, 1)$,

$$(22) \qquad \beta(I, v_s, U, v_b) = \beta^I \geqslant \frac{1}{2} \qquad \beta(U, v_s, I, v_b) = 1 - \beta^I \leqslant \frac{1}{2}$$

$$\beta(I, v_s, I, v_b) = \frac{1}{2}$$

Proposition 2 shows that a Core-Periphery Equilibrium can be sustained by some punishing strategy if the fraction of informed agents is sufficiently high and agents are sufficiently patient.

**Proposition 2.** *For each $\beta^I \in [.5, 1)$, a Core-Periphery Equilibrium satisfying (21) and (22) exists if $\phi$ is sufficiently large ($\phi \to 1$) and $r$ sufficiently small ($r \to 0$).*

*Conversely, for each $r, \phi \in (0, 1)$, there exists a $\bar{\beta} \in (.5, 1)$ such that, if $\beta^I > \bar{\beta}$, then a Core-Periphery Equilibrium does not exist.*

*Core-Periphery Equilibria are **not** efficient and feature intermediation by informed agents.*

A detailed Proof of Proposition 2 is in the Appendix and Online Appendix, where I also characterize the values and stationary distribution in the Core-Periphery Equilibria. The Proof follows the same steps as the Proof of Proposition 1.

**Equilibrium Values and Trades.** Substituting the $\mathcal{I}$ and $\beta$ conjectures in (14), (21) and (22) into the equations defining agents' value functions both in the unflagged and flagged regimes, and the stationary distribution in (6) - (13).
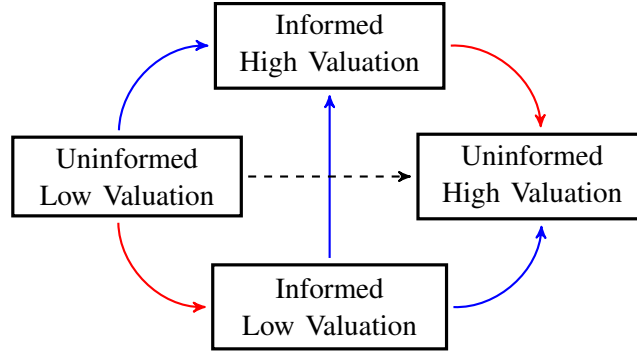
FIGURE 3. Trade pattern supported in Core-Periphery Equilibria. Blue arrows indicate portfolio balancing trades. Red arrows indicate intermediation trades. Dashed arrow indicates a trade that does not occur in this pattern due to limited commitment.

The implied stationary distribution is symmetric, as in the All-Trade Equilibrium. Let $\hat{\mu}^U$ and $\hat{\mu}^I$, the measures of uninformed and informed agents with misaligned portfolios in the Core-Periphery Equilibrium, respectively.

With some algebra, I show that the starting conjectures imply that the value of holding an asset to agent of information type $i$ and valuation type $v$ is:

$$S_H^i = \left[ \frac{1}{2(r+2\eta)} \right] (\delta_H + \delta_L) + \hat{\alpha}^i(\delta_H - \delta_L) \qquad S_L^i = \left[ \frac{1}{2(r+2\eta)} \right] (\delta_H + \delta_L) - \hat{\alpha}^i(\delta_H - \delta_L)$$

$$\text{(23)} \qquad \text{where } \hat{\alpha}^I = \frac{1}{2(r + 2\eta + \lambda(2\hat{\mu}^U \beta^I + \hat{\mu}^I))}$$

$$\text{(24)} \qquad \text{and } \hat{\alpha}^U = \left[ \frac{r + 2\eta + \lambda\beta^I(2\hat{\mu}^U + \hat{\mu}^I) + \lambda(1 - \beta^I)(\frac{\phi}{2} - \hat{\mu}^I)}{r + 2\eta + \lambda\frac{\phi}{2}(1 - \beta^I)} \right] \hat{\alpha}^I$$

Since $\beta^I \geqslant .5$, we can check that $\alpha^U > \alpha^I$, and agents' values are ordered agents' values are ordered $S_H^U > S_H^I > S_L^I > S_L^U$.

With these values, and the conjecture that positive surplus trades take place if and only if involving at least one informed trader, we can verify the trading pattern in Core-Periphery Equilibrium, which is depicted in Figure 3. As in All-Trade Equilibria, informed agents engage in portfolio balancing trades both with informed and uninformed trading partners. However, portfolio balancing trades between two uninformed agents do not take place.

Intermediation trades also occur in equilibrium, where informed sellers with high valuation sell to uninformed buyers with high valuation, and informed buyers with low valuation buy assets from uninformed buyers with low valuation.

This equilibrium thus embeds a core-periphery trade network, whereby informed agents are core traders, who trade amongst themselves, as well as with the peripheral uninformed agents. Uninformed agents form the network periphery and do not trade with each other directly, but rather have their trades endogenously intermediated by informed agents in the network's core.

In All-Trade Equilibria, intermediation stems from the surplus-sharing rule that benefits informed agents. While this channel is still present in Core-Periphery Equilibria, there is an additional motive for intermediation: informed agents at the network's core effectively have more trade opportunities and trade at a faster rate than uninformed agents in the periphery.

The difference in opportunities to trade is not inherent to the agents, but rather a feature of the equilibrium conjecture that uninformed agents do not trade with each other even if the trade has positive surplus. This conjecture is sustained in equilibrium by a punishing strategy that does not punish uninformed buyers that default on uninformed sellers. As such, the threat of default prevents trades between peripheral uninformed agents.

**Core-Periphery Equilibrium with $\beta^I = .5$.** When $\beta^I = .5$, surplus is shared evenly between buyer and seller in all meetings that result in trade, even between informed and uninformed agents. In that case, we *still* have $S_H^U > S_H^I > S_L^I > S_L^U$. To verify this, substitute $\beta^I = .5$ into (23) and (24) to find

$$\hat{\alpha}^I = \frac{1}{2(r + 2\eta + \lambda(\hat{\mu}^U + \hat{\mu}^I))} \quad \text{and} \quad \hat{\alpha}^U = \left[ \frac{r + 2\eta + \lambda\hat{\mu}^U + \frac{\lambda\phi}{4}}{r + 2\eta + \frac{\lambda\phi}{4}} \right] \hat{\alpha}^I$$

so that $\hat{\alpha}^U > \hat{\alpha}^U$ even if $\beta^I = .5$. This illustrates that, in Core-Periphery Equilibria, intermediation does not solely stem from the asymmetry in surplus sharing between informed and uninformed agents. Rather, the core-periphery structure of the trading network itself yields a strictly positive value to intermediation trades.

**Verifying Equilibrium Existence.** To verify that there exists a $\tau$ that supports the Core-Periphery Equilibrium conjectures, I follow the same steps as with All-Trade Equilibria in Section 4.1, with one caveat which I now explain.

