Trade-Off? What Trade-Off: Information Production without Illiquidity*

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September 23, 2025

Abstract

Private information in financial markets enhances the informational content of asset prices and thereby supports efficient resource allocation. Yet, informed traders extract rents at the expense of uninformed traders, generating a trade-off between price informativeness and liquidity costs. Moreover, equilibrium investment in information acquisition may be socially excessive or insufficient. We show, using a mechanism design approach, that a market structure separating the market for information from the market for liquidity can simultaneously deliver price informativeness, preserve liquidity, and align private incentives with efficient levels of information production.

Keywords: Asymmetric information, optimal mechanism, information production. *JEL Classification*: G20; G32; D82.

*We thank Bruno Biais, Piotr Dworczak, Stephen Lenkey, Marc Lipson, Yingxiang Li, Vincent Maurin, Josh Mollner, Cécilia Parlatore, Talis Putnins, Ioanid Rosu, Gideon Saar, Chaojun Wang, and participants at the 2025 SFS Cavalcade, the 2025 NYSE Market Microstructure Conference, City University of Hong Kong, HEC Brown Bag seminar, University of Warwick, UNSW and UTS research seminars for useful comments. All errors are ours.

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1 Introduction

Two important functions of financial markets are the production of information about investment opportunities and the provision of liquidity, for instance through trading in primary and secondary markets (Levine, 2005). There is a well-known tension between these two functions. On the one hand, informative markets generate social benefits by leading to more efficient capital allocations and contracts (Bond, Edmans, and Goldstein, 2012). On the other hand, information producers (e.g., institutional investors) are often rewarded through profits from buying undervalued assets or selling overvalued ones. These trading profits come at the expense of less-informed investors, who are adversely selected: they end up holding assets with relatively poor returns. Since uninformed investors are aware of this risk, they only purchase assets at a discount relative to their fair value, which reduces market liquidity.

There is, therefore, a fundamental trade-off between informativeness and liquidity in financial markets. While several studies have examined the implications of this trade-off—for example, for contracting or for the decision to go public—very few have explored how markets should be designed to optimally address this "liquidity–informativeness trade-off." In this paper, we study this question using a mechanism design approach. Our main insight is that maximal informativeness can be achieved at zero illiquidity cost by creating two separate markets: a derivatives market, which incentivizes and elicits information production (the market for information), and another market, which facilitates the transfer of asset ownership (the market for liquidity).

We study the liquidity–informativeness trade-off through a standard problem: the sale of a stake in an asset with uncertain payoff by an agent (the "seller"), such as an entrepreneur.[1] The asset payoff can be high or low with some probabilities. There are two types of buyers for the asset: experts and non experts. In the baseline case, the former have a perfect signal about the asset payoff while the latter only know its distribution. Collectively experts can only buy a fraction of the seller's stake while non experts can possibly buy the entire stake at its expected value. Hence,

[1] See, for instance, Bolton, Santos, and Scheinkman (2016) for a recent theoretical analysis of the role market design (OTC vs. exchange trading) in this context.

non experts must find optimal to participate to the sale for the sale to succeed. As buyers' types are non observable, the seller cannot restrict participation to the sale of the asset to only one type.

The seller has two motives for the sale: (i) liquidity and (ii) information acquisition about the asset's payoff (e.g., to determine the scale of investment in another project with correlated payoffs). Accordingly, the entrepreneur's utility increases both with the proceeds from the sale and with the reduction in payoff uncertainty achieved through information revealed in the transaction. The seller designs a mechanism to sell the asset to maximize her expected utility and implements this mechanism. The asset payoff becomes known to the seller and the buyers at some point in time after the sale.

In this setting, the seller faces a liquidity–informativeness trade-off whenever obtaining information requires leaving informational rents to informed buyers. To illustrate this point, we contrast the equilibrium outcomes under two possible mechanisms. The first mechanism is a fixed-price offering. Here, the seller sets a price for the asset and allows buyers to either bid for one share or abstain. Since informed buyers (experts) only bid when they know the asset payoff is high, uninformed buyers face a winner's curse. In equilibrium, the seller must therefore sell the asset at a discount relative to its expected payoff to compensate uninformed buyers for adverse selection (as in Rock (1986)). However, because aggregate demand is higher when the payoff is high than when it is low, the seller fully learns the asset's payoff through the sale. Thus, informativeness is obtained at the cost of illiquidity.

The second mechanism conditions the asset's price on aggregate demand so that experts never find it optimal to participate in equilibrium.[2] In this "No Informed Trading" (NIT) mechanism, the seller can sell the asset at its expected payoff. The asset is liquid, but the seller learns nothing about its payoff. Hence, the seller prefers the fixed price (FP) mechanism if and only if her preference for information is so strong that the utility gain from information offsets the cost of illiquidity. In other words, in choosing between the FP and NFI mechanisms, the seller faces the standard liquidity-informativeness trade-off.

[2] A similar mechanism is analyzed in Biais, Bossaerts, and Rochet (2002).

However, these mechanisms are only two among many possible ways to design the market, and neither is optimal. In fact, there exists a mechanism that allows the seller to obtain full information at zero cost. In this mechanism, the asset sale takes place in two stages. In Stage 1, the seller contacts buyers sequentially and offers them the option to purchase one of two derivative contracts whose payoffs depend on the realization of the asset payoff in the future. Stage 1 ends as soon as one buyer purchases a contract. In Stage 2, the seller discloses which contract was traded in Stage 1 and sells the asset to the remaining buyers at a price that reflects the information revealed by the choice of the contract in Stage 1. We show that it is possible to design the payoffs of these contracts and set their prices so that, in equilibrium, (i) only informed buyers (experts) participate in Stage 1, (ii) the contract chosen by the expert fully reveals her signal, and (iii) the asset is therefore sold at its true value in Stage 2.

We refer to this mechanism as a "Divide and Conquer" (DaC) mechanism, since its essence is to separate the market for information (Stage 1) from the market for liquidity (Stage 2). Under the DaC mechanism, the asset is liquid—on average, it is sold at its expected value—and the sale also resolves uncertainty. As a result, the seller attains her highest possible expected utility, making the mechanism weakly dominant. With this design, the liquidity–informativeness trade-off disappears: any seller with even the slightest preference for information strictly prefers the DaC mechanism.[3]

We then examine whether the DaC mechanism remains optimal in the more general case where experts must incur a cost c to discover the asset payoff.[4] Discovery may fail either because the information is unavailable or because experts are unable to find it. In this setting, the design of the DaC mechanism is more complex: it must not only incentivize experts to truthfully report the asset payoff when observed—by selecting the appropriate derivative contract, as in the baseline case—but also motivate them to exert effort to search for information, rather than simply choosing a contract without searching. Thus, in designing the DaC mechanism, the seller faces

[3]Of course, this claim requires the DaC mechanism to be properly specified. In particular, the payoffs and prices of the derivatives traded in Stage 1 must be carefully chosen.

[4]In this more general case, one can assume that all investors are experts. In equilibrium, some remain uninformed and play the role of non experts in the baseline model.

both an adverse selection problem and a moral hazard problem.

Nevertheless, the logic of the baseline case still applies. There exists a specification of the derivative contracts in Stage 1 such that (i) only experts participate in Stage 1, (ii) experts optimally choose to search for information when given the opportunity to trade one of these contracts, and (iii) when an expert discovers the asset payoff, her choice of contract fully reveals her signal. A key difference from the baseline case is that the seller can optimally decide to move to Stage 2 after contacting several experts who fail to obtain information and then sell the asset using the NIT mechanism. Hence, unlike in the baseline case, information may not be revealed in equilibrium. This possibility is important as it enables the seller to control the expected cost borne for information production and sets it at its efficient level.[5]

We show that this DaC mechanism delivers an expected utility arbitrarily close to what the seller can achieve in the frictionless benchmark (no adverse selection, no moral hazard, and observable buyer types). In particular, the mechanism leaves no informational rents to experts: their expected profit from trading the appropriate derivative in Stage 1 compensates them for their cost of information production but no more. Thus, as in the baseline case, the liquidity–informativeness trade-off disappears.

Our paper relates to various strands of the literature. First, it connects to work on the informational benefits of the information produced via the trading process (e.g., prices) in financial markets. Information embedded in stock prices can be used for contracting (e.g., Holmström and Tirole (1993)) or for investment decisions (e.g., Edmans, Goldstein, and Jiang (2015); see also Bond, Edmans, and Goldstein (2012), Goldstein (2022)). A related line of research examines how firms allocate shares to the public, trading off the benefits of price discovery against the costs of illiquidity, in contexts such as managerial compensation (Holmström and Tirole (1993)), going public (Subrahmanyam and Titman (1999); Faure-Grimaud and Gromb (2004)), or cross-listing (Foucault and Gehrig (2008)). Yet none of these papers analyze how

[5]Intuitively, the seller must price derivatives contracts in such a way that experts expect a profit from these contracts that at least cover their cost of information production, as otherwise they would not participate or shirk. Thus, the seller bears a cost from selling these contracts that is at least equal to the total cost borne by experts contacted in Stage 1. As the latter may never find information, contacting a too large number of experts cannot be optimal for the seller.

firms should optimally design share sales when facing this trade-off. Baldauf and Mollner (2020) use a mechanism-design framework to study how market design affects secondary-market liquidity given a level of information production by informed investors, but in their model information has no social value.

Second, our paper relates to the literature on initial public offerings (IPOs). Several papers in this area employ mechanism-design approaches to study how IPOs can be structured to mitigate adverse selection (e.g., Benveniste and Spindt (1989); Biais, Bossaerts, and Rochet (2002); Benveniste and Wilhelm (1990); Maksimovic and Pichler (2006)). However, this literature typically assumes that (a) informed buyers are exogenously endowed with private information, and (b) issuers and underwriters derive no direct benefits from the information produced during the IPO process. In these models, information gathering serves only to alleviate the adverse selection faced by uninformed investors.[6]

One exception is Sherman and Titman (2002) (see also Sherman (2005) and Bourjade (2021)). Our approach differs in two main respects. First, we allow contracts whose payoffs depend on the asset's future cash flows.[7] This assumption is natural for public firms but absent from the IPO literature. Second, the first stage of the DaC mechanism departs from the "bookbuilding stage" in Sherman and Titman (2002) (or the aforementionned papers, such as Benveniste and Spindt (1989)). Here, truthful reporting and information production are induced through derivative trades rather than share allocations, and buyers are contacted sequentially rather than simultaneously. Sequential contact ensures that the number of buyers is set so the seller's expected marginal benefit from information equals its marginal cost so that the amount invested by the seller in information production is efficient. In contrast, in Sherman and Titman (2002) this condition need not hold because all investors are contacted simultaneously.

[6]Consequently, issuers would prefer to place shares solely with investors unable to acquire information, if they could distinguish them from informed investors. In our setting, this can be achieved by using the NFI mechanism but this mechanism is not optimal if sellers derives utility from the information produced during the sale of the asset.

[7]In our model the mechanism is designed by the seller, while in the IPO literature it is designed by the underwriter. If the underwriter acts in the issuer's best interest, this distinction is immaterial.

These features imply that the DaC mechanism eliminates informational rents and allows the seller to invest efficiently information production. For this reason, it yields strictly higher expected utility to the seller than any other mechanisms in our setting (including that in Sherman and Titman (2002)). The absence of informational rents implies that there is no "underpricing" in the DaC mechanism: the average price at which the asset is sold to buyers is the expected payoff of the asset. Our goal is not to explain IPOs' underpricing but to study how asset sales should be optimally structured when sellers face a trade-off between informativeness and liquidity.[8]

The paper is organized as follows. Section 2 introduces the asset sale problem. Section 3 shows that with exogenous information, a DaC mechanism solves the seller's liquidity–informativeness trade-off. Section 4 extends this to costly information acquisition, and Section 5 shows that a DaC mechanism still achieves the seller's optimal utility under incentive constraints. Section 6 examines robustness, and Section 7 concludes.

2 Framework

An entrepreneur (the seller) owns $Q + N$ shares of a risky asset and intends to sell Q. The payoff of the asset (per share) is v_H with probability μ and v_L with probability $(1 - \mu)$, and is unknown to the seller.[9] There are $I + J \geq Q$ potential risk-neutral buyers. Among them, I are experts and J are non-experts. The former have the possibility to acquire information about the asset payoff, while the latter cannot; they only know the distribution of the asset payoff, like the seller. Each buyer can purchase at most one share. We denote by $\mathcal{I}$ and $\mathcal{J}$ the sets of experts and non experts, respectively. The seller cannot condition the price and allocations of the asset on buyers' type (experts/non experts) because she does not observe this type.

Figure 1 shows the timing of events and actions in the model. At date 0, the seller designs a mechanism $\mathcal{M}$ to sell the asset. A mechanism is a set of rules that describes how the issuer allocates the asset to buyers and at which price, possibly contingent on

[8] That is, in essence, our approach is normative. We do not try to argue that some mechanisms are close to the DaC mechanism or to explain why such mechanisms are not used.

