Cream skimming in financial markets[*]

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June 20, 2014

Abstract

We propose a model where investors can choose to acquire costly information that allows them to identify good assets and purchase them in opaque over the counter (OTC) markets. Uninformed investors trade on an organized exchange and only have access to an asset pool that has been (partially) cream-skimmed by informed dealers. We show that when the quality composition of assets for sale is fixed there is always too much information acquisition and cream skimming by dealers in equilibrium. In the presence of moral hazard in origination, we show that the social value of information acquisition and trading by dealers varies inversely with private incentives to acquire information: just when it is socially optimal to limit costly investment in information by dealers, investors' private incentives to acquire information are at their highest, and vice-versa. Thus, equilibrium entry by informed dealers in OTC markets is generically inefficient.

What does the financial industry add to the real economy? What is the optimal organization of financial markets, and how much talent is required in the financial industry? We revisit these fundamental questions in light of recent events and criticisms of the financial industry. The core issues underlying these questions is whether and how the financial industry extracts excessively *high rents* from the provision of financial services, and whether these rents attract too much talent.[1] Figure V Panel B of Philippon and Resheff (2012) plots the evolution of US wages (relative to average non-farm wages) for three subsegments of the finance services industry: credit, insurance and 'other finance.' Credit refers to banks, savings and loans and other similar institutions, insurance to life and P & C, and 'other finance' refers to the financial investment industry and investment banks. As the plot shows the bulk of the growth in remuneration in the financial industry took place in 'other finance.'

In this paper we attempt to explain the outsize remuneration in this latter sector by modeling a financial industry that is composed of two sectors: an organized, regulated, standardized, and transparent market where most retail ('*plain vanilla*') transactions take place, and an informal, *opaque* sector, where *informed* transactions take place and '*bespoke*' services are offered to clients. We refer to the transparent, standardized, markets as organized exchanges and call the opaque sector the over-the-counter (OTC) sector even though in practice not all OTC markets are opaque (e.g. markets for foreign exchange are quite transparent). The important distinction for the present paper is between opaque and transparent markets for assets with heterogenous values. A central idea in our analysis is that while OTC markets may provide valuation services to issuers of assets, their opacity also allows informed dealers to extract informational rents. What is more, OTC markets cannibalize organized exchanges by "*cream-skimming*" the juiciest deals away from them.[2] The informational rents in OTC markets in turn attract talent to the financial industry, which

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[1]Goldin and Katz (2008) document that the percentage of male Harvard graduates with positions in Finance 15 years after graduation tripled from the 1970 to the 1990 cohort, largely at the expense of occupations in law and medicine.

[2]Rothschild and Stiglitz (1976) considered a different form of cream skimming in insurance markets with adverse

may be more efficiently deployed elsewhere.

The key role of the financial sector in our model is to provide liquidity by allowing asset originators to sell their assets to investors. An additional role of the financial sector is a valuation role of assets for sale, when assets vary in quality. However, we show that unless more accurate valuations serve the role of providing better origination incentives, there is no social benefit from the valuation services provided by informed investors. Any costly information acquisition by investors then only serves the purpose of cream-skimming the best assets, which has private value for the informed investors but no social value. This result is a particular illustration of a more general observation first made by Hirschleifer (1971) about the private value of *foreknowledge information*, which in his formulation only involves "the value of *priority* in time of superior knowledge". Using simpler and more concrete language Stiglitz (1989) later described this general observation as follows in his discussion of the costs and benefits of a financial transaction tax:

> "Assume that as a result of some new information, there will be a large revaluation of some security, say from $10 to $50. Assume that that information will be announced tomorrow in the newspaper.....The information has only affected who gets to get the return. It does not affect the magnitude of the return. To use the textbook homily, it affects how the pie is divided, but it does not affect the size of the pie." [Stiglitz, 1989 pp 103]

Of course, by identifying the most valuable assets and by offering more attractive terms for those assets, informed dealers in the OTC market also serve the role of providing incentives to originators. However, we show that even when costly information acquisition provides better origination incentives, equilibrium entry by informed dealers into the OTC market is generically inefficient. The equilibrium size of dealer markets is too small when the marginal cost of originat-

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selection. In that setting, insurers are uninformed about risk types, but offer contracts that induce informed agents to self-select into insurance contracts. For an application of the Rothschild-Stiglitz framework to competition among organized exchanges see Santos and Scheinkman (2001).

ing good assets is small and too large when it is high. This is somewhat counterintuitive: when the price-elasticity of origination effort is high there is a large "bang for the buck" in increasing the size of the informed dealer market. But equilibrium incentives to enter the dealer market when a high fraction of good assets is originated are small because the surplus that informed dealers can cream-skim is then relatively small. In contrast, when the price-elasticity of origination effort is low there is little "bang for the buck" in increasing the size of the dealer market. But when the fraction of good originated assets is small, private incentives to enter the dealer market are large, for then the benefits from cream-skimming are large.

In our model OTC dealers' rents *increase* as more informed dealers enter the dealer market, because collectively dealers are able to extract larger cream-skimming rents. The reason is that more dealers cream-skimming good assets worsens the terms originators can get for their assets on the organized exchange, and therefore their bargaining power on OTC markets. This central mechanism in our model allows us to reconcile the fact that compensation in some financial sectors continued to grow even while significant new entry into these sectors took place. Our assumption that trading in OTC markets is opaque contrasts with the standard framework of trading in financial markets first developed by Grossman and Stiglitz (1980). In that class of models, privately produced information leaks out in the process of trading, and as a result *too little* costly information may be produced by 'insiders.' Since many activities in the financial industry boil down to costly private 'information acquisition', the Grossman-Stiglitz model seems better suited to explain that the financial sector could be too small. In contrast, our model helps explain how excessive rent extraction together with excessive entry into the financial industry can be an *equilibrium outcome*.

To simplify the presentation and to highlight the main economic mechanism at work we mainly focus on the situation where information can only be used in opaque OTC markets. In an extension, however, we allow for informed trading on the exchange in the presence of noise traders–as in Grossman and Stiglitz (1980)–and establish that there is then always excessive trading in OTC markets, where informed dealers can capture larger information rents.

Our paper offers a novel hypothesis to explain three related facts about the recent evolution

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of the US financial services industry, as shown by Philippon and Resheff (2012) and Philippon (2011, 2012). First, the financial services industry accounts for an increasing share of GDP even after financial services exports are excluded - an increase that accelerated starting in the mid 80s. Second, this growth has been accompanied by a substantial increase in IT spending in the financial sector. As Philippon (2012, Figures 5 and 6) shows, other sectors, such as retail, have increased the fraction of spending on IT as well, but in retail there is a *negative* time-series correlation between GDP shares and IT investments. Finally, as already mentioned, there has been a substantial increase in compensation in brokerage and asset management, the segment of finance that is most closely associated with OTC transactions. Our model suggests that developments in IT are partly responsible for these trends. As IT became cheaper, OTC activities which are information intensive became more profitable relative to exchange traded activities. The additional increase in OTC dealers' rents that resulted from the entry of more dealers, provided a reinforcement mechanism for the growth of compensation in OTC activities and prevented the dissipation of the rents from cheaper IT that was observed in retail. Others have argued that regulatory developments are behind the growth of the OTC sector. Regulatory developments, however, would also be subject to the same reinforcement mechanisms that we argue prevented the dissipation of rents from IT.

The paper is organized as follows: Section 1 outlines the model. Section 2 analyzes the pure information acquisition problem where uninformed rentier investors can become informed dealers at a cost. We show that in this situation there is always too much entry into the informed dealer market. In section 3 we introduce moral hazard in orgination and show that the equilibrium entry of rentiers into the dealer market is generically inefficient. Section 4 considers entry into the dealer market by originators and shows that there is then a double inefficiency in terms of excessive costly information acquisition and too little origination of assets. Section 5 considers two extensions: one where there is greater competition between dealers for good assets and the other where informed trading can take place both in OTC markets and on the exchange. Section 6 concludes. All proofs are in the Appendix.

Related Literature. In his survey of the literature on financial development and growth, Levine (2005) synthesizes existing theories of the role of the financial industry into five broad functions: 1) information production about investment opportunities and allocation of capital; 2) mobilization and pooling of household savings; 3) monitoring of investments and performance; 4) financing of trade and consumption; 5) provision of liquidity, facilitation of secondary market trading, diversification, and risk management. As he highlights, most of the models of the financial industry focus on the first three functions, and if anything, conclude that from a social efficiency standpoint the financial sector is too small: due to asymmetries of information, and incentive or contract enforceability constraints, there is underinvestment in equilibrium and *financial underdevelopment*.

In contrast to this literature, our model emphasizes the fifth function in Levine's list: secondary market trading and liquidity provision. In addition, where the finance and growth literature only distinguishes between bank-based and market-based systems (e.g. Allen and Gale, 2000), a key distinction in our model is between markets in which trading occurs on a bilateral basis at prices and conditions that are not observable by other participants, and organized exchanges with multilateral trading at prices observed by all.[3]

Our paper contributes to a small literature on the optimal allocation of talent to the financial industry. An early theory by Murphy, Shleifer and Vishny (1991) (see also Baumol, 1990) builds on the idea of increasing returns to ability and rent seeking in a two-sector model to show that there may be inefficient equilibrium occupational outcomes, where too much talent enters one market since the marginal private returns from talent could exceed the social returns. More recently, Philippon (2008) has proposed an occupational choice model where agents can choose to become workers, financiers or originators. The latter originate assets which have a higher social than private value, and need to obtain funding from financiers. In general, as social and private returns

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[3]The literature comparing bank-based and market-based financial systems argues that bank-based systems can offer superior forms of risk sharing, but that they are undermined by competition from securities markets (see Jacklin, 1987, Diamond, 1997, and Fecht, 2004). This literature does not explore the issue of misallocation of talent to the financial sector, whether bank-based or market-based.

from investment diverge it is optimal in his model to subsidize entrepreneurship. Biais, Rochet and Woolley (2010) propose a model of innovation with learning about risk and moral hazard, which can account for the simultaneous growth in the size of the financial industry and remuneration in the form of rents to forestall moral hazard. Neither Murphy et al. (1991), Biais et al. (2010), or Philippon (2008) distinguish between organized exchanges and OTC markets in the financial sector, nor do they allow for excessive informational rent extraction through cream-skimming.

More recently, three independent studies have analyzed problems with some common features to ours: First, Glode, Green and Lowery (2012) also model the idea of excessive investment in information as a way of strengthening a party's bargaining power. However, Glode et al. (2010) do not consider the occupational choice question of whether too much young talent is attracted towards the financial industry. Second, Fishman and Parker (2012) also consider a model in which informed buyers can extract information rents. Their model generates multiple Pareto ranked equilibria with different levels of information acquisition. As in our framework, they find that too much information may be produced in equilibrium. They also show that information acquisition can give rise to what they refer to as valuation runs, where sellers of assets that cannot be valued are unable to find buyers. Third, Biais, Foucault and Moinas (2013) analyze a model where high-frequency traders can gain a valuation advantage over other traders. They show that investment in speed by some traders (co-location, faster computers, microwave transmission, etc.) can give rise to equilibrium inefficiencies, if most of the benefits of added speed are in the form of cream-skimming from slower to faster traders.

Finally, our paper relates to the small but burgeoning literature on OTC markets, which, to a large extent, has focused on the issue of financial intermediation in the context of search models.[4] These papers have some common elements to ours, in particular the emphasis on bilateral bargaining in OTC markets, but their focus is on the liquidity of these markets and they do not address issues of cream-skimming or occupational choice.

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[4]See Duffie, Garleanu and Pedersen (2005), Vayanos and Wang (2007), Vayanos and Weill (2008), Lagos and Rocheteau (2009), Lagos, Rocheteau and Weill (2010) and Afonso (2010).

1 The model

We consider a three periods ($t = 0, 1, 2$) competitive economy divided into two sectors: a productive and a financial sector.

