

# Compensating Financial Experts \*

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## **Compensating Financial Experts**

We propose a model in which financial firms compete for skilled workers who can be assigned to over-the-counter trading or to more socially productive activities. Because of negative externalities they impose on rival firms, traders earn more than the profits they generate for their employer and more than what non-traders with similar skills earn. The compensation gap between traders and non-traders disappears, however, when firms can easily interchange workers across tasks as high trader compensation indirectly drives non-traders' compensation up above their marginal product. We also discuss the impact of restricting compensation on the efficiency of the allocation of workers.

Keywords: Traders, Compensation, Rent-Seeking, Externalities, Financial Expertise

JEL Codes: G20, J31, J44

# 1 Introduction

Compensation in the financial sector has received a lot of attention in recent years. One particular topic that has stirred controversy is the high level of pay that Wall Street traders routinely collect from their employers. The consulting firm Johnson Associates reports that senior fixed-income traders typically earn \$930,000 per year in total compensation.<sup>1</sup> More impressive is the fact that, before the recent crisis, managing directors trading exotic credit derivatives were on average making \$3.4 million per year.<sup>2</sup> And since then, some Wall Street firms have gone as far as paying some of their highly specialized traders more than their CEO to ensure these employees would not be poached by one of the very few firms that compete for their services.<sup>3</sup> But what makes hiring and retaining these traders so important for financial firms? Is it simply the profits they generate for the firms that employ them? Or is trading different than most other tasks in ways that affect the compensation of workers? And how does the high compensation traders collect affect the labor market outcomes of other skilled workers in finance?

We address all these questions through a labor market model that highlights the importance for financial firms to hire highly talented individuals as traders by offering them seemingly excessive levels of pay. When the supply of skilled workers is sufficiently limited, the compensation traders are offered in equilibrium exceeds the profits they bring into their firm, as the full benefit of hiring a trader also includes the losses avoided by preventing trading counterparties from employing this worker when bargaining with the firm. Traders may also earn significantly more than non-traders with similar skills, but the gap disappears when firms can easily interchange workers across tasks as high trader compensation indirectly drives non-traders' compensation up above their marginal product. Thus, our model not only sheds light on the elevated levels of compensation we observe for highly specialized traders but also on those we observe for the financial sector in general, even after controlling for workers' ability levels (see Philippon and Reshef 2012).

Specifically, we model a financial firm as an entity that engages in two interlinked tasks that

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<sup>1</sup>See "Some Wall Street Year-End Bonuses Could Hit Pre-Downturn Highs" by Eric Dash in the November 5, 2009 issue of The New York Times.

<sup>2</sup>See "London trader bonuses top those in U.S. - survey" published March 26, 2007 on Reuters.com

<sup>3</sup>See "Traders Beat Wall Street CEOs in Pay" by Stephen Grocer and Aaron Lucchetti in the April 6, 2010 issue of The Wall Street Journal.

require the labor of financial experts. Firms compete for a limited supply of skilled workers they can deploy as *traders* or as *surplus creators*. Deploying some workers as traders allows a firm to obtain a more precise valuation of a security before agreeing to trade it with another firm in an over-the-counter (OTC) market. Deploying some workers as surplus creators, on the other hand, raises the total gains to trade that can be split between firms, which can naturally be interpreted as resulting from expanded efforts to locate counterparties with large private benefits from trading a particular security or to design new securities with improved risk sharing properties.

When the supply of workers is low enough that firms find it optimal to hire them all in equilibrium, traders earn a premium above the profits they bring into the firm, while surplus creators may earn less than traders even when all these experts have virtually identical skills. Intuitively, when trading expertise improves each firm's ability to extract the surplus in a *fixed-sum* trading game, hiring traders imposes a negative externality on rival firms (i.e., potential trading counterparties). This then leads to defensive bidding by firms that offer traders a premium over the profits they produce for the firm. Without such a premium, traders would be hired by rival firms, who would then use this additional expertise against the firm in question. Thus, traders are paid what we call a "*defense premium*" over their *internal* marginal productivity—they extract some rents for the losses the hiring firm would experience if they instead worked for one of its trading counterparties.

If instead hiring fewer traders did not imply that rival firms would employ more traders, offering such a defense premium would not be optimal for firms and traders would only be offered their reservation payoff. Our model therefore highlights a non-monotonic effect competition can have on compensation. The more firms there are competing for workers, the more excess demand there is for traders, and the higher the likelihood is that firms will have to offer a premium over workers' reservation payoffs. However, as the number of firms increases, the probability that a firm will trade with the firm that actually hires a given trader it covets becomes smaller, hence the cost of losing this trader to another firm and the compensation he is offered in equilibrium both decrease. High trader compensation arises in our model in markets for securities that only a small number of firms trade amongst themselves and that very few qualified experts are able to value. A good example would be the trading of interest-rate derivatives by U.S. banks, which is shown by Begenau,

Piazzesi, and Schneider (2012) to be overwhelmingly dominated by three dealer banks. They note that this concentration is also common for many classes of bonds. Our model could also speak to the compensation of traders in novel markets, such as the dealer markets for junk bonds in the 1980's and for collateralized debt obligations in the 1990's, when only a very small number of firms operated and very few workers had the required skills needed to produce or value the instruments.

Our model then shows that many other skilled workers in finance could see their compensation increased by the presence of these highly specialized traders. Equilibrium wages for non-traders, or surplus creators, are determined as follows. When workers are offered contracts that are tied to a particular task, surplus creators may appear to be “underpaid” in the sense that they earn less than what they produce for the firm and a lot less than what traders earn. The nature of the trading game allows hiring for surplus creation to have positive externalities, thus reducing the temptation for firms to hire surplus creators away from rival firms. The strict inequality of pay levels in this case is guaranteed by the optimal assignment of workers within the firm, in that all workers generate the same internal marginal productivity, but rival firms see more value in poaching a trader than a surplus creator. If, however, firms assign workers to tasks *after* the labor market has closed, the dispersion in compensation between traders and surplus creators disappears, with all workers now receiving the high, trader compensation. Financial firms thus need to pay all their employees far more than their internal marginal value and labor appropriates an abnormally large share of any surplus available. The importance of the ease at which workers can be reallocated between tasks in determining compensation should therefore be a consideration in light of recent policy debates surrounding the Volcker rule and the wisdom of separating proprietary trading activities from other activities within financial firms.

Although in our model the cost of acquiring financial expertise takes the form of a transfer from firms to workers, overinvestment in some activities still generates an inefficiency. The source of the inefficiency comes from the incentives firms face to assign workers to surplus extraction, rather than to surplus creation. This inefficiency arises even though traders are, in equilibrium, “overpaid” from the perspective of the firm; firms would prefer not to hire any trader at the prevailing compensation levels, but do so out of a desire to prevent other firms from hiring them instead. We discuss, at the

end of the paper, how limiting compensation in the sector, as done in the recent crisis, can improve or worsen the inefficient allocation of workers across and within firms.

*Discussion of the Literature.*

Our paper directly contributes to growing literatures on the size of the financial sector and the determinants of pay in the sector. First, Axelson and Bond (2009), Acharya, Pagano, and Volpin (2011), Thanassoulis (2011), and Bijlsma, Boone, and Zwart (2012) all share with our paper the objective of modeling a labor market to understand equilibrium compensation in finance. Acharya, Pagano, and Volpin (2011) study a negative externality that can arise in the market for managers when dynamic poaching prevents firms from learning the ability of their employees and leads to excessive risk taking. Thanassoulis (2011) highlights the negative externality that competition for workers can have on the financial stability of hiring firms as the resulting high wages lead to lower profits and higher default risk. Axelson and Bond (2009) and Bijlsma, Boone, and Zwart (2012) focus on the role moral hazard can play in determining optimal contracts in finance. Yet, none of these papers studies the role workers' expertise plays when financial firms interact with each others and trade securities among themselves as we explicitly model in our paper. We believe it is an important topic to study given the impact that trading expertise has on financial institutions' profits, and stability — for example, the financial services firm J.P. Morgan recently lost more than \$2 billion in one massive credit-default-swap trade (representing about half of the firm's estimated earnings for the quarter).<sup>4</sup>

An alternative model of high compensation is proposed by Rosen (1981) who aims to rationalize the skewed reward distributions we observe in industries like show business and professional sports. He shows that a “superstar” effect, defined as a convex revenue-to-talent function, can result from a technological indivisibility in the consumption of labor. Similar ideas are also found in models in which managerial talent is assortatively matched with firm productivity and size (see, e.g., Lucas 1978, Gabaix and Landier 2008). Philippon and Reshef (2012), however, show that these effects can only explain a small fraction of the elevated levels of compensation recently paid to

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<sup>4</sup>See “J.P. Morgan's \$2 Billion Blunder” by Dan Fitzpatrick, Gregory Zuckerman and Liz Rappaport in the May 11, 2012 issue of The Wall Street Journal.

financial executives. In any case, our goal here is not to argue that these effects do not play a role in explaining the *cross-section* of compensation in the financial sector, but rather to highlight that when firms bid strategically for the services of workers who impose negative externalities on rival firms, such as OTC traders, the *level* of compensation offered in equilibrium can *exceed* the value created, unlike what we observe in these models. This result and others we derive about the endogenous allocation of workers across tasks, some more socially productive than others, strike us as important in the context of recent debates on the optimal size and compensation in the financial sector.

As a result, our model is closer in spirit to papers studying the social efficiency of resources allocated to different sectors of the economy, including finance. Fishman and Parker (2010), Philippon (2010), Bolton, Santos, and Scheinkman (2011), and Glode, Green, and Lowery (2011) all propose mechanisms that cause some financial activities to exist at levels that exceed the social optimum.<sup>5</sup> The current model uses the same link between trading expertise and trading outcomes as in Glode, Green, and Lowery (2011), but the focus here is on firms' strategic interactions in the labor market and the allocation of talent within these firms, neither of which were considered there. This difference allows our model to make novel predictions about optimal compensation and allocation of workers in the financial sector. A few papers also study the decision by agents to perform rent-seeking activities; that is, activities for which the private rewards agents extract exceed the social value they create, just like informed OTC trading in our model. In particular, Murphy, Shleifer, and Vishny (1991) show theoretically that skilled workers prefer to enter sectors of the economy with the most elastic production function and empirically that economic growth is slower in countries where rent-seeking activities reward talent more than entrepreneurship does. Acemoglu (1995) solve for the equilibrium allocation of talent between a productive sector and a rent-seeking sector that impedes production. Rothschild and Scheuer (2011) instead focus on how taxation schemes can reduce workers' incentives to enter a rent-seeking sector. In these papers, a continuum of workers choose whether to become rent seekers or entrepreneurs, based on private rewards available from both types of careers. Overall, we are not aware of any paper, other than ours, that models

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<sup>5</sup>See also Hirshleifer (1971), Allen (1984), and Diamond (1985) who compare the private and social benefits of acquiring information when valuing and trading financial securities.

the competition by a few firms for the services of workers performing rent-seeking tasks. It is the defensive bidding by firms resulting from this competition that allows workers to collect a defense premium in equilibrium.