[9] This assumption is standard in the IPO literature and in models of asset sales. See, for instance, Sherman and Titman (2002) or Bolton, Santos, and Scheinkman (2016).

the information generated during the sale of the asset (see below for more details). She then announces this mechanism to the buyers and implements it at date 1. We denote by $\Omega(\mathcal{M})$ the information about v generated by the implementation of mechanism $\mathcal{M}$, and by $p_{issue}(\mathcal{M})$ the price at which the asset is sold to buyers according to mechanism $\mathcal{M}$. In general, this price can depend on $\Omega(\mathcal{M})$, although the seller may also choose not to use this information. The payoff of the asset is realized at date 2.

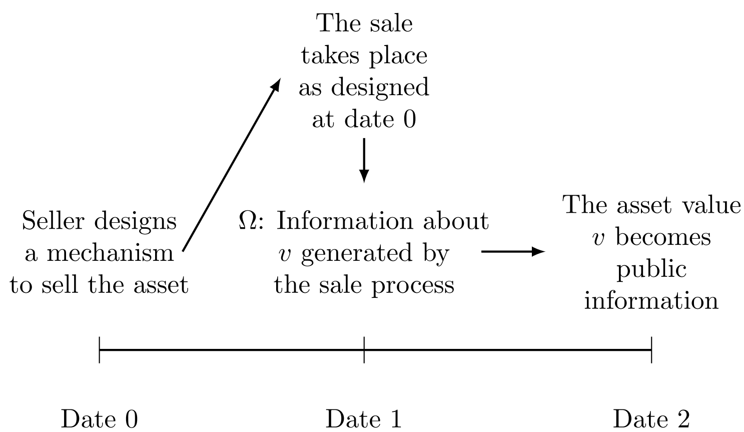

Figure 1. Timeline of the sale process

The seller's **realized** utility at date 2:

$$\Pi(\mathcal{M}) = \underbrace{R(\mathcal{M})}_{\text{Net proceeds from the sale}} + \gamma\Big(\mathrm{Var}(v) - \underbrace{\big(v - \mathsf{E}[\, v \mid \Omega(\mathcal{M})\,]\big)^2}_{\text{Forecasting Error}}\Big). \tag{1}$$

Hence, the seller's utility depends on both the revenues from the asset sale ($R(\mathcal{M})$) and the informativeness of the sale about the asset payoff. Specifically, if $\gamma > 0$, the seller's realized utility at date 2 is inversely related to the squared difference between the realized payoff of the asset at date 2 and the seller's forecast of the asset payoff just after the sale ($\mathsf{E}[\, v \mid \Omega(\mathcal{M})\,]$). Thus, other things equal, the seller's utility is inversely related to her mean-squared forecasting error, and the rate at which she is willing to trade off revenues from the sale for a reduction in her forecasting error is governed by γ. The higher γ, the greater the seller's willingness to sacrifice revenues from the sale in exchange for information. Therefore, the seller potentially faces a trade-off between liquidity and informativeness (as discussed below).

There are various reasons why the entrepreneur may benefit from more accurate forecasts about v just after the sale. For instance, as in other models (e.g.,), the seller might use the information about v obtained through the asset sale to make an investment decision at date 1 in another asset whose payoff is correlated with v.[10] This decision is more efficient, and therefore has a higher expected net present value, when the seller obtains more accurate information about v (i.e., when $(v - \mathsf{E}[\, v \mid \Omega(\mathcal{M})\,])^2$ is smaller). For brevity, we do not explicitly model how the entrepreneur derives utility from the information obtained at date 1 and instead directly assume that she has a preference for more accurate information.

The revenues from the asset sale at date 2 have two components. First, they reflect the proceeds from the asset sale at date 1, $Q \times p_{issue}(\mathcal{M})$. Second, they reflect any costs borne by the seller due to the implementation of the mechanism $\mathcal{M}$. In particular, this mechanism may involve transfers from the seller to the buyers at dates 1 and 2. We denote the total realized value of these transfers by $C_{issue}(\mathcal{M})$. Thus,

$$R(\mathcal{M}) = Q \times p_{issue}(\mathcal{M}) - C_{issue}(\mathcal{M}). \tag{2}$$

A special case is when these transfers do not exist, so that $C_{issue}(\mathcal{M}) = 0$.

Last, we assume that the entrepreneur must raise at least $Q \times v_L$ for liquidity reasons. Thus, the entrepreneur must design the mechanism for selling the asset in such a way that the asset sale succeeds and yields revenues of at least $Q \times v_L$. This can always be achieved by choosing to sell the asset at price $p_{issue} = v_L$ since all buyers (experts and non experts) make a strictly positive expected profit from buying one share at this price. This default choice yields an expected utility of $Q \times v_L$ to the entrepreneur since it generates no information (so that on average, the informational component of the seller's utility is zero). As shown below, the seller can in general achieve a larger expected utility than this with many other mechanisms.

The seller's expected utility conditional on the information generated by the sale

[10] This investment decision must be made quickly at date 1, so that the entrepreneur cannot wait until date 2 to observe v

of the asset at date 1 is:

$$\bar{\Pi}_1(\mathcal{M}) = \mathsf{E}[\,\Pi(\mathcal{M})\,|\,\Omega(\mathcal{M})] = Q\ \mathsf{E}[R(\mathcal{M})\,|\,\Omega(\mathcal{M})] + \gamma\Big(\,\mathsf{Var}(v) - \mathsf{Var}(v \mid \Omega(\mathcal{M}))\,\Big). \tag{3}$$

Thus, the seller's expected utility at date 1 increases with the reduction in uncertainty about the asset payoff due to the information revealed during the sale of the asset, $(\mathsf{Var}(v) - \mathsf{Var}(v \mid \Omega))$. If no information is generated by this sale, $\Omega =$, then $\bar{\Pi}_1(\mathcal{M}) = Q\ \mathsf{E}[R(\mathcal{M})]$.[11]

At date 0, the seller chooses a mechanism $\mathcal{M}$ to sell the asset to maximize her ex-ante expected utility. Thus, the optimal mechanism solves:

$$\max_{\mathcal{M}} \quad \bar{\Pi}_0(\mathcal{M}) \equiv \mathsf{E}\left(\bar{\Pi}_1(\mathcal{M})\right), \tag{4}$$

under the liquidity constraint that $R(\mathcal{M}) \geq Q \times v_L$. In the rest of the paper, we do not explicitly mention this liquidity constraint to simplify the exposition but it must be satisfied by any mechanism chosen by the seller. In addition, the mechanism must satisfy buyers' participation constraints (that is, at date 1, all buyers obtain positive expected profits from taking the actions they are supposed to take according to the mechanism) and possibly additional incentives constraints (more on this in Sections 3 and 4).

As will be clearer below (see, for instance, Section 3), in solving (4), the seller faces a standard trade-off. To obtain information via the asset sale, she needs to incentivize participation from informed buyers. However, such participation is a source of adverse selection for uninformed investors. This reduces the revenues from selling the asset since adverse selection costs are ultimately passed by uninformed buyers to the issuer.

3 Baseline Case: Exogenous Information

We first consider the case in which experts are exogenously endowed with perfect signals. In this case, we assume that each expert observes, at date 1 and before

[11] Note that in general $\Omega(\mathcal{M})$ is random. For a given mechanism, its realization may depend on the realization of the signals received by experts at date 1. More on this in Section 3 and 4.

deciding whether to participate in the mechanism, a perfect signal $s \in \{L, H\}$ about the asset payoff ($s = \omega$ if $v = v_\omega$). Thus, there is no cost of information production for experts. Moreover, we assume that $I < Q \leq J$. Hence, the sale of the asset cannot succeed without ensuring that non-experts are willing to buy some shares of the asset, while it can succeed without experts. This assumption will no longer be necessary when information is endogenous, but here it helps us highlight the liquidity–informativeness trade-off for the seller (see Section 3.1).

As a benchmark, it is useful to derive the largest expected utility that the seller can achieve in this case. Recall that any mechanism must at least satisfy buyers' participation constraints; that is, each buyer participating in the mechanism must expect a nonnegative profit. Thus, buyers' **aggregate** expected profit, $Q(\mathsf{E}(v) - R(\mathcal{M}))$, must be nonnegative.[12] Hence, in any mechanism, $Q\,\mathsf{E}(v) \geq R(\mathcal{M})$. It follows from (3) that the largest ex-ante expected utility the seller can obtain is

$$\bar{\Pi}^{\max} = Q\,\mathsf{E}(v) + \gamma\,\mathsf{Var}(v). \tag{5}$$

Thus, $\bar{\Pi}^{\max}$ is an upper bound on the expected utility that the seller can achieve with a mechanism that guarantees buyers' participation and the success of the sale. Accordingly, if there exists a feasible mechanism that yields $\bar{\Pi}^{\max}$ to the seller, this mechanism solves (4) and is weakly dominant. We show in Section 3.2 that one such mechanism exists in our setting.

3.1 The liquidity-informativeness trade-off

First, to build intuition about the seller's problem and the liquidity–informativeness trade-off, we contrast two mechanisms: (i) the Fixed Price (FP) mechanism (Rock (1986)) and (ii) the No Informed Trading (NIT) mechanism (Biais, Bossaerts, and Rochet (2002)). The FP mechanism yields full information revelation ($\Omega = v$) but underpricing ($\mathsf{E}(p_{issue}) < \mathsf{E}(v)$), while the NIT mechanism avoids underpricing but provides no information ($\Omega = \emptyset$). The issuer prefers the former when γ is large enough. However, as shown in Section 3.2, neither mechanism is optimal. These

[12] When there is a cost of producing information, as in Section 4, the condition is more complex since one must account for experts' cost of producing information when computing buyers' aggregate expected profit.

results set the stage for the subsequent analysis.

FP Mechanism (Rock (1986)). In this mechanism, the seller sets a fixed price p_{issue} and buyers submit an order to buy one share at this price or abstain from participating. If there is excess demand for the asset, the seller allocates shares pro rata among the buyers who have submitted an order.

Consider an issuing price such that $v_L \leq p_{issue} < v_H$. At this price, each informed buyer finds it optimal to buy one share if $s = H$ and not to participate if $s = L$. If uninformed buyers find it optimal to participate, each therefore receives $q_u(v_H) = \frac{Q}{J+I}$ shares when $v = v_H$ and $q_u(v_L) = \frac{Q}{J}$ when $v = v_L$. Uninformed buyers' expected profit is therefore:

$$\mathsf{E}(q_u(v)(v - p_{issue})) = \mu q_u(v_H)(v_H - p_{issue}) + (1-\mu)q_u(v_L)(v_L - p_{issue}). \tag{6}$$

The largest price $p_{issue}^{FP,*}(J)$ that the issuer can set while guaranteeing uninformed buyers' participation solves $\mathsf{E}(q_u(v)(v - p_{issue}^{FP,*})) = 0$, which is

$$p_{issue}^{FP,*}(J) = \beta(J)v_H + (1 - \beta(J))v_L,$$

with $\beta(J) = \frac{\mu J}{J+(1-\mu)I}$. As $0 < \beta(J) < \mu$ (since $I > 0$), it follows that $v_L < p_{issue}^{FP,*} < \mathsf{E}(v)$.

Thus, with the FP mechanism, the asset must be "underpriced," i.e., sold at a discount relative to its expected payoff ($p_{issue}^{FP,*} < \mathsf{E}(v)$). Indeed, uninformed buyers receive a larger allocation when the asset payoff is low than when it is high, as experts refrain from buying the asset if its payoff is low. Thus, they are adversely selected, and underpricing compensates them for their adverse selection costs. However, the total demand for the asset (D) reveals the asset payoff because it is larger ($D(v_H) = J + I$) when $v = v_H$ than when $v = v_L$ ($D(v_L) = J$). Hence, the equilibrium of the FP mechanism is fully revealing: $\Omega(FP) = v$.

