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

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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 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.

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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 et al., 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, as pointed out by Grossman and Stiglitz (1980). 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 optimal informativeness can be achieved without sacrificing liquidity 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 an 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: 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 buy only a fraction of the seller's stake, whereas non-experts can potentially buy the entire stake. Hence, for the sale to succeed, non-experts must find it optimal to participate. Because buyers' types are unobservable, the seller cannot restrict participation in the sale to only one type.

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

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 resulting from information revealed through the transaction. The seller therefore designs and implements a mechanism to sell the asset so as to maximize her expected utility. The asset payoff is realized and becomes known to the seller and the buyers at a later date.

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) bid only 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 in order 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 liquidity.

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

However, these mechanisms are only two among many possible ways to design the market, and neither is optimal. Indeed, there exists a mechanism that allows the seller to obtain full information at zero cost. Under 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 future realization of the asset payoff.

[2]A similar mechanism is considered in Biais et al. (2002).

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 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).[3] 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.[4]

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.[5] 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 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

[3] The literature on securities design (e.g., Gorton and Pennacchi (1990) or Boot and Thakor (1993)) shows that firms can mitigate adverse selection costs by issuing information insensitive securities. However, in this literature, firms derive no direct benefits from information.

[4] 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.

[5] 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.

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 to set it at its efficient level.[6]

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.

The optimality of the DaC mechanism stems from two forces. First, as the seller sequentially contacts experts in Stage 1, she can set the level of investment in information efficiently (she keeps contacting experts as long as the marginal expected utility benefit from additional information exceeds its cost, and stops otherwise). Second, the use of the NIT mechanism in Stage 2 implies that experts obtain no rents if they participate in Stage 2. This reduces the compensation that the seller must offer experts to incentivize them to participate in Stage 1 rather than in Stage 2.

In the last section, we show that our main result still holds even when the seller cannot use an NIT mechanism, provided she has a sufficiently strong preference for information. Intuitively, in this case, the seller optimally contacts many experts in Stage 1 and, as a result, the amount of information produced during Stage 1 is substantial. This reduces an expert's informational advantage from participating in Stage 2 to the point where the expected profit he can obtain by doing so is lower than the cost of producing information.

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

In this case, the DaC mechanism again delivers expected utility arbitrarily close to what the seller can achieve in the frictionless benchmark.

The two stages of the DaC mechanism share similarities with the organization of Initial Public Offerings (IPOs). In the first phase of an IPO, underwriters and the issuing firm conduct due diligence and produce information to prepare a prospectus that sets the initial offer price. In the second phase (the bookbuilding phase), underwriters share the prospectus with potential investors and can collect further information to determine the final offer price. As shown by Hanley and Hoberg (2010), the prospectus released at the end of the first phase contains information, and more informative prospectuses are associated with less underpricing. Moreover, underwriters receive "incentive fees" that can be contingent on IPO performance, including pricing accuracy (see Espenlaub et al. (2024)). These fees incentivize information production in phase 1 and can take the form of warrants (Dunbar (1995) or Khurshed et al. (2016)), much like the derivatives contracts in Stage 1. Thus, as information producers, underwriters can be seen as experts in our model.

Interestingly, Espenlaub et al. (2024) find that IPOs with incentive-fee clauses (50% of their sample) do not exhibit an increase in the stock price relative to the final offer price immediately after the IPO—exactly as in the DaC mechanism. Furthermore, Hanley and Hoberg (2010) note that issuers face a trade-off between incentivizing information production in the first phase and underpricing the issue in the second phase. This trade-off has received little attention, and the informational role of the premarket (Stage 1 in our setting) has been overlooked in many IPO studies. Our analysis suggests that issuers with a strong preference for information are more likely to incentivize information production in the first phase.

The paper is organized as follows. Section 2 positions our contribution in the literature. Section 3 introduces the asset sale problem considered in the paper. Section 4 shows that with exogenous information, a DaC mechanism solves the seller's liquidity–informativeness trade-off. Section 5 extends this to costly information acquisition, and Section 6 shows that a DaC mechanism still achieves the seller's optimal utility under incentive constraints. Section 7 examines the robustness of our main result to changes in the specification of experts' information structure and the ability of the seller to use a NIT mechanism. Section 8 concludes.

2 Contribution to the Literature

Our paper relates to various strands of the literature. First, it connects to work on the benefits of information produced through the trading process (e.g., through prices) in financial markets. These benefits may stem from improved contracting (e.g., Holmström and Tirole (1993)) or more efficient corporate investment decisions (e.g., Edmans et al. (2015); see Bond et al. (2012) and Goldstein (2022) for surveys). 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 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 a model in which information has no social value. Mollner (2024) studies how to allocate informed and uninformed investors between markets to achieve Pareto-allocations (that is, maximize the welfare of, say, informed for a given welfare level for uninformed). In contrast, we consider market designs that optimally trade-off adverse selection costs against utility benefits from information for asset sellers.