To ensure that no trade takes place between uninformed agents, even when trades have positive surplus, informed agents must set no punishment to default in trades between two uninformed agents. Formally, set $\tau(i_s, v_s, i_b, v_b) = 0$ whenever $(i_s, i_b) = (U, U)$. With this (non-) punishment in place, an uninformed seller foresees that an uninformed buyer will default on any price offer, and thus refuses to sell.

For all the trades $(i_s, v_s, i_b, v_b)$ that are conjectured to take place, I show that, if $r$ is sufficiently small and $\phi$ sufficiently large, then there exists a probability of punishment $\tau(i_s, v_s, i_b, v_b)$ that exactly implements the conjectured surplus sharing rule.

**Efficiency.** Constrained efficiency is not achieved in Core-Periphery Equilibria. The fact that portfolio balancing trades between uninformed agents are hindered implies that, in the stationary distribution, the proportion of misaligned agents is higher than in All-Trade Equilibria,[10] and hence the total flow payoff to the economy is not as large as it could be.

4.3. **Other Equilibria.** The complete equilibrium set is not exhausted by All-Trade and Core-Periphery Equilibria.

**Reverse-Intermediation Equilibria.** In both classes of equilibria proposed in Sections 4.1 and 4.2, informed agents are assigned higher shares of the surplus in meetings, as well as more opportunities to securely trade. As discussed, both these channels lead to intermediation trades where informed agents act as the intermediaries.

For each of the equilibria proposed, there exists a reverse equilibrium where *uninformed* agents are the intermediaries. For example, there exist "Reverse" All-Trade Equilibria where $\beta^I < .5$, in which case uninformed agents keep a higher share of trade surplus than informed ones. In that case, reverse-intermediation takes place. Equally, there exist "Reverse" Core-Periphery Equilibria where $\beta^I < .5$ and informed agents are peripheral and do not trade with each other due to the risk of default. Again, reverse-intermediation takes place.

Such equilibria are not intuitive, as they rely on informed agents coordinating on uninformed agents larger shares of the trade surplus than that of informed agents. Indeed, in Section 5, I show that Reverse-Intermediation Equilibria are not selected if informed agents can coordinate to maximize their own value.

**Other.** Equilibrium trading is determined by the ordering of agents' values $\left(S_H^I, S_H^U, S_L^I, S_L^U\right)$, as well as if when agents meet the trades are secured by the punishing strategy or not. Since agents with high valuation have a higher flow value from holding the asset, it is the case that in any equilibrium $S_H^i > S_L^j$ for $i, j \in \{I, U\}$. Moreover, the symmetry requirements in (14) and (15) imply that $(S_H^I - S_H^U) = -(S_L^I - S_L^U)$.

In any equilibrium, it is then the case that either $S_H^U \geqslant S_H^I > S_L^I \geqslant S_L^U$ or $S_H^I \geqslant S_H^U > S_L^U \geqslant S_L^I$. While the whole equilibrium set is not exhausted by the equilibria described so far, they do illustrate these two possibilities. They also illustrate that intermediation trades happen whenever $S_H^I \neq S_H^U$ and $S_L^I \neq S_L^U$ and that these differences can be generated either due to the equilibrium surplus sharing or due to the set of secured trade opportunities in an equilibrium.

## 5. MAXIMIZING VALUE TO INFORMED AGENTS

The equilibria shown in the last section help us understand the channels that generate motive for intermediation and how those can be determined by the punishing strategy in place. I now refine the set of equilibria by characterizing equilibria that are preferred by informed agents. This is a natural requirement in this model, since informed agents are the ones who coordinate on punishing strategies that sustain equilibria.

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[10]This is shown in the Appendix.

Define the objects $V^I$ and $V^U$, the value of being informed and uninformed, respectively.

$$(25) \qquad\qquad V^I \equiv \frac{V_{H0}^I + V_{L0}^I}{2}$$

$$(26) \qquad\qquad V^U \equiv \frac{V_{H0}^U + V_{L0}^U}{2}$$

The weighting in $V^I$ and $V^U$ reflects that half the agents have high valuation and half have low valuation, regardless of their information type. These values are also defined considering an agent that enters the market without holding an asset. They already account for the value of holding the asset, since these agents over time are hit by asset holding shocks, and also trade assets. The results in this section equally hold if we look at the opposite case, where the value accounts for an agent that enters the market holding an asset.

Proposition 3, shows that, while equilibria where uninformed agents act as intermediaries exist, they are not the equilibria preferred by informed agents. This result allows us to rule out Reverse-Intermediation Equilibria, as in Section 4.3, and asserts that intermediation is typically performed by informed agents (as in All-Trade and Core-Periphery Equilibria).

**Proposition 3.** *If there exists an equilibrium featuring intermediation by uninformed agents, then there exists another equilibrium, yielding a higher $V^I$, which does not feature intermediation by uninformed agents.*

The Proof of Proposition 3 is in the Appendix.

The next result states that, to the informed agent, Core-Periphery Equilibria are preferred to All-Trade Equilibria: Preventing uninformed agents from trading with each other is beneficial to informed agents. In Section 4, we saw that All-Trade Equilibria are constrained efficient and Core-Periphery Equilibria are not. One implication of Proposition 4 is thus that informed agents select inefficient equilibria in order to maximize their own value.

**Proposition 4.** *For any $\beta^I \in [.5, 1)$, the Core-Periphery Equilibrium with surplus share $\beta^I$ yields a higher $V^I$ than the All-Trade Equilibrium with that same surplus share $\beta^I$.*

The Proof of Proposition 4 is in the Appendix. All-Trade and Core-Periphery Equilibria differ in that, in the latter, uninformed agents do not trade with each other. When trade between uninformed agents is shut down, uninformed agents have less trade opportunities and are thus more eager to trade in meetings with informed agents. As such, the surplus in such meetings increases, and informed agents can extract higher value from them.

Finally, Proposition 5 states that the value to informed agents is higher when informed agents keep a larger share of surplus in trades with uninformed agents.

**Proposition 5.** *The value to informed agents ($V^I$) is increasing in $\beta^I$ both in All-Trade and Core-Periphery Equilibria.*

