

Compensating Financial Experts

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ABSTRACT

We propose a labor market model in which financial firms compete for a scarce supply of workers who can be employed as either bankers or traders. While hiring bankers helps create a surplus that can be split between a firm and its trading counterparties, hiring traders helps the firm appropriate a greater share of that surplus away from its counterparties. Firms bid defensively for workers bound to become traders, who then earn more than bankers. As counterparties employ more traders, the benefit of employing bankers decreases. The model sheds light on the historical evolution of compensation in finance.

COMPENSATION IN THE FINANCIAL sector has been a controversial topic in recent years. One particular group of workers who tend to earn extraordinary rewards for their expertise are traders in over-the-counter (OTC) markets. For instance, before the recent crisis, managing directors trading exotic credit derivatives earned on average \$3.4 million per year.¹ More recently, average salaries paid to various types of traders (e.g., commodities, securitized-products) grew by 10% in 2014 alone.²

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¹ See “London trader bonuses top those in U.S.—survey” published March 26, 2007, on Reuters.com.

² See “Traders’ salaries climb 10 percent in 2014” by John D’Antona Jr. in the August 2014 issue of *Traders Magazine*.

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In this paper, we propose a labor market model that highlights the importance for financial firms of hiring highly talented individuals as OTC traders by offering them seemingly excessive levels of pay. We assume that financial firms compete to hire a scarce supply of skilled workers who can be employed as either bankers or traders. A banker helps his employer identify profitable investment opportunities, while a trader helps his employer value securities backed by the investments of other firms, in case these firms need to trade the securities for liquidity reasons. Thus, deploying workers to banking raises the surplus that can be split between a firm and its trading counterparties, whereas deploying workers to trading allows the firm to appropriate a larger share of that surplus.

High compensation for traders arises in our model despite the presence of two factors usually presumed to mitigate it. First, we assume that the employment of traders is concentrated among a few firms, consistent with evidence of concentrated trading in derivative markets by Cetorelli et al. (2007), Atkeson, Eisfeldt, and Weill (2013), and Begenau, Piazzesi, and Schneider (2013). Second, we assume that traders are hired only to strengthen their employers' position when bargaining with other firms over a fixed pie (hence creating no social value), consistent with Wall Street insiders describing quantitative trading as "us against them" and "sharks devouring one another" (Patterson (2012, p. 17 and 181)). Our model highlights how these factors might have actually caused rather than mitigated the high levels of compensation observed in the financial sector.

Since a trader's expertise improves his employer's ability to appropriate the surplus in a zero-sum trading game, hiring traders imposes something akin to a negative externality on future trading counterparties (in the sense that the private benefit of such action exceeds its social benefit). This leads to defensive bidding by firms that offer traders what we call a "*defense premium*" above their internal marginal product. Without such a premium, the traders a firm targets would be hired by rival firms (i.e., potential trading counterparties) and their expertise would be used against the firm in question. Notable, albeit extreme, examples of traders whose hiring was detrimental to rival firms include Josh Levine, who pioneered high-frequency trading in the early 1990s and allowed the proprietary trading firm Datek to "out-trade the very best in the business. They could grind Goldman to a pulp. They could make Morgan cry," or algorithmic trader Haim Bodek, whom UBS poached from Goldman Sachs in the early 2000s "to build an options-trading desk that could go head-to-head with the likes of Hull [Goldman's electronic trading arm]" (Patterson (2012, p. 100 and 32, respectively)).

Workers deployed as bankers, however, do not earn as much as traders. When hit by liquidity shocks, firms need to sell the profitable investments their bankers have identified, sometimes at a discount, allowing their counterparties to appropriate part of the surplus these bankers helped create. As a result, hiring bankers is similar to providing a public good and bankers earn less than traders. Furthermore, as the number of traders employed by trading counterparties increases, the benefit of employing bankers decreases, resulting

in even lower compensation for bankers in equilibrium. In contrast, as firms employ more bankers and find more profitable investments, the benefit of employing traders who will later value securities backed by these investments increases, resulting in even higher compensation for traders. Thus, not only are two virtually identical workers paid very different wages when they occupy different jobs, but the compensation of a given type of worker is also greatly affected by the employment of a different type of worker by rival firms.

Using a parameterized example, we also show that the average compensation earned by financial workers can be increasing in the supply of workers. This result may help explain why average salaries in finance have continued to increase in recent decades (see Philippon and Reshef (2012) and Célérier and Vallée (2015)), despite the flood of workers entering the sector (see Goldin and Katz (2008) and Roose (2014)). Our model can also shed light on the apparent reversal in the types of occupations that have been considered the most lucrative over the years. Historically, investment banking jobs were associated with the highest compensation levels, but recently, as the finance industry has grown, highly specialized traders have taken over the highest echelons of the wage distribution (see, e.g., Options Group (2011)).³

Our paper contributes to the burgeoning literature analyzing the compensation of financial workers, which amounts to 47% of Wall Street firms' revenues according to the Office of the New York State Comptroller (2014). For instance, Thanassoulis (2012), Acharya, Pagano, and Volpin (2016), and Bénabou and Tirole (2016) highlight negative externalities that competition for workers has on financial stability, risk-taking, and work ethics, respectively. None of these papers, however, studies the role that workers' expertise plays when firms interact with each other, as we do in our model. Our model predicts that high compensation should arise in markets where most of the trading occurs among a small set of firms. For example, Begenau, Piazzesi, and Schneider (2013) show that three dealer banks overwhelmingly dominate the market for interest rate derivatives, whose total notional value surpasses \$160 trillion. From a comparative perspective, the trading concentration of U.S. interest rate options is about two-thirds greater than that of foreign exchange options, as measured by Cetorelli et al. (2007) using the Herfindahl index. Consistent with the arguments in our paper, traders in the former market earn, on average, roughly twice as much as those in the latter market (see Options Group (2011)).

Bijlsma, Boone, and Zwart (2012), Biais and Landier (2013), and Axelson and Bond (2015) emphasize the role that moral hazard plays in determining optimal contracts in finance. Although these theories help rationalize many of the unusual contract features observed in the financial sector, Célérier and Vallée (2015) argue that talent plays a more important role than moral hazard problems in driving the *level* of compensation in the sector. Using data from a survey of French engineering school graduates, they find that the large

³ Options Group is an international executive-search company that advises banks on compensation, and its executives generously agreed to provide us with compensation statistics and to discuss the ideas in the paper.

average compensation premium collected by financial workers is driven mostly by the high end of the skill distribution, in line with talent-based models like that in our paper or in Thanassoulis (2012) and Acharya, Pagano, and Volpin (2016). Another talent-based model of high compensation is proposed by Rosen (1981) to rationalize the skewed reward distributions in some industries like the entertainment sector. 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. Philippon and Reshef (2012), however, show that these effects only explain a small fraction of the elevated levels of compensation recently paid to financial executives on Wall Street. Moreover, the huge compensation gap we describe above between interest rate option traders and foreign exchange option traders would be hard to rationalize using realistic arguments centered on differences in the scalability of trading these types of securities, or in agency conflicts for that matter. Our paper provides a simple explanation for this gap that centers on trading concentration.

More broadly, our paper contributes to the growing theoretical literature that studies the social efficiency of resource allocation in the financial sector, which accounts for 9.1% of U.S. GDP according to Shiller (2012) (see also Greenwood and Scharfstein (2013)). From a social welfare perspective, the compensation paid to financial experts is simply a transfer from firms to workers, but the allocation of workers to trading rather than to banking represents a social inefficiency in our model. Unlike traders, hiring bankers is considered socially valuable in our model as bankers increase the aggregate surplus that can be split among firms and workers. Since bankers help their employers create the securities that OTC traders may later value and trade, they can be thought of as the mortgage originators who help people and corporations acquire real estate, as the financial engineers who design new securities that allow corporations to hedge currency or interest rate risk, or as the investment bankers who advise those same corporations about their hedging needs. None of our theoretical results on talent allocation and compensation would change if the surplus was instead created solely at the expense of agents not currently in our model (e.g., retail investors or nonfinancial firms), but if we interpret the surplus created by banks as socially beneficial, our model shows how the private benefits of social surplus creation can be dampened by the surplus appropriation efforts of rival firms.⁴ Glode, Green, and Lowery (2012), Bolton, Santos, and Scheinkman (2016), Biais, Foucault, and Moinas (2015), and Fishman and Parker (2015) also study new mechanisms that cause some financial activities to reach levels that

⁴ A few other papers study the decision to perform rent-seeking activities in more general terms, that is, activities for which the private rewards that agents extract exceed the social value they create, just like informed OTC trading in our model (e.g., Murphy, Shleifer, and Vishny (1991), Acemoglu (1995), Philippon (2010), Lockwood, Nathanson, and Weyl (2015), Rothschild and Scheuer (2016)). Unlike these papers, we model the competition by a few firms for the services of workers and it is the defensive bidding by firms resulting from this competition that allows workers to collect a defense premium in equilibrium. Not only do traders earn more than what they contribute to society, as is standard in the rent-seeking literature, but they also earn more than what they contribute to their rent-seeking firms.

exceed the social optimum, but they do not model the strategic hiring decisions made by financial firms, thus shutting down the labor market implications we emphasize in this paper.