Our paper therefore contributes more broadly to the literature on personnel economics (see Lazear and Oyer 2011, for a survey) by showing that workers can earn a compensation premium when they are hired to perform tasks that impose negative externalities on rival firms. From a social point of view, this result can be alarming as socially unproductive tasks might become overly attractive for skilled workers. We also show that under some conditions the compensation premium can leak to other employees who are not hired to perform these rent-seeking activities but who do have the necessary skills, potentially making socially valuable activities unprofitable for firms because of their linkage with rent-seeking activities. We apply our model to specialized trading of hard-to-value securities because it represents one of the few, though not only, areas in which: (i) a small number of sophisticated firms compete for the service of workers whose unique skills are an important driver of firms' profits and (ii) a firm's success directly implies other firms' failure. The main intuition we develop could, nonetheless, apply to other settings with similar fixed-sum game features such as a divorce litigation where two ex-partners compete for the services of the best lawyer in town or a patent race where a few innovative companies fight for the services of gifted scientists. This intuition could even apply *within* one firm when a few divisions compete for the services of an internal pool of skilled workers or managers who would allow a division to attract a larger share of the firm's total capital budget if hired (see Scharfstein and Stein 2000, who study the rent-seeking opportunities that arise with internal capital markets, but without studying the labor market implications).<sup>6</sup>

Finally, our paper relates to the literature on auctions with externalities. Jéhiel, Moldovanu, and Stacchetti (1996), Caillaud and Jéhiel (1998), Jéhiel, Moldovanu, and Stacchetti (1999), and Jéhiel and Moldovanu (2000) all study the allocation of a good that imposes externalities.<sup>7</sup> Our model

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<sup>6</sup>See Bhagwati (1982), Baumol (1990), or Murphy, Shleifer, and Vishny (1991) for more examples of rent-seeking activities.

<sup>7</sup>Similar ideas were developed in the model by McCardle and Viswanathan (1994) in which a new firm chooses between directly entering an industry or bidding for the acquisition of an incumbent firm, all based on the negative externalities that rival firms generate in a Cournot product market.

differs from most of this literature by focusing on a fungible good (i.e., labor) that can be allocated either in a way that produces positive or negative externalities, as the externality depends on the equilibrium allocation of the good within a production process (i.e., trading or surplus creation). We also consider a disaggregated labor market rather than a monopolist selling a good, and are concerned with the allocation of the labor market input among firms. Most previous work focuses on the allocation of an indivisible good, except for Eso, Nocke, and White (2010), who consider an auction for shares of production capacity to be divided among firms. Their model, however, abstracts from the design of the auction for capacity, focusing on the efficient allocations, and considers Cournot competition in an oligopolistic product market, which generates substantially different implications than our labor model. Finally, our model allows us to show that the price paid by firms for the resources that impose negative externalities (i.e., the traders) can affect the price paid for other resources (i.e., the surplus creators) based on the interchangeability of these resources.

The rest of the paper is organized as follows. In the next section we describe the environment and how trading takes place among financial firms. Section 3 studies the labor market for financial experts when firms only employ experts to value and trade securities. We show that, when the supply of workers is low, traders can earn significantly more than the profits they generate for their firms. Section 4 generalizes the concept of financial expertise and considers the situation in which firms can hire experts as traders who compete with other firms for a fixed surplus or as non-traders who work on creating that surplus. Section 5 discusses the potential impact of restricting workers' compensation on the equilibrium allocation of workers and on welfare. The last section concludes. Proofs of propositions are relegated to the Appendix.

## 2 Model

Our model has two stages. In the first stage,  $N$  financial firms compete for the hiring of a fixed supply of risk-neutral workers whose expertise is needed to value financial securities. In the second stage, firms are randomly matched with each others to trade a security of uncertain value. This section describes the trading game when firms' expertise levels are taken as given, which is identical

to the trading game in Glode, Green, and Lowery (2011). The labor market for experts, which replaces the assumption of an exogenously given (low) cost for expertise from the earlier paper, is the main focus of the current paper and is studied in the following sections.

## 2.1 Trading Game

Each firm  $i$  meets a randomly assigned counterparty  $j$ , drawn with equal probability from a set of  $N - 1$  potential trading partners, to exchange a hard-to-value security through bargaining in an ultimatum game. One of the two parties is assigned the role of buyer, who we denote as firm  $j$  for now while firm  $i$  is the seller. The buyer's valuation of the security is  $v + 2\Delta$  and the seller's valuation is  $v$ . The private value component,  $2\Delta$ , is the source of the gains to trade and could represent a hedging need a firm faces, special access to a customer willing to overpay for the security, or any other source of value that is not shared by both parties. Without this, trade would break down in this setting due to the standard no-trade theorem. Gains to trade are common knowledge to both parties, but the common value  $v$  is uncertain. It is either high,  $v_h$ , or low,  $v_l$ , with equal probabilities. The spread  $v_h - v_l$  is fixed and common knowledge to all parties. It measures the amount of uncertainty about the value of the security and will play an important role in identifying the optimal mass of experts firms want to hire and the resulting labor market equilibrium.

For simplicity, we give the buyer all the bargaining power in an ultimatum game as he makes a take-it-or-leave-it offer to buy the security at a price  $p$ . The buyer is uninformed about the value,  $v$ , and views the two possible outcomes as equally likely. This dramatically simplifies the analysis while still allowing us to illustrate the incentives to hire experts because it eliminates the complications that arise when the first mover in the game is privately informed. Glode, Green, and Lowery (2011) allow for two-sided asymmetric information and show that the intuition from the trading game with one-sided asymmetric information holds under an appropriate equilibrium refinement—the main difference being that the restriction that adverse selection imposes on the levels of expertise that preserve efficient trade is tighter with two-sided asymmetric information.

The seller can use the experts hired in the first stage to gather information about the security before responding to the buyer's offer. Specifically, these experts can generate a signal,  $s_i \in \{H, L\}$ ,

that the value of the security is  $v_h$  or  $v_l$ . The probability that firm  $i$ 's signal is correct is  $\mu_i = \frac{1}{2} + e_i$ , where  $e_i \in [0, \frac{1}{2}]$  denotes the mass of experts hired by firm  $i$  — its expertise. Such expertise is assumed to be observable by trading counterparties, as hiring highly specialized traders away from another firm is usually a visible activity on Wall Street.

The uninformed buyer considers offering one of two potential prices: the lowest price a seller would accept after receiving a low signal and the lowest price a seller would accept after receiving a high signal. These prices are, respectively, the seller's valuations given a low signal:

$$\begin{aligned} p^L &= E(v \mid s_i = L) \\ &= (1 - \mu_i)v_h + \mu_i v_l, \end{aligned} \tag{1}$$

and given a high signal:

$$\begin{aligned} p^H &= E(v \mid s_i = H) \\ &= \mu_i v_h + (1 - \mu_i)v_l. \end{aligned} \tag{2}$$

If the buyer offers the low price  $p^L$ , trade only takes place when the seller observes a low signal. The buyer's expected payoff is then:

$$\frac{1}{2}(2\Delta + E(v \mid s_i = L) - p^L) = \Delta, \tag{3}$$

and the seller's expected surplus is his reservation price of zero.

If the buyer offers the high price  $p^H$ , trade always takes place, and the inefficient loss of gains to trade is avoided. The buyer, however, shares some of the surplus with the seller. The buyer's expected surplus is:

$$\begin{aligned} E(v) + 2\Delta - p^H &= 2\Delta - (v_h - v_l) \left( \mu_i - \frac{1}{2} \right) \\ &= 2\Delta - (v_h - v_l)e_i, \end{aligned} \tag{4}$$

and the seller's expected surplus at this price (unconditionally, across both possible realizations of his signal) is:

$$\begin{aligned}
E[p^H - E(v \mid s_i)] &= p^H - E(v) \\
&= (v_h - v_l) \left( \mu_i - \frac{1}{2} \right) \\
&= (v_h - v_l)e_i.
\end{aligned} \tag{5}$$

Thus, hiring experts who generate a more accurate valuation of the security may allow the seller to extract a higher price from the buyer in this situation, even though the seller does not act on his information once the offer is made. The buyer's choice between the two prices depends on which offer yields the highest expected payoff to him. Defining  $\sigma \equiv v_h - v_l$ , we compare (3) and (4) and observe that the buyer offers the high price  $p^H$  if and only if

$$2\Delta - \sigma e_i \geq \Delta \tag{6}$$

or, equivalently,

$$e_i \leq \bar{e} \equiv \frac{\Delta}{\sigma}. \tag{7}$$

As in Hirshleifer (1971), the social value of information in this simple trading game is zero when expertise is low enough, that is:  $e_i \leq \bar{e}$ . However, our trading game also allows for expertise to trigger adverse selection and destroy social value whenever  $e_i > \bar{e}$ . The impact expertise has on adverse selection will play a key role in determining firms' demand for workers.

### 3 Hiring Traders

In the first stage, firms try to hire experts to help value the security traded in the second stage. There is a mass  $\xi$  of skilled financial workers, also known as *experts*, with a reservation payoff of  $\beta$ . Hiring a mass  $e_i$  of workers yields a probability  $\mu_i = \frac{1}{2} + e_i$  that firm  $i$ 's signal is correct.