FIGURE 4. In the top two panels, I plot the highest $\beta^I$ achievable in All-Trade and Core-Periphery Equilibria, as a function of the share of informed agents $\phi$ (left panel, keeping $r = .005$) and discount rate $r$ (right panel, keeping $\phi = .7$)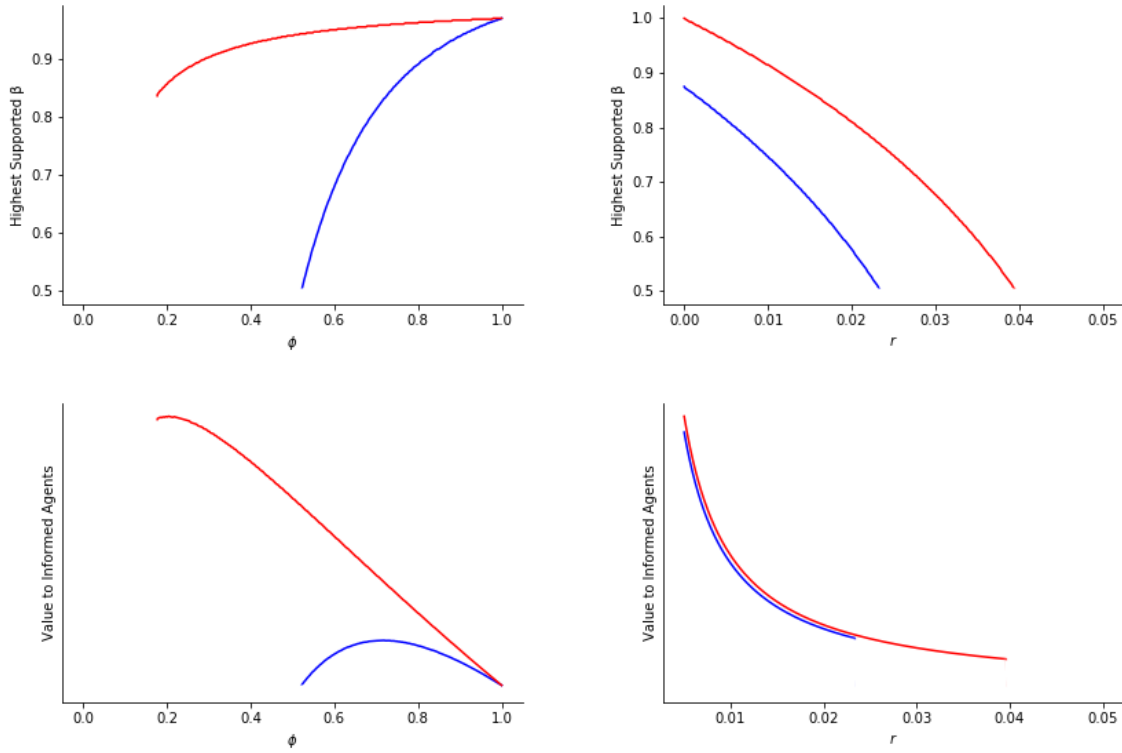. In the bottom two panels, I plot the highest $V^I$ achievable in All-Trade and Core-Periphery Equilibria, as a function of the share of informed agents $\phi$ and discount rate $r$. Other parameters are $\lambda = 2, \eta = .2, \delta_H = 1, \delta_L = 0$.

5.1. **Numerical Exercise.** Propositions 4 and 5 allow us to compare informed agents' values across different equilibria. However, they do not tell us which equilibrium maximizes informed agents' values among the equilibria that can be supported for a given set of parameters. In this numerical exercise, I compare All-Trade and Core-Periphery Equilibria that can be supported across different parameterizations.

Figure 4 displays two main results from numerical simulations.[11] First, we can see whenever an All-Trade Equilibrium can be supported by some punishing strategy, then there is also some punishing strategy that supports a Core-Periphery Equilibrium.

**Numerical Result 1.** *If an All-Trade Equilibrium with surplus share $\beta^I$ exists, then a Core-Periphery Equilibrium with surplus share of at least $\beta^I$ also exists.*

This result, along with Proposition 4, implies that when an All-Trade Equilibria exists, it is dominated – in terms of value to informed agents – by a Core-Periphery which also exists.

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[11]The qualitative features of Figure 4 described in Numerical Results 1 and 2 are robust to other parameter specifications.

In Figure 4, I confirm that the highest value to informed agents achieved by an All-Trade Equilibrium is smaller than the highest value achieved by a Core-Periphery Equilibrium.

**Numerical Result 2.** *Informed agents' value is higher under the best available Core-Periphery Equilibrium than under the best available All-Trade Equilibrium.*

## 6. Conclusion

I developed a dynamic model where agents meet bilaterally to trade and buyers cannot commit to payments. This limited commitment friction is present in many applications, such as markets for stolen goods or markets for corrupt exchange. A robust feature of equilibria in the model, empirically observed in these markets, is the presence of intermediation, where some central agents trade goods not for their own use, but rather to profit from future trade value.

In the model, equilibria with trade are supported by informed agents who threat to punish traders that do not honor payments. In illegal markets, the presence of well-connected (informed) groups is indeed important to ensure the "good" behavior of market participants. For example, Della Porta and Vanucci (2016) argue that the mafia, whose business leans on detailed knowledge of the behavior of individuals in a community, are important enforcers in the Italian Market for corrupt exchange.

In Section 3, I proposed two main classes of equilibria, which are supported by informed agents' threats to punish defaulting agents. All-Trade Equilibria are efficient and all agents are able to trade despite the limited commitment friction, and Core-Periphery Equilibria are inefficient because peripheral uninformed agents are unable to trade amongst themselves. One important result is that these latter inefficient equilibria are robust, as they yield higher value to informed agents than the former, efficient, equilibria.

Another feature of Core-Periphery Equilibria is that information about trades between uninformed agents is not used by informed agents. Consequently, they are also robust to variations in the information technology: if informed agents only had access to information about trades involving at least one informed agent, these equilibria would still be supported. On the other hand, equilibria in which uninformed agents trade with each other require informed agents to have access to all the information available.

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## 8. Appendix

### 8.1. **Proof of Proposition 1 (All-Trade Equilibria).** I build the All-Trade Equilibria through a big guess and verify.

*Guesses.*

Surplus sharing:

$$\beta(I, v_s, U, v_b) = \beta^I \geqslant \frac{1}{2} \qquad \beta(U, v_s, I, v_b) = 1 - \beta^I \leqslant \frac{1}{2}$$

$$\beta(I, v_s, I, v_b) = \frac{1}{2} \qquad \beta(U, v_s, U, v_b) = \frac{1}{2}$$

Trading pattern: $\mathcal{I}(i_s, v_s, i_b, v_b) = 1 \Leftrightarrow v_s = L$ and $v_b = H$.

*Stationary Distribution.* Given the guesses for $\mathcal{I}$, the inflow equal to outflow equations for the stationary distribution become, for $i \in \{I, U\}$:

(27) $$\mu_{L1}^U \left( \eta + \lambda(\mu_{H0}^I + \mu_{H0}^U + \mu_{L0}^I) \right) = \eta \mu_{L0}^U$$

(28) $$\mu_{H0}^U \left( \eta + \lambda(\mu_{L1}^I + \mu_{L1}^U + \mu_{H1}^I) \right) = \eta \mu_{H1}^U$$

(29) $$\mu_{L1}^I \left( \eta + \lambda(\mu_{H0}^U + \mu_{H0}^I) \right) = (\eta + \lambda\mu_{L1}^U)\mu_{L0}^I$$

(30) $$\mu_{H0}^I \left( \eta + \lambda(\mu_{L1}^U + \mu_{L1}^I) \right) = \mu_{H1}^I(\eta + \lambda\mu_{H0}^U)$$

In equation (27), substitute $\mu_{L0}^U = \frac{1-\phi}{2} - \mu_{L1}^U$ (this is true because half of uninformed agents have low valuation). Similarly, in equation (28), substitute $\mu_{H1}^U = \frac{1-\phi}{2} - \mu_{H0}^U$. Then combine the two equations to get:

(31)

$$\mu_{L1}^U \left( 2\eta + \lambda(\mu_{H0}^U + \mu_{H0}^I) \right) + \lambda\mu_{L0}^I\mu_{L1}^U = \mu_{H0}^U \left( 2\eta + \lambda(\mu_{L1}^U + \mu_{L1}^I) \right) + \lambda\mu_{H1}^I\mu_{H0}^U = \frac{\eta(1-\phi)}{2}$$

In equation (29), substitute $\mu_{L0}^I = \frac{\phi}{2} - \mu_{L1}^I$ (as before, this is true because half of informed agents have low valuation). Similarly, in equation (30), substitute $\mu_{H1}^I = \frac{\phi}{2} - \mu_{H0}^I$. Then

combine the two equations to get:

(32) $\mu_{L1}^I \left(2\eta + \lambda(\mu_{H0}^U + \mu_{H0}^I)\right) - \lambda\mu_{L0}^I\mu_{L1}^U = \mu_{H0}^I \left(2\eta + \lambda(\mu_{L1}^U + \mu_{L1}^I)\right) - \lambda\mu_{H1}^I\mu_{H0}^U = \dfrac{\eta\phi}{2}$

Adding up equations (31) and (32):

(33) $\qquad (\mu_{L1}^I + \mu_{L1}^U)\left(2\eta + \lambda(\mu_{H0}^U + \mu_{H0}^I)\right) = (\mu_{H0}^I + \mu_{H0}^U)\left(2\eta + \lambda(\mu_{L1}^U + \mu_{L1}^I)\right) = \dfrac{\eta}{2}$

(34) $\qquad \Rightarrow (\mu_{L1}^I + \mu_{L1}^U) = (\mu_{H0}^I + \mu_{H0}^U)$

Now substitute (33) back into (34) to get:

$$\lambda(\mu_{L1}^I + \mu_{L1}^U)^2 + 2\eta(\mu_{L1}^I + \mu_{L1}^U) - \dfrac{\eta}{2} = 0$$

(35) $\qquad \Rightarrow (\mu_{L1}^I + \mu_{L1}^U) = (\mu_{H0}^I + \mu_{H0}^U) = -\dfrac{\eta}{\lambda} + \sqrt{\left(\dfrac{\eta}{\lambda}\right)^2 + \dfrac{1}{2}\dfrac{\eta}{\lambda}}$

Plug (35) back into (31) and (32) to get $\mu_{H0}^U = \mu_{L1}^U =: \mu^U$ and $\mu_{H0}^I = \mu_{L1}^I =: \mu^I$, and finally:

$$\mu^U = -\left(\dfrac{\eta}{\lambda} + \dfrac{\phi}{4}\right) + \sqrt{\left(\dfrac{\eta}{\lambda}\right)^2 + \dfrac{1}{2}\dfrac{\eta}{\lambda} + \left(\dfrac{\phi}{4}\right)^2}$$

$$\mu^I = -\dfrac{\eta}{\lambda} - \mu^U + \sqrt{\left(\dfrac{\eta}{\lambda}\right)^2 + \dfrac{1}{2}\dfrac{\eta}{\lambda}}$$

*Unflagged Values.* Taking into account the guesses for $\mathcal{I}$ and $\beta$, unflagged values are given by the system

$$rV_{H0}^I = \eta(V_{H1}^I - V_{H0}^I) + \lambda\mu_{L1}^I \dfrac{V_{H1}^I - V_{H0}^I + V_{L0}^I - V_{L1}^I}{2} + \lambda\mu_{L1}^U\beta^I \left[V_{H1}^I - V_{H0}^I + V_{L0}^U - V_{L1}^U\right]$$

$$rV_{H1}^I = \delta_H + \eta(V_{H0}^I - V_{H1}^I) + \lambda\mu_{H0}^U\beta^I \left[V_{H0}^I - V_{H1}^I + V_{H1}^U - V_{H0}^U\right]$$

$$rV_{L1}^I = \delta_L + \eta(V_{L0}^I - V_{L1}^I) + \lambda\mu_{H0}^I \dfrac{V_{L0}^I - V_{L1}^I + V_{H1}^I - V_{H0}^I}{2} + \lambda\mu_{H0}^U\beta^I \left[V_{L0}^I - V_{L1}^I + V_{H1}^U - V_{H0}^U\right]$$

$$rV_{L0}^I = \eta(V_{L1}^I - V_{L0}^I) + \lambda\mu_{L1}^U\beta^I \left[V_{L1}^I - V_{00}^I + V_{L0}^U - V_{L1}^U\right]$$

$$rV_{H0}^U = \eta(V_{H1}^U - V_{H0}^U) + \lambda\mu_{L1}^I(1 - \beta^I)\left[V_{H1}^U - V_{H0}^U + V_{L0}^I - V_{L1}^I\right]$$

$$+ \lambda\mu_{H1}^I(1 - \beta^I)\left[V_{H1}^U - V_{H0}^U + V_{H0}^I - V_{H1}^I\right] + \lambda\mu_{L1}^U\frac{V_{H1}^U - V_{H0}^U + V_{L0}^U - V_{L1}^U}{2}$$

$$rV_{H1}^U = \delta_H + \eta(V_{H0}^U - V_{H1}^U)$$

$$rV_{L1}^U = \delta_L + \eta(V_{L0}^U - V_{L1}^U) + \lambda\mu_{H0}^I(1 - \beta^I)\left[V_{L0}^U - V_{L1}^U + V_{H1}^I - V_{H0}^I\right]$$

$$+ \lambda\mu_{L0}^I(1 - \beta^I)\left[V_{L0}^U - V_{L1}^U + V_{L1}^I - V_{L0}^I\right] + \lambda\mu_{H0}^U\frac{V_{H1}^U - V_{H0}^U + V_{L0}^U - V_{L1}^U}{2}$$

$$rV_{L0}^U = \eta(V_{L1}^U - V_{L0}^U)$$

Using the result from the stationary distribution and writing the system in terms of the values of holding an asset, we get:

$$rS_H^I = \delta_H - 2\eta S_H^I + \lambda\mu^U\beta^I(S_H^U - S_H^I) + \lambda\mu^I\frac{(S_L^I - S_H^I)}{2} + \lambda\mu^U\beta^I(S_L^U - S_H^I)$$

$$rS_L^I = \delta_L - 2\eta S_L^I + \lambda\mu^U\beta^I(S_L^U - S_L^I) + \lambda\mu^I\frac{(S_H^I - S_L^I)}{2} + \lambda\mu^U\beta^I(S_H^U - S_L^I)$$

$$rS_H^U = \delta_H - 2\eta S_H^U + \lambda\mu^I(1 - \beta^I)(S_L^I - S_H^U) + \lambda\frac{\phi - 2\mu^I}{2}(1 - \beta^I)(S_H^I - S_H^U) + \lambda\mu^U\frac{(S_L^U - S_H^U)}{2}$$

$$rS_L^U = \delta_L - 2\eta S_L^U + \lambda\mu^I(1 - \beta^I)(S_H^I - S_L^U) + \lambda\frac{\phi - 2\mu^I}{2}(1 - \beta^I)(S_L^I - S_L^U) + \lambda\mu^U\frac{(S_L^U - S_H^U)}{2}$$

