Is an informative stock price used less in incentive contracts?

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ABSTRACT

I address the way agency incentives evolve, from listed equity with low liquidity to highly liquid stocks with active informed speculators. I conclude that, as the informativeness of stock price about the manager's actions improves, less weight needs to be given to both equity and non-price incentives due to this higher quality. Hence managerial pay-performance sensitivity should be lower in more liquid stocks but higher in illiquid start-ups and where face-to-face monitoring is impossible (franchise contracts). The model explains why firms with low inside-ownership and high liquidity increasingly dominate the U.S. market even as the total number of listings declines.

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Moral hazard arises when the principal in an agency contract is unable to observe the actions of the agent. Holmström and Milgrom (1987, pp.323-325) (hereafter HM) develop a simple workhorse agency theory of stock price incentives in the absence of active market trading while, in an important and highly cited contribution, Holmström and Tirole (1993) (hereafter HT) incorporate Kyle's (1985) informed speculators into an agency model of monitoring based on share price. The aim of the present paper is to provide a unified theory of stock price-based incentives which integrates the path-breaking contributions of HM and HT, with the latter arguing that stock liquidity improves monitoring. Such a theory should explain incentives available to private equity with no stock price, to the evolution of incentives with the introduction of a stock price but without the benefit of either liquidity or informed speculation and, finally, in a continuous fashion, the progression from zero to the maximum possible degree of informed trading in the stock of perhaps a mega-sized firm in which informed traders have a large crowd in which to hide.

In the present paper, I initially obtain a far higher-powered stock price contract to that obtained by HM when there is no information in stock price because I, in common with HT, recognize that stock price must be grossed-up to allow for the endogeneity induced by the inclusion of incentive payments/managerial ownership. Using HT's contract specifications, which isolate the accounting signal from the price signal by deducting the price incentive payment from the realized accounting value of the firm prior to applying the accounting-earnings incentive weight, I show that the availability of a second informative signal, namely a (non-price) accounting-based signal, has no effect on the price-signal weight irrespective of the relative precision's of the two weights. This is despite the fact that the accounting earnings signal meets the conditions of Holmström's (1979) *informativeness* principle.[1] Consequently, the price signal behaves as a "sufficient statistic" for the manager's effort because it is treated as a deduction prior to the accounting incentive payment being assessed. My findings based on HT's model specification should not come as a surprise because HT's specification includes sharing rules inclusive of non-linear interactions and the outcomes from two signals whereas Holmström (1979, p.76) has a simple sharing rule based entirely on outcomes. Hence, Holmström's (1979) model is not disproved but neither may it be relevant for more realistic contracts in which the accounting-earnings base has to be measured net of equity incentive outlays.

By contrast, the accounting-signal weight itself increases in its own precision and diminishes in the precision of the price signal and thus behaves more as one would expect from the *informativeness* principle. This is presumably because the accounting earnings (non-price)

[1] The principle states: "any informative signal, regardless of how noisy it is, will have positive value in a contract".

base is a residual in HT's set-up. Hence, my findings with respect to the price weight based on HT's model specification indicate that the principle does not appear to generalize to circumstances in which the price incentive outlay is recognized prior to the assessment of the accounting incentive payment, as in HT's set-up.[2]

I obtain the main result of the paper when, inspired by HT, I introduce information into the stock price via the actions of informed speculators. As in the simple case without information, the price signal is still a "sufficient statistic" for the price weight with the accounting signal remaining irrelevant and the accounting-weight still depends on the precision's of the two signals. However, now both the price-signal and accounting-signal weights are significantly more higher-powered than in the previous model with the complete absence of information in the stock price. This is because of the introduction of a Kyle (1985)-type market-maker capable of trading against volatility induced by "noise-trading" in a now larger and more liquid market envisioned by HT. Most importantly, both incentive weights are diminishing as the informativeness of stock price (with respect to the agent's actions) improves. Hence, an implication of my model is that greater informativeness raises the managerial-action signaling-quality of stock price sufficiently such that both it and the accounting (non-price) signal now attract lower weights with the contractual overall pay-performance sensitivity falling. Pareto-efficiency rises as informativeness improves and the agent's required "inside-ownership" diminishes as the contract moves closer to the "first-best" with only a fixed wage. I also demonstrate that the agent bears the same risk in the optimal contract, irrespective of the rise in stock price volatility as more information enters the stock price, due to the stock-price weight being lowered in response to this higher managerial risk.

The main insight which emerges from both the HM and HT models is that one should reward the agent with a higher incentive weight the more precise is the signal or, in essence, maximize the signal to noise ratio, where in these models a more precise signal of stock price leads to a higher weight.[3] By contrast, my findings downplay this traditional insight to show that the stock price signal is a "sufficient statistic" for the stock price weight even in the presence of an accounting-based signal with superior precision. However, a far more important insight arises from my model when taking into account the degree to which stock price reflects the actions of the manager: a less informative stock price with minimal informed

[2]Bebchuk and Fried (2004) question the empirical relevance of the *informativeness* principle and Bolton and Dewatripont (2005) identify many areas of agency and contract theory in which the *principle* plays an important role.

[3]This is described by Murphy (1998): "The fundamental insight emerging from the traditional principal-agent models is that the optimal contract mimics a statistical inference problem: the payouts depend on the likelihood that the desired actions were indeed taken".

trading means that neither the principal nor traders, i.e., speculators, can closely observe the agent's actions. Monitoring is more difficult and hence the contract must depart further from the first-best contract with higher-powered incentives, rather than moving closer to the first-best flat wage as when speculators are more knowledgeable. Indeed, in contrast to HT's reported findings, I show that as more use needs to be made of price in incentive contracts the less, not more, information it contains. Furthermore, my findings make intuitive sense. When neither the principal, i.e., the board representing shareholders, nor informed speculators, can effectively monitor the manager or observe his actions, stock price becomes a very poor-quality signal. Higher-powered incentives are now called for to bring the manager's actions more into line with the principal's objectives when the required departure from the first-best contract is most extreme.

My model explains why small, newly listed, and illiquid start-ups that gain negligible benefit from informed traders in the limit order book require a founder/manager who is highly-incentivized with sizable inside ownership in relative terms, whereas highly liquid stocks benefit from external monitoring that raises volatility due to the rise in informativeness and hence the optimal incentive weight is lower. Relative inside ownership and pay-for-performance sensitivity is generally low in liquid stocks as passive outsiders largely displace insiders in large floats. This dichotomy between small start-ups and large liquid firms is supported by numerous empirical findings (e.g., Jensen and Murphy, 1990, Schaefer, 1998, and Baker and Hall, 2004).

While there have been many theoretical attempts to explain high inside share ownership in start-ups, for example, Bolton, Scheinkman, and Xiong's (2006) over-confident investors and Peng and Röell's (2008, 2014) stock price manipulation, they invariably instigate inefficiency and depart from fully-rational agents. By contrast, all my agents are fully rational and there is no manipulation. Moreover, unlike Prendergast (2002), I am able to preserve the necessary requirement for risk-averse agents without which there would be no second-best problem, while showing that the difficulty of monitoring the agent in illiquid start-up firms explains the observed high pay-for-performance sensitivity of agents in such risky environments.

In my framework for both my HM-related and HT-type models (in common with HT but not HM), I gross-up the stock price to account for the price-based incentive payment to the manager.[4] I also follow HT in subtracting the cost of the stock price incentive outlay from the firm's terminal realized (accounting) value, when determining the magnitude of the accounting-based incentive payment. Without the addition of this non-linear element to the

[4]Stock price conditional on the manager's effort is lowered by these payments to the manager. Hence failure to gross-up gives a misleading view of the principal's optimization problem.

model specification, the base to which the accounting incentive is applied would be distorted by neglect of the price-based incentive payment and hence overstated.

My optimal contracting solution is not just an isolated example showing that incentives must rise as the difficulty of monitoring increases. Many other contracting examples in the literature are also explained by my approach. For example, Brickley and Dark (1987) explain geographically dispersed high-powered incentive franchise contracts as a consequence of distance, with headquarters monitoring nearby in-house outlets that are easier to monitor with franchised outlets at greater distance.

What is the empirical relevance of my model? First, it explains why the propensity of firms to list is dominated by size. Doidge, Karolyi, and Stulz (2017, Figure 5, Panel A) show that in 1980, 80% of firms with over 10,000 employees were listed in the U.S. but for firms in the range, 2,500-4,999 employees, the propensity was only about 25% and far lower again for smaller firms. This literature does not attempt to show why size is so important for listing success within a coherent model that is consistent with the available evidence. My model explains this size phenomena in terms of the more effective monitoring by informed speculators with more liquid trading. However, from 1996 to 2012 the propensity to list fell by 55.53% for firms with 1,000–2,499 employees and even more for smaller firms. Only the very largest firms were least affected with a decline of only 8.2%. By comparison, listings in developed countries excluding the U.S. rose by 48% over the same period of analysis, 1996-2012. Clearly, since 1996 there has been a sizable increase in the implicit cost of being listed specifically in the U.S. Moreover, this cost rise has reserved its worst effects for medium and smaller firms but firms above a sizable size-threshold seem largely immune. Since these large and highly-liquid firms enjoy the benefits of much lower pay-performance sensitivity due to stock price being more reflective managerial actions, this savage decline in the number of listings has been accompanied by a relative shift toward large firms with higher outside- and lower inside-ownership.

These findings are supportive of my agency models as they suggest that smaller listed firms gain little from listing as non-price incentives such as accounting earnings are equally applicable to unlisted firms. Moreover, the firm has to be of some very-sizable minimum degree of liquidity to make it sufficiently liquid to benefit from monitoring stemming from speculators who observe the actions of the manager. These monitoring benefits enable liquid firms to effectively utilize lower-powered incentives that are closer to the first-best ideal since they are far more effective in motivating management. Hence, improved contracting enjoyed by liquid firms is critical for their success and survival in the face of a sizable increase in the implicit cost of being listed. The origins of this increase in implicit listing costs were not identified by Doidge, Karolyi, and Stulz (2017) but must surely relate to regulatory differences between the U.S. market and elsewhere in the world.

Could the relative immunity of large listed U.S. firms to higher implicit listing costs be simply due to the economies of scale that undoubtedly large firms enjoy? One might argue, for example, that, intrinsically, large firms should escape the worst effects of this cost increase without having to call on the lower contracting costs in highly-liquid market conditions as an explanation. No. It is true that large unlisted firms presumably also enjoy scale economies, but their contracting costs are higher because they cannot contract based on stock price informativeness. Hence, it does not pay large listed firms to forego their listed stock liquidity advantage by delisting due to management buyout or private equity acquisition.