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 et al. (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.[7]

One exception is Sherman and Titman (2002) (see also Sherman (2005) and Bourjade (2021)), in which the seller derives a benefit from a more accurate IPO price. Our approach differs in several important respects. Sherman and Titman (2002)—like most of the theo-

[7]Consequently, issuers would prefer to place shares solely with investors unable to acquire information, if they could distinguish them from informed investors.

retical IPO literature—focuses on the bookbuilding stage, in which investors simultaneously report information and receive allocations of the risky asset. By contrast, we explicitly separate the stage in which information is produced from the stage in which the risky asset is allocated to investors. This separation shifts the focus away from bookbuilding and toward the pre-bookbuilding stage, in which experts (e.g., underwriters) produce information that determines the initial offer price.

In our model, experts are incentivized to acquire and truthfully report information through contracts contingent on the asset's future cash flows. While such contingent compensation is natural for public firms, it has largely been overlooked in the IPO literature.[8] A further distinction is that the DaC mechanism allows the seller to directly control total investment in information production, since experts are induced to acquire information sequentially rather than simultaneously (as in Sherman and Titman (2002)).

These features imply that the DaC mechanism eliminates informational rents and allows the seller to invest efficiently in information production. For this reason, it yields strictly higher expected utility to the seller than any other mechanism in our setting. The absence of informational rents implies that there is no "underpricing" under the DaC mechanism: on average, the price at which the asset is sold is equal to its expected payoff. Our goal is not to explain IPO underpricing, but rather to study how asset sales should be optimally structured when sellers face a trade-off between informativeness and liquidity.[9]

Our paper is also related to the literature on expertise, in which a principal seeks to elicit information production from experts (e.g., Gromb and Martimort (2007)), when experts must exert costly and unobservable effort to produce information. There are two important differences relative to this literature. First, the principal in our case also seeks to sell an asset. The possibility for experts to trade the asset creates additional incentive issues, and the information produced by experts is relevant for pricing the asset. Second, we consider the possibility that contracts between the principal and experts are contingent on the asset's future cash flows. This feature is particularly relevant in financial markets, because asset cash flows can eventually be observed.

[8] As explained in the introduction, incentive fees and warrants are used in practice to compensate underwriters. These are contracts contingent on the asset's future payoff, just like our derivative contracts.

[9] This could help to better understand how sellers choose to incentivize information production by underwriters rather than by investors participating to the bookbuilding process (see Hanley and Hoberg (2010)).

Last, our result that the seller can design the asset sale to leave no informational rents to experts is reminiscent of Cremer and McLean (1985) and Cremer and McLean (1988), who study the sale of an object to buyers who are privately informed about their valuation of the object. They show that the seller can incentivize truth-telling (agents' truthfully report their valuations) and extract all surplus from buyers when their valuations are sufficiently correlated. To derive their result, they exploit the possibility for the seller to condition the payment of each bidder on the realization of the valuations reported by other bidders. The mechanism that we consider instead consider payments contingent on the realization of the asset cash-flows (its common value) and our findings hold even if there is just one expert.[10].

3 Framework

An entrepreneur (the seller) owns $Q + N$ shares of a risky asset and intends to sell Q of them for liquidity needs. The payoff of the asset (per share) is v_H with probability μ and v_L with probability $(1 - \mu)$. It is unknown to the seller.[11] There are $I + J \geq Q$ potential risk-neutral buyers: I experts and J non-experts. Experts can acquire information about the asset payoff, whereas non-experts cannot; like the seller, they only know the distribution of the asset payoff. We denote by $\mathcal{I}$ and $\mathcal{J}$ the sets of experts and non-experts, respectively. The seller cannot condition the price and allocation of the asset on buyers' type (expert/non-expert) because she does not observe it. Each buyer can purchase at most one share.

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 describing how the issuer allocates the asset to buyers and at which price, possibly contingent on the information generated during the asset sale (see below for more details). After choosing a mechanism, the seller 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.

[10]When information is costly, the results hold even when there is only one expert as long as the seller can repeatedly ask the expert to find information.