Finally, the externalities that workers impose on rival firms in our model link our paper to the literature on the optimal design of auctions for goods with externalities (e.g., Jéhiel, Moldovanu, and Stacchetti (1996) and Esö, Nocke, and White (2010)).⁵ These papers, however, neither study the allocation of resources across positive- and negative-externality activities nor do they study the related interactions that drive our results on the relative compensation of these activities. Our model also provides microfoundations for these externalities that are specific to the financial sector, allowing us to study how labor market outcomes can be influenced by financial firms' investment opportunities, liquidity needs, and trading networks.

The rest of the paper is organized as follows. In the next section, we describe the investment and trading activities that financial firms perform in our model. Section II illustrates why traders earn high salaries by assuming that firms can only hire traders. Section III generalizes the concept of financial expertise and allows firms to deploy workers as traders, who help their employers compete with rival firms for a fixed surplus, or as bankers, who create that surplus in the first place. Section IV highlights our model's implications for the historical evolution of compensation in the financial sector. Section V discusses the robustness of our results to various extensions. Section VI concludes. Proofs of propositions are presented in Appendix A.

I. A Model of the Financial Sector

Our model has three stages: the labor market stage, the investment stage, and the trading stage. In the first stage, $N(\geq 2)$ financial firms compete to hire a fixed supply of risk-neutral workers whose expertise is needed to identify and value investment opportunities. We analyze this labor market stage in detail later; for now we focus on the investment and trading stages, taking firms' levels of expertise as given.

In the investment stage, each firm searches for a profitable investment opportunity whose final value v is uncertain and depends on a state of the world to be realized at the end of the trading stage. With probability π_i , firm i is able to find an investment opportunity whose realized value will be $v_l (> 0)$ if state l is realized or $v_h (> v_l)$ if state h is realized. These two states are assumed to be equally likely, and thus the expected value of the investment during the investment stage is $E[v] = \frac{v_h + v_l}{2}$. With probability $(1 - \pi_i)$, however, firm i fails to identify such an opportunity and makes no investment.

The trading stage then proceeds as follows. Before v is realized, firms may be required, due to liquidity concerns, to sell their investments in an OTC

⁵ See also McCardle and Viswanathan (1994), in which a new firm chooses between directly entering an industry or bidding for the acquisition of an incumbent firm and such a decision is based on the negative externalities that rival firms generate under Cournot competition in the product market.

market. Specifically, $\frac{N}{2}$ firms are hit by a liquidity shock that forces the subset of those firms that made an investment in the earlier stage to sell a security backed by that investment. In the spirit of Diamond and Dybvig (1983), these $\frac{N}{2}$ firms can be thought of as “early consumers” in need of liquidity at the start of the trading stage and for which any investment that pays off at the end of the trading stage is worth zero. Each firm that made an investment and that is now hit by a liquidity shock is then randomly matched with one of the $\frac{N}{2}$ firms not hit by a liquidity shock to bargain over the trade of that investment. We assume that the firm selling its investment quotes a take-it-or-leave-it offer price p to the potential buyer with whom it is matched. The prospective buyer then observes a private signal s about the realization of v . The probability that firm i 's signal is accurate is given by $P(v = v_h | s = v_h) = P(v = v_l | s = v_l) = \frac{1}{2} + \theta_i$, where $0 \leq \theta_i \leq \frac{1}{2}$. (Note that $\theta_i = 0$ would imply that the signal is uninformative since we have two equally likely outcomes.) To avoid issues associated with signaling, we assume the proposing firm does not receive a signal about v and expects the two outcomes to be equally likely (we discuss the robustness of our results to signaling problems and many other extensions in Section V). Finally, we assume that π_i and θ_i , which we interpret below as firm i 's expertise levels, are observable by trading counterparties. Observable expertise greatly simplifies our analysis and is consistent with the fact that hiring experts away from rival firms tends to be a visible activity on Wall Street.⁶

If firm j is hit by a liquidity shock and tries to sell its investment to firm i , firm j optimally chooses to quote one of two prices: the highest price a buyer would accept to pay after receiving a bad signal and the highest price a buyer would accept to pay after receiving a good signal. If we define $\sigma \equiv \frac{v_h - v_l}{2}$, these prices can be, respectively, written as

$$p_l \equiv \left(\frac{1}{2} + \theta_i\right) v_l + \left(\frac{1}{2} - \theta_i\right) v_h = E[v] - 2\sigma\theta_i \quad (1)$$

and

$$p_h \equiv \left(\frac{1}{2} - \theta_i\right) v_l + \left(\frac{1}{2} + \theta_i\right) v_h = E[v] + 2\sigma\theta_i. \quad (2)$$

The buyer is only willing to pay the higher price p_h if his signal is good, which occurs with probability $\frac{1}{2}$. However, he is willing to pay the lower price p_l regardless of his signal, which means with probability one. Thus, the seller chooses to quote the low price, p_l , whenever

$$E[v] - 2\sigma\theta_i \geq \frac{1}{2}(E[v] + 2\sigma\theta_i), \quad (3)$$

⁶ For example, Options Group's annual compensation reports list key personnel moves that occurred in that year. *Traders Magazine* also provides similar information on a monthly basis in a section titled “Moves, Adds, & Changes.” See, for example, “UBS hires new equity co-heads” by John D'Antona Jr. in the May 2015 issue.

which can be rewritten as

$$\theta_i \leq \frac{E[v]}{6\sigma}. \tag{4}$$

Since, by construction, $(\frac{1}{2} + \theta_i)$ is a probability and cannot exceed one, the following assumption guarantees that inequality (4) is satisfied for any pair of firms:

ASSUMPTION 1: (*Positive benefit of information*): $E[v] > 3\sigma$.

This parametric condition will greatly simplify our derivations in the next sections as firms will always benefit from improving the informativeness of their signal. Without this condition, adverse selection concerns would dampen the incentives to increase θ_i , although the results we derive later for the labor market for financial workers would survive as long as the supply of workers is small enough.

When hit by a liquidity shock, firm j collects $E[v] - 2\sigma\theta_i$ if it has an investment and sells it to firm i . Firm i , on the other hand, pays $E[v] - 2\sigma\theta_i$ to firm j in exchange for an investment worth $E[v]$ on average, yielding an expected profit of $2\sigma\theta_i$. Firm i also gets to keep its own investment, worth $E[v]$ on average, if it has one. Overall, the payoff that firm i expects to collect at the start of the investment stage, before knowing the identity of its counterparty, is given by

$$\frac{1}{2} \left[\underbrace{\pi_i E[v]}_{\text{Keeping security } i} + \underbrace{E[\pi_j] 2\sigma\theta_i}_{\text{Buying security } j} \right] + \frac{1}{2} \left[\underbrace{\pi_i (E[v] - 2\sigma E[\theta_j])}_{\text{Selling security } i} \right], \tag{5}$$

which simplifies to

$$\pi_i E[v] + E[\pi_j \theta_i - \pi_i \theta_j] \sigma. \tag{6}$$

Equation (6) shows how the two types of expertise we model influence the payoffs collected by a firm and its counterparties. While investing expertise, π_j , creates a positive externality for firm j 's trading counterparties (e.g., firm i), trading expertise, θ_j , allows a firm to appropriate the surplus already created by these counterparties. The trading stage is played as a zero-sum game (as long as Assumption 1 is not violated) in which every dollar that firm j extracts when $\theta_j > 0$ comes at the expense of its counterparties. As a result, the ability of firm i 's counterparties to value securities in the trading stage decreases firm i 's payoff from finding good investment opportunities. Additionally, the ability of firm i 's counterparties to find good investment opportunities increases firm i 's payoff from valuing securities when providing liquidity. These externalities drive many of the results we present in the next sections regarding the labor market for financial workers.

II. The Labor Market for Traders

In the first stage, firms compete to hire workers who will help them maximize profits in later stages. A mass ξ of identical, skilled financial workers, also known as *experts*, is available, with a reservation wage of zero. To emphasize our first main result, we assume in this section that hiring experts only serves to improve trading expertise and appropriate a larger share of surplus away from counterparties. Specifically, when firm i hires a mass e_i of traders, this firm receives a signal with a precision parameter normalized to $\theta_i = e_i$ when providing liquidity to a counterparty in the trading stage. (Hiring a mass of $e_i \geq \frac{1}{2}$ of traders produces a perfect signal for the value v .) We thus set the investment expertise to $\pi_i = \pi > 0$ for all firms. We relax this restriction in the next section by allowing firms to hire workers to perform tasks that increase π_i .

The labor market for financial experts works as follows. Each firm submits a single wage offer w_i (per unit of workers) and a demand $x_i \in [0, 1]$ representing the fraction of the ξ workers that firm i is willing to hire. Workers are then allocated to firms based on their wage offers, 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 then evenly divided among the firms offering the highest wage whose total demand cannot be fully satisfied. Throughout the paper, we focus on symmetric, pure-strategy Nash equilibria in the labor market stage to simplify the exposition of our main results.