Second, my findings explain why pay-for-performance falls with firm size and as information in stock price improves and why, generally, high-powered contracts such as franchise agreements are confined to circumstances where close monitoring is difficult or virtually impossible. Third, my model explains why stock liquidity facilitates a more informative stock price and raises the effectiveness of managerial incentives, as empirically documented by Fang, Noe, and Tice (2009) and discussed below.

While this paper is in no way intended as a critique of HT's article or findings, I do derive explicit solutions to HT's model that were absent from the original and are based entirely on their model. I show that, putting aside a number of logical difficulties that are discussed in Section II below, HT actually showed that the less information there is in stock price, the higher the incentive weight. In other words, despite HT's claim to find that a lower speculator investment in information results in a lower weight on price "since price is less informative", they actually found the reverse, the same as my finding. Their mistake came about because they confused their transformed price weight, incorporating both the level of information in stock and information about their non-price weight, with the firm's actual price weight. By construction, their transformed price weight always moves in the opposite direction to their actual weight. Other logical difficulties include situations in which the price signal is a "sufficient statistic" for the non-price signal and apparent logical irregularities in the manner in which they incorporate their *normalized* contract.

I. The Model with No Informed Trading

I commence with my simplified version of HT's agency model of the firm and only add Kyle's (1985) informed trader who is in receipt of an imperfect signal of managerial actions in the next section, Section II, dealing with informed trading. These speculators can invest resources to obtain a more precise signal of the end-of-period price. The reason I do not add HT's informed trader framework at this stage is to establish the contracting framework base-case in the absence of information in the stock price to provide a solution which not only has some resemblance to HM (pp.323-325) but is also more in the tradition of standard agency models to which my solution can be compared once stock price becomes informative.

In common with HT, the model has three dates, an initial date, $t = 0$, in which the firm is founded by a risk-neutral insider and the appointed risk-averse manager (who cannot trade) signs his contract that is not subject to renegotiation. The manager makes his effort choice according to the incentives provided in the contract. In HT's formulation analyzed in the following section, risk-neutral speculators then trade on an imperfect signal of the manager's effort with the stock price determined at date $t = 1$. At the final date, $t = 2$, the firm is liquidated with gross proceeds, $\tilde{\pi}$, used to compensate the manager, that depend on the manager's actual effort level, e, and the realized values of a random accounting signal error term, $\tilde{\varepsilon}$. To enhance focus, I exclude HT's determination of inside shareholdings in the initial period and the manager's short-term earnings. I also drop HT's time subscripts for now as they play no role in my simplified framework.

Before it is possible to assess whether one's treatment of the participation of informed traders in the stock market has validity, it is necessary to address a more conventional but otherwise identical problem in the absence of informed trading in the stock market. Thus my starting point is a relatively illiquid but nonetheless listed company that possesses a stock price but, in the absence of a crowd in which informed traders can hide, there are no informed traders. My initial model is more conventional in that it is a simple extension of the famous example of an optimal linear risk-sharing contract provided by HM in the absence of a market maker and information in the stock price but differs insofar as I focus on the firm's net value, that is, net of both the firm's stock-based incentive payments to the manager and the firm's accounting earnings or non-price based incentive payments.[5]

The firm's gross stock price, p, is specified by the firm's earnings which, in turn, depend on the manager's unobservable effort, e, with effort level $e \in [0, \infty)$, but measured net of the stock-price based incentive payment to the manager, $p = e - Ap$, where $A \in [0, 1]$, is the incentive weight on stock price. Hence the stock price measured net of the incentive benefit, Ap, provided to the manager is grossed-up[6] by an amount, $1 + A$, with $p = e/(1 + A)$. Since it is cumbersome to manipulate this grossing-up term, I define a new transformed incentive weight, $\alpha \equiv A/(1 + A) < 1/2$, such that the net stock price can now be expressed as:

$$p \equiv (1 - \alpha)\, e. \tag{1}$$

[5]HM has become a workhorse agency model, see, e.g., Garen (1994).

[6]Note that HT gross-up stock price but HM do not

As in HT, earnings are related to the manager's unobservable effort, $\tilde{p} = (1-\alpha)(e+\tilde{\theta})$, with effort level $e \in [0,\infty)$ and conjectured equilibrium effort, $\bar{e}$, so that $\mathbb{E}(p) = (1-\alpha)\,\bar{e}$. The stock price has intrinsic and exogenously given volatility, σ_θ^2, whose origin is arbitrary. It could, for example, represent Kyle's (1985) random noise trading. The variance of the net price is given by $Var[p] = (1-\alpha)^2\sigma_\theta^2$. Despite stock market trading not being explicitly treated in this model, it is assumed that the stock price is informationally efficient such that it reflects the manager's effort choice. Potential model weakness due to this strong assumption is addressed in the next section once informed trading is introduced.

In the second period the firm is liquidated with stochastic accounting-based proceeds representing the accounting signal, gross of price-based incentive payments to the manager:

$$\tilde{\pi} = e + \tilde{\varepsilon}, \tag{2}$$

where the error-term in the accounting (non-price) signal, $\tilde{\varepsilon}$, satisfies $\varepsilon \sim \mathrm{N}(0, \sigma_\varepsilon^2)$. This realized value, π, must be measured net of the stock price incentive payment to the manager, as in HT. Hence, the incentive reward to the manager is given by $Ap + a(e - Ap) = [\alpha(1-a) + a]\,e$, on substituting using equation (1) and the definition of α. I exclude HT's (p.684, equation (2)) essentially redundant intrinsic stock-price error term, $\tilde{\theta}$, with volatility, σ_θ^2, noted above, from my simplified formulation of the non-price signal based on the realized firm value given by equation (2). The reason for neglect is to ensure that the price signal can never dominate the non-price signal, even when informed traders receive a perfect signal with no observational errors.[7]

Combining the two sources of firm net income from the price-based and accounting income based incentives, the firm's gross income (revenue) is given by effort, e, and revenue net of incentive payments, NR, is:

$$NR = e - [\alpha(1-a) + a]\,e = e\,(1-a)\,(1-\alpha)\,. \tag{3}$$

Since $A \equiv \alpha/(1-\alpha)$, and therefore $Ap = \alpha e$, the manager's total income expression is, $\mathbb{E}[I] = [\alpha(1-a)+a]\,e + W$, where W is the fixed wage, $A \in [0,1] \equiv \alpha/(1-\alpha)$, is the incentive weight on stock price, $\tilde{p}$, and the non-price weight, $a \in [0,1]$, is given by shares transferred from inside owners to the manager and paid for out of liquidation proceeds, representing the terminal value of assets. The value of stock appreciation rights, Ap, is

[7] In a comparison of HT's non-price signal and price signal, (p.684, equation (2) and equation (3)), when there is non-price error, $\tilde{\varepsilon} > 0$, the price signal, s, is a "sufficient statistic" for the non-price signal when the price signal error approaches zero, $\tilde{\eta} \to 0$. Hence HT's accounting weight is mechanically and progressively eliminated as stock-price informativeness improves. Also note that my notation for accounting signal variance, σ_ε^2, is used in place of HT's notation, σ_2^2.

deducted from the non-price incentive, as was also the case with HT (p.686, equation (4)).

The manager maximizes his negative exponential utility function with certainty equivalence utility:

$$\mathbb{E}\left[U\left(I,e\right)\right] = \mathbb{E}\left[I\right] - \rho Var\left[I\right]/2 - ce^2/2 = \bar{U} = 0, \tag{4}$$

where ρ is the manager's coefficient of absolute risk aversion (i.e., CARA coefficient), $\mathrm{Var}\left(I\right)$ is the variance of the manager's income, $ce^2/2 \geq 0$, is the quadratic cost of managerial effort function with marginal cost of effort, $c'\left(e\right) \equiv ce$, with marginal-cost coefficient, c, and $\bar{U}$, which is set equal to zero, represents the manager's utility in his next-best outside opportunity. While HT's expression for effort costs is slightly more general, I follow HM's simpler quadratic treatment that makes exposition easier. None of my findings depend at all on my deployment of a simple quadratic cost function.

Since the manager's expected pay is made up of incentives plus fixed remuneration, $\mathbb{E}\left[I\right] = \left[\alpha\left(1-a\right)+a\right]e + W$, the manager's optimal effort level, denoted by the accent, $\bar{e}$, is found by choosing actual effort, e, to maximize the difference between the manager's incentive payments and his effort cost, $E\left[I\right] - ce^2/2 = \left[\alpha\left(1-a\right)+a\right]e + W - ce^2/2$, to yield the manager's equilibrium choice of effort:

$$\bar{e} = \left[\alpha\left(1-a\right)+a\right]/c. \tag{5}$$

Because in my specification the covariance between the price and non-price signal is zero due to the removal of the redundant term, σ_θ^2, from the non-price signal, the variance of the manager's income becomes:

$$Var[I] = \left[\alpha^2(1-a)^2\sigma_\theta^2 + a^2\sigma_\varepsilon^2\right]. \tag{6}$$

Given that expected pay, $\mathbb{E}\left[I\right] = \left[\alpha\left(1-a\right)+a\right]e + W$, and utilizing equations (4), (5), and (6), the manager's (fixed-pay) participation constraint becomes:

$$W = ce^2/2 - \left[\alpha\left(1-a\right)+a\right]e + \rho c\left[\alpha^2(1-a)^2\sigma_\theta^2 + a^2\sigma_\varepsilon^2\right]/2c, \tag{7}$$

so that, utilizing the manager's participation constraint, fixed pay consists of his quadratic effort cost plus compensation for certainty equivalence risk measured net of his expected incentive payments. Hence, expected pay is simply the sum of the manager's quadratic cost of effort plus compensation for risk bearing:

$$\mathbb{E}\left[I\right] = \left\{\left[\alpha\left(1-a\right)+a\right]^2 + \rho c\left[\alpha^2(1-a)^2\mu\sigma_\theta^2 + a^2\sigma_\varepsilon^2\right]\right\}/2c, \tag{8}$$

with the incentive payments subsumed within these components of manager cost and hence incorporated within it.