We deduce that the seller's ex-ante expected utility with the FP mechanism is:

$$\begin{aligned}\bar{P}i_0(FP) &= Qp^{FP,*}_{issue} + \gamma\,\mathsf{Var}(v)\\ &= Q\,\mathsf{E}(v) - Q\left(\mathsf{E}(v) - p^{FP,*}_{issue}\right) + \gamma\,\mathsf{Var}(v)\\ &= \bar{\Pi}^{\max} - \underbrace{\frac{QI\mu(1-\mu)(v_H - v_L)}{J + (1-\mu)I}}_{\text{Total Adverse Selection Costs}}.\end{aligned} \tag{7}$$

Thus, the seller does not achieve the largest possible expected utility ($\bar{\Pi}^{max}$) because uninformed buyers' adverse selection costs are passed to the issuer. This is the cost paid by the issuer to obtain information about v.[13]

NIT mechanism (Biais et al. (2002)). Now consider an alternative mechanism in which the seller makes the issuance price contingent on the total demand for the asset, D. Specifically, the seller sets the price of the asset in the following way:

$$p^{*,NIT}_{issue}(D) = \begin{cases} v_H + \epsilon, & \text{if} \quad D > J \quad \text{and} \quad \epsilon > 0,\\ \mathsf{E}(v), & \text{if} \quad D \leq J.\end{cases} \tag{8}$$

In this case, the following decisions for buyers form a Nash equilibrium: (i) experts do not participate, and (ii) non-experts submit a buy order for 1 share. To see that this is an equilibrium, consider experts first. Each expert expects total demand to be J given the equilibrium actions of other buyers. Thus, if he buys the asset, its price will be $v_H + \epsilon$. Since this is higher than the largest possible payoff of the asset, not participating is a best response for an expert. Now consider a non-expert. He expects total demand from other participants to be $J - 1$ shares. Thus, if he participates, total demand will be J, and the price of the asset will be $\mathsf{E}(v)$. At this price, the

[13] The situation in which the issuer sets the price $p^{FP,*}_{issue}(J)$ and buyers behave as described above is a Nash equilibrium. There are other Nash equilibria in which only a fraction of all uninformed buyers buy the asset (in equilibrium, they are indifferent between buying or not). In these equilibria, buyers' total demand reveals the asset payoff as well and the issuing price is given by $p^{FP,*}_{issue}(J')$ where $Q \leq J' \leq J$ is the number of participating uninformed buyers. As $p^{FP,*}_{issue}(J')$ decreases with J', the issuer's expected utility is maximal in the equilibrium in which $J' = J$. Thus, $\bar{\Pi}_0(FP)$ in (7) is the largest expected utility that the issuer can obtain with the FP mechanism.

non-expert will receive $q_u = q_u(v_H) = q_u(v_L) = \frac{Q}{J}$ shares and an expected profit of:

$$\mathsf{E}\left(q_u(v)(v - p^{*,NIT}_{issue}(J))\right) = \frac{Q}{J}\left(\mu(v_H - p^{*,NIT}_{issue}(J)) + (1-\mu)(v_L - p^{*,NIT}_{issue}(J))\right) = 0.$$

The non-expert is therefore indifferent between participating or not, and participation is thus a best response to the seller's price schedule.[14]

We refer to this mechanism as the "No Informed Trading" (NIT) mechanism, since no informed buyers trade in equilibrium. Under the NIT mechanism, the asset is sold at its unconditional expected value (i.e., without underpricing), but the sale conveys no information about the payoff ($\Omega = \emptyset$), as aggregate demand is identical whether $v = v_H$ or $v = v_L$. The seller's ex-ante expected utility is therefore:

$$\bar{\Pi}_0(NIT) = Q\,\mathsf{E}(v) = \bar{\Pi}^{max} - \gamma\,\mathsf{Var}(v), \tag{9}$$

With this mechanism, the seller eliminates underpricing (illiquidity) by removing adverse selection and secures the highest expected revenue from the sale, $QE(v)$ (see the discussion after (3)). However, no information is revealed. Hence, liquidity is achieved at the cost of informativeness.

Thus, in choosing between the FP and NIP mechanism, the seller faces a trade-off between illiquidity costs due to adverse selection and information. In the latter illiquidity costs are nil but the sale generates no information while in the former the sale generates maximal information at the cost of underpricing. The optimal solution to this trade-off depends on the issuer's preference for informativeness, γ. Using (7) and (10), the seller's expected utility is larger with the FP mechanism if and only if $\gamma \geq \hat{\gamma}$ where $\hat{\gamma} = \frac{QI}{(I+(1-\mu)J)(v_H - v_L)}$. Thus, if γ is large enough, the seller is willing to sacrifice liquidity for information. The threshold $\hat{\gamma}$ increases with I because underpricing (illiquidity cost) in the FP mechanism increases with I. It decreases with $(v_H - v_L)$ because the issuer's expected utility benefit of obtaining information is larger when there is more uncertainty about the asset payoff.

However, the seller has many other ways to sell the asset beyond the NFI or FP

[14]One can construct other NIT mechanisms in which only $J' \in [Q, J)$ uninformed buyers participate. However, these equilibria lead to exactly the same expected utility for the seller.

mechanisms. By analogy with a Pareto frontier, efficient mechanisms are those that maximize the seller's expected revenues for a given reduction in uncertainty about the asset payoff. In the next section, we show that there exists one mechanism, which we call "Divide and Conquer" (DaC), in which the seller achieves the largest possible expected revenues ($Q\,\mathsf{E}(v)$) together with full information revelation ($\Omega = \{v\}$). Thus, the DaC mechanism yields an expected utility equal to $\bar{\Pi}^{\max}$, the maximum expected profit attainable by the seller. It is therefore at least weakly dominant for *all* sellers with $\gamma > 0$. This implies that, in the setting considered so far, the trade-off between informativeness and illiquidity can be resolved at zero cost.

3.2 Divide and Conquer Mechanism

The Divide and Conquer mechanism ($\mathcal{M} = DaC$) has two stages. In Stage 1, buyers are contacted sequentially and offered the possibility to purchase one of two derivative contracts whose payoffs are contingent on the realization of the fundamental value v when it is finally observed. The first contract, labeled C_L, pays $F+\epsilon$ if $v = v_L$ and zero otherwise, while the second contract, labeled C_H, pays $F+\epsilon$ if $v = v_H$ and zero otherwise. The price of each contract is F, so the dollar return for a buyer purchasing either contract can be ϵ or $-F$.[15] The values of F and ϵ are chosen by the seller. All derivative contracts expire once the fundamental value of the asset is observed. The first stage stops when one buyer decides to buy a contract or when all buyers have been contacted.

In Stage 2, the seller reveals the outcome of Stage 1 to all buyers. If one contract has been purchased, she allocates the Q shares among the remaining $J+I-1$ buyers at $p_{\text{issue}} = v_\omega$ if contract C_ω has been chosen in Stage 1, where $\omega \in \{L, H\}$.[16] If no buyer chooses a contract in Stage 1, then the seller uses the "NIT" mechanism (see previous section). As we shall see, this outcome never occurs in equilibrium. However, buyers' decisions in Stage 1 depend on how the seller sets the price of the

[15] The price of each contract must be paid at date 1 while the payoff of the contract is realized at date 2 after v is observed. A buyer can only acquire a contract if he can pay F upfront.

[16] Thus, the buyer who purchases a contract in Stage 1 receives no shares of the asset. The possibility that some participants receive no allocation given their report is standard in the mechanism design literature on IPOs. See, for instance, Benveniste and Spindt (1989) or Sherman and Titman (2002).

asset if she obtains no information in Stage 1.

We say that this mechanism induces full revelation if (i) only experts buy a contract in Stage 1, and (ii) an expert selects contract C_ω when his signal is $s = \omega$ for $\omega \in \{L, H\}$.

Proposition 1. *Suppose $\mathcal{M} = DaC$ with $F > \max\left\{\frac{(1-\mu)}{\mu}, \frac{\mu}{(1-\mu)}\right\}\epsilon$ with $\epsilon > 0$. Then, at date 1, the following actions form a Nash equilibrium: (i) A non expert never purchases a derivatives in Stage 1, (ii) an expert buys the contract C_ω when his signal is $s = v_\omega$ for $\omega \in \{L, H\}$ and (iii) the asset is sold at $p_{issue} = v_\omega$ when contract C_ω has been purchased in date 1. In this equilibrium, $\Omega = \{v\}$ (full revelation) and the expected revenue from the asset sale is $R(DaC) = Q(E(v) - \epsilon)$*

In this equilibrium, the first expert who is contacted in Stage 1 selects the derivatives that corresponds to his signal and obtains an expected profit of ϵ. The condition $\epsilon > 0$ guarantees that the expert's profit from trading the derivatives contract is strictly positive and therefore strictly dominates the expected profit that he can obtain by not trading in Stage 1 or not trading at all.[17]

With the DaC mechanism described in Proposition 1, the seller's ex-ante expected utility is:

$$\bar{\Pi}_0(DaC) = Q(\mathsf{E}(v) - \epsilon) + \gamma\,\mathsf{Var}(v) = \bar{\Pi}^{max} - \epsilon, \tag{10}$$

which can be made arbitrarily close to $\bar{\Pi}^{max}$. Thus, the DaC mechanism considered in Proposition 1 is (weakly) dominant for the seller regardless of γ. Thus, when the mechanism for selling the asset is properly designed, the liquidity-informativeness trade-off disappears.

Intuitively, the DaC mechanism separates the problem of incentivizing experts to reveal their private information from the problem of incentivizing non experts to participate to the issue. In the mechanisms considered in Section 3, these problems are bundled. The DaC mechanism separates them and guarantees that the payment to informed buyers is just sufficient to incentivize information revelation. As we assume

[17] Thus, the condition $\epsilon > 0$ just serves to break indifference between participation to Stage 1 or 2 for experts.

that there is no cost of producing information, this payment can be arbitrarily close to zero.

In Section 5, we show that the DaC mechanism remains weakly dominant for all sellers with $\gamma > 0$ in a more general setting in which the production of information is endogenous. This case is more complex because the seller must incentivize buyers to (i) pay the cost of producing information, (ii) truthfully reveal their information if they have some and (iii) not pretend they have information if they don't. Before presenting this result, in Section 4, we first extend the previous framework to allow for endogenous information production and we derive (in Proposition 3) the largest expected utility that the seller can achieve in this case in the absence of frictions (moral hazard and adverse selection). We also derive the sellers' expected utility when she uses the FP and NIP mechanisms. These will serve as benchmarks as in the case with exogenous information.

4 Endogenous Information Production: Benchmarks

In this section, we extend the baseline framework to account for costly information production and derive the equilibria of the NIT and FP mechanisms in this case (Section 4.1). We then solve for the seller's optimal mechanism when information production is observable, so that only participation constraints apply (Section 4.2). This provides an upper bound on the seller's expected utility when information production is unobservable. This case is analyzed in Section 5.

4.1 Extended Framework (endogenous information)

Henceforth we assume that all experts are initially uninformed about the asset payoff. However, in contrast to non experts, each expert has the ability to produce information about this payoff. To do so, an expert must search for information, which costs c per search. One expert's search can fail for two reasons. First, with probability $(1-\pi)$, no information is available about v (in this case, all experts will fail to find information). Second, even if information is available about v, an expert can fail to find it with probability $(1-\phi)$. When an expert does not find or does not produce information, he remains uninformed and therefore expects the payoff of the asset to be $v_U \equiv \mathsf{E}(v)$.

In sum, if an expert searches information, he finds some with probability $\phi\pi$ and none with probability $(1-\phi\pi)$. In the former case, we assume that the expert receives a signal $s \in \{H, L\}$ that perfectly reveals v ($s = \omega$ if $v = v_\omega$). Otherwise, the buyer receives an uninformative signal, $s = U$.[18] Thus, experts' signals are imperfect (if $s = U$, signals are uninformative) and imperfectly correlated (the probability that two experts receive the same signal is $\pi(1 - 2\phi(1 - \phi)) + (1 - \pi))$. The likelihood that information is discovered increases with K: If K experts produce information, at least one receives an informative signal with probability $\pi(1 - (1 - \phi)^K)$.

As in the baseline case, we assume that the seller cannot produce information about v.[19] This is a natural assumption since we want to analyze the trade-off between informativeness and illiquidity from the asset seller's viewpoint. If the asset seller can produce information, she does not need to incentivize information production in the first place and the NIT mechanism is optimal for the seller.

We first consider the NIT and FP mechanisms when experts' signals are endogenous. If the seller uses the NIT mechanism (the price schedule in (8) then it is a Nash equilibrium that (a) experts do not participate and do produce information and (b) the J non experts submit an order to buy one share. The reason is the same as in the baseline case with exogenous signals. In addition, experts optimally choose not to produce information since each anticipates that he will not trade anyway. Thus, as in the baseline case, the NIT mechanism yields an expected utility of:

$$\bar{\Pi}_0(NIT) = Q\,\mathsf{E}(v), \tag{11}$$

to the seller.

Another possibility for the seller is to use the FP mechanism. In this case, experts optimally decide whether or not to produce information before participating to the

[18] This information structure is identical to that in Benveniste and Wilhelm (1990) and Sherman and Titman (2002).

[19] This does not mean that the seller has no information. Indeed, one can assume that the seller first collects information and arrives to an estimate of $\mathsf{E}(v)$ for the firm. It just means that the cost of collecting incremental information is too high for the seller.

fixed price offering. We denote by p^{FP*}_{issue} the price sets by the seller by and by K^*_{FP}, the number of experts who produce information in equilibrium.