The expected payoff for firm i , net of compensation expenses, is then given by

$$\pi E[v] + \pi \sigma(e_i - E[e_j]) - e_i w_i. \quad (7)$$

The wage that firms find optimal to pay to traders depends greatly on other firms' demand for these workers, and as we show in the proof of the proposition that follows, in equilibrium each firm anticipates that any trader it does not hire will be hired by its counterparties. Given this excess demand for experts, we can rewrite firm i 's expected payoff as

$$\pi E[v] + \pi \sigma \left(e_i - \frac{\xi - e_i}{N - 1} \right) - e_i w_i. \quad (8)$$

The benefit of hiring traders for firm i therefore includes the weakening of its counterparties' trading expertise and in equilibrium firms are willing to compensate traders for this benefit. We formalize our main result on the high compensation of traders in the following proposition.

PROPOSITION 1: (*High trader compensation*): When $\xi \leq \frac{N-1}{2}$, in equilibrium all firms pay their traders a wage of

$$w^* = \pi\sigma \left(1 + \frac{1}{N-1}\right). \quad (9)$$

This result highlights that hiring traders has two benefits for a firm. First, it improves the firm's ability to value securities, which increases its bargaining power when providing liquidity to a counterparty. This benefit is worth $\pi\sigma$ to the firm and is increasing both in the prevalence of securities that need to be traded and in the uncertainty of their value. We refer to this first benefit as the *internal* marginal product of expertise and denote it by \bar{w} . Second, it ensures that the traders the firm hires will not be hired by any of its $(N-1)$ potential counterparties and used against the firm when hit by a liquidity shock. This benefit is worth $\pi\sigma(\frac{1}{N-1})$ to the firm and is decreasing in the number of potential counterparties a firm has. Because there is excess demand for workers in equilibrium, trader compensation is set to make firms indifferent about "poaching" traders away from their counterparties and can be written as $w^* = \bar{w} + (\frac{1}{N-1})\bar{w}$. This wage equals the internal marginal product of expertise \bar{w} , plus what we refer to as the *defense premium*. In Section V, we discuss how the defense premium would survive in alternative labor markets, but we want to point out here that what really matters is that firms can reduce employment at other firms by offering higher wages to workers.

Firms still make positive profits in equilibrium despite "overpaying" for the expertise of their traders as long as the profits from investment are large enough or the supply of workers is small enough:

$$\pi E[v] - \frac{\xi}{N} w^* = \pi E[v] - \left(\frac{\xi}{N-1}\right) \pi\sigma > 0. \quad (10)$$

As Proposition 1 makes clear, concentration in the financial sector greatly impacts traders' compensation. As the number of firms in the sector decreases (keeping the supply of workers constant), the defense premium inflates trader compensation. The reason for this is simple. As the number of a firm's potential trading partners decreases, the firm becomes more likely to trade against any worker it does not hire and the expected loss the firm incurs by letting an expert work for one of its $(N-1)$ counterparties goes up. Based on the findings of Atkeson, Eisfeldt, and Weill (2013) and Begenau, Piazzesi, and Schneider (2013) that OTC trading of complex securities in the United States tends to be overwhelmingly concentrated among three to five firms, our highly stylized model predicts that traders in those markets should earn a premium that represents between 25% and 50% of their internal marginal product—a range consistent with the average wage premium in the financial sector estimated by Philippon and Reshef (2012) and Célérier and Vallée (2015). Moreover, the much higher trading concentration of U.S. interest rate options compared to foreign exchange options (see Cetorelli et al. (2007)) might explain why the top

Wall Street firms pay their interest rate option traders roughly twice as much as their foreign exchange option traders (see Options Group (2011)).

Finally, note that in a more general model in which the probability of firms trading with each other depends on the identities of the firms, the $(\frac{1}{N-1})$ term in the defense premium paid to a worker would be replaced by the probability that the employer ends up trading with the second-highest bidder for that worker's services. For example, a large bank like Goldman Sachs would offer more for specialized traders likely to defect to J.P. Morgan than for 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 probabilities, but ultimately how much traders hurt firms that fail to hire them determines their defense premium. Empirically, large defense premia can still exist in markets (characterized, e.g., by type of securities, time period, or region) in which 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.

III. Bankers versus Traders

In the previous section, we show that OTC traders, whose sole purpose in our model is to appropriate surplus created by other firms, earn not only more than what they contribute to society (which is nothing in our model), but also more than what they contribute to their firms. Here, we allow firms to hire experts to increase either π_i , the probability of identifying a profitable investment opportunity, or θ_i , the accuracy of the signal about the value of traded securities. The first activity serves to increase the overall surplus available to firms in the financial sector while the second activity serves to appropriate a larger share of that surplus. As in Section II, employing a mass e_i of traders yields a probability $(\frac{1}{2} + e_i)$ that firm i 's signal is correct when providing liquidity in the trading stage (that is, θ_i in equation (6) is replaced by the mass of traders e_i). Now, employing a mass b_i of "bankers" yields a probability $\pi_i = S(b_i)$ that firm i finds a profitable investment opportunity in the investment stage. The function $S(\cdot)$ is assumed to be continuous, strictly increasing, and strictly concave. Our model thus makes a clear distinction, for simplicity, between surplus-appropriation jobs and surplus-creation jobs, even though in reality most jobs involve different mixtures of these activities. This perfect separation, however, allows our model to deliver stark predictions about the pecuniary incentives associated with the externalities that workers impose on other firms. In particular, we study how the interactions between investing and trading activities affect labor market outcomes, particularly when financial firms employ bankers and traders in equilibrium.

The labor market now operates in a slightly more complex manner than in Section II. To ensure that firms can predict which workers would be assigned to each job by other firms (which determines how much they earn in equilibrium), we add worker heterogeneity to our framework. The mass ξ of workers is now indexed by a continuous variable $h \in [0, 1]$, which is uniformly distributed.

This heterogeneity is modeled as an additive, per-unit benefit κh of employing a worker of type h as a banker rather than as a trader. When calculating payoffs we focus on the limit case with $\kappa \rightarrow 0$ to highlight that differences in workers' abilities do not drive the wage dispersion our model might generate. Absent this dispersion (i.e., when $\kappa = 0$), the equilibrium outcomes we characterize below for $\kappa \rightarrow 0$ still exist, but the analysis becomes more complicated as the final allocation of workers cannot necessarily be perfectly predicted by other firms.

For each type h of worker, each firm submits a wage, a task, and a measure for the quantity of workers demanded: $\{w_i(h), t_i(h), x_i(h)\}$. Here, $w_i(h)$ is the wage (per unit of workers) offered by firm i to workers of type h and $t_i(h) \in \{\text{banking, trading}\}$ is the task to which workers of type h will be assigned. The task offered, $t_i(h)$, is binding in the sense that if firm i were to offer to a type- h worker to become a trader for a wage of $w_i(h)$, the firm would not be able to later reassign the worker to banking, or vice versa, as a response to an unanticipated strategy by a rival firm. 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.⁷ In line with the simpler labor market from the earlier section, worker allocation is then determined as follows. First, all demands that can be satisfied for a given type of worker are satisfied whenever possible. However, when aggregate demand cannot be satisfied, 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, these workers are evenly allocated among the n^{th} -highest bidders. Given our focus on symmetric equilibria, solving for the quantity of workers hired and the wages paid to workers is relatively simple, but for completeness in Appendix B we describe how labor is allocated for general actions by firms.⁸

We now describe how firms pick the jobs they offer to workers, given the distribution of workers they expect to hire in equilibrium. Given equation (6), the payoff that firm i expects to collect, gross of compensation expenses, as $\kappa \rightarrow 0$ is

$$S(b_i)E[v] + E[S(b_j) e_i - S(b_i) e_j]\sigma. \tag{11}$$

⁷ Here, we use quotation marks to highlight that notions of quantity, such as a fraction, are imprecise in a setting with atomistic workers.

⁸ A couple of examples of how the labor market works when there is excess demand may prove helpful. We denote by $\mu_i(h)$ the allocation of workers of type h that firm i receives. 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 $\mu_i(h) = \frac{1}{N}$ 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 offered a wage $w_i(h)$, but firm j offered a wage very slightly below $w_i(h)$, then firm j would still obtain $\frac{\epsilon}{N}$ total workers if the other firms chose $x_i(h) = \frac{1}{N}$ 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 chose $x_i(h) = \frac{1}{N}$ or $x_i(h) = 1$; in both cases, $\mu_i(h) = \frac{1}{N}$. See Appendix B for a general description of the allocation rule $\mu_i(h)$.