One might be tempted to think that the principal's aim is to maximize the difference between the firm's expected net revenue, NR, given by equation (3) above and the manager's expected pay but this is incorrect as this would mean subtracting the manager's incentive payments twice, once in net revenue and again in managerial cost. Alternatively, one can subtract fixed pay, W, from net revenue as this pay component is not included in net revenue or, equivalently, simply maximize the principal's objective, namely, firm's expected profit, $\mathbb{E}[\Pi] = e - \mathbb{E}[I]$, the difference between expected gross revenue and expected managerial cost. But to carry out this objective, an additional transformation is required, $b \equiv \alpha(1-a)$, in the spirit of HT, to eliminate the terms involving $1-a$:

$$\underset{b,\,a}{Max} : \mathbb{E}[\Pi] = (b+a)/c - \left\{(b+a)^2 + \rho c\left(b^2\sigma_\theta^2 + a^2\sigma_\varepsilon^2\right)\right\}/2c. \tag{9}$$

Before deriving the solutions to this problem, it is useful to characterize the first-best solution as $\hat{e} = 1/c$ and fixed wage, $\hat{W} = 1/2c$, with firm profit given by half the first-best effort, $\hat{\Pi} = (1/2)\,\hat{e}$.

Perhaps not so remarkably given the opening discussion, but nonetheless contrary to the spirit it least of Holmström's (1979) *informativeness* principle, the optimal share price incentive weight does not at all depend on the efficacy of the non-price incentive weight. The first-order optimization condition for the principal's share price weight, b, becomes: equations:

$$b = (1-a)\big/\left(1 + \rho c\sigma_\theta^2\right), \tag{10}$$

and since $b \equiv \alpha(1-a)$, we immediately have:

$$\bar{\alpha} = 1\big/\left(1 + \rho c\sigma_\theta^2\right) \leq 1/2. \tag{11}$$

However, the expression for $\bar{\alpha}$ is not the end of the story as the only relevant incentive weight is the original untransformed weight, $\bar{A}$, since $A \equiv \alpha/(1-\alpha)$, whose value is given by the exceedingly simple expression:

$$\bar{A} = \left(\sigma_\theta^2\right)^{-1}\Big/\rho c \;\leq 1, \tag{12}$$

where the modified risk term meets the condition, $\rho c\sigma_\theta^2 \geq 1$. In other words, irrespective of the efficacy, i.e., "precision", of the non-price or accounting signal, the optimal share price incentive weight is given by it's precision deflated by the product of the manager's CARA risk coefficient, ρ, and cost of managerial effort, c. It is important to note that my optimal contract weight is exceedingly high-powered relative to HM's finding:

$$\bar{A}_{HM} = 1\big/\big(1 + \rho c \sigma_\theta^2\big). \tag{13}$$

The reason that HM's price weight is so much lower than mine, i.e., lower-powered, $\bar{A}_{HM} < \bar{A}$, is that HM's contract is based on the high gross stock price, rather than the low net stock price, and thus does not take into account how the nature of the contract modifies the stock price.

I now maximize the profit expression, equation (9) above, with respect to the non-price weight to obtain:

$$a = (1 - b)\big/\big(1 + \rho c \sigma_\varepsilon^2\big), \tag{14}$$

and, once again substitute for $b \equiv \alpha\,(1 - a)$ utilizing the solution for $\bar{\alpha}$ given by equation (11), I obtain:

$$\bar{a} = \sigma_\theta^2\big/\big[\sigma_\varepsilon^2\,\big(1 + \rho c \sigma_\theta^2\big)\big]\ . \tag{15}$$

If there is no stock price at all, as is the case for private equity, then the accounting (i.e., non- price) incentive is given by $\bar{a} = 1/(1 + \rho c \sigma_\varepsilon^2)$, which is less efficient at motivation than the combination of the incentives provided by equations (12) and (15).

Since start-ups and other small firms have typically high inside ownership and pay-for-performance sensitivity, despite high stock price volatility, whereas large liquid firms have low sensitivity, HM's model is not the entire story. Hence, we now turn to a model that incorporates informed traders in the stock market to provide a more comprehensive examination of managerial incentives.

One can make a general point about my HM-related model that well describes the incentive opportunities available to small, relatively illiquid, but nonetheless listed companies. Their contracting opportunities remain better than unlisted private equity but only a small proportion of such firms are listed and their survival in listed status remains problematic, as indicated by Doidge, Karolyi, and Stulz (2017).

II. Adding Informed Trading to the Model

Following HT, I now add Kyle's (1985) informed trader who is in receipt of an imperfect signal of managerial actions/performance. However, instead of just one informed trader, I generalize HT's model to n informed traders with limiting value, $n \to \infty$. Informed speculators can invest resources to obtain a more precise signal of the end-of-period price. The set-up is identical to that described above in Section I above and hence we now turn to the determination of stock price in the presence of informed traders.

A. Determination of the Equilibrium Stock Price

Drawing on the derivation by de Jong and Rindi (2009, pp.61-63), I model $n \geqslant 1$ partially-informed homogeneous strategic traders (speculators), rather than HT's single informed speculator, with $n = 1$ at its lower bound. This inclusion of multiple informed speculators adds to the richness of HT's original model by providing an additional and, importantly, observable parameter that alters stock price informativeness. At $t = 1$ each informed trader indexed by i submits a market order, $x_i(s)$, after observing an imperfect signal of the true (common) fundamental firm value in the initial period based on the trader's observation of the actual level of effort, e, arising from price-based incentives:

$$\tilde{s_i} = e + \tilde{\theta} + \tilde{\eta}, \forall i (i = 1, ..., n), \tag{16}$$

with each speculator in receipt of the same imperfect signal, $\tilde{\eta}$, and subject to a normally distributed observational error, $\tilde{\eta} \sim \mathcal{N}(0, \sigma_\eta^2)$.

The speculator, or multiple speculators, can reduce the observational error by reducing the error variance, σ_η^2, with a fixed informational cost $c_I = g\left(\sigma_\eta^2\right)^{-1}$, where the function c_I is increasing in $1/\sigma_\eta^2$ and convex, for example, the quadratic function, $c_I = (1/2)c_\eta(1/\sigma_\eta^2)^2$, with a positive constant, c_η, and where the volatility, σ_η^2, is understood to fixed at its optimal value, $\bar{\sigma}_\eta^2$, with the accent no longer shown. From an empirical testing implementation perspective it is, of course, very difficult to parameterize this observational error variance and hence my introduction of the number of informed participants, n, as an additional parameter.[8]

In HT's Kyle (1985) model framework in common with mine, liquidity is provided by "noise" trader demand given by $\tilde{y} \sim \mathcal{N}(0, \sigma_y^2)$. These traders do not receive an informative signal and are not strategic. The market maker's linear pricing rule is:

$$p(\tilde{q}) = \bar{e} - Ap(\tilde{q}) + \lambda\tilde{q}, \tag{17}$$

where $p(\tilde{q})$ is stock price, equilibrium effort, $\bar{e} \equiv \omega$ in the Appendix, is the intercept on the price axis, $\tilde{q}$ is signed order flow that alters price at the rate λ, representing Kyle's lambda measure of price impact (illiquidity), and, once again, coefficient A represents the magnitude of the manager's stock appreciation rights, effectively his incentive equity share and weight on stock price, given that in both HT and in my version of HM's model in Section

[8]This extension of the model is especially useful for empirical estimation purposes but does not play a critical role in my proposed integration of incentive determinants over the full range of liquidity possibilities.

I above, the contract is based on the net stock price that reflects outside ownership dilution due to incentive payments to the manager. In this section, I employ the same grossing-up transformation of the incentive weight as in Section I above. Hence, once again, the grossing-up factor is given by $1/(1+A) \equiv 1-\alpha$.

On rearranging this price expression, equation (17), and solving for stock price, I have the grossed-up stock price equation:

$$p\left(\tilde{q}\right) = \left(1-\alpha\right)\left(\bar{e}+\lambda\tilde{q}\right). \tag{18}$$

Each of the n strategic traders conjectures a linear trading strategy that takes the form:

$$\bar{x}_i\left(\tilde{s}_i\right) = \beta\left(\tilde{s}_i-\bar{e}\right), \quad \forall i = 1, ..., \ n, \tag{19}$$

where the accent on x_i indicates the optimum solution, and β represents the positive coefficient of trader aggressiveness. Only the total signed order flow is visible to the market maker, $\tilde{q} = nx_i\left(\tilde{s}_i\right)+\tilde{y} = n\beta\left(\tilde{s}_i-\bar{e}\right)+\tilde{y}$. Moreover, order-flow is dependent on the sum of actions of all n strategic traders plus noise trader demand. Equation (IA.2) in the Appendix indicates that

$$\beta = \frac{\sigma_y}{n^{\frac{1}{2}}\left(\sigma_\theta^2+\sigma_\eta^2\right)^{\frac{1}{2}}}. \tag{20}$$

Relying on equations (20) above and (IA.3) from the Appendix, HT's (p.691) stock price informativeness coefficient, μ, generalized to multiple informed traders, becomes:

$$0 \leqslant \mu \equiv \lambda n\beta = \frac{n}{n+1}\frac{\sigma_\theta^2}{\left(\sigma_\theta^2+\sigma_\eta^2\right)} \leqslant 1. \tag{21}$$

It is increasing in both the number of competing strategic traders, n, and intrinsic volatility, σ_θ^2, while falling in the variance of the forecast error term, $\bar{\sigma}_\eta^2$. Since coefficient n and the two variance terms are determined entirely by the decisions of informed speculators, together with the market maker, and not at all by the actions of firms, it is legitimate to treat μ as a parameter, not only suitable for comparative-static choice when investigating the impact of liquidity and information on the principal's choice of incentive structure, but also as a parameter that forms the basis of the manager's contract. Moreover, it reduces to precisely HT's (p.691, equation (17)) expression, $\mu = \sigma_\theta^2\left[2\left(\sigma_\theta^2+\bar{\sigma}_\eta^2\right)\right]^{-1}$, when $n = 1$. This extended version of HT's model includes two sources of stock price informativeness, (i) greater investment in information acquisition by individual speculators that reduces the error in the speculator's signal, $\bar{\sigma}_\eta^2$, and, (ii) the presence of a larger number of informed speculators, n, that speeds up the convergence toward the equilibrium. Apart from providing an empirical measure of information and speeding up the conversion to equilibrium, the incorporation of multiple informed traders does not fundamentally alter the nature of the equilibrium in my agency model in comparison with HT's.

As traders' incur added cost to receive a more precise signal with the lowering of the volatility of the random error term, σ_η^2, the more favorable is the signal-to-noise ratio, as the ratio $\sigma_\theta^2\left(\sigma_\theta^2+\bar{\sigma}_\eta^2\right)^{-1}$ approaches 1 in the expression for informativeness. Received agency theory would tell us that the incentive weight must go up in response to an improved signal-to-noise ratio, but this is entirely incorrect. Intuitively, one would expect that as informed speculators participate more heavily in the trading process and improve the monitoring role that the principal (here company boards) are supposed to perform, that pay-for-performance sensitivity both should and will decline in an entirely contrary fashion to received theory.