Proposition 2. *When information production is endogenous, the equilibrium of the FP mechanism is such that:*

- *The price for the asset is smaller than the unconditional expected value of the asset ($p^{FP*}_{issue} < \mathsf{E}(v)$).*
- *The number of buyers who produce information, K^*_{FP}, is such that information producers obtain zero expected profit net of the information cost and solves (32) in the proof of the proposition.*
- *The seller's expected utility is:*

$$\bar{\Pi}_0(FP) = Q\,\mathsf{E}(v) - cK^*_{FP}\gamma + \frac{\mu\pi\left(1-(1-\phi)^{K^*_{FP}}\right)\mathsf{Var}(v)}{\mu+(1-\mu)\left(1-\pi+\pi(1-\phi)^{K^*_{FP}}\right)}. \tag{12}$$

As when information production is exogenous, the asset is underpriced ($p^{*FP}_{issue} < \mathsf{E}(v)$) to guarantee uninformed buyers' participation. Moreover, in equilibrium, the number of experts searching for information adjusts in such a way that their aggregate expected profit is equal to the aggregate cost paid to produce information ($Q(\mathsf{E}(v) - p^*_{issue}) = cK^*_{FP}$). As experts' aggregate expected profits are equal to non experts' adverse selection costs (see (27) in the proof of Proposition 2), the seller's expected proceeds from the asset sale is $\mathsf{E}(R(FP)) = Q\,\mathsf{E}(v) - cK^*_{FP}$. This yields the first term in (12). The last term in $\bar{\Pi}_0(FP)$ is the expected informational benefit of the FP mechanism in equilibrium, $\gamma(\mathsf{Var}(v) - \mathsf{E}(\mathsf{Var}(v \mid \Omega(FP)))$ (see the proof of Proposition 2).[20]

4.2 Benchmark: Information Production is Observable

It is useful to first derive the first best for the seller, that is, the largest expected utility that the seller can achieve in the absence of frictions. To this end, we assume that "information production is observable" meaning that the seller can (i) observe

[20] In contrast to the case in which information is exogenous, the FP mechanism does not necessarily lead to full information revelation because no experts might find information.

who is an expert and who is not, (ii) observe whether an expert makes the effort to search information or not and (iii) that experts truthfully report the outcome of their search. This effectively enables the seller to incentivize information production at the lowest possible cost by removing incentives constraints due to adverse selection ((i) and (iii), as in the baseline case with exogenous information) and moral hazard ((ii)).

To derive the seller's largest possible expected utility when information prosuction is observable, we consider again a DaC mechanism. In Stage 1, the seller elicits information from experts. In Stage 2, the seller reports the information obtained in Stage 1 and sells the asset at a price equal to its payoff if the latter has been discovered in Stage 1. If not, the seller sells the asset only using the NIT mechanism. As shown above, in this mechanism, experts do not produce information and the asset is sold at $p_{issue} = \mathsf{E}(v)$. It will be clear below that when Stage 1 is designed optimally, it is indeed optimal for the seller to use a NIT mechanism if no information has been found in Stage 1.

When $\pi = \phi = 1$, the solution to the seller's problem is as follows. If the seller contacts one expert in Stage 1, she pays the expert c if he produces information and nothing otherwise. In this case, the expert produces information since, for this payment, he is just indifferent between producing or not producing it. Moreover, as the expert discovers information with certainty and reports it truthfully, after Stage 1, $\Omega = \{v\}$. Hence, in Stage 2, $p_{issue} = v$, which guarantees participation of uninformed buyers. The seller's expected utility is then $Q\,\mathsf{E}(v) + \gamma Var(v) - c$.

This expected utility is the largest one that the seller can obtain if she elicits information since: (i) an expert must at least expect to receive c to search for information and (ii) conditional on information being produced, the seller cannot obtain a higher expected utility than $Q\,\mathsf{E}(v) + \gamma Var(v)$, for the same reasons as in the baseline case.

Alternatively, the seller can choose to sell the asset without obtaining information by using the NIT mechanism and obtain an expected utility of $Q\,\mathsf{E}(v)$. Hence, when $\pi = \phi = 1$, the seller uses the DaC mechanism described above if $c \leq \gamma\,\mathsf{Var}(v)$ and directly sells the asset with the NIT mechanism otherwise. Intuitively, in the latter case, the utility benefit of information is too small relative to the cost of obtaining information and the seller is better off not eliciting information production.

When $\phi < 1$ and $\pi < 1$, the optimal mechanism for the seller is not as simple. The reason is that designing Stage 1 is less straightforward because experts do not obtain information with certainty. The seller may therefore need to contact several experts before acquiring information, and if $\pi < 1$, experts may never succeed. To solve the seller's problem, we first consider the case where she contacts experts sequentially in Stage 1 and explain why doing so is optimal at the end of this section.[21] When an expert is contacted, the seller offers a payment c if he produces information and nothing otherwise. As effort is observable and costs c, each buyer exerts effort and truthfully reports his signal $s \in \{H, L, U\}$ to the seller.

The seller should stop searching once an expert reports $s = H$ or $s = L$, since such a report fully resolves uncertainty. Contacting additional experts would only raise costs without adding information. It may also be optimal to proceed to Stage 2 after a few experts report $s = U$. Indeed, as the number of uninformative reports increases, the seller becomes increasingly pessimistic about the chance of finding information.

Specifically, the probability that information is available about the asset's payoff, conditional on observing $i - 1$ uninformative signals in a row, is:

$$\pi_i = \frac{(1-\phi)^{i-1}\pi}{(1-\phi)^{i-1}\pi + (1-\pi)}, \tag{13}$$

so that $\pi_K = \pi < \cdots < \pi_3 < \pi_2 < \pi_1 = \pi$ (see Figure 2).[22] Hence, at some point, the expected informational gain from contacting one additional expert ($\pi_i \phi \gamma \, \mathsf{Var}(v)$) becomes too small relative to the cost and, intuitively, the seller is better off moving to Stage 2 without information.

Hence, let K denote the maximal number of experts that the seller contacts in Stage 1 before moving to Stage 2.[23] Stage 2 stops at the random time $\tau_{stop}(K) = \min\{\tau_{find}, K\}$, where τ_{find} is the first time at which one expert finds information

[21] Contacting buyers in $\mathcal{J}$ is useless for the seller since they cannot help obtain information in Stage 1. After Proposition 3, we explain why sequential contact is optimal.

[22] The rate at which π_i decays with i increases with ϕ. Indeed, if ϕ is large, it is unlikely that failure to find information is due to bad luck.

[23] This means that after the K^{th} expert has exerted the effort to find information, the seller stops contacting experts whether or not the K^{th} expert finds information.

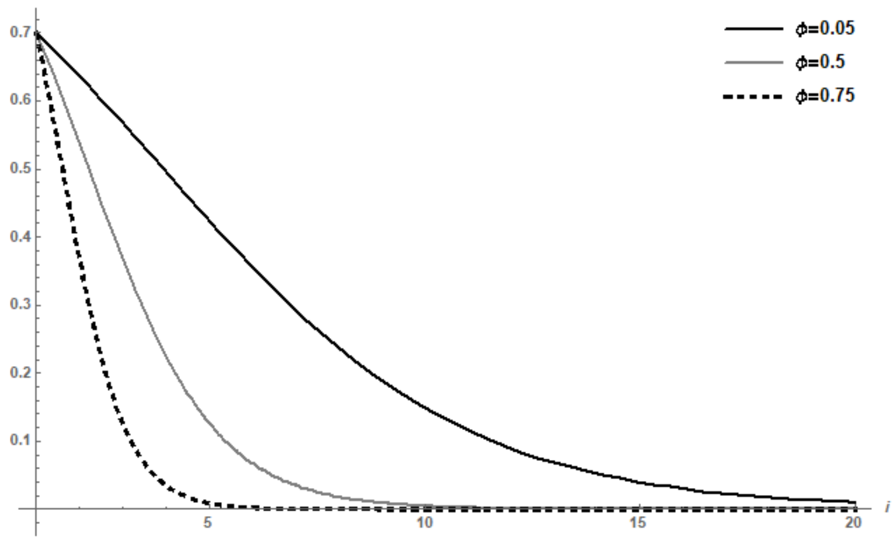

Figure 2. π_i (given by (13)) as a function of $i \in [1, 20]$ when $\pi = 0.7$.

in Stage 1. The total cost incurred by the seller in Stage 1 (the cost of obtaining information) is therefore:

$$C_{issue}(K) = \sum_{i=1}^{\tau_{stop}} c = \tau_{stop}(K) \times c. \tag{14}$$

After some algebra (see the proof of Proposition 3), we obtain that:

$$\mathsf{E}(C_{issue}(K)) = c\,\mathsf{E}(\tau_{stop}(K)) = c\left((1-\pi)K + \frac{\pi(1-(1-\phi)^K)}{\phi}\right), \tag{15}$$

and the likelihood that no information is produced in Stage 1 is

$$P_{failure}(K) \equiv \Pr(\tau_{find} \geq K) = 1 - \pi(1-(1-\phi)^K). \tag{16}$$

After Stage 1, either $\Omega = \{v\}$ if one expert has received an informative signal or $\Omega = \{\emptyset\}$ if all experts have observed $s = U$. The seller discloses Ω to all buyers. She offers to sell the asset at $p_{issue} = v$ if $\Omega = \{v\}$ and otherwise uses the NIT mechanism. With this specification, the sale succeeds with certainty and the seller expects to sell the asset at a price of $\mathsf{E}(v)$ per share, for the same reasons as in the baseline case with exogenous information.

For a given stopping rule K, we deduce from (3) that, with this mechanism, the seller's expected utility is:

$$\bar{\Pi}_0(K) = Q\,\mathsf{E}(v) - \mathsf{E}(C_{issue}(K)) + \gamma\,\mathsf{Var}(v)(1 - P_{failure}(K)), \tag{17}$$

where $\mathsf{E}(C_{issue}(K))$ and $P_{failure}(K)$ are given by (15) and (16).

As the seller can make her decision to contact the i^{th} expert contingent on π_i, she faces a dynamic optimization problem. Given her belief π_i that information is available, her optimal stopping rule, K^*, must be such that for any $i \leq K^*$, contacting the i^{th} expert is optimal while, for $i > K^*$, moving to Stage 2 without contacting a new expert is optimal.

We show in the appendix (proof of Proposition 3) that $K^* = K^{max}$, where

$$K^{max} := \sup K \in \mathbb{N}_{>0} : c < \pi_K \phi\gamma\,\mathsf{Var}(v). \tag{18}$$

Intuitively, after contacting the K^{max}th expert, the seller is so pessimistic about the existence of information on v that the expected informational gain from contacting another expert falls below the cost c.[24] In this situation, the marginal informational gain is too small relative to the cost, so the seller is better off moving to Stage 2 and using the NIT mechanism. Hence, conditional on failing to obtain information from K^{max} experts in Stage 1, it cannot be optimal to incentivize further information production in Stage 2 (e.g., through a fixed price offering). Thus, the NIT mechanism is subgame perfect after K^{max} failed attempts in Stage 1 and contacting up to K^{max} experts is optimal for the seller.

Last, if $c > \pi\phi\gamma\,\mathsf{Var}(v)$, K^{max} does not exist. In this case, the cost of producing information is so large that the seller is better off moving directly to Stage 2 and

[24] The seller may have to pay up to $K^{max}c$ to buyers in Stage 1. This is not an issue since the issue size Q can be chosen so that, even in the worst case, proceeds cover both this cost and the seller's liquidity need (i.e., $Qv_L > cK^{max}$). If this condition fails, the optimal K is the value at which it binds. We omit this case for brevity, as it adds complexity without new insights.

use the NIT mechanism to sell the asset. These observations yield the following proposition.

Proposition 3. *Suppose $c \leq \pi\phi\gamma\,\mathsf{Var}(v)$. When information production is observable and the seller sequentially contacts experts in Stage 1, she maximizes her expected utility by (i) contacting up to K^{max} experts and by (ii) selling the asset at a price equal to the asset payoff if the latter has been discovered in Stage 1 and using the NIT mechanism otherwise. With this mechanism, her expected utility is:*

$$\Pi^*_{bench} \equiv \bar{\Pi}_0(K^{max}) = Q\,\mathsf{E}(v) - \mathsf{E}(C_{issue}(K^{max})) + \gamma\pi\left(1 - (1-\phi)^{K^{max}}\right)\mathsf{Var}(v). \quad (19)$$

If instead, $c \leq \pi\phi\gamma\,\mathsf{Var}(v)$, the seller does not contact experts and sells the asset using the NIT mechanism. Her expected utility is then equal to $Q\,\mathsf{E}(v)$.