If firm i were to outbid other firms for a particular worker, firm i would be guaranteed that this worker's expertise would not be used by other firms, regardless of what task the worker would perform for firm i . Thus, when bidding for workers, firm i chooses which job to offer to each worker based solely on his internal productivity, not on the externality he would impose on firm i if employed by a rival firm. The type of externality a worker would impose if employed by a rival firm will impact his compensation in equilibrium, but it does not enter a firm's decision to allocate that worker to trading or to banking. For any value of κ , a type- h worker's internal marginal product would be

$$\sigma E[S(b_j)] \quad (12)$$

if hired as a trader and

$$E[v - \sigma e_j]S'(b_i) + \kappa h \quad (13)$$

if hired as a banker. Since worker heterogeneity, though potentially small, is nondegenerate, we can represent the optimal assignment of workers across tasks within firm i given the distribution of workers it expects to employ as a threshold $h_i^* \in [0, 1]$. In a symmetric equilibrium with full employment, each firm receives a fraction $\frac{1}{N}$ of each type h of worker. Assuming an interior solution in h_i^* and taking as given that every other firm employs a mass e^* of traders and a mass b^* of bankers, each firm picks the same threshold h^* to satisfy

$$[E[v] - \sigma e^*]S' \left(\frac{\xi}{N}(1 - h^*) \right) + \kappa h^* = \sigma S(b^*). \quad (14)$$

This condition must hold for bankers and traders to coexist in equilibrium. The left-hand side of the equation represents the internal marginal product of bankers and is increasing in h^* . The right-hand side represents the internal marginal product of traders and does not change with h^* . Optimal assignment of workers across tasks requires that in equilibrium these internal marginal products are equal for all firms. Workers of type $h \leq h^*$ are offered trading jobs by all firms and workers of type $h > h^*$ are offered banking jobs by all firms. Thus, worker heterogeneity guarantees that each firm knows in advance which workers would be assigned to trading and which would be assigned to banking by other firms. Overall, $e^* \equiv \frac{\xi}{N}h^*$ represents the mass of workers each firm hires as traders and $b^* \equiv \frac{\xi}{N}(1 - h^*)$ represents the mass of workers each firm hires as bankers. When $\kappa \rightarrow 0$, the impact of worker heterogeneity on payoffs vanishes and we can rewrite the internal marginal product of expertise in an interior equilibrium as

$$\bar{w} \equiv [E[v] - \sigma e^*]S'(b^*) = \sigma S(b^*). \quad (15)$$

Since in this section, we focus on situations in which firms hire bankers and traders in equilibrium (a condition we relax in the next section), we impose the following assumption.

ASSUMPTION 2: (Coexistence of bankers and traders): $\frac{S'(\frac{\xi}{N})}{S(\frac{\xi}{N})} < \frac{\sigma}{E[v]}$ and $\frac{S'(0)}{S(0)} > \frac{\sigma}{E[v] - \sigma \frac{\xi}{N}}$.

These two conditions state that the marginal value of banking relative to trading is sufficiently high when all workers are deployed to trading, and conversely, the marginal value of banking relative to trading is sufficiently low when all workers are deployed to banking. As we show in the proof of the proposition that follows, these restrictions ensure that the optimal assignment of workers across tasks is interior when $\kappa \rightarrow 0$ and that the internal marginal products are equalized in equilibrium.

What remains to be derived are the wage and demand schedules that hold in equilibrium. The intuition behind these derivations is similar to that developed in Section II, except that we have added workers who create a positive externality to those who create a negative externality. In particular, as was the case in Proposition 1, the proof of Proposition 2 shows that in equilibrium each firm must anticipate excess demand for all worker types. Hence, if a firm does not hire a worker, regardless of whether he is expected to become a trader or a banker, that worker is hired by one of the firm’s counterparties. The externalities that each worker is expected to impose on firms that do not hire him drives the wage this worker collects in equilibrium. The proposition that follows formalizes our second main result on the existence of a compensation gap between traders and bankers.

PROPOSITION 2: (Compensation gap): When $\xi \leq \frac{N-1}{2}$ and $\kappa \rightarrow 0$, in equilibrium all firms employ a positive mass of traders (i.e., workers with $h \leq h^*$) who earn a wage of

$$w_t^* = \bar{w} \left(1 + \frac{1}{N-1} \right), \tag{16}$$

and a positive mass of bankers (i.e., workers with $h > h^*$) who earn a wage of

$$w_b^* = \bar{w} - \sigma e^* S'(b^*) \left(\frac{1}{N-1} \right). \tag{17}$$

Proposition 2 shows that traders earn significantly more than bankers in equilibrium even though their internal marginal productivity is identical (and denoted by \bar{w}). When assigning prospective workers to the two tasks, firms optimally equate the marginal productivity of bankers and traders, but when competing with other firms for the hiring of these workers, firms compare the payoffs of employing a worker versus letting a counterparty employ him. Thus, in equilibrium the following set of inequalities holds:

$$w_t^* > \bar{w} > w_b^*. \tag{18}$$

The gap in compensation is due to the fact that OTC trading is a zero-sum game and in effect generates negative externalities on rival firms, whereas

identifying profitable investments creates positive externalities. As a result, traders earn a defense premium of $\bar{w}(\frac{1}{N-1})$ over their internal marginal product while bankers face a wage penalty of $\sigma e^* S'(b^*)(\frac{1}{N-1})$. Moreover, as more traders are hired by counterparties and it becomes harder for each firm to retain the surplus created by its bankers, firms are willing to pay less to hire bankers. In contrast, as more bankers are hired by counterparties and the surplus that can be appropriated by traders grows, firms are willing to pay more to hire traders.

As in Section II, sector concentration affects the impact of losing workers to rival firms and thus plays an important role in determining the rents extracted by workers. As the number of firms in the sector increases, the relative importance of both the defense premium and the “public good” aspect of banking decreases, which moves traders’ and bankers’ wages closer to the internal marginal product. In fact, when $N \rightarrow +\infty$, the equilibrium compensation of both types of workers converges toward the internal marginal product \bar{w} . Broadly speaking, our results may explain why, according to Options Group (2011), traditional banking jobs tend to pay significantly less than trading jobs in highly concentrated markets but only slightly less than trading jobs in more diffuse markets.

IV. Compensation Dynamics in the Financial Sector

Philippon and Reshef (2012) and C el erier and Vall e (2015) provide evidence of an astonishing rise in financial sector compensation since the 1980s, and our model, although static, highlights new mechanisms that could help explain this phenomenon. First, the recent increase in the trading of OTC derivatives, swaps, commodities, and forward contracts (see figure 1 in Bolton, Santos, and Scheinkman (2012)) should have been associated with higher compensation paid to traders, according to our model. These complex instruments are traded in markets that are far more concentrated than equity and bond markets (Cetorelli et al. (2007), Atkeson, Eisfeldt, and Weill (2013), Begenau, Piazzesi, and Schneider (2013)) and such concentration should have increased the defense premium offered to traders.

Less obvious from the earlier analysis is how worker compensation might have evolved in response to a growing supply of talent entering the sector. In recent years, large proportions of students graduating from top universities have entered the financial sector (e.g., 28% for Harvard University, 46% for Princeton University, and 30% for the University of Pennsylvania, according to Roose (2014)). Below we analyze how the labor market outcomes in our model are affected by an increase in the supply of workers.

The relationship between the supply of workers ξ and the allocation of workers across jobs can be illustrated through an implicit differentiation of the following equilibrium condition (which is derived from equation (14)):

$$\left[E[v] - \sigma \left(\frac{\xi}{N} - b^* \right) \right] S'(b^*) + \kappa h^* - \sigma S(b^*) = 0. \quad (19)$$

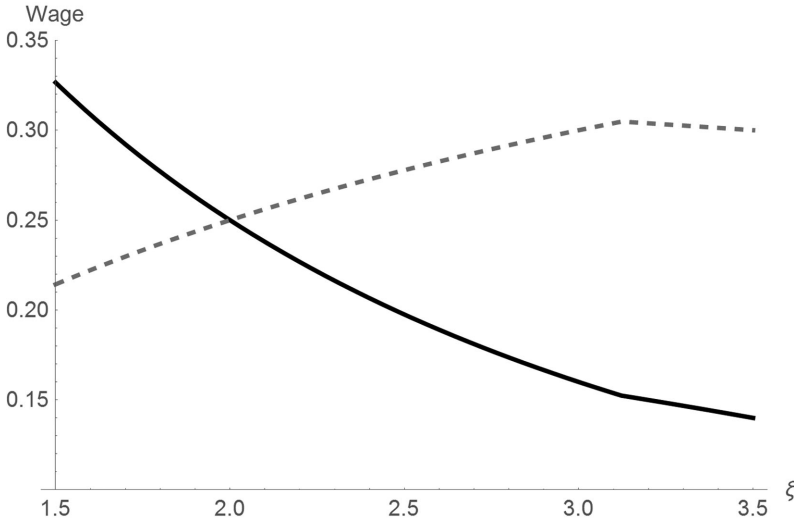


Figure 1. Shadow compensation for both jobs. In this example, we set the number of firms at $N = 2$, the average investment payoff at $E[v] = 1$, and its volatility at $\sigma = 0.25$. The solid line represents the wage offered to bankers in equilibrium and the dotted line represents the shadow wage that firms would offer to traders.