Add up the first two and the last two to get:

$$(r + 2\eta)(S_H^I + S_L^I) = \delta_H + \delta_L + 2\lambda\mu^U\beta^I(S_H^U + S_L^U) - 2\lambda\mu^U\beta^I(S_H^I + S_L^I)$$

$$(r + 2\eta)(S_H^U + S_L^U) = \delta_H + \delta_L + \frac{\lambda\phi}{2}(1 - \beta^I)(S_H^I + S_L^I) - \frac{\lambda\phi}{2}(1 - \beta^I)(S_H^U + S_L^U)$$

These imply $(S_H^I + S_L^I) = (S_H^U + S_L^U) = \frac{\delta_H + \delta_L}{r + 2\eta}$. Now from the original system, subtract the second equation from the first and the fourth from the third to find:

$$(r + 2\eta)(S_H^I - S_L^I) = \delta_H - \delta_L - \lambda(2\mu^U\beta^I + \mu^I)(S_H^I - S_L^I)$$

$$(r + 2\eta)(S_H^U - S_L^U) = \delta_H - \delta_L - \lambda\frac{\phi}{2}(1 - \beta^I)(S_H^U - S_L^U) + \lambda\left(\frac{\phi}{2} - \mu^I\right)(1 - \beta^I)(S_H^I - S_L^I)$$

$$- \lambda\mu^U(S_H^U - S_L^U)$$

Rearrange these to get the following expressions:

$$(S_H^I - S_L^I) = \alpha^I(\delta_H - \delta_L)$$

$$(S_H^I - S_L^I) = \alpha^U(\delta_H - \delta_L)$$

$$\text{where } \alpha^I = \frac{1}{2(r + 2\eta + \lambda(2\mu^U\beta^I + \mu^I))}$$

$$\text{and } \alpha^U = \left[\frac{r + 2\eta + \lambda\beta^I(2\mu^U + \mu^I) + \lambda(1 - \beta^I)(\phi/2 - \mu^I)}{r + 2\eta + \lambda(\mu^U + \phi/2(1 - \beta^I))}\right]\alpha^I$$

Which finally implies:

$$S_H^i = \left[\frac{1}{2(r + 2\eta)}\right](\delta_H + \delta_L) + \frac{\alpha^i}{2}(\delta_H - \delta_L)$$

$$S_L^i = \left[\frac{1}{2(r + 2\eta)}\right](\delta_H + \delta_L) - \frac{\alpha^i}{2}(\delta_H - \delta_L)$$

*Punishing Stategy.* To conclude that an All-Trade Equilibrium exists, all that is left to show is that there exists a punishing strategy $\tau$ under which the conjectured $\beta$ satisfies (3).

For the trades for which $\mathcal{I}(i_s, v_s, i_b, v_b) = 0$, which have non-positive surplus, as found above, we can set any punishment level. For instance, let $\tau(i_s, v_s, i_b, v_b) = 0$ if $\mathcal{I}(i_s, v_s, i_b, v_b) = 0$.

Now define $D_{va}^i = V_{va}^i - \tilde{V}_{va}^i$. The other conditions which need to be satisfied by $\tau$ in order to support the conjectured $\beta$ are:

(36) $\quad \tau(I, L, I, H)D_{H1}^I = \frac{S_H^I + S_L^I}{2}; \quad \tau(U, L, I, L)D_{L1}^I = \beta^I S_L^U + (1 - \beta^I)S_L^I;$

$$\tau(U, L, I, H)D_{H1}^I = \beta^I S_L^U + (1 - \beta^I)S_H^I; \quad \tau(I, H, U, H)D_{H1}^U = \beta^I S_H^U + (1 - \beta^I)S_H^I;$$

$$\tau(I, L, U, H)D_{H1}^U = \beta^I S_H^U + (1 - \beta^I)S_L^I; \quad \tau(U, L, U, H)D_{H1}^U = \frac{S_H^U + S_L^U}{2}$$

First, I solve for the values $D_{H1}^I$, $D_{L1}^I$ and $D_{H1}^U$. The system defining $\{D_{va}^I\}$ is:

$$rD_{H1}^I = (\eta + \lambda\mu^U)(D_{H0}^I - D_{H1}^I)$$

$$rD_{L1}^I = (\eta + \lambda\mu^U)(D_{L0}^I - D_{L1}^I) + \lambda\mu^I \frac{S_H^I - S_L^I}{2}$$

$$rD_{L0}^I = (\eta + \lambda\mu^U)(D_{L1}^I - D_{L0}^I) - \lambda\mu^U \left(\beta^I S_L^U + (1 - \beta^I)S_L^I\right)$$

$$rD_{H0}^I = (\eta + \lambda\mu^U)(D_{H1}^I - D_{H0}^I) + \lambda\mu^I \frac{S_H^I - S_L^I}{2} - \lambda\mu^U \left(\beta^I S_H^I + (1 - \beta^I)S_L^U\right)$$

Combining the first with the fourth and the second with the third:

$$r(D^I_{H1} - D^I_{H0}) = -2(\eta + \lambda\mu^U)(D^I_{H1} - D^I_{H0}) - \lambda\mu^I \frac{S^I_H - S^I_L}{2} + \lambda\mu^U \left(\beta^I S^I_H + (1 - \beta^I)S^U_L\right)$$

$$r(D^I_{L1} - D^I_{L0}) = -2(\eta + \lambda\mu^U)(D^I_{L1} - D^I_{L0}) + \lambda\mu^I \frac{S^I_H - S^I_L}{2} + \lambda\mu^U \left(\beta^I S^U_L + (1 - \beta^I)S^I_L\right)$$

Solve to find:

$$(D^I_{H1} - D^I_{H0}) = -\frac{\lambda\mu^I}{(r + 2\eta + 2\lambda\mu^U)} \frac{S^I_H - S^I_L}{2} + \frac{\lambda\mu^U}{(r + 2\eta + 2\lambda\mu^U)} \left(\beta^I S^I_H + (1 - \beta^I)S^U_L\right)$$

$$(D^I_{L1} - D^I_{L0}) = \frac{\lambda\mu^I}{(r + 2\eta + 2\lambda\mu^U)} \frac{S^I_H - S^I_L}{2} + \frac{\lambda\mu^U}{(r + 2\eta + 2\lambda\mu^U)} \left(\beta^I S^U_L + (1 - \beta^I)S^I_L\right)$$