The seller contacts at least one expert in Stage 1 iff $\gamma\,\mathsf{Var}(v)$ is large enough and K^{max} increases (stepwise) with $\gamma\,\mathsf{Var}(v)$. This is intuitive. Contacting more experts in Stage 1 raises the expected cost of obtaining information ($\mathsf{E}(C_{issue}(K))$ increases with K). It is therefore optimal to do so for the seller only if the benefit from information ($\gamma\,\mathsf{Var}(v)$) is large enough.

Figure 3 plots the optimal number of experts contacted by the seller, $K^* = K^{max}$, as a function of parameter ϕ for different values of π. For higher values of π, it is optimal for the seller to contact more experts (K^{max} increases with π) because it is more likely that information is available. In contrast, the effect of ϕ on K^* is non-monotonic. The reason is that, conditional on the existence of information, a higher ϕ increases the likelihood that an expert will find information and therefore the value of contacting another expert when previous ones have failed. However, a higher ϕ implies that the seller becomes more quickly pessimistic about the existence of information as the number of experts contacted in stage 1 increases (see Figure 2). The first force pushes for contacting more experts while the second pushes for contacting fewer. The latter dominates when ϕ is large enough.

The previous mechanism leaves no rents to buyers: (i) buyers in Stage 1 are just compensated for their cost of producing information, and (ii) buyers in Stage 2 purchase the asset at a price equal to its expected payoff given all available information.

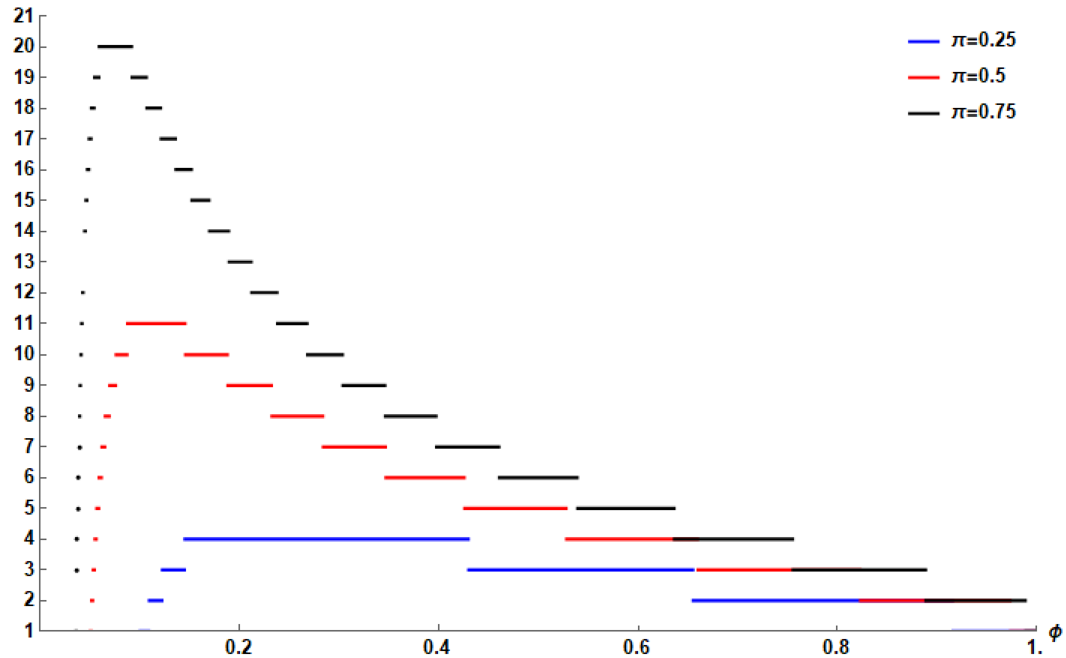

Figure 3. This figure shows $K_{\max}$ as a function of ϕ for $\pi = 0.75$ (black curve), $\pi = 0.5$ (red curve), and $\pi = 0.25$ (blue line). Other parameters are: $\gamma = 0.1$, $v_H = \$50$, $v_L = \$10$, $\mu = 0.5$, $c = \$1$.

This implies that the mechanism in Proposition 3 is weakly dominant when information production is observable. To see this, consider an alternative mechanism $\mathcal{M}'$ such that up to K experts might produce information. The unconditional likelihood that information is discovered under $\mathcal{M}'$ is $\pi\left(1-(1-\phi)^K\right)$. Hence, the ex-ante expected utility gain from information is $\gamma\pi\left(1-(1-\phi)^K\right)\mathsf{Var}(v)$. Moreover, as in any other mechanism, the largest expected revenues that the seller can obtain with $\mathcal{M}'$ is $Q\,\mathsf{E}(v)$ minus buyers' aggregate gross expected profits. These cannot be less than experts' expected aggregate cost of information production so that net of costs, buyers' aggregate expected profits are zero (otherwise some buyers' participation constraints do not hold).[25] Now experts' expected aggregate cost of information production is minimized if experts are contacted sequentially one by one, because simultaneous elic-

[25] Experts' realized aggregate cost of information production is the sum of information production costs over all experts who happen to produce information. For a given K, the number of such experts might be random, as in the mechanism considered in Proposition 3.

itation leads to duplication of effort. For instance, if all experts produce information simultaneously (e.g., as in the FP mechanism), the seller must forego at least Kc. By contrast, if the seller uses the sequential mechanism described previously, she expects to pay $\mathsf{E}(C_{issue}(K))$, as defined in (15). Since $\mathsf{E}(C_{issue}(K)) < Kc$, pooling experts is not cost-efficient. Thus, if it is optimal for the seller, $\mathcal{M}'$ must be such that experts are contacted sequentially in Stage 1, as assumed previously. But then, $\mathcal{M}'$ must be such that $K = K^{\max}$ and the seller uses the NFI mechanism if she fails to discover the asset payoff in Stage 1. It follows that $\mathcal{M}'$ must deliver the same expected utility as the mechanism considered in Proposition 3.

In sum, Π^*_{bench} is the largest possible expected utility for the seller when information production is endogenous. Thus, it serves as benchmark to measure the efficiency of the various mechanisms that the seller can use when information production is not observable (Section 5). In the next section, we show that in this case, a properly designed DaC mechanism can achieve an expected utility for the seller arbitrarily close to Π^*_{bench}.

5 Information Production is non Observable

We now assume that information production is non observable. This means that the seller cannot (i) observe who is an expert and who is not, (ii) observe whether an expert makes the effort to search information or not and (iii) observe whether experts truthfully report the outcome of their search. Thus, to achieve the same outcome as when information is observable, the seller must design Stages 1 and 2 of the DaC mechanism so that (i) experts are better off participating to Stage 1 while non experts are better off not, (ii) experts find optimal to produce information in Stage 1 rather than reporting a signal without doing so and (iii) experts find optimal to truthfully report the signal they obtain.

As in the benchmark case, the seller organizes the asset sale in two stages. First, buyers indicate whether they are willing or not to participate to Stage 1. Let $\mathcal{S}$ be the pool of buyers who do so. Then the seller contacts buyers in $\mathcal{S}$ sequentially and asks them to report their signal $s \in \{H, L, U\}$ about the payoff of the asset. We denote this report by $\sigma \in \{H, L, U\}$. A buyer in $\mathcal{S}$ is truthful if $s = \sigma$. Henceforth, we index by i, the signal and the report of the i^{th} buyer contacted by the seller in Stage 1. The seller designs Stages 1 and 2 to deter buyers who are not experts to participate to Stage 1 and to incentivize buyers in $\mathcal{S}$ (those who participate to Stage 1) to (i) produce information and (ii) truthfully reveal their signal.

We guess and verify that the seller can achieve this objective by using the following incentive scheme. First, if a buyer in $\mathcal{S}$ is contacted by the seller in Stage 1, he is "excluded" from Stage 2 (that is, receives no allocation in Stage 2).[26] Next, when a buyer is contacted, the seller discloses to the buyer his rank in the pool of buyers contacted so far in Stage 1. If the i^{th} buyer in $\mathcal{S}$ reports $\sigma_i = H$, he pays F to the seller and obtains a derivative contract C_{iH} that pays $F + f_{i,H}$ if the realization of v is v_H and zero otherwise. If he reports $\sigma_i = L$, he pays F to the seller and obtains a derivative contract C_{iL} that pays $F + f_{i,L}$ if the realization of v is v_L and zero otherwise.[27] If the buyer reports $\sigma_i = U$, there are no transactions and payments between the seller and the buyer.

The transfers F and $f = \{f_{i,H}, f_{i,L}\}_{i=1}^{i=K}$ are designed to incentivize experts to produce information and truthfully report their signals (see below). The exclusion of buyers who participate to stage 1 reduces the costs of providing incentives for truthful revelation. Indeed, it implies that a buyer who finds information has no incentive to report $\sigma = U$, in the expectation that he might obtain a larger expected profit by participating to stage 2. This also implies, as we shall see, that buyers who cannot produce information have no incentives to participate to stage 1.

Last, for the same reason as in the benchmark case (Section 4.2), it is optimal for the seller to move to Stage 2 as soon as one buyer reports $\sigma_i = H$ or $\sigma_i = L$ (since, in equilibrium, reports are truthful). Moreover, as in the benchmark case, the seller can find optimal to stop Stage 1 if many buyers fail to find information. Thus, as in the benchmark case, we denote by K the maximum number of buyers contacted by

[26] The possibility of not allocating shares to buyers is part of optimal mechanisms in the IPO literature. See, for instance, Benveniste and Spindt (1989).

[27] Each of these contracts can be replicated by issuing "butterfly spread" – a portfolio of call options written on the underlying asset. For example, the payoff of C_{iL} can be replicated by a long position in call option with strike price $f_{i,L} - F$, a short position in two call options with strike price v_L and a long position in a call option with strike price $f_{i,L} + F$.

the seller in Stage 1.

Stage 2 is organized as in the benchmark case. That is, if the seller receives the report $\sigma = H$ or $\sigma = L$ in Stage 1, she offers to sell shares to all buyers participating to Stage 2 at $p_{issue} = v_H$ if the seller has obtained the report $\sigma = H$ or $p_{issue} = v_L$ if the seller has obtained the report $\sigma = L$. If the seller stops Stage 1 without obtaining information (that is, if $\sigma_K = U$), she organizes Stage 2 using the NIT mechanism.

Of course, there are many other ways one could organize the two stages mechanisms (e.g., the seller could decide not to exclude buyers who participate in Stage 1 from Stage 2). However, as shown in Proposition 4 below, for appropriate choices of K, F and $f = \{f_{i,H}, f_{i,L}\}_{i=1}^{i=K}$, the organization we just described yields an expected utility for the seller which is arbitrarily close to the seller's expected utility when information production is observable (Π_{bench}). Hence, the organization we just described is at least weakly dominant.

Conditional on truth-telling, the previous mechanism implies that the seller expects to sell the asset at $\mathsf{E}(v)$. Thus, for the same reasons as when information production is observable, the seller's expected profit with this mechanism is:

$$\Pi(K) = Q\,\mathsf{E}(v) - \mathsf{E}(C_{issue}) + \gamma\,Var(v)(1 - P_{failure}(K)), \tag{20}$$

where the expected cost of the issue, $\mathsf{E}(C_{issue})$, is the ex-ante expected profit (gross of any cost of information production) that a buyer expects from trading in Stage 1.[28] Thus, it is determined by F and $f = \{f_{i,H}, f_{i,L}\}_{i=1}^{i=K}$. The seller's problem is therefore to choose K, F, and f to maximize $\Pi(K)$ under the following constraints: (i) Experts are (weakly) better off participating to Stage 1, (ii) Non experts are (weakly) better off not participating to Stage 1, (iii) Experts are better off producing information when they are contacted in Stage 1, (iv) Experts are better off reporting their true signal rather than misreporting.

We now present these constraints more formally. First, let $R(s_i, \sigma_i)$ be the expected profit (gross of cost of information production) of the i^{th} buyer contacted by

[28] When the mechanism is optimally designed, this expected profit is strictly positive (see Proposition 4). This implies that the derivatives contracts are not fairly priced. This "mispricing" is necessary to compensate experts for their cost of information production.

the seller if he receives signal s_i and reports σ_i. The truth-telling constraints impose:[29]

$$R(s_i, s_i) \geq R(s_i, \sigma) \text{ for all } s_i, \sigma \in \{H, L, U\}. \tag{21}$$

The second set of constraints guarantees that, given that he will report truthfully, each expert participating to stage 1 is better off producing information rather than not producing information (in which case, the expert observes $s_i = U$ for sure) when he is contacted by the seller. As each expert knows his position when he is contacted by an seller, this requires the following incentive constraints:

$$\begin{aligned} &\pi_i\phi(\mu R(H,H) + (1-\mu)R(L,L)) + (1-\pi_i\phi)R(U,U) \\ &\qquad \geq R(U,\sigma) + c, \quad \forall \sigma \in \{H, L, U\}, \quad \forall i \leq K, \end{aligned} \tag{22}$$

Furthermore, when an expert is contacted and learns that he is the i^{th} contacted buyer in $\mathcal{S}$, he must be better off participating rather than walking away with a zero expected profit, which is always a possibility for the expert. This participation constraint imposes:

$$\pi_i\phi(\mu R(H,H) + (1-\mu)R(L,L)) + (1-\pi_i\phi)R(U,U) \geq c, \quad \forall i \leq K. \tag{23}$$

Observe that when (23) holds then all experts are (at least weakly) better off participating to Stage 1 rather than waiting until Stage 2 and producing information in this stage. Indeed, if an expert does so, he gets a zero expected profit either because (i) information has been produced in Stage 1 and therefore the expert cannot benefit from private information in Stage 2 (since $p_{issue} = v$ in this case) or (ii) information has not been produced in Stage 1 and in this case the seller uses NIT mechanism (so that no expert has an incentive to produce information and participate to Stage 2).