If $\kappa \rightarrow 0$ and the conditions in Assumption 2 are satisfied, so that traders and bankers coexist in equilibrium, the change in the mass of bankers each firm employs is characterized by

$$\frac{db^*}{d\xi} = \frac{\sigma S'(b^*)}{N S''(b^*)} \frac{1}{E[v] - \sigma e^*} < 0. \tag{20}$$

Here, the inequality follows from the strict concavity of $S(\cdot)$ and the fact that $E[v] - \sigma e^* \geq v_l > 0$. Thus, in situations in which firms find it optimal to employ traders and bankers, further growth in the pool of available workers leads to a *decrease* in the equilibrium mass of bankers. All new workers are employed as traders and the increased trading expertise lowers the internal marginal benefit, for counterparties, of employing bankers. Firms thus find it optimal to reduce the mass of bankers they employ, and a larger fraction of workers are assigned to the high-paying trading task.

While the employment of more traders decreases the marginal benefit of employing bankers as well as their compensation w_b^* , the increase in the fraction of workers who collect a defense premium can, in fact, drive up the average compensation paid to financial workers. Such a scenario is illustrated through a simple parameterized example. We assume that the productivity of banking is given by $S(b) = \frac{b}{1+b}$, and we relax the boundary conditions imposed in Assumption 2 for $S(\cdot)$. By relaxing these conditions, we are able to generate scenarios for which the optimal assignment of workers across tasks is not interior, as previously implied in Section III.

Figure 1 plots the compensation associated with both jobs as we increase the supply of workers ξ but keep constant the number of firms ($N = 2$), the average investment payoff ($E[v] = 1$), and its volatility ($\sigma = 0.25$). To characterize the value of traders in our model even for cases in which ξ is small and firms find it optimal to only employ bankers, we introduce the concept of the shadow wage of traders, which is the wage that would be paid if, for reasons outside the model, an infinitesimal mass of workers was hired as traders. This situation could arise, for example, if a small subset of workers entering the financial sector turned out to be incapable of engaging in the banking task, which perhaps requires specific skills. This exercise helps us shed light on the apparent reversal in the types of financial jobs that have been considered the most lucrative over the years. Historically, investment banking jobs were associated with the highest compensation, but in recent years as the finance industry has grown, highly specialized traders have taken over the highest echelons of the wage distribution (see Options Group (2011)). When the supply of workers is small in our model, bankers have a high marginal productivity compared to traders and the shadow wage of traders is below what bankers earn. In fact, as $\xi \rightarrow 0$, the marginal productivity of banking converges to $E[v]$ in our parameterization and strictly dominates the marginal productivity of trading, which converges to zero. It is thus optimal for firms to deploy all the workers they hire as bankers. As more workers become available, the marginal productivity of banking, given by $E[v]S'(\frac{\xi}{N})$, decreases, whereas the marginal productivity of trading, given by $\sigma S(\frac{\xi}{N})$, increases. The defense premium starts pushing the shadow wage of traders above what bankers earn before the internal marginal products of both tasks are equalized. Eventually, as the supply of workers ξ continues to grow, firms begin to employ traders to equalize the internal marginal products across jobs (i.e., at $\xi \approx 3.12$ in this example) and the mass of workers who command the high wage that includes the defense premium starts to grow.

These predictions may explain why the average compensation paid in the financial sector has increased in recent decades (see Philippon and Reshef (2012) and C el erier and Vall ee (2015)), despite the flood of workers entering the sector (see Goldin and Katz (2008) and Roose (2014)). Figure 2 plots the average compensation actually paid to workers in the sector, weighted by the equilibrium mass of workers assigned to each job. The kink at $\xi \approx 3.12$ identifies when it becomes optimal for firms to start deploying a positive mass of workers as traders. In our parameterization, as a larger fraction of workers are hired as traders and command the higher wage, average compensation in the sector increases. Hence, a greater supply of workers can lead to a greater fraction of workers being allocated to high-paying trader jobs and a higher average compensation paid to the workers employed in finance.

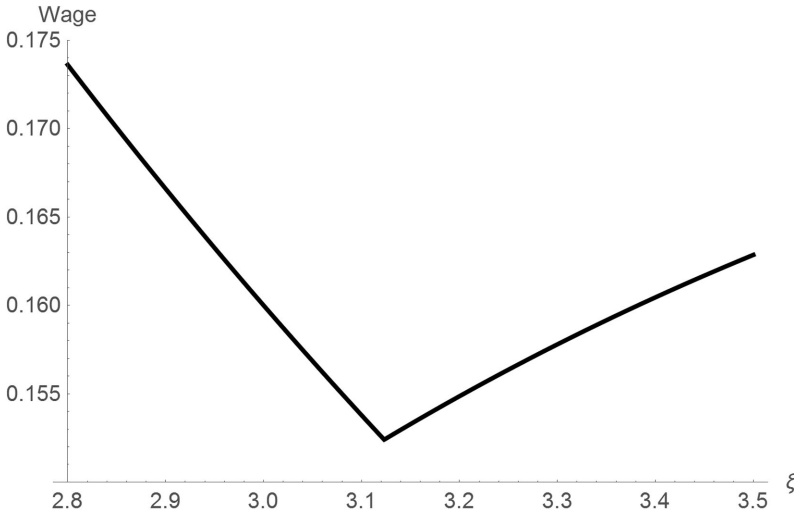


Figure 2. Average worker compensation in equilibrium. In this example, we set the number of firms at $N = 2$, the average investment payoff at $E[v] = 1$, and its volatility at $\sigma = 0.25$.

V. Robustness

In this section, we discuss the robustness of our results to a few extensions.

Alternative trading environments. Our trading stage provides us with a straightforward way to characterize the benefits of acquiring trading expertise. We are thus able to focus on the competition for talent that helps firms compete in a zero-sum trading game. These effects continue to hold, however, in more complex bilateral bargaining mechanisms. In Glode, Green, and Lowery (2012), for example, both bargaining parties receive independent signals of potentially different precision, which significantly complicates the analysis due to the signaling problem associated with the initial offer. For our purposes, the only significant change in how the trading game would proceed in equilibrium is that, under the credible belief refinement of Grossman and Perry (1986), the maximum level of expertise that allows for efficient trade and produces an expected payoff from trading as in equation (6) would be tighter than in our current setup. Our results are also robust to randomly selecting which of the two counterparties makes an offer, rather than always having the firm that sells its investment making the offer.

Our results would also survive if trading expertise θ_i were a strictly concave function $T(\cdot)$ of e_i , rather than a linear function. However, equilibrium solutions would then necessitate additional restrictions to rule out discrete deviations in firms’ demand for workers. The internal marginal product of trading expertise would be replaced by $\bar{w} = \sigma \pi T'(e^*)$ in Section II or $\bar{w} = \sigma S(b^*)T'(e^*)$ in Section III, and if the supply of workers ξ is small enough given the concavity of $T(\cdot)$, trader compensation would still be characterized by $w_i^* = \bar{w}(1 + \frac{1}{N-1})$ in equilibrium. Overall, what really matters for the existence of a defense premium is

simply that, in equilibrium, hiring traders helps a firm collect higher payoffs and, conversely, when facing a set of counterparties that employ more traders, the firm loses more on average.

Alternative labor market environments. The assumption that workers receive a job offer that specifies both a wage and a task, and that workers cannot be reassigned to different tasks by their employers as a response to an off-equilibrium deviation made by a rival firm, plays an important role in maintaining the compensation gap between bankers and traders in equilibrium. This rigidity in talent allocation is intended in part to capture a more dynamic setting in which workers develop job-specific human capital and cannot readily be switched between tasks when other workers are poached away by rival firms. At the opposite extreme, we could consider a model in which workers are hired and *then* assigned to either banking or trading. The benefit of poaching a rival firm's worker would then depend not on what task the poached worker would have been assigned to, but instead on how rival firms rebalance their workforce in response to the poaching. As worker heterogeneity vanishes and task reallocation becomes costless, poaching a banker and poaching a trader would have the same effect on a rival firm's labor allocation, as workers would be allocated to equalize the internal marginal products of both tasks in equilibrium. Importantly, the defense premium for trading and the wage penalty for banking would not disappear; instead both would apply to all workers. Which effect dominates, and thus whether wages are higher or lower when the strategic interactions in the labor market are modeled, would simply depend on parameter values.

Another labor market environment worth considering is one in which firms compete over the quantity of labor demanded, rather than on price, replacing what is effectively worker-by-worker Bertrand competition with something akin to Cournot competition. Because of the externalities imposed by traders, firms would then have an incentive to submit demands in excess of the demands driven by the internal marginal productivity of traders alone. By raising the quantity of workers demanded, a firm would inflate the wage other firms might face, leading to lower demand for traders by these firms. To capture this intuition, labor demands would have to be submitted sequentially as otherwise no firm could credibly commit to submitting an excessively high demand.