Greater informativeness about the actions of the manager enables the optimal incentive contract to more closely resemble the first-best contract in which the actions of the manager can be observed perfectly and, in such extreme circumstances, the risk-averse manager's incentives are replaced by an optimal fixed wage. It is well known that the better the principal can observe the agent's (manager's) actions, the closer will the optimal contract approach the first-best flat wage with zero pay-for-performance sensitivity. Hence, one should also expect that if it is informed speculators rather than the principal observing the manager's actions, a similar favorable optimal contractual outcome should occur.

I can now state Proposition 1:

Proposition 1: *Stock price informativeness, $\mu\equiv\lambda n\beta$, which can be contracted upon, is increasing in the number of informed speculators and improvements (i.e., reductions) in the speculators' forecast error. As the volatility of the speculator's forecast error approaches infinity, the informativeness of the stock price approaches zero, $\mu\to 0$.*

While this limiting outcome with zero information appears similar to the state of affairs in my version of HM's model in Section I above, they are in reality quite different as Kyle's market maker intervenes to eliminate stock price volatility, other than that due to informed trading, in the current section.

The ith speculator's expected trading revenue is given by: $n^{-1}\sigma_y^2\lambda$ with fixed informational costs, I_c, diminishing in the volatility of the error term in the signal, $c_I\equiv g\left(\frac{1}{\bar{\sigma}_\eta^2}\right)=\frac{1}{2}c_\eta\left(\frac{1}{\bar{\sigma}_\eta^2}\right)^2$, where c_η is a positive constant and $dc_I/d\sigma_\eta^2<0$. Hence, as HT demonstrated for single speculator case with $n=1$, the ith speculator's expected net profit is given by:

$$\mathbb{E}\left[R_i\right]=\frac{\sigma_y\sigma_\theta^2}{n^{\frac{1}{2}}\left(n+1\right)\left(\sigma_\theta^2+\bar{\sigma}_\eta^2\right)^{\frac{1}{2}}}-\frac{1}{2}c_\eta\left(\frac{1}{\sigma_\eta^2}\right)^2. \tag{22}$$

I now follow HT (p.690) and introduce a scaling factor K that multiplies both firm profit, $\tilde{\pi}$, and the magnitude of the signal, $\tilde{s}_i = K\left(e + \tilde{\theta} + \tilde{\eta}\right), \quad \forall i = 1, ..., n$. The equilibrium level of investment in information becomes:

$$f\left(K, \bar{\sigma}_\eta^2\right) = -\frac{K\sigma_y\sigma_\theta^2\left(\bar{\sigma}_\eta^2\right)^2}{2n^{\frac{1}{2}}\left(n+1\right)\left(\sigma_\theta^2 + \bar{\sigma}_\eta^2\right)^{3/2}} + \frac{c_\eta}{\left(\bar{\sigma}_\eta^2\right)} = 0, \tag{23}$$

on including HT's firm size scaling factor, K, in the first-order condition with the accent on the volatility term $\bar{\sigma}_\eta^2$ indicating the speculator's optimal choice.

Since $d\bar{\sigma}_\eta^2/dK = -f_K \big/ f_{\bar{\sigma}_\eta^2} > 0$ as $f_K > 0$ as $f_{\bar{\sigma}_\eta^2} < 0$ and $f_{\bar{\sigma}_\eta^2} < 0$, by the second-order condition for a maximum, stock price informativeness is increasing, hence $\bar{\sigma}_\eta^2$ is falling, as the scaling factor, K, augments the degree of noise trading, σ_y, and the ability of informed traders to hide in the crowd. The scaling factor does not affect the signal received by speculators directly as the scaled signal, s_i/K, is unaffected, but it does increase stock price informativeness indirectly. Moreover, denoting the first-order condition, equation (23), by $f\left(n, \bar{\sigma}_\eta^2\right)$, we have $f_n\left(n, \bar{\sigma}_\eta^2\right) > 0$. Hence, $d\sigma_\eta^2/dn = -f_n \big/ f_{\sigma_\eta^2} > 0$, and consequently informativeness in the stock price for a given speculator is diminishing in the number of informed traders due to the expense of duplicating investment in information acquisition.

Thus, while speculator proliferation makes for a more informative stock price given each speculator's investment in information, such fragmentation reduces the incentive for each speculator to acquire information in the first place. From now on and in keeping with HT, the scale factor, K, is suppressed until Section III, as is the accent on $\bar{\sigma}_\eta^2$ indicating the optimal informational choice.

The expression for the level of trading activity by the representative informed trader in the Appendix, equation (IA.1), becomes:

$$x = \beta\left(e + \tilde{\theta} + \tilde{\eta} - \bar{e}\right), \tag{24}$$

where β is given by equation (20) above, indicates that when actual effort due to the price-based incentive contact, e, exceeds conjectured equilibrium effort, $\bar{e}$, due to the same contract, there will exist systematic buying pressure and, in the reverse situation, systematic selling pressure, in addition to the random components of order flow generated by $\tilde{\theta} + \tilde{\eta}$. Of course, in equilibrium, HT's (p. 689, equation (13)) specification, $x = \beta\left(\tilde{\theta} + \tilde{\eta}\right)$, is obtained.

This out-of-equilibrium systematic informed trading pressure generates the critical price equation which is consistent with but differs from the full equilibrium price set out by HT (p.689, equation (11)), which is also correct, with HT's equation equivalent to mine in the manager's effort equilibrium when conjectured and actual effort are the same with

$$\tilde{p} = (1-\alpha)\left[\bar{e} + \mu\left(\tilde{\theta} + \tilde{\eta}\right) + \lambda\tilde{y}\right]. \tag{25}$$

Hence, on utilizing equation (25), the expected stock price becomes:

$$\mathbb{E}(p) = (1-\alpha)\,\bar{e}, \tag{26}$$

which indicates that, in both my and HT's Kyle framework and conditional on the manager's equilibrium effort, the expected stock price is grossed up by an amount which exceeds 1, $1 + A$, representing the manager's effective stock ownership. The grossing-up term indicates the firm's lower net price as effectively more equity is awarded the manager conditional on given effort. However, prior to the manager's equilibrium being reached, the grossed-up stock price, equation (IA.8) in the Appendix, is:

$$\tilde{p} = (1-\alpha)\left[(1-\mu)\,\bar{e} + \mu\left(e + \tilde{\theta} + \tilde{\eta}\right) + \lambda\tilde{y}\right], \tag{27}$$

where $\bar{e}$ is the hypothesized equilibrium effort and e is the actual effort due to stock-based price incentives, such that actual effort is determined by μ, representing the information implanted into stock prices by informed trading.[9]

B. *Determinants of the Optimal Incentive Contract*

I now address the optimal price weight, $\bar{A}$, and non-price incentive, $\bar{a}$. The manager's expected income, initially set out in equation (8) above, but now incorporating the new price expression, equation (27), becomes:

$$\mathbb{E}[I] = Ap(1-a) + ae + W = [(\alpha\mu(1-a) + a)\,e] + W. \tag{28}$$

In the Appendix, I compute the variance of stock price with information content due to informed trading as[10]:

$$Var(p) = (1-\alpha)^2\mu\sigma_\theta^2. \tag{29}$$

[9]Comfortingly, while HT does not specify the out-of-equilibrium price, equation (27), specifically in their paper, it is implicit in the derivation of their "normalized" price (HT, p.691 equation (17)), such that it is a function of actual effort, e, rather than equilibrium effort, $\bar{e}$.

[10]This expression for price variance corresponds precisely to that of HT (p.690, equation (14)) when there is but one informed trader.

Hence the variance of the manager's income, depending on the components of his incentive pay, becomes:

$$Var\,[I] = \alpha^2\mu(1-a)^2\sigma_\theta^2 + a^2\sigma_\varepsilon^2. \tag{30}$$

It is important to note that, after recognizing the effect of the incentive weight, $\alpha^2(1-a)^2$, the manager's income volatility is due to the product of information in stock price, μ, and the firm's intrinsic volatility, σ_θ^2, or "noise". Hence, as information, $\mu \to 0$, the volatility term in the manager's income also $\to 0$. Only when $\mu \to 1$ does volatility in this Kyle/HT framework rise to the same level as in the context of the HM-type model exposited in Section I above. Consequently, the contract is always more high-powered in my model inspired by HT than in my HM-related model exposited in Section I. This role of information represents an important distinction made by Baker and Jorgensen (2003) between information and "noise". As we shall see, the Pareto-efficient contract weight varies to take out all the volatility due to information, leaving only intrinsic volatility due to genuine "noise".

It is striking that the Kyle's (1985) noise trader liquidity term, $\lambda^2\sigma_y^2$, disappears from both the income and price variance expressions, but this is to be expected as informed traders endogenously alter their degree of trade aggressiveness, β, to fully exploit such liquidity. This explains the otherwise very puzzling feature of HT's volatility expression that volatility, $\mu\sigma_\theta^2$, $\to 0$ as $\mu \to 0$. In the complete absence of informed trading, stock price volatility within Kyle's model is given by random noise trader demand, σ_y^2, but Kyle's market maker neutralize this pure noise trading volatility by trading against it, eliminating the volatility. Nonetheless, in this limiting situation, and at all times, the optimal contract undoes the volatility induced by informed speculators to price only intrinsic volatility.

One can see, already, that HT have accomplished a significant improvement in the more basic model of HM that I began with in Section I. As these imperfect informed traders become more accurate in their ability to predict future price movements with $\mu \to 1$, actual price volatility reflects largely the intrinsic volatility, σ_θ^2, that is incapable of reduction and has nothing to do with the actions of the manager.

It is unsurprising that this variance, and hence the risk cost to the manager, is increasing in informativeness, μ, for a given incentive weight, making it both more expensive and inappropriate to provide the manager with higher-powered incentives in more informative markets. However, incentives in low information states will be far more high-powered due to the low share price volatility in these states.

On evaluating equation (27), the stock price itself is increasing in actual managerial effort, e, at a rate which is dependent on the product of the grossed-up pricing incentive and the degree of information in the stock price, $(1-\alpha)\,\mu$. The manager's expected income, measured net of his (quadratic) effort cost as a function of his actual level of effort, becomes:

$$\underset{e}{Max}:\mathbb{E}\left[I\right]-ce^2/2=\left[\alpha\mu\left(1-a\right)+a\right]e+W-ce^2/2, \tag{31}$$

on utilizing equations (27) and (28). Neither the manager's fixed pay, W, nor the manager's compensation for bearing risk, is directly a function of his effort and thus does not appear in the agent's objective, equation (31).