Plug this back into the original system to get:

$$(37) \quad D^I_{H1} = \frac{\eta + \lambda\mu^U}{r(r + 2\eta + 2\lambda\mu^U)} \left[\lambda\mu^I \frac{S^I_H - S^I_L}{2} - \lambda\mu^U \left(\beta^I S^I_H + (1 - \beta^I)S^U_L\right)\right]$$

$$(38) \quad D^I_{L1} = \frac{r + \eta + \lambda\mu^U}{r(r + 2\eta + 2\lambda\mu^U)} \lambda\mu^I \frac{S^I_H - S^I_L}{2} - \frac{\lambda\mu^U(\eta + \lambda\mu^U)}{r(r + 2\eta + 2\lambda\mu^U)} \left(\beta^I S^U_L + (1 - \beta^I)S^I_L\right)$$

The system defining $\left\{D^U_{va}\right\}$ is:

$$rD^U_{H1} = \eta(D^U_{H0} - D^U_{H1})$$

$$rD^U_{H0} = (\eta + \lambda\mu^U)(D^U_{H1} - D^U_{H0})$$
$$+ \lambda\mu^I(1 - \beta^I)(S^U_H - S^I_L) + \lambda(\phi/2 - \mu^I)(1 - \beta^I)(S^U_H - S^I_H) - \lambda\mu^U \frac{S^U_H + S^U_L}{2}$$

$$rD^U_{L1} = (\eta + \lambda\mu^U)(D^U_{L0} - D^U_{L1}) + \lambda\mu^I(1 - \beta^I)(S^I_H - S^U_L) + \lambda(\phi/2 - \mu^I)(1 - \beta^I)(S^I_L - S^U_L)$$

$$rD^U_{L0} = \eta(D^U_{L1} - D^U_{L0})$$

Subtract the second from the first to get:

$$r(D_{H1}^U - D_{H0}^U) = -(2\eta + \lambda\mu^U)(D_{H1}^U - D_{H0}^U) - \lambda\mu^I(1-\beta^I)(S_H^U - S_L^I)$$

$$- \lambda(\phi/2 - \mu^I)(1-\beta^I)(S_H^U - S_H^I) + \lambda\mu^U\frac{S_H^U + S_L^U}{2}$$

$$\Rightarrow (D_{H1}^U - D_{H0}^U) = -\frac{\lambda\mu^I}{r + 2\eta + \lambda\mu^U}(1-\beta^I)(S_H^U - S_L^I)$$

$$- \frac{\lambda(\phi/2 - \mu^I)}{r + 2\eta + \lambda\mu^U}(1-\beta^I)(S_H^U - S_H^I) + \frac{\lambda\mu^u}{r + 2\eta + \lambda\mu^U}\frac{S_H^U + S_L^U}{2}$$

Finally substitute this back into the original system to get:

$$(39) \qquad D_{H1}^U = \frac{\eta\lambda\mu^I(1-\beta^I)}{r(r + 2\eta + \lambda\mu^U)}(S_H^U - S_L^I) + \frac{\eta\lambda(\phi/2 - \mu^I)(1-\beta^I)}{r(r + 2\eta + \lambda\mu^U)}(S_H^U - S_H^I)$$

$$- \frac{\eta\lambda\mu^U}{r(r + 2\eta + \lambda\mu^U)}\frac{S_H^U + S_L^U}{2}$$

With these expressions in hand, we can check whether the following inequalities are satisfied:

$$D_{H1}^I(0) \geqslant \max\left\{\frac{S_H^I + S_L^I}{2}, \beta^I S_L^U + (1-\beta^I)S_H^I\right\},$$

$$D_{L1}^I(0) \geqslant \beta^I S_L^U + (1-\beta^I)S_L^I,$$

$$\text{and } D_{H1}^U(0) \geqslant \max\left\{\beta^I S_H^U + (1-\beta^I)S_H^I, \beta^I S_H^U + (1-\beta^I)S_L^I, \frac{S_H^U + S_L^U}{2}\right\}$$

It is easy to check, that these conditions hold as $\phi \to 1$ (i.e., $\mu^I > 0$, $\mu^U \to 0$) and $r \to 0$: When $\phi$ is large, the left-hand side of all three inequalities is positive; and when $r$ is small, the left-hand side grows unboundedly, while the right-hand side is bounded.

Under these parameter conditions, I can conclude that there exist $\tau(I, L, I, H)$, $\tau(U, L, I, L)$, $\tau(U, L, I, H)$, $\tau(I, H, U, H)$, $\tau(I, L, U, H)$ and $\tau(I, L, I, H)$ such that (36) are satisfied, as desired.

Moreover, notice that, for each $\phi \in (0, 1)$, there is some $\bar{\beta}$ such that, if $\beta^I > \bar{\beta}$, then $D_{H1}^U$ (given in (39)) is negative, and so $D_{H1}^U(0) < \max\left\{\beta^I S_H^U + (1-\beta^I)S_H^I, \beta^I S_H^U + (1-\beta^I)S_L^I, \frac{S_H^U + S_L^U}{2}\right\}$. In that case, there is no $\tau$ that can support the equilibrium conjecture. This proves the second part of the Proposition. Namely, that there exists some $\bar{\beta}$ such that, if $\beta^I > \bar{\beta}$, an All-Trade Equilibrium does not exist. ∎

## 8.2. **Proof of Proposition 2 (Core-Periphery Equilibria).** Once again, we build this equilibrium with a big guess and verify. The steps to solving for the equilibrium objects which I report here, are similar to the ones in All-Trade Equilibria. They can be found in the Online Appendix.

*Guesses.*

Surplus sharing:

$$\beta(I, v_s, U, v_b) = \beta^I \geqslant \frac{1}{2} \qquad \beta(U, v_s, I, v_b) = 1 - \beta^I \leqslant \frac{1}{2}$$

$$\beta(I, v_s, I, v_b) = \frac{1}{2}$$

Efficient trading iff an informed agent is involved:

$$\mathcal{I}(i_s, v_s, i_b, v_b) = 1 \Leftrightarrow (i_s, i_b) \neq (U, U) \text{ and } V_{v_s 0}^{i_s} - V_{v_s 1}^{i_s} + V_{v_b 1}^{i_b} - V_{v_b 0}^{i_b} > 0.$$

*Stationary Distribution.*

$$\mu_{L1}^U = \mu_{H0}^U = \hat{\mu}^U = \frac{1-\phi}{4+\frac{\lambda}{\eta}} \qquad \mu_{H0}^I = \mu_{L1}^I = \hat{\mu}^I = -\frac{\eta + \lambda \hat{\mu}^U}{\lambda} + \sqrt{\left(\frac{\eta + \lambda \hat{\mu}^U}{\lambda}\right)^2 + \frac{\phi}{2} \frac{\eta + \lambda \hat{\mu}^U}{\lambda}}$$

*Unflagged Values.*

$$S_H^i = \left[\frac{1}{2(r+2\eta)}\right](\delta_H + \delta_L) + \frac{\alpha^i}{2}(\delta_H - \delta_L) \qquad S_L^i = \left[\frac{1}{2(r+2\eta)}\right](\delta_H + \delta_L) - \frac{\alpha^i}{2}(\delta_H - \delta_L)$$

where $\hat{\alpha}^I = \frac{1}{2(r+2\eta+\lambda(2\hat{\mu}^U \beta^I + \hat{\mu}^I))}$ and $\hat{\alpha}^U = \left[\frac{r+2\eta+\lambda\hat{\mu}^U+\frac{\lambda\phi}{4}}{r+2\eta+\frac{\lambda\phi}{4}}\right]\hat{\alpha}^I$.