Heterogeneity in productivity. By focusing on the case in which $\kappa \rightarrow 0$, the role that worker heterogeneity plays in Section III is mainly one of equilibrium selection. Absent this dispersion (i.e., when $\kappa = 0$), the equilibrium outcomes we characterize for $\kappa \rightarrow 0$ still exist, but the analysis becomes more complicated as the final allocation of workers cannot necessarily be perfectly predicted by other firms. In fact, as long as workers are indexed in a publicly observable way, regardless of whether this index is payoff-relevant, our equilibrium remains unique within the class of symmetric, pure-strategy equilibria. Symmetry implies that all firms anticipate that rival firms will offer the same job given a worker's type, which is all we need to obtain our results. The quasi-"coordination device" that worker heterogeneity represents here simply ensures that our static model captures the idea that, in reality, firms are able to

target specific workers to poach from rival firms and set contract terms based on the jobs these workers currently occupy for their employer. The uniqueness of equilibrium outcomes for cases in which the index is payoff-irrelevant would rely crucially, however, on the assumption of symmetry, which is not the case in our model with payoff-relevant worker heterogeneity.

Our model could also accommodate a different type of heterogeneity, with a fraction of workers being generally more productive than others. Consider a situation in which there is a mass ξ' of workers who are as productive as assumed earlier and a mass ξ'' of workers whose contribution, as traders or as bankers, is ψ times the contribution of the initial experts. If we still interpret e_i and b_i as firm i 's expertise levels, the payoff functions that we derived earlier would not change, except that the supply of workers ξ would now need to be reinterpreted as the aggregate supply of expertise: $\xi' + \psi\xi'' = \xi$. The only difference in our results would be that a mass of workers would now earn ψ times the equilibrium wages we derived earlier—the better skilled workers in the financial sector would earn more than less skilled workers who occupy the same job in equilibrium. Moreover, interpreting equilibrium compensation as being per unit of talent rather than per worker allows us to link our predictions more tightly to the empirical finding by Célérier and Vallée (2015) that the large compensation premia collected by financial workers increase with measures of talent.

Endogenous entry by workers. In reality, the compensation premium offered by the financial sector has not gone unnoticed by workers and, arguably, has attracted entry into the financial sector. Our model could be expanded to account for this type of endogenous entry. Suppose that, prior to the labor market stage, workers had to decide whether to enter the financial sector without knowing their type h yet. If we assumed heterogeneous entry costs among workers, a marginal worker who is indifferent about entering the financial sector would exist and would determine the total mass of workers available to be hired by firms. In this extended model, the comparative statics on the mass of workers ξ in Section IV would be replaced by comparative statics on the distribution of entry costs, but results would otherwise remain unchanged. Lower entry costs could be associated with higher average compensation as increased endogenous entry leads to a greater share of workers being deployed to the highly paid trading job. The labor supply curve in the market would then exhibit nonmonotonic behaviors for which a given level of expected wage at entry is associated with multiple quantities of entering workers. For clarity, we omit this endogenous entry stage in our formal analysis, but our results on the compensation premium paid to traders and the compensation penalty faced by bankers are robust to this extension.

Restriction to pure strategies. Proposition 2 imposes a restriction on the supply of workers ξ that is sufficient to ensure that the bound on trading expertise (i.e., $\frac{1}{2} + e_i \leq 1$) is never reached following a deviation from a symmetric, pure-strategy equilibrium. Our results would survive under a weaker restriction since in equilibrium a positive mass of workers are employed as bankers. However, if ξ were to violate this weaker restriction, a deviation by one firm to

hiring no traders would result in the nondeviating firms not being willing to employ all the available workers as traders, hired to increase the precision of the signal, since the probability of an accurate signal cannot exceed one. In this case, the high trader wage stated in the proposition would still be needed to prevent marginal deviations, but deviating to hiring no traders would be profitable. As a result, symmetric equilibria would call for strategies that are mixed in wage offers.

VI. Conclusion

We propose a labor market model in which financial firms compete for a scarce supply of skilled workers who can be employed as either bankers or traders. While employing bankers raises the total surplus that can be split between a firm and its trading counterparties, employing traders allows the firm to extract a larger share of that surplus from its counterparties. In equilibrium, a firm that hires a trader not only improves its own ability to value securities but also ensures that he will not be employed by its trading counterparties. Since traders impose negative externalities on their employers' trading counterparties, firms bid defensively for workers suited to become traders and offer them a defense premium. When a firm hires a banker instead, the value he creates can be partially extracted by the firm's counterparties when the firm is hit by a liquidity shock, reducing how much the firm is willing to pay for his services. Moreover, higher banking expertise drives up the value of trading expertise for counterparties, while higher trading expertise depresses the value of banking expertise for counterparties.

Comparative statics on trading concentration and on the supply of workers available allow us to study the historical evolution of compensation in the financial sector. Our model offers a novel explanation for why average compensation has increased in recent decades (see Philippon and Reshef (2012) and C el erier and Vall e (2015)), despite the flood of workers entering the sector (see Goldin and Katz (2008) and Roose (2014)). It also sheds light on the reversal in the types of financial jobs that have been considered the most lucrative over recent years.

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Appendix A: Proofs

PROOF OF PROPOSITION 1: In this proof, we start by showing that firms' demand for workers, which is symmetric across firms and denoted by x^* , must satisfy $x^* \geq \frac{1}{N-1}$ in equilibrium. We then derive the equilibrium wage that traders collect. Suppose for now that the mass of workers ξ is small enough that firms do not anticipate reaching the maximal expertise that sets $e_i = \frac{1}{2}$, even if one

firm were to deviate from its equilibrium strategy. We revisit this conjecture toward the end of the proof.

First, if we had $x^* < \frac{1}{N}$ in equilibrium, there would be excess supply of workers and firms would find it optimal to offer a wage of zero; otherwise, a firm could deviate to a lower wage and still obtain the same measure of workers. But, if the wage is zero and some workers remain unemployed, any firm could profitably deviate to demanding infinitesimally more workers than x^* since, from Assumption 1, firms always benefit from improving the quality of the signal they receive about the value of counterparties' investments. This argument thus rules out the existence of equilibria with unemployment (i.e., $x^* < \frac{1}{N}$) and implies that each firm employs a mass $\frac{\xi}{N}$ of workers in equilibrium and therefore collects an expected payoff of

$$\pi E[v] + \pi \sigma \left(\frac{\xi}{N} - \frac{\xi}{N} \right) - \frac{\xi}{N} w^* = \pi E[v] - \frac{\xi}{N} w^*, \tag{A1}$$

where w^* is the wage each firm offers in equilibrium, per unit of workers.

Now suppose instead that we had $x^* \in [\frac{1}{N}, \frac{1}{N-1})$, which means that every worker is employed in equilibrium, but a positive mass of workers would become unemployed if one firm were to deviate to demanding zero workers. Such deviation to demanding no workers would result in each nondeviating firm hiring a mass ξx^* of workers and would yield an expected payoff of

$$\pi E[v] - \pi \sigma \xi x^* \tag{A2}$$

for the deviating firm. This deviation would be unprofitable as long as

$$\pi E[v] - \frac{\xi}{N} w^* \geq \pi E[v] - \pi \sigma \xi x^*, \tag{A3}$$

or equivalently, $w^* \leq \pi \sigma N x^*$. Since $x^* \in [\frac{1}{N}, \frac{1}{N-1})$, this last restriction implies that $w^* < \pi \sigma (\frac{N}{N-1})$, but then a firm could deviate to offering an infinitesimally higher wage and demanding infinitesimally more than a fraction $\frac{1}{N}$ of workers. This deviation would be profitable because hiring extra traders means that they can no longer be used against the deviating firm. In other words, firm i 's total payoff when hiring e_i traders can be written as

$$\pi E[v] + \pi \sigma \left(e_i - \frac{\xi - e_i}{N - 1} \right) - e_i w_i. \tag{A4}$$

Thus, the marginal benefit from deviating to a higher level of expertise, which can be achieved with an infinitesimal increase in the wage offer, would be

$$\pi \sigma \left(1 + \frac{1}{N - 1} \right), \tag{A5}$$

making the deviation profitable as long as w^* is below that level. But since we have already established that we need $w^* < \pi \sigma (\frac{N}{N-1}) = \pi \sigma (1 + \frac{1}{N-1})$ when

$x^* \in [\frac{1}{N}, \frac{1}{N-1})$, we can rule out the existence of symmetric equilibria with $x^* \in [\frac{1}{N}, \frac{1}{N-1})$.

However, when $x^* \geq \frac{1}{N-1}$, this last condition on w^* does not apply anymore as all available workers would stay employed if one firm were to deviate to demand zero workers. The marginal benefit from deviating to a higher level of expertise is still

$$\pi \sigma \left(1 + \frac{1}{N-1} \right), \quad (\text{A6})$$

and as a result we have all firms offering a wage of

$$w^* = \pi \sigma \left(1 + \frac{1}{N-1} \right) \quad (\text{A7})$$

in equilibrium, which is the wage that makes them indifferent between hiring traders or letting them work for one of their $(N-1)$ counterparties.