1.1 Agents

There are three types of risk-neutral agents in this economy. Type 1 agents with unit mass are *uninformed rentiers* who start out in period 0 with a large storable endowment ω, which they may consume in either period 1 or 2. Their preferences are represented by the utility function:

$$u\left(c_1, c_2\right) = c_1 + c_2. \tag{1}$$

The second type of agents is *originators* of assets, who also have unit mass. These can be thought of as either company founders who sell their business or as bankers who originate loans. Each originator has not only a storable endowment ω but also access to a productive asset that yields either $\rho \geq 1$ or $\gamma\rho$ in period 2, with $\gamma > 1$. The probability that the asset yields $\gamma\rho$ is $a \in (0, 1)$. In the baseline model we take a to be exogenously given, and in a later generalization we allow originators to exert costly effort to increase a. The realization of asset returns is independent across originators. Moreover, originators only learn the quality of her asset at time $t = 2$. Originators are subject to liquidity shocks at time $t = 1$, which compel them to sell their asset before they are able to learn the realization of the asset's return. Specifically, an originator's utility functions is given by:

$$U\left(c_1, c_2\right) = \delta c_1 + (1 - \delta)c_2, \tag{2}$$

where $\delta \in \{0, 1\}$ is an indicator variable, and prob $(\delta = 1) = \pi_o$.

The third type of agents in the economy is *dealers*, with endogenous measure μ. Each dealer also has a storable endowment ω at time 0. Dealers are able to perfectly identify date-2 asset returns at $t = 1$ and stand ready to acquire assets from originators subject to liquidity shocks. For

simplicity, we allow each dealer to acquire at most one asset at $t = 1$. We also let dealers be subject to liquidity shocks to preserve the symmetry of the model, so that their utility function is given by:

$$U(c_1, c_2) = \delta c_1 + (1 - \delta)c_2, \tag{3}$$

where $\delta \in \{0, 1\}$ is an indicator variable, and prob $(\delta = 1) = \pi_d$. We assume that liquidity shocks of originators and dealers are all independent. We shall refer to originators or dealers who are not subject to a liquidity shock as *patient*, and those who are subject to a liquidity shock as *impatient*. Thus, at $t = 1$ *impatient originators* can sell their asset to either *patient dealers* or to rentiers, who are indifferent to when they consume.

1.2 Financial Markets

A novel feature of our model is the *dual structure* of the financial system: Assets can be traded in either an *over-the-counter* (OTC) dealer market or on an organized exchange. Dealers operate in the OTC market, so that information about asset values resides in this market. On the organized exchange, on the other hand, all asset trades are uninformed trades between rentiers and originators.

In period 1 an originator has three options: i) she can sell her asset for the competitive equilibrium price p on the organized exchange; ii) she can go to a dealer in the OTC market and negotiate a sale for a price p^d, or iii) she can hold on to her asset. An impatient originator always chooses options i) or ii), while patient originators will always prefer to hold their asset to maturity.

We assume that each dealer can acquire at most one unit of the asset. Since there are $(1 - \pi_d)$ dealers with liquidity, if each dealer finds it profitable to purchase an asset, the total number of assets sold in the OTC market equals $\mu(1 - \pi_d)$.

We begin our analysis by first taking the price p as given and derive equilibrium trade and price p^d in the OTC market given p. When a asset is identified by a dealer as worth $\gamma\rho$ then the gains from trading this asset over the counter are $(\gamma\rho - p)$. We take the price p^d at which this sale is negotiated between a dealer and an originator as the outcome of bilateral bargaining.[5]

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[5]We do not assume an explicit matching protocol. One possibility is that dealers inspect all projects, then dealers

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An originator receiving an offer from a dealer thereby learns that she has a good asset, so that bargaining is effectively under symmetric information. We therefore can take the solution to this bargaining game to be the *Asymmetric Nash Bargaining Solution* where the dealer has a given bargaining power $(1 - \kappa)$ and the originator has bargaining power $\kappa \in (0, 1)$ (see Nash, 1950, 1953).[6] The price p^d is then given by:

$$p^d = \arg \max_{s \in [p, \gamma \rho]} \{ (s - p)^\kappa (\gamma \rho - s)^{(1-\kappa)} \} \qquad \Rightarrow \qquad p^d = \kappa \gamma \rho + (1 - \kappa)p.$$

A justification for the Nash bargaining solution based on the sequential strategic approach to bargaining can be found in Binmore, Rubinstein and Wolinsky, 1986 (BRW). They show that the asymmetric Nash bargaining solution can be justified as an equilibrium outcome of a strategic model of bargaining with uncertain termination time. The threat point is given by the outcome the players may obtain in the event that the bargaining process does break down. Thus our assumptions is that, if the process breaks down the dealer would simply consume his endowment and the impatient originator would sell her asset in the exchange. In BRW, the parameter κ reflects the relative subjective probabilities that each party attributes to the breakdown of the bargaining process. In particular, in the sequential strategic justification for asymmetric Nash bargaining solution developed by BRW, the number of dealers relative to originators doe not affect κ unless it affects the subjective probabilities of breakdown held by dealers or originators.

As long as $\kappa < 1$ a patient originator receiving an offer p^d is better off rejecting the offer and holding onto the asset until period 2 given that an offer p^d perfectly reveals to the originator that the asset is worth $\gamma \rho$. We can therefore assume without loss of generality that patient originators do not trade in the OTC market at date 1.

We also assume that the measure of uninformed rentiers, which we normalize to 1, is large enough to be able to absorb all asset sales in period 1, so that the equilibrium price of assets sold

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are put in a line and pick only one project, then dealers bargain with the entrepreneur. For a similar protocol in a job-search context see Board and Meyer-ter-Vehn (2011)

[6]For a similar approach to modeling negotiations in OTC markets between dealers and clients see Lagos, Rocheteau, and Weill (2010).

on the exchange is equal to their expected payoff.

Since $p^d < \gamma\rho$ dealers will acquire $\min\{\mu(1-\pi_d), a\pi_o\}$ good assets. The remaining good assets, if any, held by impatient originators will necessarily flow to the competitive exchange. Thus, the expected value of an asset, and therefore the competitive price p on the exchange equals:

$$\frac{a\pi_o - \min\{\mu(1-\pi_d), a\pi_o\}}{\pi_o - \min\{\mu(1-\pi_d), a\pi_o\}}\gamma\rho + \frac{(1-a)\pi_o}{\pi_o - \min\{\mu(1-\pi_d), a\pi_o\}}\rho,$$

which after some algebra can be written as

$$p = \rho + \frac{\max\{a\pi_o - \mu(1-\pi_d), 0\}}{\pi_o - \min\{\mu(1-\pi_d), a\pi_o\}}(\gamma - 1)\rho. \tag{4}$$

The price on the exchange equals the value of a bad asset plus the incremental value of a good asset times the expected fraction of good assets sold on the exchange. Note that an increase in the measure of dealers μ means that more good assets are *cream-skimmed* off the exchange. This lowers the fraction of good assets on the exchange and consequently the price p. Moreover, as a result of the reduction in p the price p^d is also reduced. Thus, remarkably, as the measure of dealers μ increases the fraction of the surplus that dealers extract in each OTC transaction, $\gamma\rho - p^d = (1 - \kappa)(\gamma\rho - p)$, also increases.

It is a dominant strategy in period 1 for impatient originators to attempt to first approach a dealer. They understand that with probability a the underlying value of their asset is high, in which case they are able to negotiate a sale with a dealer at price $p^d > p$ with probability $m \in [0, 1]$. If they are not able to sell their asset for price p^d to a dealer, originators can turn to the organized market in which they can sell their asset for p.

We assume that the probability m is simply given by the ratio of the total mass of patient dealers $\mu(1-\pi_d)$ to the total mass of high quality assets up for sale by impatient originators $a\pi_o$ so that

$$m = \min\left\{\frac{\mu(1-\pi_d)}{a\pi_o}, 1\right\}. \tag{5}$$

2 Dealers versus Rentiers

We consider first the situation where dealers and rentiers come from the same pool of agents represented by the interval $[0, 1]$ and we take the proportion of good assets originated by originators, a, to be exogenously given. Each rentier who chooses to be come a dealer $d \in [0, 1]$ incurs a cost $\varphi(d) > 0$ (in units of utility) of acquiring the skills to distinguish the quality of assets, where $\varphi(.)$ is a strictly convex and increasing in d. Given that dealers and rentiers come form the same population with the same utility function it is natural to assume that dealers are not subject to liquidity shocks, so that $\pi_d = 0$. In addition our assumptions on φ allows us to restrict ourselves to a set of dealers of the form $[0, \mu]$.

WE are interested in cases where the dealers are in the short side of the market, that is that there are more good projects for sale than dealers. We will thus assume that $\varphi(d) = \infty$ for $d \geq \bar{d}$ where

$$a\pi_o - \bar{d} > 0. \tag{6}$$

We start by characterizing the payoffs of dealers and originators for a given $\mu < \bar{d}$ and then derive the equilibrium measure of dealers.

2.1 Payoffs of Dealers and Originators

Let $U(\mu)$ be the expected payoff of an originator when the measure of dealers is μ. Similarly let $V(d \mid \mu)$ be the expected payoff of dealer $d \leq \mu$ when the measure of dealers is μ. We have already argued that a patient originator, if approached by a dealer, would always reject the dealer's offer. Since the price in the exchange reflects the expected value of a asset conditional on that asset not having been picked up by a dealer, a patient originator who went to the OTC market is indifferent between selling in the exchange or keeping her asset to mature. Thus a patient originator never attempts to sell his asset, so that an originator's expected payoff at time 0 is:

$$U(\mu) = \omega + \pi_o \left[am(\mu)p^d(\mu) + (1 - am(\mu))p(\mu) \right] + (1 - \pi_o)\rho \left[1 + a(\gamma - 1) \right] \tag{7}$$

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where:

$$p^d(\mu) = \kappa\gamma\rho + (1-\kappa)\,p(\mu) \quad \text{with} \quad p(\mu) = \rho + \left(\frac{a\pi_o - \mu}{\pi_o - \mu}\right)(\gamma - 1)\rho. \tag{8}$$

and $m(\mu)$ is given by

$$m(\mu) = \frac{\mu}{a\pi_o}. \tag{9}$$

In expression (7) the first term in brackets is the utility of an originator that is subject to a liquidity shock, which occurs with probability π_o. If he draws a asset yielding $\gamma\rho$, which occurs with probability a, and gets matched to a dealer, which happens with probability $m(\mu)$, then he is able to sell the asset for $p^d(\mu)$, the price for high quality assets in the dealers' market. If one of these two things does not occur, an event with probability $(1 - am(\mu))$, then the originator needs to sell his asset in the uninformed exchange for a price $p(\mu)$. Finally, the second term in brackets is the utility of the originator conditional on not receiving a liquidity shock.

A dealer's equilibrium expected payoff is:

$$V(d \mid \mu) = \omega - \varphi(d) + (1-\kappa)(\rho\gamma - p(\mu)), \tag{10}$$

and a rentier's equilibrium payoff is simply ω the value of the rentier's endowment.

The next proposition provides a characterization of both $U(\mu)$ and $V(d \mid \mu)$ as a function of the measure of dealers μ.

Proposition 1 *(a) The utility of an originator is a decreasing and concave function of the measure of dealers, μ, and (b) the utility of dealer d is an increasing and convex function of the measure of dealers, μ.*

To better understand the previous proposition it is useful to consider first the following result, which is an immediate consequence of equations (8) and (9).

Proposition 2 *(a) The matching probability $m(\mu)$ is a strictly increasing function of the measure of dealers and (b) the price in the uninformed exchange $p(\mu)$ is a strictly decreasing and concave function of the measure of dealers.*

Part (a) is obvious, but part (b) is at the heart of our results. As the number of dealers increases, originators with good assets are more likely to get matched with some dealer. This can only come at the expense of worsening the pool of assets flowing into the uninformed exchange, which leads to lower prices there. In other words, dealers in the OTC market *cream skim* the good assets and thereby impose a *negative externality* on the organized market. Cream skimming thus improves terms for dealers in the OTC market and worsens them for originators looking to sell assets. Note also that any infra-marginal dealer $d \in [0, \mu]$ gets a rent (given by $\varphi(\mu) - \varphi(d)$) which is increasing in the measure of dealers μ.