The manager determines his optimal effort according to his concave and binding incentive compatibility constraint with his equilibrium level of effort:

$$\bar{e}=\left[\alpha\mu\left(1-a\right)+a\right]/c, \tag{32}$$

so that effort is increasing in the price incentive weight, $\alpha\geq 0$, the degree of stock price informativeness, μ, and, naturally, is falling in effort cost, c. As the non-price incentive weight, a, increases, this has ambiguous effects with more weight on accounting-related effort and with a falling weight on stock price.

Utilizing the income volatility term (equation (30)) above, the manager's certainty equivalence utility now differs from his initial constraint in the absence of information, equation (4) above, to become:

$$U\left(I,e\right)=W+\left(\alpha\mu\left(1-a\right)+a\right)e-\rho c\left(\alpha^2(1-a)^2\mu\sigma_\theta^2+a^2\sigma_\varepsilon^2\right)/2c-ce^2/2=\bar{U}=0, \tag{33}$$

which will be binding in equilibrium, and hence the manager's fixed pay to cover both risk and effort costs becomes:

$$W=ce^2/2-\left(\alpha\mu\left(1-a\right)+a\right)e-\rho c\left[\alpha^2\mu(1-a)^2\sigma_\theta^2+a^2\sigma_\varepsilon^2\right]/2c. \tag{34}$$

Thus, on substituting for equilibrium effort and simplifying, the total expected cost to the principal of hiring the manager is simply the sum of his incentive plus fixed payment:

$$\mathbb{E}\left[I\right]=\left\{\left[\left(\alpha\mu\left(1-a\right)+a\right)\right]^2+\rho c\left(\alpha^2\mu(1-a)^2\sigma_\theta^2+a^2\sigma_\varepsilon^2\right)\right\}/2c, \tag{35}$$

which is made up of the cost of the manager's effort plus required compensation for bearing risk.

Once again, as in the previous HM-type model given by equation (9) above without information in stock price, the Principal's aim can be expressed as maximizing profit, consisting of gross revenue given by $\mathbb{E}\left(p\right)=\bar{e}$, net of the entire expected cost of hiring the manager, $\mathbb{E}(\Pi)=\bar{e}-\mathbb{E}\left(I\right)$. Moreover, his choices are once again made over $b\equiv\alpha\left(1-a\right)$ and a, with this transformation for b used to simplify equations (32) to (35). Thus, the principal chooses b and a optimally to maximize the concave expression:

$$\underset{b,\,a}{Max} : E\left[\Pi\right] = (b\mu + a)/c - \left[(b\mu + a)^2 + \rho c\left(b^2\mu\sigma_\theta^2 + a^2\sigma_\varepsilon^2\right)\right]/2c. \tag{36}$$

As with the absence of information in stock price in Section I above, it is essential to avoid double-counting of managerial outlays.[11]

The principal's choice of b yields:

$$b = (1-a)/\left(1 + \rho c\sigma_\theta^2\right), \tag{37}$$

and, on evaluating b, the optimal transformed price weight, $\bar{\alpha}$:

$$\bar{\alpha} = 1/\left(\mu + \rho c\sigma_\theta^2\right), \tag{38}$$

and, finally, on solving for the initial incentive weight, $\bar{A}$, the paper's main result:

$$\bar{A} = 1/\left(\mu - 1 + \rho c\sigma_\theta^2\right). \tag{39}$$

Hence, like the optimal price weight in the HM-related problem with no information in stock price, equation (12) above, the stock price signal is a "sufficient statistic" for the stock price weight.

The optimal non-price, i.e., accounting, weight is found by first optimizing firm profit, equation (36), with respect to a to obtain:

$$a = (1-b)/\left(1 + \rho c\sigma_\varepsilon^2\right), \tag{40}$$

and, on substituting for $b \equiv \bar{\alpha}\,(1-a) = (1-a)/(\mu + \rho c\sigma_\theta^2)$, obtain the equilibrium accounting weight:

$$\bar{a} = \sigma_\theta^2/\left[\sigma_\varepsilon^2\left(\mu + \rho c\sigma_\theta^2\right)\right]\ . \tag{41}$$

Not only is the accounting weight diminishing as more information is added to stock price, $\partial\bar{a}/\partial\mu < 0$, as does the stock price weight, but is also always more high-powered than the accounting-based contract in the absence of information in stock price given by equation (15) in Section I above, except when stock price reaches its informative upper-bound, $\mu \to 1$.

The relative relationship between the accounting weight, a, and the α price weight, with the price weight entirely independent of the accounting weight, is summarized by

[11] It is significant that no-where does HT allude to this double-counting problem or how to avoid it.

$\bar{a}/\bar{\alpha} = \sigma_\theta^2/\sigma_\varepsilon^2$, reflecting no more that the relative precision's of the two signals and is reminiscent of the *informativeness* principle insofar as only relative precision's matter. However, the more relevant comparison is with respect to the actual relative weights, $\bar{a}$, and $\bar{A}$ for which it is easily shown that $\partial\left(\bar{a}/\bar{A}\right)/\partial\mu > 0$. Hence a more informative stock price simultaneously improves contracting with respect to both accounting and stock price incentives with both contractual relationships getting closer to the first-best. Nonetheless, the stock price weight converges faster toward Pareto efficiency than the accounting weight.

We now have the main finding of the paper in the form of Proposition 2:

Proposition 2: *The optimal price incentive weight, $\bar{A}$, in equation (39) is not only surprisingly simple but is almost identical to the optimal weight in the absence of information in stock price, equation (12) above, with the addition of the informative term, $-1 \geq \mu - 1 \leq 0$, to the denominator of the incentive weight. It is not only independent of the non-price incentive weight but obviously always declining in stock price informativeness, while greater risk aversion and cost of managerial action lowers the incentive weight, as before. Hence, greater informativeness, due to higher liquidity or firm size, lowers pay-for-performance sensitivity and propels the optimal incentive contract closer to the first-best. However, except in the limit as $\mu \to 1$, an informative market always employs higher-powered contracts than does a market with no information because of the important role of the market maker in the former who stabilizes prices due to "noise-trading".*

Better contracting might explain why only large, liquid firms are relatively immune from the higher implicit cost of being listed and, naturally, why large, unlisted firms cannot enjoy the same contracting advantages as the stock price on which to contract is entirely absent.

Notice the surprising finding that the degree of stock price informativeness, μ, which directly alters stock price volatility, $\mu\sigma_\theta^2$, nonetheless, has no influence on the agent's willingness to bear risk, as represented by the weight on the CARA value, ρ. It is only intrinsic volatility, σ_θ^2, that prices risk, $\rho c\sigma_\theta^2$, due to the manner in which the optimal contract varies as information alters.

I now explore comparative-static findings based on both the stock and accounting price signals. From equations (32), (38), (39), and (41), the manager's equilibrium effort is unambiguously rising in informativeness:

$$\partial\bar{e}/\partial\mu = Sign\left[\sigma_\varepsilon^4\sigma_\theta^2\rho c\right] > 0. \tag{42}$$

Hence greater stock price liquidity which enables a more informative stock price unambiguously improves managerial performance and firm value with both stock price and accounting signal performance enhanced. Examining the manager's expected pay from equation (35), since $\partial \mathbb{E}(I)/\partial\mu > 0$, a rise in informativeness results in higher equilibrium pay despite the fall in the incentive weight. Obviously, higher higher equilibrium effort as a result of higher informativeness also raises stock price and improves every aspect of firm governance. Finally, since $\partial Var(p)/\partial\mu > 0$, a more informative stock price would raise both managerial risk and expected pay in the absence of the offsetting fall in the optimal incentive weight, $\bar{A}$, as informativeness improves, making it more expensive otherwise to compensate the risk-adverse manager.

I have how established Proposition 3:

Proposition 3: *As already indicated, higher market liquidity induces higher stock market informativeness, μ, which not only lowers the optimal incentive weight, $\bar{A}$, but also raises the manager's effort level, firm profitability, managerial pay, stock price, and stock price volatility, but with only the intrinsic stock price volatility, not the observed stock price volatility, $\mu\sigma_\theta^2$, being priced. Consequently, the optimal incentive contract moves closer to the first-best contract in which the actions of the manager can be directly observed with lower pay-for-performance sensitivity but with no effect on the priced risk borne by the risk averse manager. Since large, highly liquid firms gain the most from higher effort incentives and enhanced stock price, only these firms are largely immune from higher implicit U.S. listing costs with smaller firms most adversely affected.*

Proof: See the comparative-static results presented above. □

I have established a positive relationship between effort and firm profitability with respect to informativeness and, for the first time, Proposition 2's finding of an inverse relationship between stock price informativeness and the contract weight. This declining contract weight with both informativeness and firm size helps to explain the success of the modern large listed corporation with relatively low and declining inside ownership with both scale and informativeness. It also explains why firm size and liquidity plays such an important part in listing success and why, with a yet to be explained rise in the cost of being listed in the U.S., the number of listed firms has halved with a corresponding rise in average firm size.

If the relationship went the other way then it is hard to see the modern large listed corporation, as such, being viable. I expect that what we would see is something more akin to private equity and managerial buy-outs, with very high inside ownership. Stock price informativeness is valuable to the insider shareholder (i.e., the firm) because it means that, with greater informativeness, share price is more reflective of the actions (here "efforts") of the manager. Informed traders responding to a signal of the manager's actions move the stock price significantly and, as a result, incentivized managers increase their level of effort/performance.

Given that equation (23) above and Kyle (1985) demonstrate that informativeness increases in firm size, my theoretical finding that pay sensitivity must decline in informativeness is consistent with the already cited empirical findings of the effect of rising firm scale in reducing sensitivity.

C. Why HT's Findings are Quite Different to Mine

HT claim to derive their model from their price equation (p.689, equation (11)), which in pre-equilibrium terms is my equation (27) above. Utilizing HT's transformations (HT p.692, equation (20)), price can be expressed as:

$$\tilde{p} = \left[(1-\mu)\,\bar{e} + \mu\left(e + \tilde{\theta} + \tilde{\eta}\right) + \lambda\tilde{y}\right]\left[(1-a)\,\mu - b\right]\Big/\left[(1-a)\,\mu\right]. \tag{43}$$

Now HT's model (p.693, equation (22)) utilizing their *normalized* performance measure, can be expressed in my notation as:

$$\max_{a,\,b}\left\{\bar{e} - c\bar{e}^2 - (\rho/2)\left[a^2\left(\sigma_\varepsilon^2 + \sigma_\theta^2\right) + 2b^2\left(\sigma_\theta^2 + \sigma_\eta^2\right) + 2ab\sigma_\theta^2\right]\right\}, \tag{44}$$

where effort, $\bar{e} = (a+b)/c$, since in my simplified framework, effort is a quadratic expression, and from HT (p.692, equation (20)), $A = b/[(1-a)\,\mu - b]$, and, consequently, HT's b is defined by:

$$b = [A/(1+A)]\,(1-a)\,\mu \equiv \alpha\,(1-a)\,\mu. \tag{45}$$

Since in transformed terms, HT's price expression is given by equation (43), it is not clear to me as to how HT's new objective function, equation (44), can be derived from HT's original model, that is, HT's objective, (p.693, equation (22)), seems unrelated to their original model. This is because HT appear to violate the rules of logic by replacing their original contract by a so-called *normalized* contract rather then by deriving the latter from the former.