The only condition that remains to be verified is that $(\frac{1}{2} + \xi x^*) \leq 1$, since this quantity denotes a probability measure. This condition can be satisfied if and only if $\xi \leq \frac{N-1}{2}$. ■

PROOF OF PROPOSITION 2: Many arguments that we use in this proof resemble those made in the proof of Proposition 1. However, the interactions between trading and banking activities imply that a few extra arguments need to be made when solving for an equilibrium. For clarity, we split the proof into four main steps. Before we do so, we start by conjecturing that the mass of workers ξ is small enough that firms do not anticipate surpassing the maximal trading expertise that sets $e_i = \frac{1}{2}$, even if one firm were to deviate away from its equilibrium strategy. We also conjecture that in equilibrium a positive mass of workers are hired as traders and a positive mass of workers are hired as bankers. We revisit these two conjectures in steps 3 and 4 of the proof.

(1) *Trader wage.* The arguments required to derive the equilibrium wage for traders are almost identical to those used in Proposition 1. Here, worker heterogeneity implies that all firms offer workers of type $h \leq h^*$ a job as traders, and in equilibrium firms' demand for these workers must satisfy $x^*(h) \geq \frac{1}{N-1}$ just as earlier. If firms were to submit lower demands for these worker types instead, a firm would profitably deviate to hiring none of them when their wage $w^*(h) \geq \bar{w}(1 + \frac{1}{N-1})$ since some workers would end up unemployed after the deviation. In contrast, when $w^*(h) < \bar{w}(1 + \frac{1}{N-1})$, a firm would profitably deviate to offering an infinitesimally higher wage and marginally increasing its employment of workers, since the internal marginal benefit of this increase is \bar{w} (regardless of whether the deviating firm deploys these workers as bankers or traders) and the marginal value of reducing the employment of traders by other firms is $\bar{w}(\frac{1}{N-1})$. The demand for workers who will be deployed to trading by rival firms (workers whose $h \leq h^*$) must therefore satisfy $x^*(h) \geq \frac{1}{N-1}$ and the wage must be $w_i^* \equiv \bar{w}(1 + \frac{1}{N-1})$ to prevent deviations to hiring infinitesimally more workers (at an infinitesimally higher wage) or fewer workers (at a wage

of zero). Since a firm’s payoff is linear in both its own trading expertise and that of its counterparty, ruling out infinitesimal deviations is sufficient to rule out deviations to any other level of trading expertise.

(2) *Banker wage.* We start by showing that firms’ demand $x^*(h)$ for workers of type $h > h^*$ must exceed $\frac{1}{N}$ in equilibrium. We then establish the wage that bankers must receive when $x^*(h) > \frac{1}{N}$ to prevent firms from deviating to a marginally higher wage. Finally, we show that $x^*(h) \geq \frac{1}{N-1}$ supports this wage as an equilibrium.

If we had $x^*(h) < \frac{1}{N}$ for $h > h^*$, there would be unemployed workers of type $h > h^*$. The wage $w^*(h)$ offered to workers whose $h > h^*$ would then have to be zero; otherwise, a firm could deviate to a lower wage and still obtain the same measure of workers. But if $w^*(h) = 0$, there would be a profitable deviation to increasing $x^*(h)$ and hiring additional workers (who would otherwise remain unemployed), since the internal marginal value of a banker is $\sigma S(b^*) > 0$ in equilibrium. Hence, we can rule the existence of equilibria where $x^*(h) < \frac{1}{N}$.

If instead we had $x^*(h) = \frac{1}{N}$ for these workers, it remains true that no wage that exceeds workers’ reservation wage of zero would sustain an equilibrium, since any firm could reduce wages and still maintain the same level of employment. We can show, however, that $w^*(h) = 0$ cannot sustain an equilibrium here because firms would then have an incentive to increase the wage infinitesimally to increase their employment of workers of type $h > h^*$. This deviation would provide a direct benefit of \bar{w} (regardless of whether the deviating firm deploys these workers as bankers or traders), but would also come at the cost of removing workers from the other firms, which is $\sigma e^* S'(b^*) (\frac{1}{N-1})$ for values of $b_i > b^*$. This cost follows from the fact that the payoff to an individual firm i given equilibrium allocations of e^* and b^* for all other firms is

$$S(b_i)E[v] + \left(S\left(\frac{\xi - b_i}{N - 1}\right)e^* - S(b_i)e^* \right) \sigma \tag{A8}$$

for values of $b_i > b^*$ when $x^*(h) \geq \frac{1}{N}$. That is, when there is full employment, deviating to hiring more workers of type $h > h^*$ means that the other firms will hire fewer bankers. The inequalities below, which rely on Assumption 1, the fact that $N \geq 2$, and the above conjecture that $e^* \leq \frac{1}{2}$, guarantee that the net value of hiring away these workers is greater than zero and that the proposed deviation is profitable:

$$\begin{aligned} & \bar{w} - \sigma e^* S'(b^*) \left(\frac{1}{N - 1} \right) \\ &= (E[v] - \sigma e^*) S'(b^*) - \sigma e^* S'(b^*) \left(\frac{1}{N - 1} \right) \\ &= S'(b^*) \left[E[v] - \sigma e^* \left(\frac{N}{N - 1} \right) \right] \end{aligned}$$

$$\begin{aligned} &\geq S'(b^*) \left[E[v] - \sigma \left(\frac{1}{2} \right) \left(\frac{N}{N-1} \right) \right] \\ &\geq S'(b^*)(E[v] - \sigma) > 0. \end{aligned} \tag{A9}$$

Thus, this deviation rules out equilibria where $x^*(h) = \frac{1}{N}$.

Now, if instead $x^*(h) > \frac{1}{N}$ for $h > h^*$, then we can rule out marginal deviations to hiring more (by deviating to offering a higher wage) or fewer (by deviating to demanding fewer workers) workers by setting $w^*(h)$ equal to the total marginal benefit of bankers, accounting for the negative effect from having these workers not being employed by a firm’s potential counterparties. As earlier, equation (A8) shows that this net benefit is $(E[v] - \sigma e^*)S'(b^*) - \sigma e^*S'(b^*)\left(\frac{1}{N-1}\right) = \bar{w} - \sigma e^*S'(b^*)\left(\frac{1}{N-1}\right)$, that is, the wage described in the proposition. This follows because, with $x^*(h) > \frac{1}{N}$, equation (A8) holds for b_i marginally above and below b^* . Thus, any symmetric pure-strategy equilibrium must be associated with $w_b^* \equiv \bar{w} - \sigma e^*S'(b^*)\left(\frac{1}{N-1}\right)$ being offered to bankers (i.e., workers whose $h > h^*$).

We still need to verify that there exist demand schedules $x^*(h)$ that support the above equilibrium wage against more general deviations to a lower wage (which implies a discrete drop in the mass of bankers employed by the deviating firm). Without loss of generality, we can consider only a deviation to zero wage, since any other wage lower than w_b^* would be strictly dominated by an infinitesimally positive wage. If we have $x^*(h) \geq \frac{1}{N-1}$, then any deviation to a lower wage for a subset of worker types expected to become bankers would lead to the deviating firm employing none of these worker types, in which case there can be no profitable deviation to offering them zero wage. This result follows since the wage w_b^* is set to make firms indifferent between marginal changes in banking employment and the losses from further deviations can only increase with the magnitude of a deviation, due to the concavity of $S(\cdot)$ and the linearity of the wage bill in the mass of bankers employed. Specifically, the payoff to a deviation that results in any $b_i \neq b^*$ when all other firms submit $x^*(h) \geq \frac{1}{N-1}$ is concave, since the second derivative of this payoff is

$$S''(b_i)(E[v] - \sigma e^*) + \frac{1}{(N-1)^2} S''\left(\frac{\xi - b_i}{N-1}\right) \sigma e^* < 0. \tag{A10}$$

This concavity also guarantees that ruling out a marginal deviation to hiring more workers at an infinitesimally higher wage than w_b^* rules out the profitability of hiring an even larger share of workers also at the marginally higher wage. Thus, setting $x^*(h) \geq \frac{1}{N-1}$ for workers whose $h > h^*$ is sufficient to prove the existence of equilibria at the posited wage w_b^* , although there may also be outcome-equivalent equilibria (i.e., the same equilibrium wages and allocations of workers) supported by demands within the region: $x^*(h) \in \left(\frac{1}{N}, \frac{1}{N-1}\right)$. It is unnecessary, however, to pin down the minimal value on $x^*(h)$ needed to establish our proposition, since the equilibrium allocation of workers and their compensation have already been pinned down.