The labor market for experts works as follows. Each firm submits a single wage offer  $w_i$  (per

unit of workers) and a demand for workers  $x_i \in [0, 1]$ , representing the fraction of the  $\xi$  workers that the firm  $i$  is willing to hire at  $w_i$ . Workers are then allocated to firms based on wage, with the firm offering the highest wage receiving its full demand for workers, the firm offering the second highest wage receiving the maximum of its demand and the residual mass of workers available, and so forth. If two (or more) firms offer the same wage but there are too few workers available to satisfy their total demand, workers are evenly divided among the firms offering the highest wage whose total demand cannot be satisfied. In later sections, we introduce ex-post and ex-ante heterogeneity over workers and the labor market triggers, effectively, worker-by-worker competition. In the current setup, the simpler labor market is adequate as results are equivalent with a setup in which firms compete separately for each infinitesimal worker.

To ensure that some traders are hired in equilibrium, we impose the condition that their reservation payoff is low, that is:  $\beta \leq \frac{\sigma}{2}$ . Note that, for now, hiring experts only serves to appropriate a larger share of the surplus  $2\Delta$  and does not create social value—in fact, hiring too many might destroy some of the gains to trade. In the next section, we generalize our model of financial expertise by allowing firms to also hire workers to perform value-creating tasks. This assumption will trigger predictions about the allocation of experts within the financial sector and how the tasks they perform impact their compensation.

Before knowing its role as a buyer or as a seller, firm  $i$ 's expected payoff from participating in a trade with firm  $j$  is given by:

$$\frac{\sigma}{2}e_i I\left(e_i \leq \frac{\Delta}{\sigma}\right) + \frac{1}{2}\left[\Delta + (\Delta - \sigma e_j)I\left(e_j \leq \frac{\Delta}{\sigma}\right)\right], \quad (8)$$

where  $I(\cdot)$  is an indicator function. It is obvious from this equation that no firm acquires expertise above the level  $\bar{e} \equiv \frac{\Delta}{\sigma}$ , even if unemployed workers are willing to work for free. Specifically, we know from Glode, Green, and Lowery (2011) that if the cost of expertise is low enough, all firms want to acquire an expertise level of  $\bar{e}$ . This, however, is where the fixed supply of financial experts changes things and becomes important in the current paper. The supply  $\xi$  of experts determines how financial firms compete for these workers through compensation. With a labor market, financial firms now strategically interact with each other not only at the trading stage but also at the hiring

stage. The limits on firms' expertise that adverse selection imposes will imply equilibrium levels of (un)employment for financial workers.

Throughout the paper, we focus on symmetric equilibria for brevity. We first study the case in which the supply of workers binds, even when one firm decides to deviate from the equilibrium and hires no worker.

### 3.1 Low Supply of Experts

When the supply of workers is low, that is  $\xi < (N - 1)\bar{e} = (N - 1)\frac{\Delta}{\sigma}$ , the  $N$  firms compete in the hiring of workers as the limited supply of workers binds. Further, if one firm chooses not to hire any workers, all workers can still be employed by the remaining firms without generating adverse selection. Firm  $i$ 's expected payoff from trade is given by:

$$\Delta + \frac{\sigma}{2}(e_i - E[e_j]), \quad (9)$$

since all firms hire no more than  $\bar{e}$  traders, a condition that is optimal for all firms to satisfy and that ensures efficient trade. Equilibrium compensation is, obviously, affected by the binding supply of workers. However, our model highlights the impact of the fixed-sum game nature of trading on workers' compensation.

We now solve for the equilibrium demand for workers and their wages. If demand is fully satisfied for all firms, i.e.,  $x_i \leq \frac{1}{N}$ , the wage offered must be no more than  $\frac{\sigma}{2}$ , since this is exactly what one unit of traders produces for the firm. If the wage is above this level, there is a profitable deviation to hiring fewer workers because the demand by other firms is fully satisfied and the workers will remain unemployed. But, if the wage is  $\frac{\sigma}{2}$  or lower, then there is a profitable deviation to offering a slightly higher wage and demanding slightly more than a mass  $\frac{\xi}{N}$  of workers. The benefit of hiring extra workers now includes the fact that they no longer work against the firm itself. When the supply of workers is low, all experts not hired by firm  $i$  end up working for some of the firm's counterparties, making the expected payoff from trade:

$$\Delta + \frac{\sigma}{2} \left[ e_i - \left( \frac{\xi - e_i}{N - 1} \right) \right]. \quad (10)$$

Thus, the (per-unit) benefit from deviating to an infinitesimally higher wage and to an infinitesimally higher demand is  $\frac{\sigma}{2} \left(1 + \frac{1}{N-1}\right) = \frac{\sigma}{2} \left(\frac{N}{N-1}\right)$ , which is greater than  $\frac{\sigma}{2}$ . This deviation is profitable as long as the wage is less than  $\frac{\sigma}{2} \left(\frac{N}{N-1}\right)$ , so the equilibrium wage for traders can only be:

$$w^* = \frac{\sigma}{2} \left(\frac{N}{N-1}\right). \quad (11)$$

At such a wage, it is profitable for a firm to deviate to hiring fewer traders only if it anticipates that some of the workers the firm does not hire will remain unemployed. Thus, in any symmetric equilibrium, the equilibrium demand of traders must satisfy  $x^* \geq \frac{1}{N-1}$  because then each firm knows that deviating to hiring no traders would result in these traders working for rival firms. The marginal loss due to the hiring of traders by rival firms is positive only when the adverse selection limit on trading expertise does not bind. Hence, a deviation to hiring no trader and saving on the high wages that traders command cannot be profitable as long as the  $(N-1)$  rival firms are expected to hire all traders without triggering trade breakdowns when bargaining with the deviating firm. This condition is satisfied only when  $\xi \leq (N-1) \frac{\Delta}{\sigma}$ .

To summarize, the total benefit of hiring an additional trader depends on two things when the supply of experts is sufficiently low. First, by hiring an expert firm  $i$  improves its ability to value securities, which increases its bargaining power when responding to an offer. This benefit is worth  $\frac{\sigma}{2}$  to the firm. Second, by hiring an expert firm  $i$  ensures that this worker is not hired by potential counterparties and thus lowers their bargaining power when responding to an offer from firm  $i$ . This benefit is worth  $\frac{\sigma}{2} \frac{1}{N-1}$  to the firm. Hence, when hiring workers the firm does not only value the increase in its own trading expertise, but it also values the decrease in the expertise it needs to defend itself against. When the supply of workers is low enough given the number of firms, equilibrium compensation  $w^*$  is such that firms are indifferent about “poaching” workers from their counterparties, so it includes a defense premium. Traders are paid more than the value they create by improving their employers’ ability to value securities as they also extract some rents from the fact that hiring them lowers the ability of their employer’s counterparties.

### 3.2 High Supply of Experts

We now study two cases that can arise when the supply of workers is too large for the equilibrium above to exist, that is when  $\xi > (N - 1)\frac{\Delta}{\sigma}$ .

We start with the simple case in which the supply of workers is the highest, that is:  $\xi \geq N\frac{\Delta}{\sigma}$ . Then, the  $N$  firms do not hire all workers in equilibrium, even if workers are willing to work for free. The reason is that hiring more than a mass  $\bar{e} = \frac{\Delta}{\sigma}$  of workers within one firm would result in a separating equilibrium in the trading stage and destroy some of the gains to trade. Thus, the supply of experts does not bind, financial firms only hire a mass  $\bar{e}$  of workers by offering them the reservation payoff of  $\beta$ . A positive mass  $(\xi - N\bar{e})$  of workers remain unemployed.

The second, and more complex, case has the supply of workers being small enough that the  $N$  firms are still able to hire all available workers without destroying gains to trade, i.e.,  $\xi < N\frac{\Delta}{\sigma}$ . As with a low supply of workers, no equilibrium with some unemployment can exist because workers' reservation payoff is lower than their marginal productivity. The only wage that can make marginal deviations unprofitable is given by equation (11). However, at that wage it is optimal for a firm to deviate to hiring no traders. The wage in question makes firms indifferent between hiring or not these workers only if rival firms would hire and use against the firm all the workers that the firm does not hire. But if a firm does not hire any trader, its expected profit becomes:

$$\Delta - \frac{\sigma}{2} \frac{\Delta}{\sigma} = \frac{1}{2}\Delta, \quad (12)$$

which, in the current region of  $\xi$ , is greater than the expected profit from offering a wage  $w = \frac{\sigma}{2} \left( \frac{N}{N-1} \right)$  and hiring  $\frac{\xi}{N}$  of the workers:

$$\Delta - \frac{\sigma}{2} \frac{\xi}{N-1}. \quad (13)$$

Consequently, when  $(N - 1)\frac{\Delta}{\sigma} < \xi < N\frac{\Delta}{\sigma}$ , no symmetric pure strategy Nash equilibrium exists. This non-existence is driven by the property that the value of trading expertise increases linearly in the mass of experts hired as long as trade is efficient, but the payoff drops discontinuously when expertise crosses the boundary where trade breaks down with positive probability.

As we show in the Appendix, there exists a unique symmetric, mixed strategy equilibrium over this region and such equilibrium implies, effectively, a continuous transition from the high supply to the low supply pure strategy equilibria. For  $\xi$  close to  $(N-1)\frac{\Delta}{\sigma}$ , the mass of wage offers becomes arbitrarily concentrated around  $\frac{\sigma}{2}\left(\frac{N}{N-1}\right)$ , the pure strategy wage offer for  $\xi < (N-1)\frac{\Delta}{\sigma}$ . Similarly, as  $\xi$  converges to  $N\frac{\Delta}{\sigma}$ , the mass becomes arbitrarily concentrated around  $\beta$ , the equilibrium wage offer with a high supply of experts. In between, each firm demands a mass  $\frac{\Delta}{\sigma}$  of workers and mixes over an interval of wage offers  $w \in [\beta, \bar{w}]$ , where  $\bar{w}$  is defined as:

$$\bar{w} = \beta + \left(\frac{\sigma}{2}\left(\frac{N}{N-1}\right) - \beta\right) \left(N - \frac{\xi}{\frac{\Delta}{\sigma}}\right). \quad (14)$$

The equilibrium wage offer is thus effectively continuous between the two regions over which the wage is determined as part of a pure strategy Nash equilibrium. Traders extract part of the surplus they would have extracted if the supply of experts was lower and a symmetric pure strategy equilibrium existed. Also, since this unique candidate for a symmetric mixed strategy equilibrium does not exist outside the intermediate region, the symmetric pure strategy equilibria we derive above represent the unique symmetric equilibrium that exists in each respective region.