Maximization of HT's objective, equation (44) yields two equations:

$$a = \left[1 - b\left(2 + \rho c\sigma_\theta^2\right)\right]\Big/\left[2 + \rho c\left(\sigma_\varepsilon^2 + \sigma_\theta^2\right)\right], \tag{46}$$

and

$$b = \left[1 - a\left(2 + \rho c\sigma_\theta^2\right)\right]\Big/\left[2 + \rho c\sigma_\theta^2/\mu\right], \tag{47}$$

which are solved simultaneously to yield explicit solutions to HT's model:

$$a = (1-\mu)\,\sigma_\theta^2\Big/\left\{\sigma_\theta^2\left[(1-\mu)\left(2 + \rho c\sigma_\theta^2\right) + \rho c\sigma_\varepsilon^2\right] + 2\mu\sigma_\varepsilon^2\right\}, \tag{48}$$

and

$$b = \mu\sigma_\varepsilon^2 / \left\{\sigma_\theta^2 \left[(1-\mu)\left(2+\rho c\sigma_\theta^2\right) + \rho c\sigma_\varepsilon^2\right] + 2\mu\sigma_\varepsilon^2\right\}. \tag{49}$$

It is easily shown that these two solutions yield all the findings described by HT. For example, taking the ratio of equations (49) and 48) indicates:

$$b/a = [\mu/(1-\mu)]\left(\sigma_\varepsilon^2/\sigma_\theta^2\right) \equiv n\sigma_\varepsilon^2 / \left[\sigma_\theta^2 + (n+1)\,\sigma_\eta^2\right], \tag{50}$$

on utilizing equation (21) above. Adopting HT's assumption of a single speculator, $n = 1$, yields HT's result (p.693; equation (24)), with $b/a = \sigma_\varepsilon^2/\left(\sigma_\theta^2 + 2\sigma_\eta^2\right)$.

HT (p.694) write in relation to this equation: "if the speculator invests less in information (increases σ_η^2), b ["the weight on market price"] will become smaller since price is less informative". But, even if HT's equation were correct, HT actually find the opposite as b is not the weight on market price, rather A is HT's weight on market price and the smaller weight, b, means a higher weight on market price since A moves in the opposite direction to b in response to an alteration in the level of information. To see this, note that HT's informational parameter, μ, falls in response to the rise in σ_η^2, i.e., $\partial\mu/\partial\sigma_\eta^2 < 0$ and that, from equation (45), $b/a \equiv \alpha\,[(1-a)/a]\,\mu$. Hence:

$$\alpha \equiv [1/(1-\mu)]\left(\sigma_\varepsilon^2/\sigma_\theta^2\right)[a/(1-a)]\,, \tag{51}$$

on equating b/a in the two expressions, and, conditional on a, a reduction in μ must not only lower b, as HT correctly point out, it must simultaneously raise the price weight, α. Moreover, since $A \equiv \alpha/(1-\alpha)$, and $dA/d\alpha > 0$, this rise in α must raise HT's actual price weight, A, rather than reduce it as claimed.

Since this result is conditional on a, the full solution for α is found by substituting for the term, $a/(1-a)$, in equation (51) using:

$$a/(1-a) = \sigma_\theta^2\,(1-\mu) / \left\{\sigma_\theta^2\left[(1-\mu)\left(1+\rho c\sigma_\theta^2\right)\right] + \sigma_\varepsilon^2\left(2\mu + \rho c\sigma_\theta^2\right)\right\}, \tag{52}$$

derived from equation (48), to obtain HT's explicit solution for the price weight in its α transform form:

$$\bar{\alpha} = \sigma_\varepsilon^2 / \left\{\sigma_\theta^2\left[(1-\mu)\left(1+\rho c\sigma_\theta^2\right)\right] + \sigma_\varepsilon^2\left(2\mu + \rho c\sigma_\theta^2\right)\right\}. \tag{53}$$

This solution bears no relation to my equivalent solution, equation (38), to HT's initially specified problem, given by my far simpler and intuitive expression: $\bar{\alpha} = 1/(\mu + \rho c\sigma_\theta^2)$. The reason that HT were apparently unable to correctly solve their original problem, following their derivation of their *normalized* contract (p.691), is because HT's equations (21a) and (22a) do not seem to be obtained by utilizing HT's substitutions into their grossed-up stock price equation (11). As a result, by imposing an entirely new and unrelated contract, HT's equation (22a) differs considerably from my equivalent objective, equation (36) above.

Returning now to HT's two explicit solutions, equations (48) and 49), and examining the perfectly predicted future stock price with $\mu \to 1$, we have a zero weight on the non-price signal, $a = 0$, and $b = \alpha = 1/(2 + \rho c \sigma_\theta^2)$. Hence, despite HT's claim (p.693) that there will always exist a positive weight on the non-price signal in their model, this is not the case if the price signal is perfect and there is competition in informed market-making. This is because, comparing HT's non-price signal, (p.684, equation (2)), with their price signal, equation (3), for all values of the non-price error, $\tilde{\varepsilon} > 0$, the price signal, s, is a "sufficient statistic" for the non-price signal when the signal error term approaches zero, $\tilde{\eta} \to 0$, in HT's model, but not in mine. This is because I remove HT's (equation (2), p.684) redundant error term, $\tilde{\theta}$, from my specification for the accounting signal.[12]

III. Applications and Tests of the Incentive Model

HT are not content just to derive their comparative-static results but use their model to address a number of important issues relating to stock market liquidity, the magnitude of stock exchanges and market design. In this section I report attempts to empirically test aspects of HT's model and address a number of applications of my optimal agency contract to issues such as when franchise contracts will be used rather than in-house, and the existence of the modern corporation.

A. Some Empirical Tests

Kang and Liu (2008) provide empirical support for HT's Proposition 3 using the PIN (Probability of Informed Trading) based on Easley, Hvidkjaer, and O'Hara (2002) as a proxy for information in the stock price and, additionally, analyst forecast errors and forecast dispersion. They conclude that pay-for-performance sensitivity is increasing in information in the stock price. However, their use of PIN as a measure of private information in the stock price is questionable as Duarte, Han, Harford, and Young (2008), show that PIN captures asymmetry of information in illiquid stocks. Hence Kang and Liu's (2008) findings are in reality supportive of my model's demonstration that illiquid stocks with low information

[12] As noted in Section I above, HT's assumption forces the price signal to be a "sufficient statistic" for managerial effort when the signal is viewed without error.

content must have high pay-for-performance sensitivity.

Kang and Liu (2010) extend HT by allowing for an endogenous number of informed traders but model only HT's transformed incentive and pay sensitivity. They conclude that price sensitivity is always increasing in stock price informativeness. They differ slightly from HT by assuming that the realized firm value perfectly measures the non-price accounting earnings signal and is independent of stock price (Kang and Liu (2010, p.686)) and, in common with Baiman and Verrecchia (1995), conclude that there should be a negative weight placed on accounting earnings to better inform the principal of the manager's effort. They present both a calibrated model and empirical tests, once again based on a version of the PIN measure. Hence, once again their findings are actually supportive of my finding that liquidity not only raises stock price informativeness but also lowers the price incentive weight.

Fang, Noe, and Tice (2009) show that stock liquidity results in higher firm performance, as measured by Tobin's Q, due largely to higher operating profitability and the relationship is causal. Importantly, they find it operates via the entry of informed investors who make stock prices more informative and by enhancing the value of performance-incentive managerial compensation exactly as in my HT-inspired Section II above. Moreover, they are able to rule out other possible explanations such as blockholder intervention. Hence, their findings unambiguously support my hypothesis that the dominance of stock markets and global markets generally by large highly-liquid firms is due to conferred contracting benefits.

B. *Size of the Float*

One of the most important issues HT address is the size of the firm's initial float, which they define in terms of the firm's expected profit, my equation (36) above which, when evaluated in equilibrium and in the case of the absence of a non-price signal, becomes:

$$(1-\delta)\,\bar{\pi} = (1-\delta)\,(1/2)\,\mu/\left[\left(2+\mu+\rho c\sigma_\theta^2\right)c\right]. \tag{54}$$

where δ is retained inside ownership in the IPO. Both HT and I agree that better liquidity, which is increasing in the magnitude of the float, improves contracting. Hence, I would have expected that HT would recommend that δ be set at its minimum, such that inside ownership be restricted to the amount necessary for efficient contracting, namely $\bar{A}$ as specified in equation (39) above.

However, HT (pp.696-697) rejects this conclusion in favor of their view that the speculator's profit, $ER = \sigma_y\lambda$, see HT (p.689, equation (16)), must be deducted from IPO revenue since this reflects the losses accruing to noise traders. While HT are correct in their statement that ER reflects the losses incurred by noise traders, they are incorrect when they assert that the stock price at the IPO is lower by this cost in support of the theory proposed by Amihud and Mendelson (1986a) which finds that the price of a stock must be discounted by the present value of transaction costs.

An examination of either HT's (p.689, equation (11)) or my equilibrium price, $\bar{p} = (1-\bar{\alpha})\,\bar{e} = (1-\bar{\alpha})\,\bar{\alpha}\mu\Big/c \equiv \bar{A}\mu\Big/\Big[c\big(1+\bar{A}\big)^2\Big]$ shows that the equilibrium stock price, $\bar{p}$, depends only on the effort level, $\bar{e}$, and not at all on the costs of trading reflected in the Kyle lambda. This is because, as shown in Dey and Swan (2018), buyers are deterred by higher buying costs and sellers are also discouraged by the same amount such that they cancel out in the Kyle (1985) framework with symmetric buyer and seller preferences. Nonetheless, HT are correct in pointing out that high information asymmetry, i.e., sizable Kyle lambda, can reduce the return to the founder from the IPO but this is because the seller (founder in the IPO) has to bear the half-spread cost of trading, like any other trader.