(3) *Interior solution in h^* .* Using the internal productivity of workers established in equations (12) and (13), we know that in equilibrium all workers are deployed to banking if and only if

$$S' \left(\frac{\xi}{N} \right) E[v] \geq \sigma S \left(\frac{\xi}{N} \right), \tag{A11}$$

and all workers are deployed to trading if and only if

$$\sigma S(0) \geq \left(E[v] - \sigma \frac{\xi}{N} \right) S'(0). \tag{A12}$$

Under Assumption 2, neither of these conditions holds and there exists a symmetric, pure-strategy labor market demand schedule for which an interior assignment of workers between trading and banking tasks is the best response to that same interior assignment by other firms. This result follows from the continuity of $S(\cdot)$, which allows us to rewrite the condition for an interior equilibrium as

$$S' \left(\frac{\xi}{N} - x \right) (E[v] - \sigma x) = \sigma S \left(\frac{\xi}{N} - x \right) \tag{A13}$$

for some $x \in (0, \frac{\xi}{N})$, since the violation of the conditions for a boundary solution already implies that

$$S' \left(\frac{\xi}{N} - x \right) (E[v] - \sigma x) < \sigma S \left(\frac{\xi}{N} - x \right) \text{ for } x = 0, \tag{A14}$$

$$S' \left(\frac{\xi}{N} - x \right) (E[v] - \sigma x) > \sigma S \left(\frac{\xi}{N} - x \right) \text{ for } x = \frac{\xi}{N}. \tag{A15}$$

The equilibrium assignment of workers across tasks, which is captured by the threshold h^* , simply sets $\frac{\xi}{N}h^* = x$ so that the interior marginal products of the two jobs are equalized.

(4) *Valuable trading expertise.* The only condition that remains to be verified is that $(\frac{1}{2} + e_i) \leq 1$ for any scenario we may have considered so far in the proof (especially for the discrete deviation by one firm to hiring no traders), since this quantity denotes a probability measure. In Proposition 1, the restriction that $\xi \leq \frac{N-1}{2}$ was necessary and sufficient for our result as it ensured that trading expertise was valuable to all firms even if one firm were to deviate to hiring no traders. In the current setting where a mass $\xi(1 - h^*)$ of workers are assigned to banking, the same restriction (i.e., $\xi \leq \frac{N-1}{2}$) is sufficient for our result since it guarantees that $\xi h^* \leq \frac{N-1}{2}$. The condition we impose is thus stronger than necessary, given that in equilibrium a positive mass of workers are deployed to banking. We impose the stronger condition as part of our proposition to keep the proof as concise as possible (recall that the mass of bankers employed is an equilibrium outcome, so simply imposing the restriction $\xi h^* \leq \frac{N-1}{2}$ would be

problematic), and in Section V we briefly discuss what would happen without this restriction. ■

Appendix B: Formal Description of the Labor Market

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.

Allocation functions $\mu_i(h)$ 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 to the extent that they determine the total mass of workers allocated to a firm and the distribution of worker types within that allocation.

Now, we define rules for the allocation of workers for any wage/demand pairs submitted by firms. These rules state mathematically the allocation rules mentioned in the main text. They ensure that all demands that can be satisfied are satisfied, and that when total demand cannot be satisfied the available supply of workers is allocated evenly among the high demanders. In such instances, a firm receiving its full allocation must receive weakly less than the partial allocation going to firms that posted a higher demand and offered the same wage, and firms posting identical demands and wages must receive identical allocations.

For a given supply of workers ξ , the mass of workers of type less than y allocated to firm i is given by

$$\int_0^y \mu_i(h) \xi dh, \quad (\text{B1})$$

where $\mu_i(h)$ is given as follows:

- If $\sum_{j=1}^N x_j(h) \mathbf{1}_{\{w_j(h) \geq w_i(h)\}} \leq 1$, then $\mu_i(h) = x_i(h)$. 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 $N_{w_i(h)}$ is 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 $\mu_i(h) = \frac{1 - \sum_{j=1}^N x_j(h) \mathbf{1}_{\{w_j(h) > w_i(h)\}}}{N_{w_i(h)}}$.

– 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 $\frac{1 - \sum_{j=1}^N x_j(h) \mathbf{1}_{\{w_j(h) > w_i(h)\}} - \sum_{j=1}^k x_j(h)}{N_{w_i(h)} - k} \geq x_k(h)$. For $j \leq k$ under the reordering, $\mu_i(h) = x_i(h)$. For $j > k$, $\mu_i(h)$ is equal to the left-hand side of the above inequality.

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

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

$$\int_0^y \mu_i(h) w_i(h) \xi dh. \quad (\text{B2})$$

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

REFERENCES

- Acemoglu, Daron, 1995, Reward structures and the allocation of talent, *European Economic Review* 39, 17–33.
- Acharya, Viral, Marco Pagano, and Paolo Volpin, 2016, Seeking alpha: Excess risk taking and competition for managerial talent, Working paper, New York University.
- Atkeson, Andrew G., Andrea L. Eisfeldt, and Pierre-Olivier Weill, 2013, The market for OTC credit derivatives, Working paper, UCLA.
- Axelson, Ulf, and Philip Bond, 2015, Wall Street occupations, *Journal of Finance* 70, 1949–1996.
- Begenau, Juliane, Monika Piazzesi, and Martin Schneider, 2013, Banks' risk exposures, Working paper, Stanford University.
- Bénabou, Roland, and Jean Tirole, 2016, Bonus culture: Competitive pay, screening, and multi-tasking, *Journal of Political Economy* 124, 305–370.
- Biais, Bruno, Thierry Foucault, and Sophie Moinas, 2015, Equilibrium fast trading, *Journal of Financial Economics* 116, 292–313.
- Biais, Bruno, and Augustin Landier, 2013, The (ir)resistible rise of agency rents, Working paper, Toulouse School of Economics.
- Bijlsma, Michiel, Jan Boone, and Gijsbert Zwart, 2012, Competition for trader and risk, Working paper, Tilburg University.
- Bolton, Patrick, Tano Santos, and Jose A. Scheinkman, 2012, Shadow finance, in Alan S. Blinder, Andrew W. Lo, and Robert M. Solow, eds.: *Rethinking the Financial Crisis* (Russell Sage Foundation and The Century Foundation, New York).
- Bolton, Patrick, Tano Santos, and Jose A. Scheinkman, 2016, Cream skimming in financial markets, Columbia University, 71, 709–736.
- Célérier, Claire, and Boris Vallée, 2015, Returns to talent and the finance wage premium, Working paper, Harvard Business School.
- Cetorelli, Nicola, Beverly Hirtle, Donald Morgan, Stavros Peristiani, and João Santos, 2007, Trends in financial market concentration and their implications for market stability, *FRBNY Economic Policy Review*, March, 33–51.
- Diamond, Douglas W., and Philip H. Dybvig, 1983, Bank runs, deposit insurance, and liquidity, *Journal of Political Economy* 91, 401–419.

- Esó, Péter, Volker Nocke, and Lucy White, 2010, Competition for scarce resources, *RAND Journal of Economics* 41, 524–548.
- Fishman, Michael J., and Jonathan A. Parker, 2015, Valuation, adverse selection, and market collapses, *Review of Financial Studies* 28, 2575–2607.
- Glode, Vincent, Richard C. Green, and Richard Lowery, 2012, Financial expertise as an arms race, *Journal of Finance* 67, 1723–1759.
- Goldin, Claudia, and Lawrence F. Katz, 2008, Transitions: Career and family life cycles of the educational elite, *American Economic Review* 98, 363–369.
- Greenwood, Robin, and David Scharfstein, 2013, The growth of finance, *Journal of Economic Perspectives* 27, 3–28.
- Grossman, Sanford, and Motty Perry, 1986, Perfect sequential equilibrium, *Journal of Economic Theory* 39, 97–119.
- Jéhiel, Philippe, Benny Moldovanu, and Ennio Stacchetti, 1996, How (not) to sell nuclear weapons, *American Economic Review* 86, 814–829.
- Lockwood, Benjamin B., Charles G. Nathanson, and E. Glen Weyl, 2015, Taxation and the allocation of talent, Working paper, Northwestern University.
- McCardle, Kevin F., and S. Viswanathan, 1994, The direct entry versus takeover decision and stock price performance around takeovers, *Journal of Business* 67, 1–43.
- Murphy, Kevin M., Andrei Schleifer, and Robert W. Vishny, 1991, The allocation of talent: Implications for growth, *Quarterly Journal of Economics* 106, 503–530.
- Office of the New York State Comptroller, 2014, The Securities Industry in New York City, Report 9–2015, October 2014, New York, NY.
- Options Group, 2011, *2011–2012 Global Financial Market Overview & Compensation Report* (New York, NY).
- Patterson, Scott, 2012, *Dark Pools* (Crown Business, New York, NY).
- Philippon, Thomas, 2010, Engineers vs. financiers: Should the financial sector be taxed or subsidized? *American Economic Journal: Macroeconomics* 2, 158–182.
- Philippon, Thomas, and Ariell Reshef, 2012, Wages and human capital in the U.S. financial industry: 1909–2006, *Quarterly Journal of Economics* 127, 1551–1609.
- Roose, Kevin, 2014, *Young Money* (Grand Central Publishing, New York, NY).
- Rosen, Sherwin, 1981, The economics of superstars, *American Economic Review* 71, 845–858.
- Rothschild, Casey, and Florian Scheuer, 2016, Optimal taxation with rent-seeking, Stanford University, 83, 1225–1262.
- Shiller, Robert J., 2012, *Finance and the Good Society* (Princeton University Press, Princeton, NJ).
- Thanassoulis, John, 2012, The case for intervening in bankers' pay, *Journal of Finance* 67, 849–895.