### 3.3 Discussion

Studying the effects of changes in the uncertainty  $\sigma$ , while fixing the number of firms  $N$  and the supply of workers  $\xi$ , highlights that highly volatile settings could be associated with lower demand for traders, but also with their higher compensation. A lower demand for traders usually means that these workers are less likely to earn a surplus over their reservation payoffs. However, conditional on seeing excess demand for workers, which then drives wages higher than  $\beta$ , traders' compensation increases as the value of the security becomes more uncertain. This seemingly counterintuitive relationship results from trading expertise becoming more valuable while its limits due to adverse selection also become more restrictive when uncertainty increases.

Overall, the degree of competition in the sector affects in a non-monotonic fashion the allocation and compensation of workers hired to perform tasks that impose negative externalities on rival firms. As we increase the number of firms but keep the supply of workers fixed, we are less likely

to observe unemployment of experts and more likely to see compensation premia offered to them. As  $N$  increases, it becomes easier to satisfy the condition necessary for the defense premium, that is:  $\xi \leq (N - 1)\frac{\Delta}{\sigma}$ . We also observe, however, that when the limited supply of experts binds, and therefore a premium is paid, the magnitude of this premium decreases with the number of firms. The reason for this is simple. As we increase the number of potential trading partners a firm has, hiring an expert still allows the firm to improve its own bargaining power but it also decreases the expected losses incurred by letting this expert work for another firm. At the margin, payoffs from trade are less sensitive to the exact allocation of workers, and these workers become less able to extract a compensation premium for the negative externality they impose. For a given  $\xi$ , workers' compensation is then non-monotone in the number of firms  $N$ . It is  $\beta$  for any  $N \leq \frac{\xi}{\epsilon}$ , then increases to  $\frac{\sigma}{2} \left( \frac{N}{N-1} \right)$  until  $N \geq 1 + \frac{\xi}{\epsilon}$ , and then decreases and converges toward  $\frac{\sigma}{2}$  as  $N$  grows.

Note that in a more general model in which the probability of firms trading with each other depends on the pairing, the term  $\frac{1}{N-1}$  in the defense premium would be replaced by the probability that a firm ends up trading with the second highest bidder for the services of a worker. For example, a large bank like Goldman Sachs would offer more to the specialized traders likely to defect to J.P. Morgan than to those likely to defect to a small hedge fund with which the bank trades less often. In the current model, we focus on the simple case in which firms meet randomly with equal probability, but ultimately the size of the negative externality a trader imposes on firms that fail to hire him is what determines his defense premium. Empirically, large defense premia can still exist in markets (e.g., securities, time periods, or regions) where the number of firms is large, as long as some firms with frequent trading interactions happen to target and bid for the same skilled workers.

The magnitude of the defense premium, which is also the difference between workers' compensation and marginal product, thus depends on how firms interact with each others in the industry. Changes in the structure of the industry (e.g., entries or exits) should impact the compensation of workers, even after controlling for their effects on firms' actual profits. In that sense, our implications differ from those in superstar models such as Rosen (1981) or Gabaix and Landier (2008) where production functions are independent across firms and agents (which makes sense in models

of generalist CEOs employed in various industries, but not if we are modeling specialized OTC traders working for a very small set of financial firms). There, the demand for the services of agents is convex in their quality, which results in the cross-sectional prediction that the best agents create, and extract, significantly more value than agents of slightly lower quality. In our model, instead, workers who impose negative externalities on rival firms can extract more than they create. This difference has important implications for recent policy debates on the optimal size of and compensation in the financial sector. Still, one could combine in a more complicated model the industrial organization modeled in the current paper with heterogeneous workers and firms in superstar models to generate even more cross-sectional variation in rewards to skill than in those models, thanks to the amplification effect that our defense premium has on compensation. We leave such endeavor for future work and instead focus, in the next section, on showing how firms' defensive bidding for traders can affect the compensation offered to workers with virtually identical skills, but who occupy different jobs.

## 4 Socially Valuable Expertise

We now generalize the concept of workers' expertise by allowing firms to assign some workers to a socially valuable task. We show that the “overcompensation” of traders not only survives this generalization, but it may also leak to non-traders. The mass  $\xi$  of experts can now be hired by the  $N$  financial firms to work on two different tasks—each worker can be hired to increase the accuracy of the firm's signal about the value of the security, which as before only affects the division of the surplus from trade between firms, or be hired to increase the size of the overall surplus available. This second task is socially valuable and could, for example, represent the creation of securities that allow for more efficient risk sharing or the search for better matching trade partners. Specifically, a firm will hire a mass  $e_i$  of workers to become trading experts who work on appropriating a larger share of the surplus  $2\Delta$  through bargaining and will hire a mass  $m_i$  of workers to become intermediation experts who work on increasing the available surplus  $2\Delta$ .

As before, employing a mass  $e_i$  of traders yields a probability  $\mu_i = \frac{1}{2} + e_i$  that firm  $i$ 's signal is correct. The ex-ante gains to trade when firm  $i$  proposes to buy from firm  $j$  are now denoted

by  $\Delta(m_i, m_j)$ , which depend on  $m_i$  and  $m_j$ , the number of experts the two counterparties hire to work on surplus creation. For simplicity, we use a reduced-form characterization of  $\Delta(m_i, m_j)$  and assume that it is strictly increasing and concave in its two arguments. We also assume that both the level of the gains to trade and the marginal productivity of surplus creation are more sensitive to the buyer's own expertise than to the expertise of the counterparty. First, we impose that  $\Delta_1(m, m) > \Delta_2(m, m)$  to ensure that each firm captures more benefits from its own effort than from the efforts of other firms (since in our model the gains to trade accrue to the firm who is selected as the buyer rather than the seller). Second, we impose that  $\Delta_{12}(m_i, m_j) = 0$ , which greatly simplifies the analysis in subsection 4.2 but is not necessary for our results.<sup>8</sup> In the more complicated two-task setup below, we focus on the case in which the supply of workers would bind even if one firm were to deviate from the equilibrium and hire no traders. This region is the analog to the region in which our one-task model produced its most novel and interesting predictions. Finally, to ensure that surplus creators and traders are hired in equilibrium, we impose the boundary conditions that  $\Delta_1(0, m_j) \rightarrow +\infty$  and  $\Delta_1\left(\frac{\xi}{N}, \frac{\xi}{N}\right) < \frac{\sigma}{2}$ .

The labor market operates as follows. There is a mass  $\xi$  of workers indexed by a continuous variable  $h \in [0, 1]$ , which will represent worker heterogeneity, and there is a parameter  $\kappa > 0$  that determines the importance of such heterogeneity. Values of  $h$ , the worker's type, are uniformly distributed. Heterogeneity is modeled as some additive, orthogonal (per-unit) benefit  $\kappa h$  of employing a worker as a surplus creator rather than as a trader. For example, some workers may be easier to train for certain tasks than others. Note, however, that nothing in our results depends on the specific role of worker heterogeneity. All that matters is that there is some ex ante difference between workers that makes some of them marginally more suited to one task versus the other. Furthermore, the equilibrium of the game with heterogeneity we describe in this section still exists in the limiting case with homogenous workers (where  $\kappa \rightarrow 0$ ), but directly analyzing a model in which  $\kappa = 0$  can become more involved for reasons that will become clear later.

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<sup>8</sup>This condition is sufficient for the existence of a symmetric, pure strategy equilibrium, but such an equilibrium would exist under much milder conditions.

## 4.1 Rigid Assignment of Workers between Tasks

In this subsection, we assume that each of the  $N$  financial firms submits for each type of worker  $h$  a wage offer, a job type, and a measure for the quantity of workers demanded:  $\{w_i(h), \tau_i(h), x_i(h)\}$ . Here,  $w_i(h) \geq 0$  is the wage offered by firm  $i$  to type  $h$  and  $\tau_i(h) \in \{\text{Surplus Creation, Trading}\}$  is the task to which type  $h$  will be assigned. For now, we assume that the task offered,  $\tau_i(h)$ , is binding, in the sense that if firm  $i$  offers to a worker of type  $h$  to become a trader for a wage of  $w_i(h)$ , then firm  $i$  cannot later reassign the worker to surplus creation, or vice versa, as a response to an unanticipated strategy by a rival firm. We relax this assumption in subsection 4.2, where the assignment of workers to the two tasks takes place after workers have been matched to firms through the wage bidding process. Finally,  $x_i(h) \in [0, 1]$  is the “fraction” of workers of type  $h$  that firm  $i$  is willing to hire at that wage.<sup>9</sup> Aggregate demand for workers of type  $h$  is then  $\sum_{i=1}^N x_i(h)$ . If this quantity is less than or equal to 1, all firms obtain the fraction of workers they desire. If aggregate demand exceeds the supply of workers, firms instead receive an allocation  $\gamma_i(h) \leq x_i(h)$  of workers of type  $h$ . The functions  $\{\gamma_i\}_{i=1}^N$  are determined as follows. Workers allocate themselves to the highest wage offers first. If several firms offer the same wage and demand more workers than available at that wage (which will be the case in equilibrium) the workers are divided evenly. No firm ever receives more workers than it requests.

A couple of examples of how the labor market works may prove helpful. If all firms offer the same wage schedule (i.e.,  $w_i(h) = w_j(h)$  for all  $i, j \in \{1, \dots, N\}$  and  $h \in [0, 1]$ ), and all firms choose  $x_i(h) = 1$  for all  $h$ , then  $\gamma_i(h) = \frac{1}{N}$  for all  $h$  and for all firms. If one firm (say,  $j$ ) were to deviate by offering a slightly higher wage than  $w_i(h)$  to each type  $h$  with  $x_j(h) = 1$ , then the deviating firm would hire all workers. Less trivially, if all firms except  $j$  offer a wage  $w_i(h)$ , but firm  $j$  offers a wage very slightly below  $w_i(h)$ , then firm  $j$  would still obtain  $\frac{\epsilon}{N}$  total workers if the other firms choose  $x_i(h) = \frac{1}{N}$  for all  $h$ , but would obtain no workers at all if  $x_i(h) \geq \frac{1}{N-1}$ . If *all* firms, including  $j$ , had offered  $w_i(h)$ , the allocation of workers would be the same regardless of whether all firms choose  $x_i(h) = \frac{1}{N}$  or  $x_i(h) = 1$ ; in both cases,  $\gamma_i(h) = \frac{1}{N}$ . Put simply, all demands for workers that can be satisfied are satisfied whenever possible. However, when aggregate demand cannot be satisfied,

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<sup>9</sup>Here, we use quotation marks to highlight that notions of quantity, such as a fraction, are imprecise in a setting with atomistic workers.

the demand of the highest bidding firms is satisfied first, then the demand of the second highest bidding firms is satisfied, and so on. As soon as the supply of remaining workers to be allocated to firms that are the  $n$ -th highest bidders is insufficient to satisfy their total demand, workers are evenly allocated among the  $n$ -th highest bidders. In the Appendix, we describe in greater details how labor is allocated for general actions by firms. Given our focus on symmetric equilibria, solving for the quantity of workers hired and the wages paid to workers is relatively simple, but we include general expressions in the Appendix for completeness.