A problem with HT's analysis of the IPO decision is that prior to the IPO the firm has access to the non-price, e.g., accounting, signal but, following the IPO, the degree of liquidity is assumed to be sufficient to support informed trader monitoring. Moreover, a small listed firm may have high volatility, not necessarily the low volatility implied by Kyle's (1985) framework when μ is small. An implication of a minimal required liquidity level before informed trading is sufficiently important to develop informational content, a sizable μ, is that larger companies will be the major beneficiaries of both the IPO process and listing itself. Hence a much higher proportion of large companies should be listed, rather than smaller companies, as indeed is the case (Doidge, Karolyi, and Stulz, 2017).

C. Control Issues

HT (p.698) examine control issues such as vertical integration that may require high inside ownership, thus reducing both the free-float and noise-trader demand to induce low stock price informativeness. My Proposition 2 shows that the manager is likely to be highly incentivized and thus far from a pareto-efficient first-best contract due to a lack of informed speculators forcing price to the fundamentals determined by managerial action. Thus, illiquidity carries with it the need to provide high-powered incentives, imposing high risk-bearing costs on inside shareholders due to them having to compensate the manager for bearing this risk. By its very nature, private equity inclusive of leveraged management buy-outs (LBOs) is illiquid, requiring exceedingly high managerial and board incentives (as shown, e.g., by Leslie and Oyer (2013)).

HT (p.698) refers to the reluctance of the subordinate to make relationship-specific investments as a potential cost of vertical integration, as identified by Grossman and Hart (1986), and rightly add that monitoring issues may represent an even greater obstacle to efficient vertical integration. Relative to HT, I see vertical integration as being far more problematic since I show that high-powered incentives may be required to make up for the absence of price-based divisional incentives driven by informed trading and thus departing further from the first-best contract.

As HT (p.699) point out, dual-class shares enable the inside shareholder to enjoy his control rights cake and eat it too, but my interpretation is different. Insiders predominantly hold subordinate, control-rich shares while cash-rich shares are widely held and traded, increasing informativeness and enabling more efficient and lower cost, lower-powered managerial incentives.

D. Large Shareholders, Inside Monitoring, and Takeovers

HT (p.699) argues that there may be reasons for high inside ownership, and thus lower liquidity and what they term *speculative* information due to informed market trading, if *strategic* information is more important. I agree that strategic information is likely to be important in relation to takeovers and that a sizable shareholder may make negotiating a successful takeover easier. However, this does not mean that the acquiring firm will not benefit from having informed speculators value the acquisition announcement and assess the likelihood of the match succeeding.

E. Market Monitoring and the Size of the Stock Exchange

HT (p.706) put forward an argument to justify the empirical findings of Amihud and Mendelson (1986 *a* and *b*) which indicate a substantial illiquidity premium in stock returns and a theoretical turnover frequency which is far higher than the observed frequency. A recent paper by Dey and Swan (2018) finds no evidence of any illiquidity effect in stock returns and rejects the theoretical model on which their empirical findings are based.

F. In-house versus Franchise Contracts and Multitasking

Holmström and Milgrom (1987, 1991, 2004) make important contributions to understanding agency issues but may fall short because there are no semi-public informative signals in these models, unlike my model based on a reformulated HT model. Holmström and Milgrom (1991, 1994) and Holmström (2017) argue that the "higher-powered" incentives provided to commission agents, independent contractors, and in franchise contracts can be explained by multitasking. It is asserted that employees inside the firm have substitutable easy-to-measure and important difficult-to-measure tasks with lower precision of estimation due to high signal variance. Thus, in order to avoid misallocating too much effort to more easily assessed tasks, in-house employees are given only lower-powered incentives rather than the essentially superior higher-powered incentives observed in franchise contracts. By contrast, in my own contractual solution, equation (39) above, there is but one task with no multitasking issues treated here. Why should it be impossible to explain the coexistence of in-house and franchise contracts when the task is the same, and could this reflect the difficulty faced by some agency models in explaining real-world contracting problems?

When it comes to franchise agreements, Holmström and Milgrom (2004, p.988) are puzzled by the evidence they cite from Brickley and Dark (1987) which shows that the "harder it is to monitor a unit (as proxied by its distance from headquarters), the *more likely* it is that the unit is franchised." While they points out that *"the relationship is opposite"* (italics added) to their own model (Holmström and Milgrom, 2004) it is supported by the implications of my Proposition 2 showing that, the weaker the signal of manager effort stemming from a paucity of informed traders, i.e, the harder it is to monitor internally due to the absence of such signals, the greater the reliance on high-powered incentives. Consequently, my model predicts that, in order to facilitate more effective and closer to face-to-face monitoring, in-house fast-food outlets will be located closer to company headquarters than will franchisee outlets and, similarly, multiple units belonging to any multi-unit franchisee contractor will be located close to the contractor's headquarters (see Kalnins and Lafontaine, 2004). To put it simply, distant fast-food outlets are deficient in face-to-face monitoring and thus require high-powered franchise incentives, just as illiquid listed stocks require high-powered price-based incentives.

Drawing on equations (12) and (15), which represent my version of HM's model portrayed in Section I above, the small independent contractor or franchisee suffers from a volatile accounting signal without the benefit of a stock price. Hence in conventional agency theory the price incentive weight in these franchise contracts should be lower in comparison with the in-house alternative. In the conventional story, once (say) MacDonald's franchisees are brought in-house, higher-powered incentives are in order as diversification and aggregation reduces both risk and the volatility of the signal. This is why, HM's agency theory does not suffice and a multitasking story is required, as in Holmström and Milgrom (1991, 2004), to justify the empirical finding that franchisee contracts are higher-powered in comparison with the in-house alternative.

Krueger (1991) shows that company-owned outlets pay their shift managers 9% more than does the franchisee outlet and the tenure-earning profile is steeper at company outlets with this deferred reward presumably required to provide adequate incentive given that the franchisee owner has a much stronger monitoring incentive than does the company manager. Hence, once again, we see my Proposition 2 in action. The in-house worker incentive contract has to be far higher-powered to compensate for the low-powered incentives of the internal manager. Other characteristics of franchise contracts compared with in-house operations are also consistent with my Proposition 2. For example, Lafontaine and Bhattacharyya (1995) find more output variability and lower sales under franchising than under company management and contracting which makes use of the franchisee's information. This is precisely describing the high-powered incentives that my model predicts for smaller, relatively illiquid, firms.

G. *Explanation for the Existence of the Modern Corporation*

One of the many nice aspects of HT's paper which have helped to make it so famous is its focus on informed trading and the way the paper promotes the role of the stock market in explaining the success of large, liquid firms traded on global stock exchanges. I add to this by showing that higher liquidity begets more informed trading and greater effort on the part of the manager. The resulting higher volatility as a consequence of this informed trading makes inside ownership more problematic for risk averse managers with the principal's optimal response being lowered inside ownership. Ironically, this was also HT's finding had they not confused their transformed price incentive with the actual weight.

Recognizing the scaling factor, K, introduced in equation (23) above, my optimal incentive contract given by equation (39) becomes:

$$\bar{A} = 1/\big(\mu - 1 + \rho c K^2 \sigma_\theta^2\big), \tag{55}$$

such that the dollar volatility term, K^2, in this expression, (55), for the optimal weight, dramatically drives down the inside shareholding optimal weight, $\bar{A}$, with firm scale. It does so for two reasons, (i) the larger the firm, the higher the dollar volatility and hence the more risk borne by the incentivized-manager owning a given percentage of the stock; and (ii) the larger the company, the greater the liquidity and thus the greater is the scope for informed traders to drive the share price in the direction of the manager's actions, good or bad.

I now propose my final, and perhaps most controversial, proposition, Proposition 4:

Proposition 4: *The presence of informed stock trading is the main distinguishing feature of listed equity in comparison with private equity. This informed trading has made possible the separation of ownership and control with sizable essential monitoring of management* *delegated to the market and is thus contributing to the existence and growth of the modern corporation.*

No one doubts that the largest and highly liquid stocks, e.g., Apple, Alphabet, Microsoft, Amazon, Berkshire Hathaway, etc., dominate the world with the top 100 global stocks valued at $17.4 trillion in 2017, but the names of illiquid private equity and hedge funds are perhaps not quite as well known.[13] McKinsey (2017), in defining private assets very broadly, obtains an AUM of $4.7 trillion in 2016.

McKinsey (2017) finds that private assets have been growing rapidly relative to listed assets since 2008 and, as mentioned, Doidge, Karolyi, and Stulz (2017) show that the number of U.S. listed companies have been reduced from 8,025 domestically incorporated companies in 1996 to only 4,102 by 2012. There have also been a number of very large IPOs recently, like the $22(bn) Alibaba, $18(bn), Visa Inc, $22(bn), and Lyft, $22(bn) floats, indicating that firms may be delaying their IPO debuts.

Nearly 250 years ago Adam Smith (1776, p.405-406), observing the south seas bubble at first-hand, pointed to what should have been the fatal flaw in joint stock companies: they manage other people's money, not their own, and thus ought to fail to take proper care of their outside investors.[14] The governance problem due to the dilution of inside ownership alluded to by Adam Smith worsens with increases in firm size as more relatively passive outside shareholders dominate the share register.

Berle and Means (1932) built on Smith's insight to propose corporate governance failure due to the separation of ownership and control. Yet the large joint stock corporate form has become the modern corporation which not only persists but also thrives. Jensen and Meckling (1976, p.330) ask: "Why, given the existence of positive costs of the agency relationship, do we find the usual corporate form of organization with widely diffuse ownership so widely prevalent?" Moreover, they point out (p.348) that "the larger the firm becomes the larger are the total agency costs because it is likely that the monitoring function is inherently more difficult and expensive in a larger organization."

But Jensen and Meckling (1976, p.356) admit that their analysis requiring either inside ownership or (internal) monitoring is not applicable to "the very large modern corporation

[13]The largest private equity partnerships include The Blackstone Group, Kohlberg Kravis Roberts, The Carlyle Group, TPG Capital, and Warburg Pincus.

[14]Smith states: "The directors of such [joint-stock] companies, however, being the managers rather of other people's money than of their own, it cannot well be expected, that they should watch over it with the same anxious vigilance with which the partners in a private company frequently watch over their own." Smith (1776) provides many examples of poorly managed joint stock companies, such as the South Seas company with its immense number of proprietors, for which "folly, negligence, and profusion, should prevail in the whole management of their affairs", but at that time there was little in the way of informed trading on the stock market.

whose managers own little or no equity." It is interesting that four of the world's largest companies, Apple, Alphabet, Microsoft, Amazon, and Berkshire Hathaway, retain a sizable founder ownership which undoubtedly helps, but does not explain why the majority of large companies have negligible inside ownership.