The intuition behind Proposition 1 follows from the previous logic. Start with the dealers' expected payoffs. The larger their measure, the lower the price of the asset in the uninformed exchange and thus the higher the surplus that accrues to them, $(1 - \kappa)(\gamma\rho - p(\mu))$ when they acquire high quality assets from originators in distress at date 1. This results in an increasing expected payoff for the dealers as a function of μ, holding fixed the action of originators. The additional rents that accrue to dealers when their measure increases can only come at the expense of the originator's rents. It follows that the originator's expected payoff is a decreasing function of μ.

That the originator's expected payoff is a decreasing function of μ is a more subtle result than may appear at first. Indeed notice that an increase in the number of dealers has two effects on originator payoffs. On the one hand the probability of being matched with an informed dealer goes up as μ rises, which benefits those originators with good assets. But an increase in the number of dealers also lowers prices on the exchange due to the greater *cream skimming*, which in turn leads dealers to bid less for assets in OTC markets. On net, Proposition 1 establishes that originators who must trade in period 1 are hurt on average by the reduction in asset prices that follows from the increase in μ.

2.2 Equilibrium and Optimum Measure of Dealers

Under the assumption embedded in equation (6), all dealers will be able to purchase a good asset in any equilibrium for a profit, given that no more than $\bar{d}$ rentiers will ever choose to become dealers. Under free entry into the dealer market, the equilibrium measure of dealers $\widehat{\mu}$ must be such that the marginal dealer $\widehat{d} = \widehat{\mu}$ breaks even:

$$(1 - \kappa)(\gamma\rho - p(\widehat{\mu})) \leq \varphi(\widehat{\mu}) \ (= 0 \text{ if } \widehat{\mu} > 0), \tag{11}$$

where the notation emphasizes the dependence of the equilibrium price on the exchange on the number of dealers (note that since both sides of (11) are increasing with $\widehat{\mu}$ it is possible to have multiple solutions μ).

Given that $\varphi(d)$ is increasing in d, and that $p(\mu)$ is decreasing in μ (Proposition 2(b)), it follows immediately that when

$$(1 - \kappa)(\gamma\rho - p(0)) - \varphi(0) = (1 - \kappa)(1 - a)(\gamma - 1)\rho - \varphi(0) > 0 \tag{12}$$

every equilibrium is such that $\widehat{\mu} > 0$. In words, when the costs of becoming dealers are small at least for some rentiers, then these rentiers will enter the dealer market. Their cream skimming activities, in turn, will make it more attractive for other rentiers with higher costs to enter this market.

What is the socially optimal measure of dealers μ^S? For any given measure of dealers μ the total expected surplus $W(\mu)$ generated in the economy is simply the sum of total payoffs for each type of agent, rentiers, dealers and originators:

$$\begin{aligned} W(\mu) &= (1 - \mu)\omega + \mu(\omega + (1 - \kappa)(\gamma\rho - p(\mu))) - \int_0^\mu \varphi(x)dx \\ &\quad + \omega + (1 - \pi_o)\rho(1 + a(\gamma - 1)) + \pi_o\left[a(\kappa\gamma\rho + (1 - \kappa)p(\mu)) + (1 - a)\,p(\mu)\right] \end{aligned}$$

Or, rearranging:

$$W(\mu) = \omega + \mu\gamma\rho + (\pi_o - \mu)p(\mu) - \int_0^\mu \varphi(x)dx + \omega + (1 - \pi_o)\rho(1 + a(\gamma - 1))$$

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Substituting for $p(\mu)$ we thus obtain:

$$W(\mu) = \omega - \int_0^\mu \varphi(x)dx + [\omega + \rho(1 + a(\gamma - 1))]. \tag{13}$$

It immediately follows that $W(\mu)$ is decreasing in μ, so that the socially optimal measure of dealers is $\mu^S = 0$. We are thus able to conclude that:

Proposition 3 *If condition (12) holds all equilibria involve inefficiently large dealer markets:* $\widehat{\mu} > 0.$

The economic logic behind Proposition 3 is straightforward: from an ex ante perspective all that informed dealers do is extract a transfer of surplus away from originators. This activity creates no social value. But, in order to be able to cream-skim dealers must incur socially wasteful costs to acquire the valuation skills that allow them to discriminate good assets from bad ones. Thus, it would be efficient in this simple model to simply shut down the dealer market.

The utility of the inframarginal dealer $d < \mu$ is given by

$$V(d|\mu) = \varphi(\mu) - \varphi(d), \tag{14}$$

which is increasing in the measure of dealers. The reason is that as μ increases so do cream skimming activities. This lowers the price in the exchange (see Proposition 2) which increases the rents that accrue to dealers. Thus the larger is the dealer market the larger is the compensation of the most efficient dealers.

3   Dealers versus Rentiers and Moral Hazard in Origination

In this section we broaden and deepen our analysis by considering how information acquisition in dealer markets can improve originators' incentives to select higher quality assets. To the extent that an originator with a good asset is able to get a better price in the OTC market than on the organized exchange, $p^d > p$, this should encourage her to put more effort to originate a good

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asset. This positive effect must, of course, be weighed against the value destroying effects of rent extraction through cream skimming to determine the overall efficiency of OTC dealer markets. By introducing moral hazard in origination we not only take into account an important real effect of information acquisition in financial markets, but we are also thereby able to uncover the fundamental mechanism that underlies inefficient entry into dealer markets. As our analysis below makes clear, the key source of inefficiency is that information acquisition by dealers is motivated by the rent $\gamma\rho - p^d$ they are extracting, which rises rapidly with new entry into the dealer market when origination of good assets is costly and slowly when origination of good assets involves low effort costs. As a result, equilibrium entry into the dealer market is high when information acquisition by dealers has a low social value, and it is low when it has a high social value. This is the main result emerging from our analysis below.

3.1 Assumptions and Definition of Equilibrium

Without much loss of generality and to simplify our analytical expressions we assume throughout this section that $\pi_o = 1$. In other words, all originated assets are distributed in period 1 and none are held to maturity by originators. With a measure μ of dealers and origination effort a the fraction of originators that find a dealer is then simply:

$$m(a, \mu) = \min\left\{\frac{\mu}{a}, 1\right\}.$$

The probability of originating a good asset $a \in [\underline{a}, 1]$ can now be increased by originators at effort cost $\psi(a, \theta)$. Given that all originators are ex-ante identical and face the same incentives, we restrict attention to symmetric equilibria where all originators choose the same a. We begin by imposing mild assumptions on the function $\psi(a, \theta)$ and $\varphi(d)$ that guarantee uniqueness of an interior *symmetric equilibrium* $(\widehat{a}, \widehat{\mu})$.

Assumption A1: (i) $\underline{a} = 0$, $\psi_a(0, \theta) = 0$ for each θ ; (ii) $\psi_a \geq 0$; (iii) $\psi_{aa} > 0$; (iv) $\psi_{aaa} > 0$; and (v) $\psi_{a\theta} > 0$.

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Assumption A2: (i) $\varphi_d > 0$; (ii) there exists $\overline{d} < 1$ such that $\lim_{d \to \overline{d}} \varphi(d) = +\infty$, and (iii) $\varphi(0) < (1 - \kappa)\rho(\gamma - 1)$.

Assumption A3: $(1 - d)\varphi(d)$ is non-decreasing in $[0, \overline{d}]$.

Assumptions A1 to A3 are quite standard, with two possible exceptions. The assumption that $\psi_{aaa} > 0$ corresponds to assuming a convex marginal cost of action and is standard in much of the contract theory literature. It plays no role on our existence result below but will be useful when we establish the (in)efficiency of equilibria. Assumption A3 requires that dealers' costs of becoming informed are sufficiently low for the most efficient dealers and rise sufficiently fast for the other dealers.

Definition of Equilibrium: An equilibrium is given by: (i) prices $\widehat{p}$ and $\widehat{p}^d$ in period 1 at which the organized and OTC markets clear; (ii) occupational choices by rentiers in period 0, which map into an equilibrium measure of dealers $\widehat{\mu}$ and rentiers $(1 - \widehat{\mu})$ (with all rentiers $d \in (0, \widehat{\mu})$ strictly preferring to become dealers); and (iii) incentive compatible effort choices $\widehat{a}$ by originators, which in turn map into an equilibrium matching probability $\widehat{m} \equiv m(\widehat{a}, \widehat{\mu})$.

Although there exists a degenerate equilibrium with $\widehat{\mu} = \widehat{a} = 0$, Assumption A2 (iii) insures that this equilibrium is unstable. In addition, it should be obvious that $\widehat{a} = 1$ can never be an equilibrium, since if $\widehat{a} = 1$ any originator that defects to $a = 0$ would be better off. In what follows we let $(\widehat{a}, \widehat{\mu})$ be an interior equilibrium if $\widehat{a} > 0$ (so that $0 < \widehat{a} < 1$) and $\widehat{\mu} > 0$.

The choice of a by an originator is, of course, not observable to rentiers and dealers. However, all investors can form rational expectations on originators' best effort choice. Also, recall that originators do not know for sure in period 1 what quality of asset they have been able to originate, and they can only discover that they have a good asset when they get an offer p^d from a dealer.

3.2   Existence and Uniqueness of Equilibrium

Our analysis in this section is focused around one key parameter, θ, which drives the marginal effort cost of origination. When θ is high the marginal cost of originating good assets is high. In

that case the fraction of good assets a that is originated is not very responsive to financial market incentives.

The equilibrium $(\widehat{a}, \widehat{\mu})$ in this extended model is given by the solution to two first-order conditions, one for optimal origination effort a and the other for optimal entry into the dealer market μ. Consider a candidate equilibrium $(\widehat{a}, \widehat{\mu})$. The utility of an originator that chooses action a is:

$$U(a|\widehat{a}, \widehat{\mu}) = \omega - \psi(a, \theta) + a\widehat{m}\widehat{p}^d + (1 - a\widehat{m})\,\widehat{p}. \tag{15}$$

The first-order condition for origination effort a is thus:

$$\psi_a(a, \theta) = \widehat{m}\left(\widehat{p}^d - \widehat{p}\right). \tag{16}$$

The originator chooses the effort level a that equalizes the marginal cost of effort with the marginal benefit of effort, which is given by the probability of being matched to an informed dealer when the originator produces a good asset, $\widehat{m}$, times the price improvement from selling the good asset in the OTC market $\left(\widehat{p}^d - \widehat{p}\right)$.

Since φ is smooth and strictly increasing, if $(\widehat{a}, \widehat{\mu})$ is an equilibrium,

$$\varphi(\widehat{\mu}) = \min\left\{1, \frac{\widehat{a}}{\widehat{\mu}}\right\}(1 - \kappa)(\gamma\rho - \widehat{p}). \tag{17}$$

That is, the expected rents associated with cream skimming received by the marginal dealer just compensate for the costs of acquiring information. All dealers with $d < \widehat{\mu}$ are infra-marginal and earn positive rents. All potential dealers with $d > \widehat{\mu}$ choose to stay uninformed. Notice that if $\widehat{a} < \widehat{\mu}$ dealers are not guaranteed a good asset in the OTC market. We assume in that case that dealers get matched randomly with originators with probability $\widehat{a}/\widehat{\mu}$. Our equilibrium conditions, thus, depend on whether there is excess demand for good assets ($\widehat{a} \le \widehat{\mu}$ and $\widehat{m} = 1$) or whether there is excess supply of good assets in the dealer market ($\widehat{a} > \widehat{\mu}$ and $\widehat{m} < 1$). We are interested in the case when there are relatively few dealers in equilibrium, so that $\widehat{a}/\widehat{\mu} \ge 1$. For this case to obtain, we may require an upper bound on θ since if the marginal cost of effort is prohibitively high

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so few good projects may be originated in equilibrium that $\widehat{a}/\widehat{\mu} < 1$. In light of these considerations we are able to establish the following proposition.

Proposition 4 *Under Assumptions A1-A3, there exists a $\overline{\theta} > 0$ such that (i) for $\theta \leq \overline{\theta}$ there exists a unique interior equilibrium $(\widehat{a}(\theta), \widehat{\mu}(\theta))$ and furthermore $\widehat{a}(\theta) \geq \widehat{\mu}(\theta)$; and (ii) If $\theta > \overline{\theta}$ there exists no interior equilibrium $(\widehat{a}(\theta), \widehat{\mu}(\theta))$ such that $\widehat{a}(\theta) \geq \widehat{\mu}(\theta)$.*

In what follows we will assume that $\theta \leq \overline{\theta}$. For this relevant set of parameter values we further establish the following key comparative statics results.