While workers' heterogeneity described above allows for various distributions of type for the workers hired by each firm, it will not play a role in our analysis because we will focus on what happens as we let  $\kappa \rightarrow 0$ . Thus, when calculating payoffs, we will not account for the small benefits received from assigning a worker to surplus creation versus trading. The limit case as  $\kappa \rightarrow 0$  will highlight that differences between workers' abilities do not drive the wage dispersion we obtain in this model. The only role worker type plays is that it allows firms to predict which workers will be assigned to each job by other firms. Absent this dispersion, the equilibrium we identify still exists, but the analysis become more complicated as the final allocation of workers cannot be predicted by other firms. The pseudo "coordination device" that workers' heterogeneity represents is a simple way to ensure that our static model captures the idea that, in reality, firms are able to target specific workers they want to poach from rival firms and set contract terms based on the jobs these workers currently occupy for their employer.

We now describe how firms pick the jobs they offer to workers, given the distribution of workers they expect to hire. Before knowing its role as buyer or seller, firm  $i$ 's expected payoff from participating in a trade with firm  $j$  is:

$$\frac{\sigma}{2} e_i I \left( e_i \leq \frac{\Delta(m_j, m_i)}{\sigma} \right) + \frac{1}{2} \left[ \Delta(m_i, m_j) + (\Delta(m_i, m_j) - \sigma e_j) I \left( e_j \leq \frac{\Delta(m_i, m_j)}{\sigma} \right) \right], \quad (15)$$

where  $I(\cdot)$  is an indicator function. The highest bidder for a given worker can offer him a job in surplus creation or in trading. Since workers' heterogeneity, though potentially small, is non-degenerate, we can represent the optimal assignment of expertise within firm  $i$  as a threshold  $h_i^* \in [0, 1]$ , where the mass of experts assigned to trading in firm  $i$  becomes  $\int_0^{h_i^*} \gamma_i(h) \xi dh$ . In a

symmetric equilibrium with full employment,  $\gamma_i(h) = \frac{1}{N}$  for each firm  $i$ , so the total mass of workers that receive and accept a job offer as traders in a symmetric equilibrium is given by  $\frac{\xi}{N}h^*$ , and as surplus creators by  $\frac{\xi}{N}(1 - h^*)$ , where the threshold  $h^*$  is the same for all firms.

We can now study equilibrium employment and wages for surplus creators and traders. An equilibrium wage requires that no firm would strictly benefit from hiring more workers at the equilibrium wage. Any wage offer infinitesimally above the equilibrium wage would permit employment of more workers, so the condition for equilibrium is that no firm would prefer to hire a larger mass of workers for either task at the prevailing wage. This is, however, not a statement about the demand for workers in equilibrium,  $x_i(h)$ ; firms may still submit demands in excess of what they expect to receive on the equilibrium path, and in fact such demands play a crucial role in the equilibrium of the labor market. The requirement is rather that no firm would be willing to pay an infinitesimally higher wage in order to hire more workers of a given type.

It is immediate that wage dispersion among experts who perform the same task must vanish as  $\kappa \rightarrow 0$ . If some surplus creators, for example, were to earn more than others, then whichever firm is hiring these workers could hire fewer workers at this high wage and replace them by offering lower wage workers from other firms a slightly higher wage. Thus, in any equilibrium, for  $\kappa \rightarrow 0$ , at most two wage levels,  $w_m$  for surplus creators and  $w_e$  for traders, can coexist.

In equilibrium, the wage schedule depends on the total supply of experts. In the situation we focus on, the mass of available workers is sufficiently small that there is no unemployment and firms are indifferent between hiring the marginal expert for surplus creation or for trading.<sup>10</sup> Equilibrium wages differ depending on the task, even as we let workers' heterogeneity  $\kappa \rightarrow 0$ .

We first need to derive the optimal assignment of experts within a firm in a conjectured symmetric equilibrium with full employment. For the same reasons as before, we can focus on solving for a symmetric equilibrium where no breakdowns in trade occur. To find this equilibrium, we solve the maximization problem of a single firm, given that it is able to hire an equal fraction of each

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<sup>10</sup>In the interest of space, we omit analysis of the game with a high or intermediate supply of skilled workers; this analysis proceeds largely along the lines of the analysis of the case in which only traders are hired but is more involved because of considerations involving allocations of workers between tasks following deviations. As in the model with traders only, there is a pure strategy equilibrium with low wages when the supply of experts is high and only a mixed strategy equilibrium in the intermediate region for supply.

worker type. At this stage the wage bill is fixed (taking as given how much the firm needs to pay to get the conjectured mass of workers) and therefore does not enter into the firm's decision problem.

The total mass of workers hired by the firm is  $\frac{\xi}{N}$  by the conjecture that we are in a symmetric, full employment equilibrium. In that case, the threshold on  $h$  that differentiates workers who receive job offers as traders or as surplus creators is given by  $\bar{m} \equiv (1 - \bar{h})\frac{\xi}{N}$ , where  $\bar{m}$  satisfies:<sup>11</sup>

$$\Delta_1(\bar{m}, \bar{m}) + \kappa \bar{h} = \frac{\sigma}{2}. \quad (16)$$

The definition for  $\bar{m}$  implies that, when all firms hire a mass  $\bar{m}$  of workers as surplus creators, their marginal benefit is equal to that of hired traders, which is constant as long as efficient trade is preserved. Note here that the marginal benefit of hiring surplus creators does not account for the fact that larger gains to trade reduce adverse selection problems and allow for the hiring of more traders. Therefore, this definition for an optimal  $m_i$  will only be relevant when the limit on  $e_i$  for efficient trade does not bind.

When the supply of workers is low, i.e.,  $\xi < N \left[ \bar{m} + \frac{\Delta(\bar{m}, \bar{m})}{\sigma} \right]$ , and all workers are employed because  $\beta$  is low, each firm would like to hire a mass  $\bar{m}$  of workers as surplus creators and the remaining  $\frac{\xi}{N} - \bar{m}$  as traders. The supply of workers is small enough that all workers who are not hired as surplus creators are hired as traders and efficient trade still takes place. No allocation of workers other than  $h^* = \bar{h}$  can be sustained in a symmetric pure strategy equilibrium with a sufficiently low supply of workers, because it would allow for a strictly profitable reassignment of some hired workers. What remains to be derived are the wage and demand schedules that sustain this symmetric equilibrium assignment of workers for each firm. Since the intuition behind these derivations is similar to that developed in Section 3, except that now we add workers who create a positive externality rather than a negative one, we relegate these derivations to the proof of the proposition below, which can be found in the Appendix.

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<sup>11</sup>Throughout, we denote the partial derivative of a function with respect to its  $n$ th argument, evaluated at the point  $\{x_1, x_2, \dots\}$ , as  $f_n(x_1, x_2, \dots)$ .

**Proposition 1** For  $\xi < (N - 1)\frac{\Delta}{\sigma}$ , as  $\kappa \rightarrow 0$ , the unique symmetric pure strategy equilibrium with rigid assignment of workers has each firm hiring a mass  $\bar{m}$  of surplus creators at a wage of:

$$w_m^* = \max \left\{ \frac{\sigma}{2} - \frac{1}{N-1} \Delta_2(\bar{m}, \bar{m}), \beta \right\}, \quad (17)$$

and a mass  $\frac{\xi}{N} - \bar{m}$  of traders at a wage of:

$$w_e^* = \frac{\sigma}{2} \left( \frac{N}{N-1} \right). \quad (18)$$

In the limiting case in which workers' heterogeneity vanishes and the supply of workers is small, our model predicts that traders will be better compensated than surplus creators. Although surplus creators can also earn a premium over their reservation payoff  $\beta$ , their wage ends up being dominated by the wage paid to traders. This difference in wage is due to the fact that trading activities are part of a fixed-sum game and surplus creation is not. When assigning potential workers between the two tasks, firms equate the payoffs of allocating workers to surplus creation and trading. But when competing with rival firms for the hiring of workers, firms compare the payoffs of employing a worker versus having a competitor employ him. If the gains to trade a firm can extract increase when counterparties hire surplus creators, surplus creation becomes a public good and reduces firms' incentives to retain these workers. Comparatively, "poaching" experts who would have become traders for a counterparty is more profitable because of the fixed-sum game nature of trading. Outbidding other firms for the services of traders not only improves a firm's expertise in valuing a security but it also lowers the expertise of counterparties the firm trades with. The equilibrium assignment of experts across tasks is then inefficient, as some workers who could generate a social surplus through surplus creation are instead trying to appropriate a larger share of the surplus for the firm that employs them.

Note that the heterogeneity in workers' type delivers a unique equilibrium outcome in terms of worker allocation and wages in this setup. We have focussed our analysis on the limited case in which this heterogeneity converges to zero and the type of equilibria described above still exists. The crucial characteristic of these equilibria is that all firms anticipate and agree perfectly on

which workers will be assigned to each task. But when experts are ex ante identical, other types of equilibria may also emerge. Any such equilibrium exists only in the knife-edge case with ex ante homogeneity, which is not the case for the type of equilibria we focus on. These other equilibria are unlikely to describe an actual labor market for financial experts, in which firms can target specific workers they want to poach from rival firms and find it optimal to set contract terms based on the jobs these workers currently occupy for their employer.

## 4.2 Flexible Assignment of Workers between Tasks

Up to this point, we have assumed that workers are hired for a specific task. This assumption is realistic if, for example, the different tasks are carried out by different divisions within a firm. This environment is particularly relevant in finance where regulations such as Sarbanes-Oxley or the Volcker rule require stark divisions of tasks across units of a single firm. It is also appropriate if we view the static model as an abstraction for a richer, dynamic environment in which workers develop task-specific skills as they engage in one task or the other and firms pay them just enough to discourage poaching in the future.