How is it then that when outside owners largely replace inside owners, effective monitoring of management not only continues but seems to improve? Fama and Jensen (1983) refer broadly to market monitoring as a possible solution but provides no specific model. Jensen (1986) points to severe conflicts between management and shareholders over payout policy and seeks high debt as a substitute for equity to help overcome the conflict with "going private" and leveraged buyouts as possible solutions.[15] Cornelli, Kominek, and Ljungqvist (2013) demonstrate how effective is the board structure and monitoring of the CEO by unlisted private equity backed firms with largely "soft" information used to displace non-performing CEOs. Such strong internal governance systems are not surprising as these firms lack the benefit of market monitoring by informed speculators. Market monitoring can help to account for the failure of Smith's (1776, p.700) dire prediction that, due to the separation of ownership and control, "negligence and profusion ... must always prevail, more or less, in the management of the affairs of [joint-stock] companies."

The answer to Adam Smith (1776), Berle and Means (1932), Jensen and Meckling (1976), Jensen (1986), and many other theorists is that sizable inside ownership is not a requirement for the large modern corporation as external, third-party, informed traders can be a better substitute for inside ownership in terms of demonstrated ability to monitor. Doubtless, HT also believed this, but several slips got in their way. Inside ownership is there to provide incentives for monitoring, but if outside parties are better at it because they force the share price to reflect the actions of the manager - both good and bad - then it can be largely but, critically, never dispensed with, even as passive outside ownership comes to dominate. This explanation opens up a new field encompassing agency theory, corporate governance, and market microstructure and how governance through trading (e.g., Gallagher, Gardner, and Swan, 2013) complements our understanding of incentives and board structure.

The findings in this paper indicate that the combination of managerial risk aversion and exceedingly high dollar volatility of returns in large traded companies makes high-powered incentives, not only generally unfeasible, but also unnecessary and undesirable. Hence, the observed diminishing inside ownership with size is not a peculiar aberration, as theorists from Adam Smith onward have speculated. Nor does the success of these large companies

[15] If the success of large companies were simply due to reaping scale economies rather than due to an informative stock price that disciplines management and complements board monitoring then, according to my theory, the global economy could equally be dominated by illiquid private equity rather than giant listed corporations, the latter the beneficiaries of informed trading.

relative to illiquid private equity with no informed trading remain a mystery, as an enduring puzzle that has lasted nearly 250 years.

IV. Conclusion

The main thrust of this paper is to show how internal monitoring difficulties due to the absence of information from external monitors (here informed traders) leads to higher-powered incentives. My model is not only applicable to managerial incentives but to all forms of contracting. I show, for example, that it is because of the greater ease of monitoring that the franchisor and the multiple-unit franchisee retain ownership of outlets in-house located nearby and the outlet provider franchises only more distant outlets. This is different to Holmström and Milgrom (1991, 1994) who argue that lower monitoring costs encourage the use of external contracting.

Not only do I indicate a whole range of important reinterpretations as a result of my model, I also help to explain the evolution of the modern corporation. From 1776 onward to the present day, agency theorists such as Adam Smith and his modern-day counterparts, have lamented the rise of large, liquid, joint-stock companies fearing that passive outside shareholders will become the victims of inside shareholders who, while they monitor management for their own benefit, have little if any incentive to care for the interests of outside shareholders.

My findings indicate that these fears are largely groundless since large listed companies dominate even sizable private equity due to vastly superior contract efficiency. This is because stock market liquidity promotes the rise of informed traders that actively monitor management to successfully predict future stock price movements. This enhanced informativeness of stock price sufficiently improves the effectiveness of managerial incentives to induce both lower share-price and accounting (non-price) weights, falling pay-performance sensitivity, and higher managerial effort. Hence, in the modern corporation, information concerning the manager's actions contained in the stock price substitutes for inside shareholders who have mostly been displaced by largely passive outside shareholders with limited monitoring capability.

Finally, the approach adopted in this paper explains many otherwise puzzling well-known empirical findings. For example, the dramatic decline in pay for performance sensitivity with each doubling of firm size, the preponderance of liquid firms with superior Tobin's Q performance and with small listed companies exceedingly marginal and likely to be acquired. Hence the halving in the number of listed U.S. companies since 1996 documented by Doidge, Karolyi, and Stulz (2017) due to a regulatory-induced rise in the implicit cost of being listed.

Internet Appendix

A. Determination of the Equilibrium Stock Price

Each partially-informed speculator (excluding the manager banned from trading) maximizes his expected end-of-period profits, $x_j(s_j) = \beta(\tilde{s}_j + \omega/\beta)$:

$$\mathbb{E}\left[(\tilde{\pi} - [\alpha/(1-\alpha)]\, p(\tilde{q}))\, x_i \,|\tilde{s}_i = \omega_i\right],$$

giving rise to the maximand:

$$\underset{x_i}{Max}\ \pi = \mathbb{E}\left[\left(\tilde{\pi} - \left(\omega + \lambda\left(\sum_{j\neq i}^{N} \bar{x}_j + \tilde{y}\right)\right)\right) x_i - \lambda x_i^2 \,|\tilde{s}_i = s_i\right]$$

Recognizing that in equilibrium each homogeneous speculator chooses the same trade, on evaluating the conjecture the ith first-order condition gives rise to:

$$\bar{x}_i \equiv \beta(\tilde{s}_i - \omega) = \frac{1}{(n+1)}\frac{\sigma_\theta^2}{\lambda\left(\sigma_\theta^2 + \sigma_\eta^2\right)}\left(e + \tilde{\theta} + \tilde{\eta} - \bar{e}\right), \tag{IA.1}$$

where e refer to the manager's actual effort.

Comparing equation (IA.1) with the original conjecture, equation (19) in the body of the paper, the individual speculator's trade aggressiveness coefficient:

$$\beta = \frac{\sigma_\theta^2}{(n+1)\lambda\left(\sigma_\theta^2 + \sigma_\eta^2\right)}, \tag{IA.2}$$

and the demand intercept $\omega = \bar{e}$, where once again the accent denotes the optimum value. Utilizing equation (17), Kyle's lambda measure of illiquidity becomes:

$$\lambda = \frac{n\beta\sigma_\theta^2}{(n\beta)^2\left(\sigma_\theta^2 + \sigma_\eta^2\right) + \sigma_y^2}. \tag{IA.3}$$

Evaluating the grossed-up linear pricing rule, equation (17) in the body of the paper, incorporating the manager's stock appreciation right allocation, $Ap \equiv [\alpha/(1-\alpha)]p$, yields:

$$\frac{1}{1+\alpha} p(\tilde{q}) = \mathbb{E}\left[\tilde{v}\,|\tilde{q} = q\right] = \mathbb{E}(\tilde{v}) + \frac{Cov(\tilde{v},\tilde{q})}{Var(\tilde{q})}\left[\tilde{q} - \mathbb{E}(\tilde{q})\right].$$

Hence, on simplification:

$$p\left(\tilde{q}\right)=\left(1-\alpha\right)\left[\bar{e}+\frac{n\beta\sigma_{\theta}^{2}}{n^{2}\beta^{2}\left(\sigma_{\theta}^{2}+\sigma_{\eta}^{2}\right)+\sigma_{y}^{2}}\left(\tilde{q}\right)\right], \tag{IA.4}$$

where, once again, $\bar{e}=\omega$ represents the manager's equilibrium action with respect to stock price based incentives. On solving equations (IA.2) and (IA.3) for β by eliminating λ, I obtain the representative partially-informed trader's demand:

$$x=\beta\left(e+\tilde{\theta}+\tilde{\eta}-\bar{e}\right)\equiv\frac{\sigma_{y}}{n^{\frac{1}{2}}\left(\sigma_{\theta}^{2}+\sigma_{\eta}^{2}\right)^{\frac{1}{2}}}\left(e+\tilde{\theta}+\tilde{\eta}-\bar{e}\right). \tag{IA.5}$$

Kyle's lambda, specified by equation (IA.3), becomes,

$$\lambda=\frac{\sigma_{\theta}^{2}n^{\frac{1}{2}}}{\sigma_{y}\left(n+1\right)\left(\sigma_{\theta}^{2}+\sigma_{\eta}^{2}\right)^{\frac{1}{2}}}. \tag{IA.6}$$

Defining information in stock price as:

$$\mu\equiv\lambda n\beta=n(n+1)^{-1}\sigma_{\theta}^{2}\left(\sigma_{\theta}^{2}+\sigma_{\eta}^{2}\right)^{-1}. \tag{IA.7}$$

and the grossed-up stock price derived from equations (17), (IA.4), and (IA.7):

$$\tilde{p}=\left(1-\alpha\right)\left[\left(1-\mu\right)\bar{e}+\mu\left(e+\tilde{\theta}+\tilde{\eta}\right)+\lambda\tilde{y}\right], \tag{IA.8}$$

where $\bar{e}$ is the hypothesized equilibrium effort and e is the actual effort due to stock price incentives. □

B. *Proof that* $Var\left(p\right)=\left(1-\alpha\right)^{2}\mu\sigma_{\theta}^{2}$

From equations (IA.6) and (IA.7) we derive:

$$\lambda^{2}\sigma_{y}^{2}=\frac{\left(\sigma_{\theta}^{2}\right)^{2}\frac{n}{(n+1)}}{\left(n+1\right)\left(\sigma_{\theta}^{2}+\sigma_{\eta}^{2}\right)}.$$

Also

$$\mu\left(n\sigma_{\theta}^{2}\right)^{-1}=\left(n+1\right)^{-1}\left(\sigma_{\theta}^{2}+\sigma_{\eta}^{2}\right)^{-1},$$

and

$$\lambda^{2}\sigma_{y}^{2}=\mu\left(\sigma_{\theta}^{2}\right)^{2}n(n+1)^{-1}\left(n\sigma_{\theta}^{2}\right)^{-1}=\mu\sigma_{\theta}^{2}(n+1)^{-1}.$$

Now

$$\frac{1}{(1-\alpha)^2} Var\,(p) = \lambda^2 n^2 \beta^2 \left(\sigma_\theta^2 + \sigma_\eta^2\right) + \lambda^2 \sigma_y^2 = \mu^2 \left(\sigma_\theta^2 + \sigma_\eta^2\right) + \frac{\mu\sigma_\theta^2}{n+1},$$

$$= \mu^2 n \sigma_\theta^2 [\mu\,(n+1)]^{-1} + \mu\sigma_\theta^2 (n+1)^{-1} = \mu\sigma_\theta^2\,(1+n)\,(1+n)^{-1} = \mu\sigma_\theta^2. \tag{IA.9}$$

□

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