Moreover, after producing information and receiving his signal, an expert in Stage 2 must be better off reporting the signal than walking away, which imposes another

[29]These constraints must be satisfied even if the cost of information production has been paid because once the cost has been paid, a buyer can still misreport.

set of participation constraints:

$$R(s_i, s_i) \geq 0, \quad \forall s_i \in \{H, L, U\}. \tag{24}$$

Last, non experts must optimally choose to participate to Stage 2 rather than Stage 1. In Stage 2, their expected profit is zero since either the asset payoff is revealed or sold at its expected payoff via the NIT mechanism (if no information was discovered in Stage 1). Thus, their expected profit from participation to Stage 2 must be negative. The largest expected profit that a non expert can obtain in Stage 1 is $\max_{\sigma \in \{H,L,U\}} R(U, \sigma)$ since he can always produce at no cost any message σ (while $s = U$ for a non expert). The incentive constraints (21) impose that $\max_{\sigma \in \{H,L,U\}} R(U, \sigma) = R(U, U)$. Thus, non experts optimally choose not to participate to Stage 1 if and only if $R(U, U) \leq 0$. Thus, $R(U, U) = 0$ as otherwise (24) cannot hold. This is the case since when a buyer reports $\sigma = U$, (a) there is no transfer between the seller and the buyer and (b) the buyer cannot participate to Stage 2 (receives no allocation in Stage 2).[30]

This observation is important. As $R(U, \sigma) \leq R(U, U)$ for $\sigma = H$ or $\sigma = L$ (truth-telling constraints (21)), it follows that if experts' participation constraint (23) and truth-telling constraints (21) are satisfied then incentives constraints (22) (moral hazard) are satisfied as well.

In sum, if K, F and $f = \{f_{i,H}, f_{i,L}\}_{i=1}^{i=K}$ are chosen such that (21), (23) and (24) are satisfied and buyers who report U get no payments and are excluded from Stage 2, then (i) only experts choose to participate to Stage 2, (ii) each expert produces information when she is contacted by the seller, and (iii) each expert truthfully reports his signal to the seller. Thus, for a given K and for a given realization of experts' signals, the seller's information at the end of Stage 1 is identical to that in the benchmark case. The only difference is that the choice of K is now potentially

[30]Observe that, in contrast to the benchmark case, the fact that $R(U, U) = 0$ is necessary implies that if an expert produces information and reports $\sigma = U$, he receives nothing. This implies that an expert must be compensated by a larger expected profit on the derivatives contracts when he reports $\sigma = H$ or $\sigma = L$. This explains why the payments to the buyers are larger than c in equilibrium when they report $\sigma = H$ or $\sigma = L$ (see Proposition 4). However, in expectation, the experts expect to receive just c since (23) binds (as explained in the next paragraph).

constrained by incentives and participation constraints and the transfers F and f (the specifications of the derivatives contracts) must be chosen to satisfy these incentives constraints. The optimal choice of K, F and f for the seller is given in the next proposition.

Proposition 4. *Suppose $c \leq \pi\phi\gamma\,\mathsf{Var}(v)$. With the DaC mechanism, the seller can achieve an expected utility arbitrarily close to $\bar{\Pi}^*_{bench}$ (given in (3)) by choosing:*

- $K^*_{DaC} = K^{max}$, *where K^{max} is as defined in Section 4.2*
- $f_{i,L} = f_{i,H} = \varepsilon + \frac{c}{\pi_i \phi}$ *with arbitrarily small $\varepsilon > 0$ and $F > \max\{\frac{\mu}{(1-\mu}, \frac{(1-\mu)}{\mu}\}\left(\varepsilon + \frac{c}{\phi\pi_{K_{\max}}}\right)$;*

With this specification of the Divide and Conquer mechanism, the seller's expected utility is:

$$\Pi^*_{\mathbf{DaC}} \quad = \quad \Pi^*_{bench} - \epsilon\pi(1-(1-\phi)^{K_{\max}}).$$

When $c > \pi\phi\gamma\,\mathsf{Var}(v)$, the seller maximizes her expected utility by using the NIT mechanism.

Thus, with an appropriate specification of the derivatives contracts C_H and C_L and K, the seller can achieve an expected utility that is ϵ close to that in the first best.

The intuition is as follows. The mechanism induces an equilibrium behavior such that an expert obtains a profit only when (i) she is contacted in Stage 1 and (ii) finds information. Indeed, conditional on being contacted, the expected profit of an expert is: $\phi\pi_i(\mu f_{i,H} + (1-\mu)f_{i,L}) - c = \epsilon > 0$.[31] This rent for the experts breaks experts' indifference between participating or not (so that (23) holds strictly). It is realized only when one expert finds information in stage 1, which happens with probability $\pi(1-(1-\phi)^{K_{\max}})$. To break indifference, ϵ must be strictly positive but it can be arbitrarily small. This implies that the Divide and Conquer mechanism, with the specification in Proposition 4, is weakly dominant for the seller. As this

[31] Indeed, an expert's expected profit is $\pi_i\phi(\mu R(H,H) + (1-\mu)R(L,L)) + (1-\pi_i\phi)R(U,U)$ and $R(U,U) = 0$, $R(H,H) = f_{iH} + F - F = f_{iH}$ and $R(L,L) = f_{iL}$.

is the case for all $\gamma > 0$, all sellers choose this mechanism independently of their preference for information, γ. Thus, when the mechanism chosen by the seller is properly designed, there is no trade-off between informativeness and illiquidity, as in the case with exogenous information.

It is surprising that, despite the incentives constraints, the seller can achieve an expected utility arbitrarily close to the first best. There are two reasons for this. First, by using two stages for the issue, the seller separates the problem of incentivizing information production from the problem of selling shares. This avoids inefficient information production as in the FP mechanism (see Figure 4 for an illustration). Second, the possibility for the seller to exclude buyers who participate in Stage 2 from participation in Stage 1 and the use of the NIT mechanism in Stage 2 when no information is obtained in stage 1 helps to provide incentives. Indeed, it implies that those with the ability to produce information can only profit from their information by participating to Stage 1. This suppresses, at zero cost, their incentives to misreport in Stage 1 in the hope of making profits in Stage 2 or to refrain from participating in Stage 1 in the hope of making larger profits in Stage 2. Overall, the results show that the Divide and Conquer mechanism also works well when information production needs to be incentivized.

Figure 4 provides a numerical example. It compares the seller's expected issuing cost (expected loss relative to $Q\,\mathsf{E}(v)$), expected utility gain from information ($\gamma(\mathsf{Var}(v) - \mathsf{E}((v \mid \Omega)))$ and the seller's expected utility in the three mechanisms considered in the section when information production is endogenous: (i) an optimally designed Divide and Conquer (DaC) mechanism (Proposition 4), (ii) the fixed price mechanism (Proposition 2) and (iii) the NIT mechanism in which the seller's expected utility is $Q\,\mathsf{E}(v)$. In the NIT, the seller incurs no expected cost but does not gather information. In the FP mechanism, she obtains some information but there is either underproduction of information (when π is small) or overproduction (when π is large) in the sense that the expected cost borne by the issuer in equilibrium is either below or above the expected cost that she bears if she uses the optimal DaC mechanism. Moreover, in any case, the FP is less informative than the optimal DaC, even in the knife-edge case in which both mechanisms results in the same expected cost for the seller ($\pi \approx 0.34$).

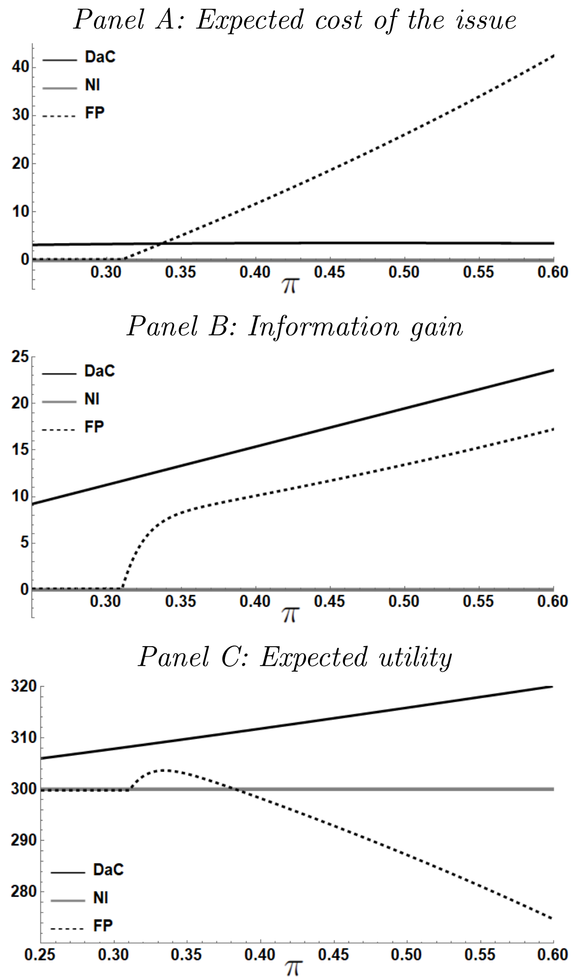

Figure 4. Expected cost, information gain and expected utilities.

This figure plots the expected cost (Panel A), information gain (Panel B) and the expected utility at the optimal strategy as a functions π in the three described mechanisms: DaC (black solid line), NI (gray line) and FP (dashed line). The parameters are as follows: $\gamma = 0.1$, $v_H = \$50$, $v_L = \$10$, $\mu = 0.5$, $\phi = 0.25$, $H = 15$, $Q = 10$.

6 Robustness (to be completed)

In the previous section, we have shown that even when information production is not observable, the DaC mechanism enables the seller to eliminate the trade-off between liquidity and informativeness (the mechanism in Proposition 4 is weakly dominant for all $\gamma > 0$). In this section we discuss a few assumptions that are key for this result.

Firstly, the DaC mechanism is sequential. This is an important difference with related papers (e.g., Sherman and Titman (2002)). As explained in Section 4.2, it enables the seller to elicit information production in a cost efficient way. In reality, this sequential process may take time and generates delay. In the presence of delay costs for the seller, the DaC mechanism might not be optimal anymore.

Secondly, we assume that the expert who buys a derivatives C_ω in Stage 1 cannot resell it before ist expiration at date 2 (as, for instance, stock options granted to managers cannot be transferred). If he could do so then incentives constraints would be different and the DaC mechanism might not be optimal.

Another important assumption is the absence of an active market for shares before the derivative contracts trade (Stage 1). This assumption makes sense in the case of IPOs but does not hold in other situations (e.g., SEOs). In the presence of an active parallel market, the mechanism would still lead to the production of information and its full revelation in equilibrium. However, the availability of a market where the buyer could trade after having acquired information would make it more difficult to incentivize his participation to Stage 1 and therefore lower expected revenues with the DaC for the seller.

7 Conclusion

This paper develops a mechanism design approach to analyze the trade-off between informativeness and liquidity in asset sales. We show that the seller can achieve informativeness without sacrificing liquidity by separating the market for information from the market for liquidity, via the use of a Divide and Conquer (DaC) mechanism. By using derivative contracts in a preliminary stage, the DaC mechanism elicits information from informed investors while ensuring that uninformed investors can still participate at fair prices in the subsequent stage. As a result, the seller obtains information without bearing unnecessary adverse selection costs.

Beyond the baseline case with exogenous signals, we extend the analysis to costly and uncertain information acquisition. Even under these more demanding conditions, the DaC mechanism can be designed to provide the right incentives for experts to search for information and to truthfully disclose it. Crucially, this design aligns private incentives with socially efficient levels of information production, leaving no informational rents to experts and enabling the seller to come arbitrarily close to the first-best benchmark. In this way, our analysis demonstrates that the liquidity–informativeness trade-off can be effectively eliminated under an appropriately structured process for the asset sale.