We can, alternatively, allow firms to choose how to assign workers within the firm *after* the labor market has closed. In equilibrium, the assignment of workers between the tasks will be identical to what we derived earlier, since firms correctly anticipate how they and their opponents will assign workers when making offers in the labor market stage. Wages, however, will differ dramatically. We show this by establishing the existence, when the supply of workers is low enough, of a pure strategy, symmetric equilibrium. When experts are essentially perfect substitutes for each other, each non-deviating firm responds to poaching by a rival firm by moving the threshold for assigning workers to surplus creation so as to exactly offset the loss of surplus creators. Consequently, as  $\kappa \rightarrow 0$ , traders and surplus creators get paid the same wage, which includes the defense premium, in equilibrium.

**Proposition 2** For  $\xi < (N - 1)\frac{\Delta}{\sigma}$ , as  $\kappa \rightarrow 0$ , the unique pure strategy symmetric equilibrium with flexible assignment of workers has each firm hiring a mass  $\bar{m}$  of surplus creators and a mass  $\frac{\xi}{N} - \bar{m}$  of traders, all at a wage of:

$$w^* = \frac{\sigma}{2} \left( \frac{N}{N - 1} \right). \quad (19)$$

If  $\xi \leq (N - 1)\frac{\Delta(0,0)}{\sigma}$ , all firms make positive profits, net of compensation expenses.

With flexible assignment of workers, price dispersion collapses because, for small  $\kappa$ , deviating from the symmetric equilibrium by hiring more experts who would have otherwise been deployed as surplus creators by rival firms has the same effect on rival firms' trading expertise as deviating by poaching their traders. The near perfect substitutability of experts across tasks ensures that if a firm finds itself hiring fewer workers than expected due to a deviation by a rival firm, it will respond by reallocating workers until the returns to the two activities are again equalized. When  $\kappa > 0$ , this substitution effect is not complete; poaching workers expected to work as surplus creators in equilibrium from other firms will, in fact, lead to less surplus creation because any worker reassigned from trading to surplus creation to make up for the loss of surplus creators will have a lower idiosyncratic payoff for surplus creation than the poached workers. Thus, the level of surplus creation that equalizes the marginal value of surplus creation and the marginal value of trading will be lower. The wedge in compensation between surplus creators and traders diminishes, and even disappear completely, if  $\kappa \rightarrow 0$ , when workers can be redeployed within firms in response to a deviation by other firms. The implications of this new labor structure are markedly different than with rigid assignment of workers where traders, assumed to create no value, are paid a premium over what they bring in for the firm, and experts assigned to a socially productive task are paid less than their marginal product. When we allow for optimal reassignment of workers following a deviation, the presence of the fixed-sum trading task raises the wages of *all* experts.<sup>12</sup>

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<sup>12</sup>Given the constant returns to trading expertise and the decreasing returns to surplus creation expertise, the equilibrium wage all workers receive is the trader wage from earlier sections. However, if we complicated the model by assuming that returns to trading expertise are decreasing as well, the defense premium would be smaller than with rigid assignment as firms would then *partially* replace their poached traders with surplus creators. Such premium would, however, still apply to all workers for the same reasons as in the current setup.

### 4.3 Discussion

Obviously, in reality, distinctions between rent-seeking careers and surplus-creating careers are not as clean as in our model and most jobs involve different mixtures of these types of activities. The full separation of these two types of activities, however, allows our model to make stark predictions about the pecuniary incentives associated with the externalities workers impose on other firms. Specifically, the analysis of the two structures of the labor market has two potentially important implications which are outside of the model we consider but warrant comment.

First, if workers can take actions prior to the job market that influence their suitability for one type of activities versus the other (for example, through choice of classes in an MBA program or through other means to develop technical skills), the setup without immediate reassignment suggests that they would greatly favor investment in skills useful for surplus extraction rather than for surplus creation. The setup with optimal reassignment then ameliorates this effect as workers who develop skills associated with a socially useful task are now able to obtain some, if not all, of the the wage premium that develops from the existence of the fixed-sum game activities. The setup with optimal reassignment consequently generates a wage bill for the financial firms that is much higher than the wage bill without reassignment, even though the actual assignment of workers is identical. If financial firms face shocks to their capital, this higher wage bill could have a destabilizing effect on the financial sector.

## 5 Discussion on Restricting Workers' Compensation

Even though we model the cost of financial expertise for a firm as a transfer from its owners to its workers, our model also highlights that optimal competition for workers among firms can result in social inefficiencies. These inefficiencies originate from the incentives firms have to assign some workers to trading, and appropriate a greater share of the surplus, rather than to the tasks that create the actual surplus. We can use some of the model's insights to analyze the effects of a type of policy intervention that was suggested during the recent crisis: restricting the compensation a subset of financial firms can pay to their workers. Constrained firms could, for example, represent

the financial firms that require extraordinary assistance from the government or central bank in times of crisis and that may be forced to limit workers' compensation until they have repaid taxpayers. To ease the exposition, we discuss the impact of these policies on the aggregate level of social surplus that financial firms create with more involved derivations available on request from the authors.

The corrective effect of limiting compensation in the financial sector will vary with the level of the wage cap as well as with the number of firms it constrains. In many cases, restraining wages does not affect the aggregate surplus that financial firms create for the economy, as all it does is move some experts from constrained firms to unconstrained firms and possibly transfer some of the rents from workers to unconstrained firms. It does not make constrained firms (e.g., those that owe taxpayers money) better off nor does it increase the aggregate surplus. In fact, if the limit on workers' compensation is low enough to affect the wages of non-traders, it might actually reduce the surplus firms create as some workers hired to create more surplus in the unconstrained equilibrium are instead hired by unconstrained firms to work as traders in the constrained equilibrium. On the other hand, imposing a high wage cap that only restricts trader wages paid by constrained firms can, in some cases, reduce the inefficiencies highlighted in our model. When the supply of experts is large enough that unconstrained firms cannot hire all the workers who would be traders in the unconstrained equilibrium without violating the efficient trade condition imposed on trading expertise, the aggregate surplus can be greater with wage constraints than without wage constraints. The reason is that unconstrained firms now find it optimal to hire some or all of the experts who would otherwise work as traders for constrained firms and to assign some of them to surplus creation. Effectively, the wage constraints reduce the number of firms able to hire traders in equilibrium and unconstrained firms then hire more than a mass  $\bar{m}$  of surplus creators as they do not want to violate the condition that allows for efficient trade.<sup>13</sup>

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<sup>13</sup>Acharya, Pagano, and Volpin (2011) also find that imposing salary caps can improve social efficiency. In their model, salary caps serve to facilitate efficient risk-sharing between employees and firms, leading to better incentives and less excessive risk taking.

## 6 Conclusion

We propose a labor market model that highlights the importance for financial firms to retain their skilled traders. Firms bid for a limited supply of financial workers who can be assigned to information production in OTC trading or to more socially productive activities. When the supply of workers is sufficiently low, hiring an additional trader has two benefits. By hiring a trader a firm not only improves its own ability to value securities but also ensures that this worker will not be hired by trading counterparties. Equilibrium compensation for the trader is thus given by the difference between the firm's profits when hiring the worker and the firm's profits when losing the worker to a counterparty who is then better armed to bargain against the firm over the trade of a financial security. Because of the fixed-sum game nature of informed OTC trading among financial firms, traders extract some rents from the fact that hiring them lowers the expertise of counterparties the hiring firm trades with. When substituting these workers with the firm's other workers is easy, the presence of the fixed-sum trading task can raise the wages of *all* workers who could potentially be poached away from the firm, making the overall compensation of financial workers higher than their marginal product.

Finally, although we apply our model to specialized trading in finance, our paper also provides a new rationale for why other types of jobs garner seemingly high levels of compensation. For example, highly skilled litigation lawyers, professional athletes in team sports, and Silicon Valley software engineers are all the object of a few parties' competition for their services and their work imposes negative externalities on the parties that failed to hire them. If we believe that their talent is scarce, we should then not be surprised to observe that these workers earn what we call a defense premium.

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## A Appendix

### A.1 Equilibrium with Intermediate Supply of Workers

We solve for the mixed strategy equilibrium that prevails in the region where no symmetric pure strategy equilibrium exists. As in the main text, we focus on the case with  $\beta < \frac{\sigma}{2}$ .

We claim that the following is a symmetric, mixed-strategy Nash equilibrium. Each firm demands a mass  $\bar{e} = \frac{\Delta}{\sigma}$  of experts, which is the maximum quantity of experts a firm can hire without creating adverse selection. Using notation from the main text, this means that each firm demands a fraction  $x^* = \frac{\Delta}{\sigma}/\xi$  of the total supply of workers. The wage offer is random, as firms draw the offer  $w$  from a cumulative distribution function (CDF) given by:

$$G(w) = 1 - \left[ \frac{\left( \frac{\sigma}{2} \left( \frac{N}{N-1} \right) - \beta \right) (N\Delta - \xi\sigma) - \Delta(w - \beta)}{\left( \frac{\sigma}{2} \left( \frac{N}{N-1} \right) - w \right) (N\Delta - \xi\sigma)} \right]^{\frac{1}{N-1}}. \quad (20)$$

Since we consider only the range  $\xi \in ((N-1)\frac{\Delta}{\sigma}, N\frac{\Delta}{\sigma})$ , the CDF in (20) is strictly positive for  $w > \beta$ , equal to zero at  $w = \beta$ , and implies an upper bound on wage of

$$\bar{w} = \beta + \left( \frac{\sigma}{2} \left( \frac{N}{N-1} \right) - \beta \right) \left( N - \frac{\xi}{\frac{\Delta}{\sigma}} \right). \quad (21)$$

Thus,  $\bar{w} < \frac{\sigma}{2} \left( \frac{N}{N-1} \right)$  since  $\left( N - \frac{\xi}{\frac{\Delta}{\sigma}} \right) \in (0, 1)$  in the region of interest and  $G$  is a well defined distribution function for a mixed strategy with support  $w \in [\beta, \bar{w}]$ .