This confirms that the conjectured $\mathcal{I}$ and $\beta$ indeed satisfy (4) and (5).

*Punishing Stategy.* To support the Core-Periphery Equilibrium, I need to find a $\tau$ that supports the conjectures. Once again, for the trades for which $\mathcal{I}(i_s, v_s, i_b, v_b) = 0$, this is trivial, and we can set $\tau(i_s, v_s, i_b, v_b) = 0$ when $\mathcal{I}(i_s, v_s, i_b, v_b) = 0$. For all other trades, we need $\tau$ to satisfy:

(40) $\tau(I, L, I, H)D_{H1}^I = \frac{S_H^I + S_L^I}{2}; \quad \tau(U, L, I, L)D_{L1}^I = \beta^I S_L^U + (1 - \beta^I)S_L^I;$

$\tau(U, L, I, H)D_{H1}^I = \beta^I S_L^U + (1 - \beta^I)S_H^I; \quad \tau(I, H, U, H)D_{H1}^U = \beta^I S_H^U + (1 - \beta^I)S_H^I;$

$\tau(I, L, U, H)D_{H1}^U = \beta^I S_H^U + (1 - \beta^I)S_L^I;$

We can use the same steps as in the Proof of Proposition 1 to find:

$$D_{H1}^I = \frac{\eta + \lambda\hat{\mu}^U}{r(r + 2\eta + 2\lambda\hat{\mu}^U)}\left[\lambda\hat{\mu}^I\frac{S_H^I - S_L^I}{2} - \lambda\hat{\mu}^U\left((1 - \beta^I)S_H^I + \beta^I S_L^U\right)\right]$$

$$D_{L1}^I = \frac{r + \eta + \lambda\hat{\mu}^U}{r(r + 2\eta + 2\lambda\hat{\mu}^U)}\lambda\hat{\mu}^I\frac{S_H^I - S_L^I}{2} - \frac{\eta + \lambda\hat{\mu}^U}{r(r + 2\eta + 2\lambda\hat{\mu}^U)}\lambda\hat{\mu}^U\left((1 - \beta^I)S_L^U + \beta^I S_L^I\right)$$

$$D_{H1}^U = \frac{\eta\lambda\hat{\mu}^I}{r(r + 2\eta)}(1 - \beta^I)(S_H^U - S_L^I) + \frac{\eta\lambda(\phi/2 - \hat{\mu}^I)}{r(r + 2\eta)}(1 - \beta^I)(S_H^U - S_H^I)$$

With these expressions in hand, we can check whether the following inequalities are satisfied:

$$D_{H1}^I(0) \geqslant \max\left\{\frac{S_H^I + S_L^I}{2}, \beta^I S_L^U + (1 - \beta^I)S_H^I\right\},$$

$$D_{L1}^I(0) \geqslant \beta^I S_L^U + (1 - \beta^I)S_L^I,$$

$$\text{and } D_{H1}^U(0) \geqslant \max\left\{\beta^I S_H^U + (1 - \beta^I)S_H^I, \beta^I S_H^U + (1 - \beta^I)S_L^I\right\}$$

It is easy to check, that these conditions hold as $\phi \to 1$ (i.e., $\mu^I > 0$, $\mu^U \to 0$) and $r \to 0$: When $\phi$ is large, the left-hand side of all three inequalities is positive; and when $r$ is small, the left-hand side grows unboundedly, while the right-hand side is bounded.

Under these parameter conditions, I can conclude that there exist $\tau(I, L, I, H)$, $\tau(U, L, I, L)$, $\tau(U, L, I, H)$, $\tau(I, H, U, H)$, $\tau(I, L, U, H)$ and $\tau(I, L, I, H)$ such that (40) are satisfied.

Moreover, notice that, for each $\phi \in (0, 1)$, there is some $\bar{\beta}$ such that, if $\beta^I > \bar{\beta}$, then $D_{H1}^U(0) < \max\left\{\beta^I S_H^U + (1 - \beta^I)S_H^I, \beta^I S_H^U + (1 - \beta^I)S_L^I\right\}$. In that case, there is no $\tau$ that can support the equilibrium conjecture. This proves the second part of the Proposition. Namely, that there exists some $\bar{\beta}$ such that, if $\beta^I > \bar{\beta}$, a Core-Periphery Equilibrium does not exist.

*Showing that there are more misaligned agents than in the symmetric equilibrium.*

In All-Trade Equilibria, the inflow-outflow equations can be written as:

$$\mu^U(\eta + \lambda(\mu^U + \phi/2)) = \left(\frac{1 - \phi}{2} - \mu^U\right)\eta$$

$$\mu^I(\eta + \lambda(\mu^U + \mu^I)) = \left(\frac{\phi}{2} - \mu^I\right)\eta$$

(41)
$$\Rightarrow \lambda(\mu^U + \mu^I)^2 + 2\eta(\mu^U + \mu^I) = \eta/2$$

In Core-Periphery Equilibria, the inflow-outflow equations can be written as:

$$\hat{\mu}^U(\eta + \lambda\phi/2) = \left(\frac{1-\phi}{2} - \hat{\mu}^U\right)\eta$$

$$\hat{\mu}^I(\eta + \lambda(\hat{\mu}^U + \hat{\mu}^I)) = \left(\frac{\phi}{2} - \hat{\mu}^I\right)(\eta + \lambda\hat{\mu}^U)$$

(42)
$$\Rightarrow \lambda(\hat{\mu}^U + \hat{\mu}^I)^2 + 2\eta(\hat{\mu}^U + \hat{\mu}^I) = \eta/2 + \lambda(\hat{\mu}^U)^2$$

To satisfy (41) and (42), it must be that $\hat{\mu}^U + \hat{\mu}^I > \mu^U + \mu^I$. ∎

8.3. **Proof of Proposition 3.** Suppose an equilibrium exists where uninformed agents act as intermediaries. In such equilibrium, it must hold that $S_H^I \geqslant S_H^U > S_L^U \geqslant S_L^I$. If these inequalities are not strict, then agents are indifferent between engaging in intermediation trades or not. In that case, there is another equilibrium where no intermediation trades take place and $V^I$ and $V^U$ stay the same, which confirms the statement in the proposition.