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Appendix

Proof of Proposition 1. We first show that, given the specification of the derivative contracts and the actions of other buyers, it is a best response for each expert to select contract C_w when $s = w$, with $w \in L, H$.

Consider first the case in which $s = H$. If an expert is contacted and purchases contract C_H, his profit is $F + \epsilon - F = \epsilon > 0$ with certainty. If instead the expert purchases contract C_L, the profit is $-F < 0$ with certainty. If the expert does not trade in Stage 1 and waits for Stage 2, the expectation is that the next expert will select contract C_H in equilibrium, so that $p_{issue} = v_H$. Hence, the expected profit from waiting until Stage 2 is zero. Purchasing contract C_H is therefore a best response. By similar reasoning, purchasing contract C_L is a best response when $s = L$.

Now consider a non-expert. If a non-expert is contacted in Stage 1 and trades contract C_H, his expected profit is $(\mu\epsilon - (1 - \mu)F)$, which is strictly negative if $F > \left(\frac{\mu}{1-\mu}\right)\epsilon$. If instead the non-expert trades contract C_L, the expected profit is $((1-\mu)\epsilon - \mu F)$, which is strictly negative if $F > \left(\frac{1-\mu}{\mu}\right)\epsilon$. Thus, if $F > \max\{\frac{(1-\mu)}{\mu}, \frac{\mu}{1-\mu}\}\epsilon$, not trading in Stage 1 is a best response for non-experts.

Finally, because there is full revelation of the asset payoff in Stage 1, all buyers are indifferent between trading the asset at $p_{issue} = v$ and not trading in Stage 2. Thus, trading at $p_{issue} = v$ is a best response. $\square$

Proof of Proposition 2.

Step 1. We first derive the equilibrium price of the FP mechanism when $K_{FP} \leq I$ experts decide to produce information. We denote this price by $p^*_{issue}(K_{FP})$. This is the largest price that guarantees participation of uninformed , that is, such that uninformed buyers obtain zero expected profits. We conjecture and verify below that $v_L < p^*_{issue}(K_{FP}) < v_H$.

Let $k \in [0, K_{FP}]$ be the number of experts who actually obtain an informative signal ($s \in \{H, L\}$). We refer to experts who find information as being informed buyers. Experts who do not find information are uninformed. Thus, the actual number of uninformed buyers in is $J + I - k$. Given our assumptions, k is random and that $\Pr(k = j) = \pi\binom{K_{FP}}{j}(1-\phi)^{K_{FP}-j}(\phi)^j$ for $0 < j \leq K$ and $\Pr(k = 0) = \pi(1-\phi)^{K_{FP}} + (1-\pi)$.

As $p_{issue} \in (v_L, v_H)$, informed buyers demand one share when $s = H$ and demand no shares when $s = L$. Moreover as p_{issue} must satisfy uninformed buyers' participation constraint, the latter are at least weakly better off demanding one share. Thus, there is excess demand in the issue whether $v = v_H$ or $v = v_L$ since $J > Q$. Let $q_i(v)$ be informed buyers' allocation and $q_u(v)$ be uninformed buyers' allocation in equilibrium when the asset payoff is v. We have:

1. $q_u(v_H) = q_i(v_H) = \frac{Q}{J+I}$
2. $q_u(v_L) = \frac{Q}{J+I-k}$, $q_i(v_L) = 0$

The clearing condition implies that all shares sold are allocated to buyers, that is:

$$(J + I - k)q_u(v) + kq_i(v) = Q \quad \text{for} \quad \forall k \in [0, K] \text{ and } \forall v \in \{v_H, v_L\}. \tag{25}$$

Thus, uninformed buyers' aggregate expected profit is:

$$\mathsf{E}((J + I - k)q_u(v)(v - p^*_{issue})) = Q(\mathsf{E}(v - p^*_{issue}) - \underbrace{\mathsf{E}(kq_i(v)(v - p^*_{issue}))}_{\text{Adverse Selection Cost}}, \tag{26}$$

As this aggregate expected profit is zero in equilibrium (so that uninformed buyers' participation constraint binds), we deduce from (26) that:

$$Q(\mathsf{E}(v - p^*_{issue})) = \underbrace{\mathsf{E}(kq_i(v)(v - p^*_{issue}))}_{\text{Adverse Selection Cost}}. \tag{27}$$

Therefore

$$p^*_{issue}(K_{FP}) = \frac{\mathsf{E}(v)Q}{Q - \mathsf{E}(kq_i(v))} - \frac{\mathsf{E}(kq_i(v)v)}{Q - \mathsf{E}(kq_i(v))}. \tag{28}$$

Now, let $\tilde{\tau}(k)$ denote the fraction of the issue allocated to informed buyers when

$v = v_H$: $\tilde{\tau}(k) \equiv \frac{k}{J+I}$. Given our assumptions:

$$\mathsf{E}(\tilde{\tau}(k)) = \pi \sum_{k=1}^{K_{FP}} \binom{K_{FP}}{k} (1-\phi)^{K_{FP}-k} \phi^k \left(\frac{k}{k+J} \right). \tag{29}$$

When $v = v_L$, informed buyers do not trade. Thus, we have:

$$\mathsf{E}(kq_i(v)v) = E(\tilde{\tau}(k))Q\mu v_H, \text{ and}$$

$$\mathsf{E}(kq_i(v)) = E(\tilde{\tau}(k))Q\mu.$$

We deduce that

$$p^*_{issue}(K_{FP}) = \beta v_H + (1-\beta)v_L \tag{30}$$

with $\beta = \frac{\mu(1-\mathsf{E}(\tilde{\tau}(k)))}{1-\mathsf{E}(\tilde{\tau}(k))\mu}$. Observe that $0 < \beta < \mu < 1$ if $E(\tau(k)) > 0$. Thus, $v_L < p^*_{issue}(K_{FP}) < v_H$ as conjectured. Moreover, $p^*_{issue}(K_{FP}) < \mathsf{E}(v)$, which proves the first part of the proposition. As when private information is exogenous, informed trading generates underpricing due to adverse selection.

Step 2. In a second step, we derive the equilibrium number of experts K^*_{FP} who choose to produce information. Each expert who searches for information expects a profit of

$$\Pi_i(K_{FP}) \equiv \frac{E(kq_i(v)(v - p^*_{issue}(K_{FP})))}{K_{FP}} = \frac{Q(E(v) - p^*_{issue}(K_{FP}))}{K_{FP}}, \tag{31}$$

where the second equality follows from (27). As K_{FP} increases, $\Pi_i(K_{FP})$ decreases. We assume that I is large enough so that $\Pi_i(I) < c$ and that c is small enough so that $\Pi_i(0) > c$. Thus, ignoring the integer constraint, there is a value K^*_{FP} that solves $\Pi_i(K^*_{FP}) = c$. This value is the equilibrium number of experts who decide to search for information (a larger number would result in negative expected profit for experts and a smaller number would result in strictly positive expected profits). Using (31) and ignoring the integer constraint, we deduce that this zero expected profit condition for experts is equivalent to

$$Q(E(v) - p^*_{issue}(K^*_{FP})) = K^*_{FP} \times c, \tag{32}$$

where $p^*_{issue}(K^*_{FP})$ is given by (28). This establishes the second claim in the proposition.

Step 3. We now compute the seller's expected utility in equilibrium with the FP mechanism. We first compute the informational gain for the seller given the information revealed in the FP mechanism in equilibrium, that is, $\mathsf{Var}(v) - \mathsf{E}(Var(v \mid \Omega))$.

As in the case with exogenous information, the seller obtains information via the realization of the aggregate demand, D. In equilibrium, the aggregate demand for the asset is $D = J + I$ when $v = v_H$ and $D = J + I - k$ when $v = v_L$. Let $\mu(D = J + I) = \Pr(v{=}v_H \,|\, D{=}J{+}I)$. Then:

$$\begin{aligned}
\mu(D{=}J{+}I) &= \frac{\Pr(D = J + I \mid v = v_H)Pr(v = v_H)}{\Pr(D{=}J{+}I \,|\, v{=}v_H)\Pr(v{=}v_H){+}\Pr(D{=}J{+}I \mid v = v_L)\Pr(v{=}v_L)} \\
&= \frac{\mu \times 1}{\mu \times 1 + (1-\mu)\Pr(k=0)} = \frac{\mu}{\mu + (1-\mu)(1{-}\pi{+}\pi(1{-}\phi)^{K_{FP}})}. \quad (33)
\end{aligned}$$

Observe that $\mu(D = J{+}I) > \mu$. Observing that $D = J{+}I$ is good news as it indicates the possibility that $v = v_H$. Note also that $\mu(D < J{+}I) = \Pr(v = v_H \mid D < J{+}I) = 0$ (a demand weaker than $J{+}I$ reveals that some informed buyers did not buy the asset and therefore $v = v_L$). It follows that $Var(v \,|\, D{<}J{+}I){=}0$ and

$$\begin{aligned}
Var(v \mid D = J + I) &= \mu(D = J + I)(1 - \mu(D = J + I))(v_H - v_L)^2 \\
&= \frac{\mu(1-\mu)\left(1 - \pi + \pi(1-\phi)^{K^*_{FP}}\right)(v_H - v_L)^2}{\left(\mu + (1-\mu)\left(1 - \pi + \pi(1-\phi)^{K^*_{FP}}\right)\right)^2} \\
&= \frac{Var(v)\left(1 - \pi + \pi(1-\phi)^{K^*_{FP}}\right)}{\left(\mu + (1-\mu)\left(1 - \pi + \pi(1-\phi)^{K^*_{FP}}\right)\right)^2}. \quad (34)
\end{aligned}$$

Hence:

$$\begin{aligned}
\mathsf{E}(Var(v \mid D)) &= \mathsf{Var}(v \mid D = J + I)\Pr(D = J + I) \\
&= \mu(D = J + I)(1 - \mu(D = J + I)(v_H - v_L)^2 \\
&= \frac{\mathsf{Var}(v)\left(1 - \pi + \pi(1-\phi)^{K^*_{FP}}\right)}{\mu + (1-\mu)\left(1 - \pi + \pi(1-\phi)^{K^*_{FP}}\right)}. \quad (35)
\end{aligned}$$

Therefore, the expected informational gain of the seller if he uses the FP mechanism is:

$$\mathsf{Var}(v) - \mathsf{E}(Var(v \mid \Omega)) = \frac{\gamma\mu\pi\left(1-(1-\phi)^{K^*_{FP}}\right)Var(v)}{\mu+(1-\mu)\left(1-\pi+\pi(1-\phi)^{K^*_{FP}}\right)}. \tag{36}$$

Now, from (27), we deduce that the seller's expected proceeds from the issue is:

$$Qp^*_{issue}(K^*_{FP}) = Q\,\mathsf{E}(v) - \mathsf{E}(kq_i(v)(v-p^*_{issue}(K^*_{FP}))) = Q\,\mathsf{E}(v) - K^*_{FP}\times c, \tag{37}$$

where the last equality follows from (32).

Combining (36) and (37), we deduce that the seller's expected utility with the FP mechanism is:

$$\begin{aligned}\Pi^*_{FP} &= QE(p^*_{issue}) + \gamma(Var(v) - E(Var(v \mid D)))\\ &= QE(v) - cK^*_{FP} + \frac{\gamma\mu\pi\left(1-(1-\phi)^{K^*_{FP}}\right)Var(v)}{\mu+(1-\mu)\left(1-\pi+\pi(1-\phi)^{K^*_{FP}}\right)},\end{aligned}$$

which proves the third claim of the proposition.

Step 4. In a last step, we show that $\Pi^*_{FP} < \Pi_{bench}(K^*)$ defined in (19). By definition of K^*, $\Pi(K^*_{FP}) \leq \Pi(K^*)$, where $\Pi(K)$ is defined in (17). Hence, we have

$$\begin{aligned} & \Pi^*_{FP} - \Pi(K^*) \leq \Pi^*_{FP} - \Pi(K^*_{FP})\\ = \;& cK^*_{FP}(1-\pi) + \frac{c\pi(1-(1-\phi)^{K^*_{FP}})}{\phi} - \gamma\pi\left(1-(1-\phi)^{K^*_{FP}}\right)Var(v)\\ - \;& cK^*_{FP} + \frac{\gamma\mu\pi\left(1-(1-\phi)^{K^*_{FP}}\right)Var(v)}{\mu+(1-\mu)\left(1-\pi+\pi(1-\phi)^{K^*_{FP}}\right)}\\ < \;& -cK^*_{FP}\pi + \frac{c\pi(1-(1-\phi)^{K^*_{FP}})}{\phi}\\ + \;& \gamma\pi\left(1-(1-\phi)^{K^*_{FP}}\right)Var(v) - \gamma\pi\left(1-(1-\phi)^{K^*_{FP}}\right)Var(v)\\ = \;& \frac{c\pi}{\phi}\left(1-(1-\phi)^{K^*_{FP}} - K^*_{FP}\phi\right) < 0. \end{aligned} \tag{38}$$

□

Proof of Proposition 3.