Given the demand for experts by all firms, a firm hires  $\frac{\Delta}{\sigma}$  if it turns out to outbid at least one rival firm and  $\xi - (N-1)\frac{\Delta}{\sigma}$  otherwise. The payoff for any wage offer  $w \in [\beta, \bar{w}]$  is thus:

$$\begin{aligned} & (1 - (1 - G(w))^{N-1}) \left[ \Delta + \frac{\sigma}{2} \left( \frac{\Delta}{\sigma} - \frac{N-2}{N-1} \frac{\Delta}{\sigma} - \frac{1}{N-1} \left( \xi - (N-1) \frac{\Delta}{\sigma} \right) \right) - w \frac{\Delta}{\sigma} \right] \\ & + (1 - G(w))^{N-1} \left[ \Delta + \frac{\sigma}{2} \left( \xi - (N-1) \frac{\Delta}{\sigma} - \frac{\Delta}{\sigma} \right) - w \left( \xi - (N-1) \frac{\Delta}{\sigma} \right) \right]. \end{aligned} \quad (22)$$

Differentiating the above expression with respect to  $w$  gives 0 for all  $w \in (\beta, \bar{w})$ , implying that the firm is indifferent among any interior wage offer. When the wage offer is either  $\beta$  or  $\bar{w}$ , the

firm obtains a mass of experts  $\xi - (N - 1)\frac{\Delta}{\sigma}$  and  $\frac{\Delta}{\sigma}$ , respectively, with probability 1. Payoffs are thus continuous around  $w = \beta$  and  $w = \bar{w}$ , and firms are indifferent between the endpoints of the distribution of wages and interior wage offers. It remains to check whether there is a profitable deviation outside of the interval  $w \in [\beta, \bar{w}]$  and whether there is a profitable deviation to a different quantity of demand for workers. First, it is immediate that there is no value to deviating to a higher wage offer, as an offer of  $w = \bar{w}$  guarantees that the firm can hire  $\frac{\Delta}{\sigma}$  workers with probability 1. Thus, any higher wage is wasted. A deviation to a wage lower than  $\beta$  implies that the deviating firm hires zero experts. But, for  $\beta < \frac{\sigma}{2}$ , always offering  $\beta$  instead dominates this deviation.

Next, we consider deviations on quantity. Any demand of workers between  $\xi - (N - 1)\frac{\Delta}{\sigma}$  and  $\frac{\Delta}{\sigma}$  makes the deviating firm strictly worse off since its realized expertise is unchanged when it turns out to offer the lowest wage of all firms, but it is lower otherwise. The workers who are not hired by the deviating firm now end up working for the firm that made the lowest wage offer, which implies a decrease in trading profits of  $\frac{\sigma}{2} \left( \frac{N}{N-1} \right)$  times the size of the deviation. But, since wage is lower than  $\frac{\sigma}{2} \left( \frac{N}{N-1} \right)$ , this is an unprofitable deviation. If the firm instead deviates by demanding fewer than  $\xi - (N - 1)\frac{\Delta}{\sigma}$  workers, the firm is then guaranteed to have its demand fulfilled. Therefore, the firm should choose to offer a wage of  $\beta$  because this is the lowest wage that workers will accept. But, we know that at a wage of  $\beta$ , which is lower than  $\frac{\sigma}{2}$ , the firm would strictly prefer to hire  $\xi - (N - 1)\frac{\Delta}{\sigma}$  workers rather than fewer workers. Hence, deviating to a demand for less than  $\xi - (N - 1)\frac{\Delta}{\sigma}$  workers generates a lower payoff than the payoff the firm gets on the equilibrium path. This confirms that no deviation on quantity can be profitable at any wage offer.

Thus, the posited  $G$  and demand of  $\frac{\Delta}{\sigma}$  is a mixed-strategy Nash equilibrium of the game, and in fact is the only symmetric Nash equilibrium. We have already shown that no symmetric pure-strategy equilibrium exists. Consequently, uniqueness can be proved using standard arguments that establish that the wage distribution must be atomless, and the fact that the posited distribution is the only distribution that satisfies the required indifference over wages. That is, any symmetric mixed strategy of the game must be the solution to a differential equation given by setting the derivative of equation (22) with respect to  $w$  equal to zero. The lower bound of the distribution of wage must be  $\beta$ ; otherwise, there would be a profitable deviation from the lowest wage offer to  $\beta$ .

These two conditions imply a unique solution for  $G$ , which also pins down a unique equilibrium since the demand posited is the only possible equilibrium demand.<sup>14</sup> Any higher demand would generate adverse selection losses whenever the demand is satisfied and would imply a reduced payoff. A lower demand could be improved upon for reasons symmetric to why there is no profitable deviation to a lower demand from the demand  $\frac{\Delta}{\sigma}$ .

These arguments also establish that the pure strategy equilibrium derived for the high and low supply of workers is the unique symmetric equilibrium. Otherwise, the mixed strategy equilibrium would have the same form described here. From equation (21), the upper bound on wages in the region where a pure strategy exists either falls below  $\beta$ , which implies zero employment and cannot be an equilibrium, or exceeds  $\frac{\sigma}{2} \left( \frac{N}{N-1} \right)$ , which also cannot be an equilibrium since any firm employing traders at such a wage would prefer to hire zero traders.

The mixed strategy equilibrium has the following characteristics. For  $\xi$  close to  $(N-1)\frac{\Delta}{\sigma}$ , the mass of wage offers becomes arbitrarily concentrated around  $\frac{\sigma}{2} \left( \frac{N}{N-1} \right)$ , the pure strategy wage offer for  $\xi < (N-1)\frac{\Delta}{\sigma}$ . Similarly, as  $\xi$  converges to  $N\frac{\Delta}{\sigma}$ , the mass becomes arbitrarily concentrated around  $\beta$ , the high expertise wage offer. In between, each firm mixes over the interval of wage offers. Thus, the equilibrium wage offer is effectively continuous between the two regions over which the wage is determined as part of a pure strategy Nash equilibrium.

## A.2 Formal Description of Labor Market in Section 4

Here, we present a formal description of the allocation of workers in the labor market. We describe how to calculate the distribution of wages and worker types within a firm for any arbitrary set of actions taken by firms. These quantities are necessary to calculate the payoffs for any set of strategies employed by firms. The payoffs simplify greatly both along the equilibrium paths studied and for all unilateral deviations from these equilibria, so the general expressions do not play a role in our main analysis. We include them here only for completeness.

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<sup>14</sup>To be strictly formal, we note that there are equilibria that differ from the posited equilibria for events that occur with zero probability. For example, playing  $G$  as posited with a demand of  $\frac{\Delta}{\sigma}$  whenever the wage offer is greater than  $\beta$ , but submitting a demand between  $\xi - (N-1)\frac{\Delta}{\sigma}$  and  $\frac{\Delta}{\sigma}$  when the wage offer turns out to be  $\beta$ , is also an equilibrium. As is standard, we ignore such alternative, but payoff equivalent, equilibria when describing the uniqueness of our equilibrium.

Allocation functions  $\gamma_i(h)$  depend on demand functions  $x_i(h)$  for firm  $i$  and worker type  $h$ . Since each worker type represents only an infinitesimal share of the mass of workers, the quantities demanded and allocated are meaningful only as they determine the total mass of workers allocated to a firm and the distribution of worker types within that allocation.

Now, we define the allocation of workers for any wage/demand pairs submitted by firms. This is simply the mathematical statement of the allocation rules presented in the main text.

The mass of workers of type less than  $y$  allocated to firm  $i$  is given by:

$$\int_0^y \gamma_i(h) \xi dh.$$

where  $\gamma_i(h)$  is given by:

- If  $\sum_{j=1}^N x_j(h) \mathbf{1}_{\{w_j(h) \geq w_i(h)\}} \leq 1$ , then  $\gamma_i(h) = x_i(h)$ . That is, if the total demand for workers by firms offering a wage greater than or equal to the wage offered by the firm in question leaves enough of the type of worker to satisfy the firm's demand, then that firm receives all the workers it demands.
- If  $\sum_{j=1}^N x_j(h) \mathbf{1}_{\{w_j(h) > w_i(h)\}} < 1$ , but  $\sum_{j=1}^N x_j(h) \mathbf{1}_{\{w_j(h) \geq w_i(h)\}} > 1$ 
  - If we define  $N_{w_i(h)}$  as the number of firms offering  $w_i(h)$  and  $x_j(h) > \frac{1 - \sum_{j=1}^N x_j(h) \mathbf{1}_{\{w_j(h) > w_i(h)\}}}{N_{w_i(h)}}$  for all  $j$  such that  $w_j(h) = w_i(h)$ , then  $\gamma_i(h) = \frac{1 - \sum_{j=1}^N x_j(h) \mathbf{1}_{\{w_j(h) > w_i(h)\}}}{N_{w_i(h)}}$ .
  - Otherwise, ordering the firms  $j$  offering  $w_j(h) = w_i(h)$  by  $x_j(h)$  such that  $x_1 \leq x_2 \leq \dots x_k \leq \dots$ , find the largest  $k$  such that  $k$  is the highest index assigned to a given demand and:

$$\frac{1 - \sum_{j=1}^N x_j(h) \mathbf{1}_{\{w_j(h) > w_i(h)\}} - \sum_{j=1}^k x_j(h)}{N_{w_i} - k} \geq x_k(h).$$

For  $j \leq k$  under the reordering,  $\gamma_i(h) = x_i(h)$ . For  $j > k$ ,  $\gamma_i(h)$  is equal to the left-hand side of the above inequality.

- For all other firms,  $\gamma_i(h) = 0$ . Supply is completely exhausted by firms offering higher wages, so these low bidders receive no workers.

These rules simply ensure that all demands that can be satisfied are satisfied, and that when a demand cannot be satisfied the remaining supply is allocated evenly among the high demanders. Any firm receiving its full allocation must receive less than the partial allocation for the firms that chose a higher demand, and that identical demands must receive identical allocations.

In order to calculate firms' payoffs, we need to be able to calculate the total wages paid to a worker of type less than  $y$ :

$$\int_0^y \gamma_i(h) w_i(h) \xi dh.$$

In equilibrium, there will be at most two levels of wages for the case with  $\kappa \rightarrow 0$ , so the calculation of the wage bill is quite simple. However, the expressions for the distribution of worker types and wages is necessary to fully specify the payoff functions of the game.