Proposition 5 *Assume A1-A3 hold. Then for $\theta \in (0, \overline{\theta})$, $\widehat{a}_\theta < 0$, $\widehat{\mu}_\theta > 0$ and consequently $\widehat{p}_\theta < 0$.*

That is, while it is to be expected that the equilibrium origination of good assets decreases as origination effort costs rise with the parameter θ, it is surprising that the equilibrium measure of dealers is actually *increasing* with θ. The more costly it is to originate good assets the more dealers enter the OTC market in equilibrium. The reason is that when the cost of originating good assets increases there are fewer good assets that are brought to the uninformed exchange. This has the effect of lowering the price of assets on the exchange $\widehat{p}$ and, in turn, increases the incentives to acquire information and therefore the measure of informed dealers $\widehat{\mu}$ that enter in equilibrium, as seen in condition (17).

Proposition 5 highlights the central mechanism at work in this model. Since $\widehat{\mu}_\theta > 0$ the equilibrium incentives to acquire information for dealers are rising with the costs of originating good assets. As we will show in the next subsection, the social returns from information acquisition by dealers are decreasing with θ. Thus, just when the planner would like to reduce costly investment in information by dealers, the equilibrium incentives to acquire information are at their highest. This is the basic tension arising from cream skimming: the returns from cream skimming are rising when a higher fraction of good assets are distributed in the dealer market, so that the fraction of good assets sold on the exchange, $\widehat{a} - \widehat{\mu}$, is smaller. When the marginal cost of origination effort θ is high, the best-response of originators $\widehat{a}(\theta)$ is relatively inelastic, so that the fraction

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$(\widehat{a}(\theta) - \widehat{\mu}(\theta))$ of good assets sold on the exchange is highly elastic to changes in $\widehat{\mu}(\theta)$. This is why cream-skimming activities are rewarded the most when their social value is the lowest.

Recall that the net income of the marginal dealer must be zero and hence the net income of an inframaginal dealer d is given by $\varphi(\widehat{\mu}(\theta)) - \varphi(d)$. It follows that:

Corollary 6 *If $d < \widehat{\mu}(\theta)$ the income of dealer d is an increasing function of θ. That is, dealer d is better off the higher is the marginal cost of originating quality assets.*

3.3 Efficiency of Equilibrium

We now analyze the efficiency of equilibria in the presence of moral hazard in origination. Our efficiency benchmark is the size of a dealer sector μ^S chosen by a planner that maximizes total social surplus, subject to the constraint that originators will always choose an origination effort $\tilde{a}(\mu, \theta)$ that is a best response. That is, if the cost of effort parameter is θ and there are μ dealers and every originator chose effort $\tilde{a}(\mu, \theta)$ then an individual originator has no incentive to deviate. Notice that if $\tilde{a}(\mu, \theta) > \mu$ then it necessarily satisfies

$$\psi_a(a, \theta) = \frac{\mu}{a} \kappa \rho(\gamma - 1) \left(\frac{1 - a}{1 - \mu} \right) \tag{18}$$

Equation (18) is formally established in the Appendix (see section A.2) , and follows from the first order conditions for originators when $a \geq \mu$. In this case $m = \frac{\mu}{a}$ and

$$p^d - p = \kappa \rho(\gamma - 1) \left(\frac{1 - a}{1 - \mu} \right),$$

and thus equation (18). On the other hand if $\tilde{a}(\mu, \theta) < \mu$ then $p^d - p = \kappa \rho(\gamma - 1)$, $m = 1$ and thus $\tilde{a}(\mu, \theta)$ necessarily satisfies[7]

$$\psi_a(a, \theta) = \kappa \rho(\gamma - 1) \tag{19}$$

Under Assumption A1 this *best response function* $\tilde{a}(\mu, \theta)$ satisfies the following properties.

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[7] Again see section A.2.

Proposition 7 *Under Assumption A1:* (i) *for any θ the function $a(\mu, \theta)$ that solves equation (18) is such that $a_\mu > 0$. Moreover, there exists at most one $\tilde{\mu}(\theta)$ such that $a(\tilde{\mu}(\theta), \theta) = \tilde{\mu}(\theta)$. The function $a(\cdot, \theta)$ is strongly concave in $(0, \tilde{\mu})$.*

(ii) *$\tilde{a}(\mu, \theta) = a(\mu, \theta)$ if $\mu < \tilde{\mu}(\theta)$ and $\tilde{a}(\mu, \theta) = a(\tilde{\mu}(\theta), \theta)$ otherwise. The function $\tilde{a}(\cdot, \theta)$ is smooth except at $\tilde{\mu}(\theta)$ and concave.*

Proposition 7 defines an equilibrium best-response of originators as a function of the number of dealers for each cost parameter θ. The proposition guarantees that the equilibrium response is a concave function of μ.

We compare the equilibrium outcome $\widehat{\mu}$ to the solution of the following optimization problem for a social planner:

$$\max_{\mu} W(\mu, \theta) = \rho[1 + \tilde{a}(\mu, \theta)(\gamma - 1)] - \psi(a) - \int_0^\mu \varphi(u) du. \tag{20}$$

We begin by showing that $W(\mu, \theta)$ satisfies an important property that greatly simplifies our analysis.

Proposition 8 *Assume A1-A3. Then $W(\mu, \theta)$ is strictly a concave function of μ which is decreasing for $\mu > \tilde{\mu}(\theta)$.*

Proposition 8 allows us to use first-order conditions to compare the measure of dealers that obtain in equilibrium with the measure of dealers that maximize welfare. It also insures that there exists a unique $\mu^S(\theta)$ that solves the planner's problem. Our main result is:

Proposition 9 *Under A1-A3 there exists a unique $\widehat{\theta} < \bar{\theta}$ such that for $\theta < \widehat{\theta}$, $\mu^S(\theta) \geq \widehat{\mu}(\theta)$ and for $\theta > \widehat{\theta}$, $\mu^S(\theta) < \widehat{\mu}(\theta)$.[8]*

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[8]The excessive number of dealers in equilibrium when $\theta > \bar{\theta}$ holds more generally and is quite intuitive. When $\theta > \bar{\theta}$, $\widehat{\mu} > \widehat{a}$ and originators' actions are not changed if a central planner chooses μ slightly smaller than $\widehat{\mu}$. The concavity of the welfare function then guarantees that $\mu^S < \widehat{\mu}$.

The equilibrium size of dealer markets is too small when θ is small and too large when θ is large. This is a striking and at first sight counterintuitive result. When θ is small the $(p^d - p)$-spread-elasticity of origination effort is high. The planner then gets a large origination efficiency improvement by increasing the dealer market. This leads the planner to choose a relatively high μ^S and results in a high a^S, as can be seen in Figure 1 below. But when the fraction of good assets that is originated a^S is high the equilibrium incentives to enter the dealer market are small because the surplus that dealers can cream-skim is then relatively small. To see this consider the extreme case where $a^S \longrightarrow 1$. The price of an asset on the exchange p then converges to $\rho\gamma$. But this means that in the limit there can be no cream-skimming for dealers and therefore almost no entry by rentiers into the dealer market. In contrast, when θ is large the $(p^d - p)$-spread-elasticity of origination effort is low. The planner then gets a low origination response by increasing the measure of dealers and prefers a lower μ^S and a^S as is illustrated in Figure 1. But when a^S is low the incentives to enter the dealer market are large. To see this, note that when $a^S \longrightarrow 0$, $p \longrightarrow \max\{\rho(1 - \frac{\mu}{1-\mu}(\gamma - 1)), 0\}$, so that the total surplus from trading in the dealer market is large (it is close to $\gamma\rho$ when p is close to zero). As a result, a lot of rentiers will be induced to enter the dealer market.

To further develop the intuition behind this result, consider the following quadratic effort function

$$\psi(a) = \frac{\theta}{2}a^2.$$

We solve for the equilibrium and planner solution numerically with the following parameter values for $\varphi(d)$, κ, ρ and γ:

$$\varphi(d) = .1 + d; \quad \kappa = .35; \quad \rho = 2; \quad \gamma = 1.25.$$

We vary θ over the following interval: $\theta \in [0, 0.78]$, making sure that our assumptions A1 to A3 hold and that $\theta \leq \overline{\theta} = 0.78$. The figure below plots the equilibrium $(\widehat{a}, \widehat{\mu})$ and constrained optimum (a^S, μ^S) for these values of θ. As shown in Proposition 5 origination incentives are decreasing with θ and the measure of informed dealers $\widehat{\mu}$ is increasing in θ.

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Figure 1: Equilibrium effort, $\widehat{a}$, measure of informed intermediaries $\widehat{\mu}$, together with the constrained optimum $\left(a^S, d^S\right)$ (dashed lines) as a function of θ.
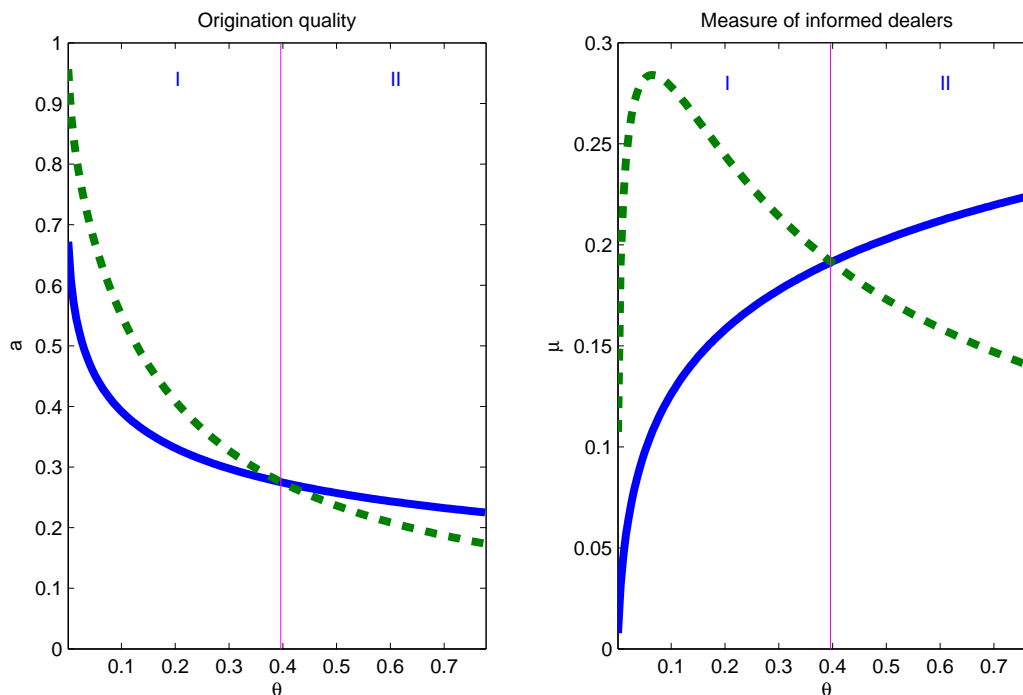
Panel A illustrates that both $\widehat{a}$ and a^S are decreasing in θ, but $\widehat{a}$ declines more gradually than a^S because the planner fully internalizes the costs of information acquisition for dealers, while the equilibrium only partially reflects these costs. Thus, when the marginal cost of effort θ increases beyond 0.08 the planner responds by cutting the measure of dealers μ^S, as Panel B illustrates. The reason is that dealers cost the same but provide a weaker origination incentive when θ is higher. In contrast, the equilibrium measure of dealers $\widehat{\mu}$ is always *increasing* in θ, as the cream-skimming incentives for dealers increase with θ. Therefore, equilibrium origination effort $\widehat{a}$ declines less sharply than the socially optimal effort a^S. As seen in Proposition 9, for the value $\widehat{\theta} = .4$ the two schedules intersect and in region II the measure of informed dealers is above the constrained optimum, $\widehat{\mu} > \mu^S$, whereas it is below in region I.