Now suppose instead that the inequalities are strict: $S_H^I > S_H^U > S_L^U > S_L^I$ This ordering implies that, in that equilibrium, there is no intermediation by informed agents. The values to informed agents with aligned portfolios then are given by:

$$V_{L0}^I = \frac{\eta S_L^I}{r}$$

$$V_{H1}^I = \frac{\delta_H - \eta S_H^I}{r}$$

While the values to uninformed agents with aligned portfolios are given by:

$$V_{L0}^U = \frac{\eta S_L^U + \lambda \mu_{L1}^I (1 - \beta(I, L, U, L))(S_L^U - S_L^I)}{r} \geqslant \frac{\eta S_L^U}{r}$$

$$V_{H1}^U = \frac{\delta_H - \eta S_H^U + \lambda \mu_{H0}^I \beta(U, H, I, H)(S_H^I - S_H^U)}{r} \geqslant \frac{\delta_H - \eta S_H^U}{r}$$

Rewriting (25) and (26):

$$V^I = \frac{1}{2}(V_{H1}^I + V_{L0}^I) - \frac{1}{2}S_H^I = \frac{\delta_H}{2r} - \frac{\eta}{2r}(S_H^I - S_L^I) - \frac{1}{2}S_H^I$$

$$V^U = \frac{1}{2}(V_{H1}^U + V_{L0}^U) - \frac{1}{2}S_H^U \geqslant \frac{\delta_H}{2r} - \frac{\eta}{2r}(S_H^U - S_L^U) - \frac{1}{2}S_H^U$$

Since $S_H^I \geqslant S_H^U$ and $S_L^U \geqslant S_L^I$, then it must be that $V^U \geqslant V^I$.

Therefore, we can construct a new equilibrium, which mirrors the equilibrium we started out with, by flipping the labels $U$ and $I$. This new equilibrium yields a higher value to informed

agents, equal to the value to uninformed agents in the original equilibrium. Moreover, in the new equilibrium, there is no intermediation by uninformed agents. ∎

8.4. **Proof of Proposition 4.** I proceed in three steps.

**Step 1.** Let $\mu^I$ and $\mu^U$ be the measures of misaligned agents in the All-Trade Equilibria, and $\hat{\mu}^I$ and $\hat{\mu}^U$ the measures of misaligned agents in the Core-Periphery Equilibria.

In the Proof of Proposition 2, I show that $\mu^I + \mu^U < \hat{\mu}^I + \hat{\mu}^U$ (fact i.).

Similarly manipulating the inflow-outflow equations, we can also establish two more facts: ii. $\mu^U < \hat{\mu}^U$; and iii. $\mu^I/\mu^U > \hat{\mu}^I/\hat{\mu}^U$.

**Step 2.** Take $\alpha^I$ and $\alpha^U$ as given by (18) and (19) in the All-Trade Equilibria, and $\hat{\alpha}^I$ and $\hat{\alpha}^U$ as given by (23) and (24) in the Core-Periphery Equilibria.

Then facts i. and ii. in Step 1 imply $\alpha^I > \hat{\alpha}^I$.

Moreover, we can show that $\mu^U(\alpha^U - \alpha^I) < \hat{\mu}^U(\hat{\alpha}^U - \hat{\alpha}^I)$. To show this, we can first write:

$$(43) \qquad \mu^U(\alpha^U - \alpha^I) = \frac{\lambda(2\beta^I - 1)(\mu^U + \mu^I)}{r + 2\eta + \lambda(\mu^U + \phi/2(1 - \beta^I))} \; \frac{\mu^U}{r + 2\eta + \lambda(2\mu^U \beta^I + \mu^I)}$$

$$(44) \qquad \hat{\mu}^U(\hat{\alpha}^U - \hat{\alpha}^I) = \frac{\lambda(2\beta^I - 1)(\hat{\mu}^U + \hat{\mu}^I) + \lambda\hat{\mu}^U}{r + 2\eta + \lambda\phi/2(1 - \beta^I)} \; \frac{\hat{\mu}^U}{r + 2\eta + \lambda(2\hat{\mu}^U \beta^I + \hat{\mu}^I)}$$

Facts i. and ii. in Step 1 imply that the first term in the right-hand side of (44) is larger than the first term in the right-hand side of (43). And facts ii. and iii. imply that the second term in the right-hand side of (44) is larger than the second term in the right-hand side of (43).

**Step 3.** Using the trading pattern in All-Trade Equilibria, we can rewrite (25) as:

$$(45) \qquad \begin{aligned} V^I &= \frac{1}{2}(V_{H1}^I + V_{L0}^I) - \frac{1}{2}S_H^I \\ &= \frac{\delta_H}{2r} - \frac{\eta}{2r}(S_H^I - S_L^I) - \frac{1}{2}S_H^I + \frac{\lambda\mu^U\beta^I}{2r}\left[(S_H^U - S_H^I) + (S_L^I - S_L^U)\right] \\ &= \frac{\delta_H}{2r} - \frac{\eta}{2r}\alpha^I(\delta_H - \delta_L) - \frac{1}{2}\left[\frac{1}{2(r + 2\eta)}(\delta_H + \delta_L) + \alpha^I(\delta_H - \delta_L)\right] \\ &\quad + \frac{\lambda\beta^I}{r}\mu^U(\alpha^U - \alpha^I)(\delta_H - \delta_L) \end{aligned}$$

Likewise for Core-Periphery Equilibria, we write (25) as:

$$(46) \qquad V^I = \frac{1}{2}(V_{H1}^I + V_{L0}^I) - \frac{1}{2}S_H^I$$

$$= \frac{\delta_H}{2r} - \frac{\eta}{2r}(S_H^I - S_L^I) - \frac{1}{2}S_H^I + \frac{\lambda\hat{\mu}^U\beta^I}{2r}\left[(S_H^U - S_H^I) + (S_L^I - S_L^U)\right]$$

$$= \frac{\delta_H}{2r} - \frac{\eta}{2r}\hat{\alpha}^I(\delta_H - \delta_L) - \frac{1}{2}\left[\frac{1}{2(r+2\eta)}(\delta_H + \delta_L) + \hat{\alpha}^I(\delta_H - \delta_L)\right]$$

$$+ \frac{\lambda\beta^I}{r}\hat{\mu}^U(\hat{\alpha}^U - \hat{\alpha}^I)(\delta_H - \delta_L)$$

Using these expressions and the inequalities found in Steps 1 and 2, we can straightforwardly check that the Proposition holds. ■

8.5. **Proof of Proposition 5.** It is immediate to see that $\alpha^I$ and $\hat{\alpha}^I$ are decreasing in $\beta^I$.

Now rewrite (43) as:

$$\alpha^U - \alpha^I = \frac{\lambda(\mu^U + \mu^I)}{r + 2\eta + \lambda(\mu^U + \phi/2(1 - \beta^I))} \frac{(2\beta^I - 1)}{(r + 2\eta + \lambda(2\mu^U\beta^I + \mu^I))}$$

The first term in the right-hand side is increasing in $\beta^I$. The second term is increasing in $\beta^I$ as well, since $\beta^I/(2\beta^I - 1)$ is decreasing in $\beta^I$.

Thus, $(\alpha^U - \alpha^I)$ is increasing in $\beta^I$. We can similarly check that $(\hat{\alpha}^U - \hat{\alpha}^I)$ is increasing in $\beta^I$ as well.

Now use this and (45) and (46) to verify that the Proposition holds. ■