### A.3 Proofs of Propositions

**Proof of Proposition 1:** First, as explained in the body of the paper, the internal optimal assignment condition in equation (16) needs to be satisfied in equilibrium, hence  $h^* = \bar{h}$ . And similar to Section 3, if the demand for an expert expected to be hired as a trader is fully satisfied for all firms, i.e.,  $x_i(h) \leq \frac{1}{N}$ , the wage offered must be no more than  $\frac{\sigma}{2}$ , since this is exactly what the trader produces for the firm. But, if the wage is  $\frac{\sigma}{2}$  or lower, then there is a profitable deviation to offering a higher wage and demanding more than a mass  $\frac{\xi}{N}$  of that type of worker. This deviation is profitable as long as the wage is less than  $\frac{\sigma}{2} \left( \frac{N}{N-1} \right)$ , so the equilibrium wage schedule for traders must be:

$$w_e^* = \frac{\sigma}{2} \left( \frac{N}{N-1} \right), \tag{23}$$

and includes the defense premium we observed in the model with trading jobs only. With such wage schedule, it is profitable for a firm to deviate to hiring marginally fewer traders only if it anticipates that other firms would not hire anyone whom the firm in question does not hire. Thus, in any symmetric equilibrium, the total demand for traders must at least exceed supply, i.e.  $x^*(h) > \frac{1}{N}$  whenever  $h < \bar{h}$ .

The wage of the surplus creator, on the other hand, turns out to be potentially less than the value

he creates for the firm. If the wage offered to surplus creators is below  $\Delta_1(\bar{m}, \bar{m}) - \frac{1}{N-1}\Delta_2(\bar{m}, \bar{m}) + \kappa h$ , then firms will prefer to hire more workers of the types expected to engage in surplus creation by paying an infinitesimally higher wage. Assume for now that  $\beta$  is lower than this level, then if the wage exceeds this level, firms will want to reduce their employment of these workers. However, if the aggregate demand for workers equals their supply, a firm will have a profitable deviation unless the wage is the reservation payoff  $\beta$ . Hence, in equilibrium, demands for workers expected to become surplus creators, i.e., with  $h \geq \bar{h}$ , must exceed the supply and the wage must therefore be:

$$w_m^*(h) = \Delta_1(\bar{m}, \bar{m}) - \frac{1}{N-1}\Delta_2(\bar{m}, \bar{m}) + \kappa h. \quad (24)$$

These conjectured equilibrium wages rule out most possible discrete deviations by construction. First, at these wages hiring significantly more than the equilibrium levels of traders and surplus creators is not an attractive deviation given the concavity of  $\Delta(\cdot, \cdot)$  and the linearity of trading payoffs. Similarly, if a firm is thinking of hiring fewer surplus creators, the concavity of  $\Delta(\cdot, \cdot)$  and the restriction on the sensitivity of payoffs to own versus counterparty investments make this deviation strictly suboptimal. Now, given the linear payoff function from trading (as long as  $e_j \leq \frac{\Delta(m_i, m_j)}{\sigma}$ ), hiring fewer traders could imply that rival firms would hire all these otherwise unemployed traders and the savings in wages from this deviation would equal the loss in trading profits. Therefore, if not hiring these traders implies that rival firms will hire them and still satisfy the efficient trade condition on trading expertise, hiring fewer traders cannot be a profitable deviation.

However, if hiring fewer traders means that rival firms, who have excess demand for these workers, will end up with so many traders that the conditions for efficient trade are violated or that these workers will become surplus creators in rival firms or unemployed, then the deviation can be profitable. Hence, in equilibrium the demand for workers who become traders, those with  $h < \bar{h}$ , must be greater or equal to  $\frac{1}{N-1}$ , and the resulting level of trading expertise by rival firms cannot prevent efficient trade, i.e.,

$$\xi \leq N\bar{m} + (N-1)\frac{\Delta(\bar{m}, \bar{m})}{\sigma}. \quad (25)$$

This condition rules out the remaining discrete deviations and is more restrictive than the condition imposed on  $\xi$  earlier in the subsection.

In the case where  $\beta$  is greater than the equilibrium wage mentioned above for surplus creators, firms just pay surplus creators  $\beta$  without changing the allocation of workers. Equilibrium wages still fall below what surplus creators produce for the firm; wages are depressed by the fact that experts produce positive externalities when they are hired by other firms. Since a worker would exit the sector entirely in favor of his reservation payoff if the firm were to pay him a wage lower than  $\beta$ , then the incentive to decrease wages below  $\beta$  disappears. This holds as long as  $\beta \leq \frac{\sigma}{2}$ , which is the parameter range of interest for our model. ■

**Proof of Proposition 2:** We start by conjecturing a symmetric, pure strategy equilibrium with full employment where optimal expertise levels do not reach their adverse selection boundary. As before, the marginal value of surplus creation must equal the marginal value of trading, hence  $h^* = \bar{h}$ . To ensure that no firm deviates from this equilibrium, we must determine the allocation of workers by all firms after a deviation by one firm. This is the major distinction between this setup and the earlier one. It is immediate that, if a firm deviates to offering an infinitesimally higher wage to a small mass of experts of the type deployed as traders by other firms on the equilibrium path, the deviating firm will deploy the new experts it hires as traders. Furthermore, rival firms will choose exactly the same level of surplus creation as they would have without the deviation. Thus, traders must be paid a wage  $\frac{\sigma}{2} \left( \frac{N}{N-1} \right)$  to prevent poaching, as in all the previous setups.

On the other hand, a deviation to hiring a small mass of additional workers who would have been deployed as surplus creators by other firms results in a reassignment of workers both within the deviating firm and within the other  $(N - 1)$  firms. When the poached surplus creators come from the interior of  $[h^*, 1]$ , the deviating firm will assign the poached workers to surplus creation but will reassign some of the marginal surplus creators to trading. The firms facing the deviation, on the other hand, will respond by partially compensating for the lost surplus creators by moving marginal traders to surplus creation. Defining  $\tilde{h}$  as the new threshold for the deviator and  $\hat{h}$  as the new threshold for the non-deviators, the deviator and non-deviators solve the following two maximization problems in response to a deviation to poach an additional  $\varepsilon$  surplus creators from

other firms:

1) For the deviator:

$$\max_{\tilde{h}} \Delta(\bar{m} + \varepsilon - \frac{\xi}{N}(\tilde{h} - h^*), \bar{m} - \frac{\varepsilon}{N-1} + \frac{\xi}{N}(h^* - \hat{h})) + \frac{\sigma}{2} \frac{\xi}{N}(\tilde{h} - h^*) - \frac{\xi}{N} \int_{h^*}^{\tilde{h}} \kappa h dh + W, \quad (26)$$

where  $W$  is a constant that does not depend on  $\tilde{h}$ .

2) For each of the  $(N - 1)$  non-deviators:

$$\begin{aligned} & \max_{\hat{h}} \frac{1}{N-1} \Delta(\bar{m} - \frac{\varepsilon}{N-1} + \frac{\xi}{N}(h^* - \hat{h}), \bar{m} + \varepsilon - \frac{\xi}{N}(\tilde{h} - h^*)) \\ & + \frac{N-2}{N-1} \Delta(\bar{m} - \frac{\varepsilon}{N-1} + \frac{\xi}{N}(h^* - \hat{h}), \bar{m} - \frac{\varepsilon}{N-1} + \frac{\xi}{N}(h^* - \check{h})) \\ & + \frac{\sigma}{2} \frac{\xi}{N}(\hat{h} - h^*) - \frac{\xi}{N} \int_{h^*}^{\hat{h}} \kappa h dh + V, \end{aligned} \quad (27)$$

where  $V$  is a constant that does not depend on  $\hat{h}$ , and  $\check{h}$  denotes the reaction of the other non-deviating firms.

Recalling that  $\Delta_{12}(m_i, m_j) = 0$ , we can define  $\hat{\Delta}'(m) \equiv \Delta_1(m, m_j)$  and  $\hat{\Delta}''(m) \equiv \Delta_{11}(m, m_j)$  for all  $m_j$ . This produces the following system of first-order conditions:

$$\hat{\Delta}'(\bar{m} + \varepsilon - \frac{\xi}{N}(\tilde{h} - h^*)) + \kappa \tilde{h} = \frac{\sigma}{2} \quad (28)$$

$$\hat{\Delta}'(\bar{m} - \frac{\varepsilon}{N-1} + \frac{\xi}{N}(h^* - \hat{h})) + \kappa \hat{h} = \frac{\sigma}{2} \quad (29)$$

From equation (29), we can derive the rate at which  $\hat{h}$  changes with  $\varepsilon$  in a neighborhood of 0. This is given by

$$\frac{d\hat{h}}{d\varepsilon} = - \left( \frac{\frac{1}{N-1} \hat{\Delta}''(\bar{m})}{\frac{\xi}{N} \hat{\Delta}''(\bar{m}) - \kappa} \right). \quad (30)$$

As  $\kappa \rightarrow 0$ , then  $\frac{\xi}{N} \frac{d\hat{h}}{d\varepsilon} = -\frac{1}{N-1}$ , meaning that when experts are essentially perfect substitutes for each other every non-deviating firm responds to poaching by moving the threshold for assigning

workers to surplus creation so as to exactly offset the loss of surplus creators. Consequently, as  $\kappa \rightarrow 0$  traders and surplus creators get paid the same wage in equilibrium.

For  $\kappa > 0$ , a deviation to hire slightly more surplus creators leads to a partial offsetting of the loss of surplus creators by non-deviating firms, and thus the discount for surplus creators from the baseline setup survives partially. Poaching surplus creators rather than traders leads to a decrease in positive externalities and is thus easier to prevent. As a result, surplus creators' wages are adjusted downward to account for the fact that poaching them is not as attractive to rival firms as poaching traders because poaching surplus creators does not decrease trading expertise as much as poaching traders (and it also reduces the gains to trade generated by rival firms).

The conditions on wages described here must hold in any symmetric, pure strategy equilibrium, or a firm will have an incentive to deviate to hiring a slightly different level of experts. We have yet to rule out larger deviations. A firm may profit by reducing surplus creation sufficiently that the adverse selection boundary binds for the other firm. Once the adverse selection boundary binds, workers hired away from the firm deviating to lower employment are not deployed as traders, and thus the loss in profits from reducing employment decreases for large enough deviations. It is clear, however, that as long as the supply of workers  $\xi$  is sufficiently small relative to the initial level of gains to trade  $\Delta(0, 0)$ , the equilibrium demands for workers can sufficiently exceed their supply and no deviation by a single firm can lead to the adverse selection boundary binding for other firms. ■