3.4 Comparative Statics with respect to the Cost of Information

Our analysis in the previous subsection can be straightforwardly extended to consider the effects of changes in the cost of information for dealers. We model changes in information acquisition costs for dealers by specifying a cost function $\varphi(d, \eta)$ with $\eta > 0$ and such that $\varphi_\eta(d, \eta) > 0$. By making the obvious changes to Assumptions A2 and A3 above we are able to establish an analog of Proposition 4.

Assumption A2′: (i) $\varphi_d > 0$; (ii) There exists $\bar{d} < 1$ such that $\lim_{d \to \bar{d}} \varphi(d, \eta) = \infty$, for each η; (iii) $\varphi(0, \eta) < (1 - \kappa)\rho(\gamma - 1)$ for each η; (iv) $\lim_{\eta \to \infty} \varphi(d, \eta) = \infty$ for each $d > 0$; (v) $\lim_{\eta \to 0} \varphi(d, \eta) = 0$ for any $d < \bar{d}$; and (vi) $\varphi_\eta > 0$.

Assumption A3′: $(1 - d)\varphi(d, \eta)$ is non-decreasing in $d \in [0, \bar{d}]$ for every η.

Proposition 10 *Under Assumptions A1, A2′ and A3′, there exists an $\bar{\eta} > 0$ such that (i) for $\eta \geq \bar{\eta}$ there exists a unique interior equilibrium $(\hat{a}(\eta), \hat{\mu}(\eta))$ and furthermore $\hat{a}(\eta) \geq \hat{\mu}(\eta)$; and (ii) If $\eta < \bar{\eta}$ there exists no interior equilibrium $(\hat{a}(\eta), \hat{\mu}(\eta))$ such that $\hat{a}(\eta) \geq \hat{\mu}(\eta)$.*

In analogy to our earlier analysis, we will restrict attention to the situation where $\eta \geq \bar{\eta}$, since we are primarily interested in cases where in equilibrium there are many good projects for sale relative to dealers. The following is an analogue to the earlier proposition establishing comparative statics with respect to θ:

Proposition 11 *Assume A1, A2′ and A3′ hold. Then for $\eta > \bar{\eta}$, $\hat{a}_\eta < 0$, $\hat{\mu}_\eta < 0$.*

In words, equilibrium origination of good assets and the equilibrium measure of dealers are both decreasing functions of the parameter η that measures the cost of information acquisition for a dealer.

Recall that the net income of the marginal dealer must be zero and hence the rent of an infra-marginal dealer d equals $I(d, \eta) = \varphi(\hat{\mu}(\eta), \eta) - \varphi(d, \eta)$. Hence, the change in infra-marginal rents with respect to η is given by:

$$I_\eta(d, \eta) = \varphi_\mu \widehat{\mu}_\eta + \varphi_\eta(\widehat{\mu}(\eta), \eta) - \varphi_\eta(d, \eta)$$

Thus a decrease in the cost parameter η increases the income of an infra-marginal dealer provided that $\varphi_{\eta d} \leq 0$. That is, provided that the cost reduction is at least as large for a more efficient dealer.

Corollary 12 *If $\varphi_{\eta d} < 0$ the rent of an infra-marginal dealer increases as η decreases.*

Proposition 11 and Corollary 12 establish that when the cost of information for dealers decreases, the equilibrium measure of dealers, the number of OTC transactions and the income of every dealer increase. One important source of information cost savings in the past three decades is the spread of information technology (IT), which has facilitated the relative valuation of assets and lowered trading costs. As we highlight in Bolton, Santos and Scheinkman (2012), during this period of rapid spread of IT we have also witnessed abnormal growth in the size of OTC derivatives, swaps, commodities, and forward markets.[9] Philippon and Resheff (2012) have shown that the abnormal growth in median compensation in the financial industry since the early 1980s is driven in large part by the compensation of broker-dealers, which constitute the main entry in their 'other finance' category (see Figure 1 below). Broker-dealers, of course, are the main players in OTC markets along with units inside commercial banks and insurance companies, such as AIG's infamous Financial Products group, which have been richly rewarded during the boom years prior to the crisis. Philippon (2012) has also shown that unlike other sectors financial intermediation has not become cheaper as a result of investments in IT technology. To the extent that all efficiency gains from IT investments are appropriated by dealers as rents this is not entirely surprising.

Accordingly, a simple way of explaining the growth in this sector is in terms of the comparative statics of this section. Of course, our analysis is cast in a static model and cannot lend itself to a

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[9]In particular, Figure 2 in Bolton, Santos and Scheinkman (2012) shows that in 1998-2011 OTC contracts for interest rate derivatives grew by a factor of 14, while exchange traded interest rate futures grew by a factor of 3. Commodity forwards and futures display a similar pattern, except that the volume in OTC commodity contracts collapsed after the crisis.

full dynamic explanation. Still, our simple comparative static exercises above can explain how this IT revolution has increased the number of dealers, which in turn has led to higher compensation of dealers.[10]

Two examples provide a simple illustration of the role IT technology has played in financial innovation and customization. The first is commodities forward contracts, which have been increasingly geographically customized in recent years thanks to satellite imaging technology and IT applications such as Google Earth. Due to their more accurate geographic footprint, these contracts offer more valuable insurance, which in turn enables dealers in these contracts to extract higher profits. The second is energy derivatives such as those offered by Enron Capital and Trade Resources (ECT) a subsidiary of Enron, which set up a "gas bank"–essentially a financial intermediary between buyers and sellers of natural gas–offering both price stability and local gas-supply and demand assurance. As Tufano (1996, pp 139) puts it "ECT's risk managers have clear instructions to develop a hedging strategy that minimizes net gas exposures, and the company has invested millions of dollars in hardware, software, and hundreds of highly trained personnel to eliminate mismatches and ensure that fluctuations in gas prices do not jeopardize the company's existence." It is interesting to recall that before its eventual collapse, Enron, and in particular ECT, received numerous awards for these innovations.

4   Dealers versus Originators

In this section we consider the more realistic situation where dealers come from the ranks of potential originators. In other words, suppose now that dealers and originators come from the same pool of agents represented by the interval $[0, 1]$. For simplicity, we will only analyze the case

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[10]Deregulation, which some commentators (*e.g.* Philippon and Resheff, 2012) suggest was responsible for the phenomenal growth of the financial services industry in the past quarter century, would have a similar effect: the decrease in costs in OTC activities would generate a larger OTC market, higher compensation for dealers, and lower ex-ante profits for entrepreneurs.

when a the probability of originating a good asset is fixed. The analysis of this situation is similar to the case where dealers come from the rentier ranks. The main modeling difference is that since dealers and originators come from the same pool, with the same utility function, dealers now have the same probability of a liquidity shock as originators. That is, we now have $\pi_d = \pi_o$.

The main substantive difference with the previous situation is that when dealers come from the ranks of potential originators, there is an additional welfare costs of a growing dealer sector: the lost assets that would have been available had agents chosen a career in business (as originators) rather than in finance (as dealers).

If the measure of dealers is given by $\mu \in [0, 1]$ the probability that an impatient originator meets a patient dealer in the OTC market is now:

$$m(\mu) = \min \left\{ \frac{\mu(1 - \pi_o)}{a\pi_o(1 - \mu)}, 1 \right\}. \tag{21}$$

We restrict attention to the case where there are few dealers in equilibrium so that $m(\mu) = \frac{\mu(1-\pi_o)}{a\pi_o(1-\mu)} < 1$. The numerator of $m(\mu)$ is the total mass of *patient dealers* ready to purchase a good asset. On the denominator of $m(\mu)$ is the total supply of good assets by *impatient origina-tors*. The expected payoff of an originator when $m(\mu) < 1$ is:

$$
\begin{aligned}
U(\mu) &= \omega + \pi_o \left[am(\mu)p^d(\mu) + (1 - am(\mu))p(\mu) \right] \\
&+ (1 - \pi_o)\rho \left[1 + a(\gamma - 1) \right],
\end{aligned} \tag{22}
$$

where now the equilibrium expected value of assets sold on the exchange is:

$$p(\mu) = \rho + \frac{\pi_o a(1 - \mu) - \mu(1 - \pi_o)}{\pi_o(1 - \mu) - \mu(1 - \pi_o)}(\gamma - 1)\rho, \tag{23}$$

(and as before $p^d(\mu) = \kappa\gamma\rho + (1 - \kappa)p(\mu)$).

In equilibrium, any dealer must prefer to work in finance rather than in business (and vice-versa any originator must prefer to be in business than in finance), so that the following condition must hold for the marginal dealer $\widehat{\mu}$:

$$
\begin{aligned}
(1 - \pi_o)\rho \left[1 + a(\gamma - 1) \right] + \pi_o \left(am(\widehat{\mu})p^d(\widehat{\mu}) + (1 - am(\widehat{\mu}))p(\widehat{\mu}) \right) &\geq \\
(1 - \pi_o)[(1 - \kappa)(\gamma\rho - p(\widehat{\mu}))] - \varphi(\widehat{\mu}) \quad \text{(with equality if } \widehat{\mu} > 0). \tag{24}
\end{aligned}
$$

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Again, there may be multiple equilibria, but when:

$$(1 - \pi_o)(1 - \kappa)(1 - a)(\gamma - 1)\rho - \varphi(0) > \rho[1 + a(\gamma - 1)] \tag{25}$$

every equilibrium is such that $\widehat{\mu} > 0$.

As before the total expected surplus, $W(\mu)$ is the sum of total payoffs for each type of agents, rentiers, dealers and originators:

$$
\begin{aligned}
W(\mu) &= \omega + \mu \left[\omega + (1 - \pi_o)(1 - \kappa)(\gamma\rho - p(\mu)) - \int_0^\mu \varphi(x)dx\right] \\
&+ (1 - \mu)\left[\omega + (1 - \pi_o)\rho(1 + a(\gamma - 1)) + \pi_o(a(\kappa\gamma\rho + (1 - \kappa)p(\mu)) + (1 - a)p(\mu))\right]
\end{aligned}
$$

Or, rearranging and substituting for the expression of $p(\mu)$ in (23):

$$W(\mu) = \omega - \int_0^\mu d\varphi(d) + (1 - \mu)[\omega + \rho(1 + a(\gamma - 1))] \tag{26}$$

Comparing the expressions for the expected social surplus in (13) and (26) it is immediately apparent that there is now a higher cost of letting potential originators undertake a career in finance. There is not only the wasted cost of acquiring skills to become a dealer, but also the lost expected output that would have been produced in the real sector. Accordingly, in this situation it is even more efficient to keep the measure of dealers as small as possible and to set $\mu^S = 0$. We summarize this discussion in the proposition below:

Proposition 13 *When dealers come from the ranks of potential originators and when condition (25) holds all equilibria involve inefficiently large dealer markets.*

An obvious interpretation of our model is that originators are entrepreneurs creating new businesses. One of the social costs of dealer markets then takes the form of reduced entrepreneurship and excessive entry into the financial industry by, as Paul Volcker put it, "young talent, particularly of a numerical kind".[11] Another somewhat less obvious interpretation of our model is, in line with Biais, Foucault and Moinas (2013), as an illustration of *front-running* through, say, high

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[11] Taken from the following quote by Paul Volcker: "How do I respond to a congressman who asks if the financial

frequency trading. By this interpretation dealers are high frequency traders who, sometimes at great cost and ingenuity, can find out in advance the price at which an asset available for purchase will sell at a later date (sometimes just a few milliseconds later). The dealers then purchase the assets that they know will see a price improvement (the good assets) so as to sell them at a later date and realize an easy capital gain. Michael Lewis refers to this type of activity as "scalping" and remarks that one of the unfortunate consequences of the rise in high frequency trading is all the talent it has attracted that might have been deployed more productively elsewhere.[12]

5 Extensions

5.1 Competition between Dealers

So far we have assumed that an originator's bargaining power κ is invariant to the measure of dealers, μ. The bargaining power of dealers in OTC markets derives from the fact that dealers are not committed to their quotes, so that there cannot by direct bidding for assets as in organized exchanges where dealers must post firm quotes. Thus, even when the measure of dealers increases a seller of assets will still be negotiating bilaterally with any given dealer. Still, it is plausible that as the measure μ of dealers increases relative to the volume of good assets for sale $a\pi_o$ so does the

sellers' bargaining power. This hypothesis can be captured formally in our model by letting the originator's share of the surplus from trade with a dealer, $\kappa\left(.\right)$, be an increasing function of $\mu/a\pi_o$. Our main qualitative results are robust this generalization.