Step 1. We first derive the expression for $E(C_{issue}(K)$ given in (15). The random variable $\tau_{stop}(K)$ takes values from 1 to K with the following distribution:

$$
\begin{aligned}
&\Pr(\tau_{stop} = 1) = \pi\phi \\
&\Pr(\tau_{stop} = 2) = \pi\phi(1-\phi) \\
&\dots \\
&\Pr(\tau_{stop} = i) = \pi\phi(1-\phi)^{i-1} \\
&\dots \\
&\Pr(\tau_{stop} = K-1) = \pi\phi(1-\phi)^{K-2} \\
&\Pr(\tau_{stop} = K) = \underbrace{\pi\phi(1-\phi)^{K-1}}_{K\text{'s expert finds the info}} + \underbrace{\pi(1-\phi)^{K^{max}}}_{\text{Info exists but no-one finds it}} + \underbrace{(1-\pi)}_{\text{Info doesn't exist}}
\end{aligned}
$$

We deduce that:

$$\mathsf{E}[\tau_{stop}] = K(1-\pi) + K\pi(1-\phi)^K + \pi\phi\sum_{i=1}^{K} i(1-\phi)^{i-1}.$$

The last term is the sum of the first K elements of an arithmetic-geometric progression with the first element equals to 1, common difference 1 and the common ratio $(1-\phi)$. Applying the formula for the sum of its first K terms yields

$$
\begin{aligned}
\mathsf{E}[\tau_{stop}] &= K(1-\pi) + K\pi(1-\phi)^K \\
&+ \pi\left[1-(1+(K-1)(1-\phi)^K + \frac{(1-\phi)\left(1-(1-\phi)^K\right)}{\phi}\right] \\
&= K(1-\pi) + \frac{\pi(1-(1-\phi)^K)}{\phi}.
\end{aligned}
$$

Therefore:

$$\mathsf{E}(C_{issue}(K)) = c \times K(1-\pi) + \frac{\pi(1-(1-\phi)^K)}{\phi}. \tag{39}$$

Step 2. In a second step we solve for the optimal stopping rule K^*. To this end, let $\Pi(K, i)$ be the seller expected utility before contacting the i^{th} expert conditional on all previous experts having failed to find information. Obviously, $\Pi(K,1) = \Pi(K)$. Moreover, for $i \leq K$, we have:

$$\Pi(K,i) = \phi\pi_i(Q\,\mathsf{E}(v) + \gamma Var(v)) - c + (1-\phi\pi_i)\Pi(K,i+1), \tag{40}$$

and for $i > K$, $\Pi(K,i) = Q\,\mathsf{E}(v)$.

Eq.(41) follows from the fact that contacting the i^{th} expert costs c whether the expert finds or not information. Moreover, if the i^{th} expert finds information (probability $\phi\pi_i$), the seller obtains an expected utility of $QE(v) + \gamma Var(v)$ because she then moves to Stage 2 and issues the asset at price equal to its true value ($\Omega = \{v\}$), while if the expert does not find information (probability $(1-\phi\pi_i)$) and $i \leq K-1$, the seller contacts again another experts and faces the same problem. For $i > K$, the seller does not new experts and sells the asset at its expected value, without obtaining information. Therefore $\Pi(K,i) = Q\,\mathsf{E}(v)$ for $i > K$.

Observe that for $i \leq K$, (41) is equivalent to:

$$\Pi(K,i) - Q\,\mathsf{E}(v) = \phi\pi_i\gamma Var(v) - c + (1-\phi\pi_i)(\Pi(K,i+1) - Q\,\mathsf{E}(v)). \tag{41}$$

The L.H.S of this equation is the difference between the expected utility of contacting the i^{th} expert conditional on all previous experts having failed to find information and the expected utility of moving to Stage 2 without contacting the i^{th} expert. At the optimal policy K^*, it must be positive for $i \leq K^*$. This implies in particular that $\Pi(K^*,K^*) - QE(v) = \gamma\phi\pi_{K^*}Var(v) - c > 0$ since $\Pi(K^*,K^*+1) = Q\,\mathsf{E}(v)$. Thus, K^* cannot be larger than K^{max}, the largest value of K for which $\gamma\phi\pi_K Var(v) - c > 0$, that is the largest value of K such that:

$$\frac{c}{\gamma\,\mathsf{Var}(v)\phi} < \pi_K. \tag{42}$$

The threshold $K^{max} \geq 1$ if and only if $\frac{c}{\gamma Var(v)\phi} < \pi$. Suppose this condition is satisfied. Now suppose that $K^* < K^{max}$ (to be contradicted). For this, it must be the case that the seller does not find optimal to contact the $K^* + 1$'s expert after

K^*'s experts have found no information (by definition of K^*). However:

$$\Pi(K^*, K^*+1) - Q\,\mathsf{E}(v) = \phi\pi_i\gamma Var(v) - c + (1-\phi\pi_i)(\Pi(K^*, K^*+1) - Q\,\mathsf{E}(v)) > 0, \quad (43)$$

where the last inequality follows from the fact that $K^* + 1 \leq K^{max}$ if $K^* < K^{max}$. A contradiction. Hence we have established that $K^* = K^{max}$ when $\frac{c}{\gamma\,\mathsf{Var}(v)\phi} < \pi$.

The expression for Π^*_{bench} follows from the expression for $\Pi(K^*)$ given by 17)) and the expressions $E(C_{issue}(K^*))$ and $P_{failure}(K^*)$. When $\frac{c}{\gamma Var(v)\phi} > \pi$, it is not optimal for the seller to contact any experts since for $K^* = 1$, $\Pi(K^*, K^*) = \phi\pi\gamma\,\mathsf{Var}(v) - c < 0$. The last part of the proposition follows. □

Proof of Proposition 4.

The case in which $c > \pi\phi\gamma\,\mathsf{Var}(v)$ is straightforward. In this case, we have shown in the proof of Proposition 7 that even in the absence of informational frictions (truth-telling and moral hazard constraints), the seller maximizes her expected utility using the NIT mechanism. Thus, this is also the case in the presence of frictions since these frictions add Incentive Compatibility constraints to the seller's optimization problem. Now consider the case in which $c \leq \pi\phi\gamma\,\mathsf{Var}(v)$

Step 1. We first verify that the truth-telling conditions (21) are satisfied. For this, observe that given the specifications of the derivatives contracts, we have:

$$R(H, H) = F + \varepsilon + f_{iH} - F = \varepsilon + \frac{c}{\phi\pi_i} > 0.$$

Similarly $R(L, L) = \varepsilon + \frac{c}{\phi\pi_i} > 0$. Moreover, as explained in the text $R(U, U) = 0$.

Now consider the case in which an expert receives a signal $s_i = U$. If the expert deviates and reports $s_i = H$, he obtains:

$$R(U, H) = \mu\left(\varepsilon + \frac{c}{\phi\pi_i}\right) - (1-\mu)F < R(U, U), \quad (44)$$

where the last inequality follows from $R(U,U)=0$ and the fact that

$$F \; > \; \max\left\{\frac{\mu}{1-\mu},\, \frac{1-\mu}{\mu}\right\}\left(\varepsilon+\frac{c}{\phi\pi_{K_{\max}}}\right) \; > \; \max\left\{\frac{\mu}{1-\mu},\, \frac{1-\mu}{\mu}\right\}\left(\varepsilon+\frac{c}{\phi\pi_i}\right)$$

where the first inequality is the condition given in the text and the second follows from $\pi_i > \pi_{K_{\max}}$. If instead the expert deviates and reports $s_i = L$, he obtains:

$$R(U,L) = (1-\mu)\left(\varepsilon+\frac{c}{\phi\pi_i}\right) - \mu F < R(U,U), \tag{45}$$

using the same reasoning as for the first deviation. Hence, we deduce that for $s_i = U$, the truth-telling constraints are satisfied.

Now consider $s_i = H$. If the expert is truthful he obtains $R(H,H) = \varepsilon + \frac{c}{\phi\pi_i} > 0$. If he deviates he obtains either $R(H,U) = 0$ (since then he cannot participate to Stage 2 and there is no payment by the seller in Stage 1) or $R(H,U) = -F$ since he buys contract L at F and receives a zero payoff on this contract with certainty. Thus, $R(H,H) > R(H,U) > R(H,L)$ and it is a best response for the expert to be truthful. Using the same logic, we obtain: $R(L,L) > R(L,U) > R(L,H)$ and therefore an expert receiving $s_i = L$ reports $\sigma_i = L$.

Step 2. Second, we check that the participation constraint (23) is satisfied. This constraint imposes:

$$\pi_i\phi(\mu R(H,H) + (1-\mu)R(L,L)) + (1-\pi_i\phi)R(U,U) \geq c, \quad \forall i \leq K. \tag{46}$$

Substituting $R(H,H)$, $R(L,L)$ and $R(U,U)$ by their values, we obtain that:

$$\pi_i\phi(\mu R(H,H) + (1-\mu)R(L,L)) + (1-\pi_i\phi)R(U,U) = \epsilon + c.$$

Thus, as $\epsilon > 0$, (23) holds. Last, participation constraints (24) hold since $R(s_i,s_i) \geq 0$ for all $s_i \in \{H,L,U\}$.

Step 3. We show that the stopping rule for the seller is the same as in the benchmark case for ϵ small enough. In equilibrium, only experts participate to Stage 1. Moreover, they all produce information when contacted by the seller and report truthfully. Last, the expected payment to each buyer contacted in Stage 1 is $c + \epsilon$. Thus, in choosing the stopping rule, the seller faces the same problem as in the benchmark case with c replaced by $c + \epsilon$. Hence, as in the benchmark case, it is optimal for the Seller to stop after contacting the K^*_{DaC}th buyer in Stage 1 where K^*_{DaC}th is the largest K such that $\gamma\phi\pi_{K^*_{DaC}} Var(v) - c - \epsilon > 0$. Thus, for ϵ small enough, $K^*_{DaC} = K^*$.

Step 4. Finally in the last step, we compute the seller's expected utility. To this end, we compute first the expected cost of the issue for the seller. In the DaC mechanism considered in Section 5, this expected cost is equal to the expected profit (gross of the cost of information production) of the buyer who purchases a derivative contract in Stage 1. Since buyers are truthful, conditional on buying a contract (that is receiving a signal $s_i = H$ or $s_i = L$), they expect a profit of $\frac{c}{\phi\pi_i} + \epsilon$. Moreover, the likelihood that this expected profit is obtained by the i^{th} buyer is $\pi\phi(1-\phi)^{i-1}$ for $i = 1, ..., K^{max}$. Moreover a buyer who does not find information obtains a zero profit. Therefore, we have

$$\begin{aligned}
\mathsf{E}(C_{issue}) &= c\sum_{i=1}^{K^{max}} \frac{\pi\phi(1-\phi)^{i-1}}{\phi\pi_i} + \epsilon\phi\pi\sum_{i=1}^{K^{max}}(1-\phi)^{i-1} \\
&= c\sum_{i=1}^{K^{max}} \left((1-\phi)^{i-1}\pi + (1-\pi)\right) + \epsilon\phi\pi\sum_{i=1}^{K^{max}}(1-\phi)^{i-1} \\
&= cK^{max}(1-\pi) + \frac{c\pi(1-(1-\phi)^{K^{max}})}{\phi} + \epsilon\pi(1-(1-\phi)^{i-1}) \\
&= \mathsf{E}(C^{bench}_{issue}) + \epsilon\pi(1-(1-\phi)^{i-1}),
\end{aligned}$$

where $\mathsf{E}(C^{bench}_{issue})$ is the expected cost of the issue in the benchmark model given in (39).

Moreover, as explained in the text, for a given realization of buyers' signals in Stage 1, the seller has exactly the same information as in the benchmark case since buyers report their signals truthfully and only experts participate to Stage 1. Thus, the seller's expected informational benefit is as in the benchmark case. We deduce from these observations that:

$$
\begin{aligned}
\Pi^*_{\text{DaC}} &= Q\ \mathsf{E}(v) - cK^{\max}(1-\pi) - \frac{c\pi\big(1-(1-\phi)^{K^{\max}}\big)}{\phi} \\
&\quad - \gamma\pi\big(1-(1-\phi)^{K^{\max}}\big)\,\mathsf{Var}(v) - \epsilon\pi\big(1-(1-\phi)^{K^{\max}-1}\big) \qquad (47) \\
&= \Pi^*_{\text{bench}} - \gamma\pi\big(1-(1-\phi)^{K^{\max}}\big)\,\mathsf{Var}(v) - \pi\big(1-(1-\phi)^{K^{\max}-1}\big)\,\epsilon. \qquad (48)
\end{aligned}
$$

$\square$