Consider first Proposition 3, which states that when condition (12) holds all equilibria involve excessively large dealer markets. Suppose now that $\kappa\left(.\right)$ is a continuously differentiable increasing function of μ with a bounded derivative $\kappa_\mu > 0$ for all $\mu > 0$. Then, if condition (12) is slightly amended as follows:

$$(1 - \kappa(0))(1 - a)(\gamma - 1)\rho - \varphi(0) > 0, \tag{27}$$

it is then straightforward to verify that when the modified condition (27) holds all equilibria involve inefficiently large dealer markets. Basically, only in the extreme case where any positive entry by informed dealers $\mu > 0$ immediately results in a $\kappa(\mu) = 1$ can excessive entry be avoided.

The same analysis applies to Proposition 13 and condition (25). It is again straightforward to verify that if this latter condition is modified to:

$$(1 - \pi_o)(1 - \kappa(0))(1 - a)(\gamma - 1)\rho - \varphi(0) > \rho[1 + a\left(\gamma - 1\right)], \tag{28}$$

then all equilibria involve inefficiently large dealer markets.

Consider next the model with moral hazard in origination. To see how our main result on inefficient entry by informed dealers in Proposition 9 is affected when $\kappa\left(.\right)$ is an increasing function of μ it is helpful to look at Figure 1. The effect of greater competition among dealers on the planner's solution is essentially to move the $\mu^S(\theta)$ schedule upwards, as entry into dealers markets now results in stronger origination incentives. In contrast, the effect of greater competition on the equilibrium entry schedule $\widehat{\mu}(\theta)$ is a downward shift, as incentives for dealers to enter the dealer market are now reduced as a result of the greater competition. On net, therefore, the overall effect of greater competition in dealer markets is to shift the cutoff $\widehat{\theta}$ to the right. In other words, the parameter region for which there is insufficient entry into dealer markets in equilibrium is then larger. Note finally that when $\kappa\left(.\right)$ is an increasing function of μ it is also less likely that a situation will arise where the volume of good assets originated a is less than the measure of dealers μ. In

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other words, the cutoff $\overline{\theta}$ will be higher. In particular, if $\kappa = 1$ whenever there is excess demand for good assets $(\mu \geq a)$ then an equilibrium situation such that $\widehat{\mu} \geq \widehat{a}$ cannot arise.

5.2   Informed Trading on the Public Exchange

In this subsection we explore the consequences of allowing for informed trading both in the OTC market and on the organized exchange. To this end we extend the model by introducing two choices for informed intermediaries: To become an OTC dealer incurring a personal cost $\varphi(d)$ or an *informed exchange trader* who incurs a smaller cost $\lambda\varphi(d)$, with $\lambda < 1$. Each type of intermediary can determine perfectly the value of the asset and the key difference between the two types is the context in which they trade. OTC dealers trade in an opaque market and their offers are not publicly disclosed. In contrast, dealers trading in the exchange have to disclose their quotes. As a result, their private information may be (partially) inferred by uninformed investors, who can revise their bids in light of this information and therefore compete with informed traders. The assumption that $\lambda < 1$ is to reflect a higher fixed costs involved in over-the-counter trading. To highlight the trade-off between dealers and informed traders and simplify other aspects of the model we will assume that the measure of dealers plus informed traders is fixed.

Over-the-counter dealers trade exactly as in our base model. We consider the following trading protocol in the organized exchange. First, all assets are put up for sale simultaneously at some price p_u. Any buyer willing to bid more than p_u can make a targeted bid for a specific asset; all these bids are public information. Then, any other buyer can submit counterbids on these targeted assets using what they inferred from the first round of bidding, after which all assets are sold to the highest bidder.

In the absence of any additional signals the most an uninformed buyer is willing to bid is p_u. Thus, if an informed trader bids more than p_u to secure the purchase of a good asset that he has identified, his information would leak out to all buyers and he will face competition from uninformed buyers. If this information leaks out perfectly, then uninformed buyers are willing to

bid up to $\gamma\rho$ (the value of the good asset that has been identified), thus completely bidding away the informed trader's information rent. If that is the case, no costly information about asset values will be produced; there will be no 'price discovery' in equilibrium in the organized exchange.

To avoid this outcome we follow the literature spawned by Grossman and Stiglitz (1980) and introduce a form of noise traders adapted to our model, which we refer to as uninformed '*noise buyers*'. Each noise buyer makes a bid $\phi\rho$, with $\gamma > \phi > 1$, on an asset for which she has an especially high private consumption value. We assume informed traders move first by bidding for valuable assets and that noise buyers move second by bidding for an asset they particularly favor. Uninformed traders only see that an asset received a bid and if, in equilibrium, informed and noise buyers bid the same, the uninformed cannot tell whether the bid is from an informed or a noise buyer. By bidding precisely $\phi\rho$ informed traders can hide behind noise traders and partially protect their information. To simplify our expressions we assume that no asset receives multiple bids.

Let μ be the fraction of rentiers that choose to become dealers and i the fraction that choose to become informed traders. The fractions μ and i will be determined in equilibrium, but $f = \mu + i$ is given.

Let υ denote the measure of noise buyers. In our candidate equilibrium informed and noise buyers make targeted bids $\phi\rho$ for assets. To ensure that uninformed buyers cannot gain by bidding on targeted assets we assume that υ is large enough so that the conditional expected value of targeted assets to the uninformed buyers is less than $\phi\rho$.

As before, originators with liquidity needs first pursue the free option to sell their asset in the OTC market. We again simplify the analysis without loss of generality by setting $\pi_o = 1$. Let $\widehat{a}$ be the equilibrium probability of originating a good asset for a given strictly positive measure of dealers in the OTC market $\mu = f - i > 0$. We will show that by moving some dealers from the OTC market to the exchange we not only lower the cost of information acquisition but also increase incentives to originate good assets. As a result, it is then possible to reduce the measure f and thus to reduce overall information acquisition costs, while maintaining the same origination effort incentives.

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If an originator has a good asset she will receive a (weakly) more attractive bid with probability m_μ, and if she doesn't obtain a bid she can always put her asset up for sale on the exchange. Thus, after OTC dealers have cream-skimmed a mass of good assets μ there are respectively

$$q_g = \widehat{a} - \mu \qquad \text{and} \qquad q_b = 1 - \widehat{a}, \tag{29}$$

good and bad assets for sale on the exchange. For simplicity, we shall assume that there are enough good assets for sale to meet the demands of both dealers and informed traders:

$$\widehat{a} - f > 0. \tag{30}$$

After informed traders have bid, the remaining pool of assets has proportions

$$\chi_g = \frac{\widehat{a} - f}{1 - f} \qquad \text{and} \qquad \chi_b = \frac{1 - \widehat{a}}{1 - f}. \tag{31}$$

of good and bad assets. Note that noise buyers buy random assets and therefore do not affect the proportion of good and bad assets for sale. Thus in equilibrium, the price paid by (risk-neutral) uniformed buyers is

$$p_u = \chi_g \gamma \rho + \chi_b \rho, \tag{32}$$

which only depends on the size of the financial sector f, and not on the relative number of dealers and informed traders.

To insure that uninformed investors do not want to out-bid targeted bids we assume that the mass υ of noise buyers is large enough so that:

$$\left(\frac{\upsilon}{\upsilon + i}\right) p_u + \left(\frac{i}{\upsilon + i}\right) \gamma \rho < \phi \rho. \tag{33}$$

The left hand side of condition (33) is the conditional expected value of a targeted asset for an uninformed investor, which is lower than the cost $\phi \rho$ under condition (33).

A good asset for sale on the organized exchange gets a bid $\phi \rho$ from an informed trader with probability

$$m_i = \frac{i}{\widehat{a} \pi - \mu} \quad . \tag{34}$$

If a good asset for sale on the exchange does not get a bid from an informed trader, it would get a bid from a noise buyer with probability

$$m_n = \frac{\upsilon}{\pi - f} \quad . \tag{35}$$

Thus, the expected value of a selling a good asset on the exchange is given by:

$$p\left(\mu\right) = m_i \phi \rho + \left(1 - m_i\right) \left\{m_n \phi \rho + \left(1 - m_n\right) p_u\right\}, \tag{36}$$

and the price that a dealer pays an originator with a good asset on the OTC market is now:

$$p^d\left(\mu\right) = \kappa \gamma \rho + \left(1 - \kappa\right) p\left(\mu\right).$$

If we hold the size of the financial sector f constant, but increase the relative number of OTC dealers then m_i decreases and m_n stays constant. Therefore $p\left(\mu\right)$, the expected value of selling a good asset on the exchange, also decreases. In other words, a shift of informed buying to the OTC market away from the exchange worsens the terms (whether it is $p\left(\mu\right)$ or $p^d\left(\mu\right)$) at which originators can hope to sell good assets, and therefore increases the informational rents of dealers on the OTC market. This observation is formalized in the next proposition.

Proposition 14 *The terms of trade $p\left(\mu\right)$ and therefore also $p^d\left(\mu\right)$ are a decreasing function of the number of dealers μ.*

If $p^d\left(\mu\right) < \phi \rho$ then originators with good assets are worse off when there is a switch of informed trading from the exchange to the OTC market. We will show that in any equilibrium with a strictly positive number of dealers μ and informed traders i we must have $p^d\left(\mu\right) < \phi \rho$. As a result, in any such equilibrium there are too many dealers trading in the OTC market. In an equilibrium with a strictly positive number of dealers and informed traders the marginal agent $\widehat{\mu}$ must be indifferent between becoming a dealer or an informed trader:

$$-\varphi\left(\widehat{\mu}\right) + \left(\gamma \rho - p^d\left(\widehat{\mu}\right)\right) = -\lambda \varphi\left(\widehat{\mu}\right) + \left(\gamma - \phi\right)\rho$$

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or,[13]

$$\phi\rho = p^d\left(\widehat{\mu}\right) + (1-\lambda)\,\varphi\left(\widehat{\mu}\right). \tag{37}$$

Now unless $\widehat{\mu} = 0$, equation (37) can only hold if $p^d\left(\widehat{\mu}\right) < \phi\rho$. It follows that any equilibrium such that $\widehat{\mu} > 0$ must be inefficient: a small decrease in the number of dealers, holding the incentives for originating effort $\widehat{a}$ constant, keeps originators indifferent while lowering the overall cost of information acquisition. We summarize this argument in the following proposition.

Proposition 15 *When informed trading can take place on or off the exchange, then there are too many dealers trading on the OTC market in equilibrium.*

The logic behind this result is particularly simple and compelling: Any shift in informed trading away from the exchange and onto the OTC market results in a worsening of the terms of trade for originators with good assets and therefore undermines incentives towards origination of good assets. This reduction in origination incentives must then be compensated with a larger number of informed dealers to maintain origination incentives, which results in an efficiency loss.

6 Conclusion

We have presented a model where individual agents can either work in the real sector and engage in productive activities, or in the financial sector and provide liquidity as well as valuation services. We have asked whether in such an occupational choice model the equilibrium size of the financial sector is efficient. We have identified a novel externality, cream skimming in OTC-like markets, that tends to generate an inefficiently large OTC sector, in which dealers are overly compensated for their valuation and liquidity-provision services.

Our theory helps explain the simultaneous growth in the size of the financial services industry and the compensation of dealers in the most opaque parts of the financial sector. OTC markets

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[13]Again, the solution is not necessarily unique since the right hand side of (37) is not monotone in μ.

emerge even in the presence of well functioning exchanges. The reason is that both originators and informed dealers have an incentive to meet outside the exchange: Originators with good assets may get better offers from informed dealers than are available on the exchange, and dealers can use their information to cream-skim good assets. Our model thus offers a novel theory of endogenous segmentation of financial markets, where "smart-money" investors deal primarily in opaque OTC markets to protect their information, and uninformed investors trade on organized exchanges. This is in contrast with models in the vein of Grossman and Stiglitz (1980), where instead smart-money investors are assumed to be trading on the exchange, and where as a consequence too little (costly) information may be produced, given that part of it is expected to leak out to uninformed investors through price movements driven by information-based trades.

In an extension of our benchmark model we allow for smart-money trading both on the organized exchange and on OTC markets. When financiers have a choice of becoming either informed traders on the exchange or informed dealers in an OTC market, we show that in equilibrium OTC markets are always too large relative to the organized exchange. The reason is that substitution of informed trading on a transparent exchange for trading on opaque OTC markets results in worse terms of trade for originators with good assets. Therefore, to maintain the same origination incentives of good assets by originators a larger informed financial sector is required. Given that information rents are bigger in opaque OTC markets, financiers' private incentives are to switch trading to OTC markets even if this tends to undermine originators' ex-ante incentives to originate good assets, which explains why OTC markets are too large in equilibrium.

Informed dealers profit from the opaqueness of OTC transactions and this is one reason why broker-dealers have generally resisted the transfer of trading of the most standardized OTC contracts onto organized platforms, as required by the Dodd-Frank Act of 2010.[14] This is also

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[14]The furious lobbying activity of some banks, as well as the ISDA on their behalf, to avoid any major changes in the organization of OTC markets has been amply documented in the press. See for example Leising (2009), Morgenson (2010) and Tett (2010). In fact centralized clearing seems to be *less* of a problem for dealers than execution. For instance, Harper, Leising, and Harrington (2009) write:" [T]he banks ... are expected to lobby to remove any

why the largest Wall Street firms are so intent on avoiding disclosure of prices and fees in the new exchanges set up in response to the Dodd-Frank Act.[15] Interestingly, in a heterogeneous world, firms with a high probability of generating good assets also benefit (*ex-ante*) from the option of trading in opaque markets. It is, thus, not surprising that some firms have also been keen to keep OTC markets in their present form.[16] All in all, we therefore expect that a first line of defense by the financial industry to the new regulations required under the Dodd-Frank Act is likely to be to over-customize derivatives contracts and to offer fewer standardized, plain-vanilla, contracts (which will be required to trade on organized exchanges); the second line of defense will be to set up clearinghouses that maintain opacity and do not require disclosure of quotes; and a third line will be to ensure that the operation of clearinghouses remains under the control of the main dealers.

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requirements that the contracts be executed on exchanges because that would cut them out of making a profit on the trades, according to lawyers working for the banks."

[15]See for example Story (2010), who reports on the efforts by the largest banks to thwart an initiative by Citadel, the Chicago hedge fund, to set up an electronic trading system that would display prices for CDSs.

[16]See Scannell (2009), who writes "Companies from Caterpillar Inc. and Boeing Co. to 3M Co. are pushing back on proposals to regulate the over-the-counter derivatives market, where companies can make *private deals* to hedge against sudden moves in commodity prices or interest rates".(Emphasis ours).

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A Appendix

A.1 Proof of Proposition 1

From Proposition 2, $p(\mu)$ is decreasing and concave and thus $V(d|\mu)$ in (10) is increasing and convex in μ, that is (b). From equation (7),

$$U_\mu = \pi_o \{p_\mu + a\kappa \left[m_\mu \left(\gamma\rho - p(\mu)\right) - m(\mu) p_\mu\right]\}. \tag{A.1}$$

Furthermore from equations (8) and (9) it is immediate that

$$\gamma\rho - p(\mu) = -\left(\frac{1 - am(\mu)}{a}\right)\frac{p_\mu}{m_\mu}, \tag{A.2}$$

where p_μ and m_μ are the derivatives of the price in the exchange and the matching probability with respect to μ. Using (A.2) in (A.1), we obtain:

$$U_\mu = (1 - \kappa)p_\mu$$

(a) then follows from Proposition 2. □

A.2 Proof of Propositions 4 and 5

We start by characterizing interior equilibria that satisfy $\widehat{a} \geq \widehat{\mu}$.

Write $U(a|\tilde{a}, \mu)$ for an entrepreneur's expected payoff in period 0 when the measure of dealers is μ and when all other entrepreneurs are choosing origination effort $\tilde{a}$. If $\widehat{p}(\tilde{a}, \mu)$ ($p^d(\tilde{a}, \mu)$) is the competitive (*resp.* OTC) price that would prevail if there are μ dealers and the average action is $\tilde{a}$ and if $\tilde{a} \geq \mu$ then

$$
\begin{aligned}
U(a|\tilde{a}, \mu) &= \omega_e - \psi(a, \theta) + am(\tilde{a}, \mu) p^d(\tilde{a}, \mu) + (1 - am(\tilde{a}, \mu))\widehat{p}(\tilde{a}, \mu) \\
&= \omega_e - \psi(a, \theta) + \frac{a\mu}{\tilde{a}}(\kappa\gamma\rho + (1 - \kappa)\widehat{p}(\tilde{a}, \mu)) + \left(1 - \frac{a\mu}{\tilde{a}}\right)\widehat{p}(\tilde{a}, \mu). \tag{A.3}
\end{aligned}
$$

Since the average action satisfies $\tilde{a} \geq \mu$, then

$$\widehat{p}(\tilde{a}, \mu) = \rho + \frac{\tilde{a} - \mu}{1 - \mu}(\gamma - 1)\rho \tag{A.4}$$

Thus,

$$U(a|\tilde{a}, \mu) = \omega_e - \psi(a, \theta) + \frac{a\mu}{\tilde{a}}\kappa\rho(\gamma - 1)\left(\frac{1 - \tilde{a}}{1 - \mu}\right) + \rho + \frac{\tilde{a} - \mu}{1 - \mu}(\gamma - 1)\rho \tag{A.5}$$

Differentiating $U(a|\tilde{a}, \mu)$ with respect to a and setting $a = \tilde{a}$ in the FOC for a

$$\psi_a(\tilde{a}, \theta) = \frac{\mu}{\tilde{a}}\kappa\rho(\gamma - 1)\left(\frac{1 - \tilde{a}}{1 - \mu}\right) \tag{A.6}$$

which must characterize any interior symmetric equilibrium origination-effort response $\tilde{a}$ to a given measure of dealers μ, when it satisfies satisfies $\tilde{a} \geq \mu$.

On the other hand, if the average action is a and the number of dealers is $\tilde{\mu} \leq a$ then the gain of becoming informed by a dealer μ is given by:

$$\gamma\rho - p^d(a, \tilde{\mu}) - \varphi(\mu) = (1 - \kappa)(\gamma\rho - \widehat{p}(a, \tilde{\mu})) - \varphi(\mu) \tag{A.7}$$

As in equation (A.4), since $a \geq \tilde{\mu}$,

$$\widehat{p}(a, \tilde{\mu}) = \rho + \frac{a - \tilde{\mu}}{1 - \tilde{\mu}}(\gamma - 1)\rho$$

Since φ is strictly increasing, we obtain that given an average action $a > 0$ by originators, if the equilibrium number of dealers $\tilde{\mu}(a) \geq a$, then it must satisfy:

$$(1 - \tilde{\mu}(a))\varphi(\tilde{\mu}(a)) = (1 - \kappa)\rho(\gamma - 1)(1 - a) \tag{A.8}$$

Consider the following system of equations:

$$\varphi(\mu) = (1 - \kappa)(\gamma - 1)\rho \tag{A.9}$$

$$\psi_a(\mu, \bar{\theta}) = \kappa(\gamma - 1)\rho \tag{A.10}$$

Assumption A2 guarantees that there exists a unique $\bar{\mu}$ that satisfies (A.9) and Assumption A1 insures that there exists a unique solution $\bar{\theta}$ to this system of equations. For such $\bar{\theta}$, $\tilde{a} = \bar{\mu}$ is an equilibrium response by originators if there are $\bar{\mu}$ dealers (cf. equation (A.6)).

We are now ready to prove:

Lemma A.1 *Under Assumptions A1-A3, there exists a $\bar{\theta} > 0$ such that (i) for $\theta \leq \bar{\theta}$ there exists a unique equilibrium $(\widehat{a}(\theta), \widehat{\mu}(\theta))$ satisfying $\widehat{a}(\theta) \geq \widehat{\mu}(\theta) > 0$. In addition, $\widehat{a}_\theta < 0$ and $\widehat{\mu}_\theta > 0$. Furthermore, if $\theta > \bar{\theta}$ there exists no interior equilibrium $(\widehat{a}(\theta), \widehat{\mu}(\theta))$ such that $\widehat{a}(\theta) \geq \widehat{\mu}(\theta)$.*

Proof: Consider the following system of equations:

$$\psi_a(a, \theta) = \frac{\mu}{a}\kappa\rho(\gamma - 1)\left(\frac{1 - a}{1 - \mu}\right) \tag{A.11}$$

$$(1 - \mu)\varphi(\mu) = (1 - \kappa)\rho(\gamma - 1)(1 - a) \tag{A.12}$$

Any candidate equilibrium for a given θ, $(\widehat{a}(\theta), \widehat{\mu}(\theta))$, with $\widehat{a}(\theta) \geq \widehat{\mu}(\theta)$ must satisfy equations (A.11) and (A.12). Since $\frac{a}{1-a}\psi_a$ is a strictly increasing function of a that is onto $(0, \infty)$ there is a unique $a(\mu, \theta)$ that solves equations (A.11) with $\frac{\partial a}{\partial \mu} > 0$ and $\frac{\partial a}{\partial \theta} < 0$. Thus $\frac{(1-\mu)\varphi(\mu)}{1-a(\mu,\theta)}$ is a strictly increasing function of μ and there is a unique $\mu(\theta)$ that solves

$$(1 - \mu)\varphi(\mu) = (1 - \kappa)\rho(\gamma - 1)(1 - a(\mu, \theta))$$

Let $a(\theta) = a(\mu(\theta), \theta)$. The implicit function theorem applied to the system (A.11) and (A.12) guarantees that $a_\theta < 0$ and $\mu_\theta > 0$. In particular, $\mu_\theta - a_\theta > 0$. However at $\bar{\theta}$ equations (A.11) and (A.12) have a solution with $a = \mu$, so there are no solutions to (A.11) and (A.12) when $\theta > \bar{\theta}$ that satisfy $\mu \leq a$.

Notice that Lemma A.1 almost implies Propositions 4 and 5, except that the Proposition 4 claims that equilibrium is unique for $\theta \leq \bar{\theta}$, while the Lemma still allows for other equilibria with $\widehat{a} < \widehat{\mu}$. To rule out other equilibria for $\theta \leq \bar{\theta}$ we must examine candidate equilibria with $\hat{a} < \hat{\mu}$. Suppose there are μ dealers and the average action is $\check{a}$ with $\check{a} < \mu$. Then $m = 1$ and,

$$U(a|\check{a}, \mu) = \omega_e - \psi(a, \theta) + ap^d(\check{a}, \mu) + (1 - a)p(\check{a}, \mu)$$

$$= \omega_e - \psi(a, \theta) + a(\kappa\gamma\rho + (1 - \kappa)\widehat{p}(\check{a}, \mu)) + (1 - a)\widehat{p}(\check{a}, \mu), \tag{A.13}$$

Since there are more dealers than good projects, $\widehat{p}(\check{a}, \mu) = \rho$ and $p^d(\check{a}, \mu) = \rho + \kappa\rho(\gamma - 1)$.

An entrepreneur that chooses action a would obtain utility:

$$U(a|\check{a}, \mu) = \omega_e - \psi(a, \theta) + a\left(\rho + \kappa\rho(\gamma - 1)\right) + (1 - a)\rho$$

If $\check{a}$ is an equilibrium response by originators when there are μ dealers then,

$$\psi_a(\check{a}, \theta) = \kappa\rho(\gamma - 1) \tag{A.14}$$

Notice that Assumption A1 guarantees that for each θ there exists solution $\check{a}(\theta)$ with $\check{a}_\theta < 0$. In particular, in any equilibrium in which the average action exceeds the number of dealers, the average action is independent of the number of dealers.

Given the average action of originators a and $\check{\mu} > a$ dealers, recall that each dealer only finds a good project with probability $\frac{a}{\mu}$. Using our earlier observation that $\hat{p}(a, \check{\mu}) = \rho$ and, $p^d(a, \check{\mu}) = \rho + \kappa\rho(\gamma - 1)$, and the fact that a is necessarily equal to $\check{a}(\theta)$ we obtain that the marginal dealer $\check{\mu}$ must satisfy:

$$\varphi(\check{\mu}) = \frac{\check{a}(\theta)}{\check{\mu}}(1 - \kappa)(\gamma - 1)\rho. \tag{A.15}$$

The right hand side of this expression is the expected gross payoff of an informed dealer. Notice that since $\varphi_\mu > 0$ there exists at most one solution $\check{\mu}(\theta)$ to equation (A.15) for each $\check{a}(\theta)$. Furthermore, the implicit function theorem and Assumption A2 guarantee that this solution exists. If an equilibrium $(\hat{\mu}, \hat{a})$ with $\hat{\mu} > \hat{a}$ exists for a given θ, then the solution $\check{\mu}(\theta)$ of (A.15) is such that $\check{\mu}(\theta) > \check{a}(\theta)$.

Lemma A.2 *For $\theta \leq \bar{\theta}$ there does not exists any equilibria $(\hat{a}, \hat{\mu})$ with $\hat{\mu} > \hat{a}$.*

Proof: The implicit function theorem guarantees that $\check{a}_\theta < 0$, that $\check{\mu}$ is a smooth function of θ and furthermore:

$$sign(\check{\mu}_\theta - \check{a}_\theta) = sign(\check{\mu}\varphi_d(\check{\mu}) + \varphi(\check{\mu}) - (1 - \kappa)(\gamma - 1)\rho)$$

Notice that if $\check{\mu}(\theta) = \check{a}(\theta)$ then $\check{\mu}(\theta)$ and θ solve equations (A.9) and (A.10) . Thus $\theta = \bar{\theta}$ and since,

$$sign(\check{\mu}_\theta(\bar{\theta}) - \check{a}_\theta(\bar{\theta})) = sign(\check{\mu}\varphi_d(\check{\mu})) > 0$$

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we obtain that for $\theta \leq \bar{\theta}$, $\check{a}(\theta) > \check{\mu}(\theta)$. Thus for $\theta \leq \bar{\theta}$ there exists no equilibrium $(\hat{\mu}, \hat{a})$ with $\hat{\mu} > \hat{a}$. $\qquad \square$

Lemma A.2 completes the proof of Propositions 4 and 5.

A.3   Proof of efficiency results

Proof of Proposition 7: We already showed in the proof of Lemma A.1 that $\frac{\partial a}{\partial \mu} > 0$. The implicit function theorem yields

$$a_\mu (\mu, \theta) \equiv \frac{\partial a}{\partial \mu}(\mu, \theta) = \frac{\kappa \rho(\gamma - 1)(1 - a)^2}{(1 - \mu)^2(\psi_{aa}a(1 - a) + \psi_a)} \qquad (A.16)$$

Hence if $a(\mu, \theta) = \mu$, $\frac{\partial a}{\partial \mu}(\mu, \theta) < \frac{\kappa \rho(\gamma - 1)}{\psi_a} = 1$. Thus the function $a(\cdot, \theta)$ crosses at most once the 45 degree line, and there exists at most one $\tilde{\mu}(\theta)$ such that $a(\tilde{\mu}(\theta), \theta) = \tilde{\mu}(\theta)$.

Since $\psi_{aaa} \geq 0$, then for $\mu \in (0, \tilde{\mu}(\theta))$:

$$\frac{\partial^2 a}{\partial \mu^2} \sim -2(1 - a)(1 - \mu)^2(\psi_{aa}a(1 - a) + \psi_a) -$$

$$(1 - a)^2 \left[-2(1 - \mu)(\psi_{aa}a(1 - a) + \psi_a) - (1 - a)^2(1 - \mu)^2[\psi_{aaa}\tfrac{\partial a}{\partial d}a(1 - a) + (2 - 2a)\psi_{aa}\tfrac{\partial a}{\partial \mu}] \right]$$

$$< 2(1 - a)(1 - \mu)(\psi_{aa}a + \psi_a)(\mu - a) \leq 0,$$

Notice that $\tilde{\mu}(\theta)$ also satisfies

$$\psi_a(\tilde{\mu}, \theta) = \kappa \rho(\gamma - 1).$$

That is, $a = \tilde{\mu}$ is the optimal action for an originator that faces $\mu \geq \tilde{\mu}$ dealers and forecasts that all other originators choose $a = \tilde{\mu}$. In addition, it is obvious that our $\tilde{a}$ is the unique symmetric reaction function. $\qquad \square$

Proof of Proposition 8: For any $\mu < \tilde{\mu}(\theta)$,

$$W_\mu = \rho(\gamma - 1)\tilde{a}_\mu(\mu, \theta) - \psi_a(\tilde{a}(\mu, \theta), \theta)\tilde{a}_\mu(\mu, \theta) - \varphi(\mu)$$

and

$$W_{\mu\mu} = \rho(\gamma - 1)\tilde{a}_{\mu\mu}(\mu, \theta) - \psi_{aa}(\tilde{a}_\mu(\mu, \theta))^2 - \psi_a(\tilde{a}(\mu, \theta), \theta)\tilde{a}_{\mu\mu}(\mu, \theta) - \varphi_\mu(\mu)$$

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Concavity over the open interval $[0, \tilde{\mu}(\theta))$ follows from the concavity of $\tilde{a}$ with respect to μ and the fact that $\psi_a a(\mu, \theta) < \kappa\rho(\gamma - 1)$.

Furthermore, for $\mu > \tilde{\mu}(\theta)$ we have

$$W_\mu = -\varphi(\mu).$$

Thus W is also concave over the interval $\mu > \tilde{\mu}(\theta)$. However, at $\tilde{\mu}(\theta)$ the derivative from the left of W is

$$\rho(\gamma - 1)\tilde{a}_\mu(\mu, \theta) - \psi_a(\tilde{a}(\mu, \theta), \theta)\tilde{a}_\mu(\mu, \theta) - \varphi(\mu) > -\varphi(\mu),$$

the derivative from the right of W. Thus W is everywhere concave. $\square$

Proof of Proposition 9: Recall that, as seen in Proposition 8, W is concave in μ. Then it is enough to evaluate W_μ at $\mu = \widehat{\mu}$, the equilibrium measure of informed dealers for a given θ and show that there exists a unique $\widehat{\theta} \in (\underline{\theta}, \overline{\theta})$ such that $W_\mu > 0$ for $\theta \le \widehat{\theta}$ and $W_\mu < 0$ for $\theta > \widehat{\theta}$. First using the first order condition (A.11) in (A.16) we can write

$$a_\mu(\mu, \theta) = \frac{\kappa\rho(\gamma - 1)(1 - a)}{(1 - \mu)\left[a(1 - \mu)\psi_{aa} + \frac{\mu}{a}\kappa\rho(\gamma - 1)\right]} \tag{A.17}$$

The derivative of W with respect to μ, evaluated at $\mu = \widehat{\mu}$ is

$$W_\mu(\widehat{\mu}) = [\rho(\gamma - 1) - \psi_a] a_\mu(\widehat{\mu}, \theta) - \varphi(\widehat{\mu}). \tag{A.18}$$

Evaluating (A.11), (A.12) and (A.17) at $\mu = \widehat{\mu}$ substituting in (A.18) and noting that $\widehat{a} = a(\widehat{\mu}, \theta)$ we obtain

$$
\begin{aligned}
W_\mu(\widehat{\mu}) &= \rho(\gamma - 1)\left[1 - \kappa\frac{\widehat{\mu}(1 - \widehat{a})}{\widehat{a}(1 - \widehat{\mu})}\right]\frac{\kappa\rho(\gamma - 1)\frac{1 - \widehat{a}}{1 - \widehat{\mu}}}{\widehat{\mu}(1 - d)\psi_{aa} + \frac{\widehat{\mu}}{\widehat{a}}\kappa\rho(\gamma - 1)} \\
&\quad - (1 - \kappa)\rho(\gamma - 1)\frac{1 - \widehat{a}}{1 - \widehat{\mu}} \\
&= \rho(\gamma - 1)\left(\frac{1 - \widehat{a}}{1 - \widehat{\mu}}\right)[\Omega(\theta) - (1 - \kappa)], \tag{A.19}
\end{aligned}
$$

where

$$\Omega(\theta) = \rho(\gamma - 1)\left[1 - \kappa\frac{\widehat{\mu}(1 - \widehat{a})}{\widehat{a}(1 - \widehat{\mu})}\right]\frac{\kappa}{\widehat{a}(1 - \widehat{\mu})\psi_{aa} + \frac{\widehat{\mu}}{\widehat{a}}\kappa\rho(\gamma - 1)}. \tag{A.20}$$

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The sign of $W_\mu(\widehat{\mu})$ is thus determined by $\Omega(\theta) \gtrless 1 - \kappa$. We show that $\Omega_\theta < 0$, $\Omega(0) = \infty$ and $\Omega(\bar{\theta}) < 1 - \kappa$. First notice that we can write the function $\Omega(\theta)$

$$\Omega(\theta) = \left(\frac{\widehat{a}}{\widehat{\mu}}\right)\left[1 - \kappa\frac{\widehat{\mu}(1 - \widehat{a})}{\widehat{a}(1 - \widehat{\mu})}\right]\left(\frac{1}{1 + (1 - \widehat{a})\Lambda(\theta)}\right), \tag{A.21}$$

where we have used expression (A.11) and defined

$$\Lambda(\theta) = \frac{\psi_{aa}}{\psi_a}a. \tag{A.22}$$

Notice that given Assumption A1 and Proposition 5

$$\Lambda_\theta > 0 \qquad \frac{\partial}{\partial \theta}\left(\frac{1}{1 + (1 - \widehat{a})\Lambda(\theta)}\right) < 0 \qquad \frac{\partial}{\partial \theta}\left(\frac{\widehat{a}}{\widehat{\mu}}\right) < 0 \quad \text{and} \quad \frac{\partial}{\partial \theta}\left[1 - \kappa\frac{\widehat{\mu}(1 - \widehat{a})}{\widehat{a}(1 - \widehat{\mu})}\right] < 0,$$

which implies that $\Omega_\theta < 0$. Notice that as $\theta \to 0$

$$\lim_{\theta \to 0}\widehat{a}(\theta) = 1 \qquad \text{and} \qquad \lim_{\theta \to 0}\widehat{\mu}(\theta) = 0 \qquad \Rightarrow \qquad \lim_{\theta \to 0}\Omega(\theta) = \infty. \tag{A.23}$$

Finally when we evaluate $\Omega(\theta)$ at $\theta = \bar{\theta}$ then $\widehat{a} = \widehat{\mu}$ and therefore:

$$\Omega(\bar{\theta}) = (1 - \kappa)\left(\frac{1}{1 + (1 - \widehat{\mu})\Lambda(\bar{\theta})}\right) < 1 - \kappa. \tag{A.24}$$

In sum, $\Omega(\theta)$ is monotonically decreasing, $\lim_{\theta \to 0}\Omega(\theta) > 1 - \kappa$ and $\Omega(\bar{\theta}) < 1 - \kappa$. Thus there exists a unique $\widehat{\theta}$ such that $\Omega(\widehat{\theta}) = 1 - \kappa$. It follows from (A.19) that for $\theta < \widehat{\theta}$, $W_\mu > 0$ and $W_\mu < 0$ for $\theta > \widehat{\theta}$ which completes the proof. □

A.4   Proof of Propositions 10 and 11

The proof of Propositions 10 and 11 parallel the proofs in section A.2, by considering instead of equations (A.11) and (A.12), the system:

$$\psi_a(a) = \frac{\mu}{a}\kappa\rho(\gamma - 1)\left(\frac{1 - a}{1 - d}\right) \tag{A.25}$$

$$(1 - \mu)\varphi(\mu, \eta) = (1 - \kappa)\rho(\gamma - 1)(1 - a) \tag{A.26}$$

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