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

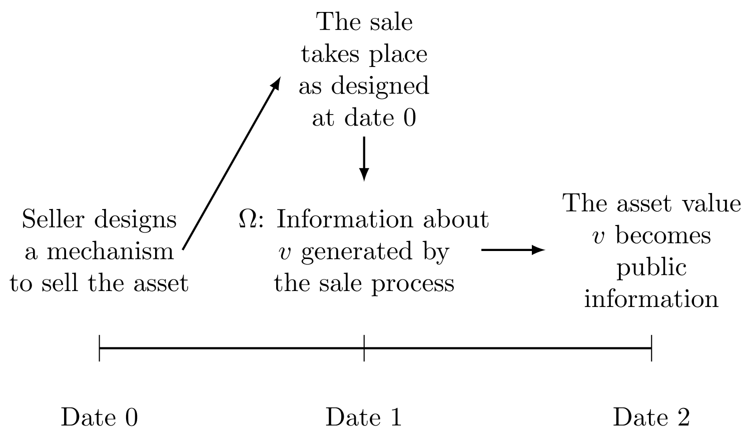

Figure 1. Timeline of the sale process

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

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

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, all else 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, 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.[12] 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

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

$(v - \mathsf{E}[\, v \mid \Omega(\mathcal{M})\,])^2$ is smaller). We do not explicitly model how the entrepreneur derives utility from the information obtained at date 1, since the exact reason why the entrepreneur values accuracy is not key for our results.

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 $Q \times v_L$ to satisfy its liquidity needs. 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 $p_{issue} = v_L$ because 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 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, $\Omega = \emptyset$, then $\bar{\Pi}_1(\mathcal{M}) = Q \;\mathsf{E}[R(\mathcal{M})]$.

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 4 and 5).

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

4 Baseline Case: Exogenous Information

We first consider the case in which experts are exogenously endowed with perfect signals. Each expert observes, at date 1 and before 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 4.1).

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.[13]

[13]When there is a cost of producing information, as in Section 5, the condition is more complex since one must account for experts' cost of producing information when computing buyers' aggregate expected profit.

Hence, in any mechanism, $Q\,\mathsf{E}(v) \geq R(\mathcal{M})$. It follows from (3) that

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

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. A mechanism that yields $\bar{\Pi}^{\max}$ (under participation and incentives constraints) is therefore weakly dominant for the seller. We show in Section 4.2 that one such mechanism exists in our setting, even after accounting for participation and incentives constraints.

4.1 The liquidity-informativeness trade-off

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 et al. (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 4.2, neither mechanism is optimal. These 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 $p^{FP,*}_{issue}(J)$ that the issuer can set while guaranteeing uninformed buyers' participation solves $\mathsf{E}(q_u(v)(v - p^{FP,*}_{issue})) = 0$, which is

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

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

Thus, with the FP mechanism, the asset must be "underpriced," i.e., sold at a discount relative to its expected payoff ($p^{FP,*}_{issue} < \mathsf{E}(v)$). 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, uninformed buyers are adversely selected, and underpricing compensates them for their adverse selection costs. However, the total demand for the asset, $D(v)$, 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:

$$\begin{aligned} \bar{\Pi}_0(FP) &= Qp^{FP,*}_{issue} + \gamma\,\mathsf{Var}(v) \\ &= Q\,\mathsf{E}(v) - Q\left(\mathsf{E}(v) - p^{FP,*}_{issue}\right) + \gamma\,\mathsf{Var}(v) \\ &= \bar{\Pi}^{\max} - \underbrace{\frac{QI\mu(1-\mu)(v_H - v_L)}{J + (1-\mu)I}}_{\text{Total Adverse Selection Costs}}. \end{aligned} \tag{7}$$

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.[14]

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.

[14] 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.

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 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.[15]

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.

[15] 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.

Thus, in choosing between the FP and NIP mechanism, the seller faces a trade-off between illiquidity costs due to adverse selection and information. 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 NIT or FP mechanisms are just two ways to sell the asset among many other ones. 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, and neither the NIT, nor the FP mechanisms are on the frontier. Indeed, in the next section, we show that there exists one mechanism, which we call "Divide and Conquer" (DaC), with 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.

4.2 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 asset payoff v at date 2. 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 $-F$.[16] The values of F and ϵ are chosen by the seller. The first stage stops when one buyer buys 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

[16] 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 pays F upfront.

contract C_ω has been chosen in Stage 1, where $\omega \in \{L, H\}$.[17] 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 is off the equilibrium path. However, buyers' decisions in Stage 1 depend on how the seller sets the price of the 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 $F > \max\left\{\frac{(1-\mu)}{\mu}, \frac{\mu}{(1-\mu)}\right\}\epsilon$ and $\epsilon > 0$. At date 1, the following actions form a Nash equilibrium: (i) A non-expert never purchases a derivative 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 Stage 1. In this equilibrium, $\Omega = \{v\}$ (full revelation) and the expected revenue from the asset sale is $R(DaC) = QE(v) - \epsilon$.*

In this equilibrium, the first expert who is contacted in Stage 1 selects the derivative 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 derivative 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.[18]

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. This implies that, 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

[17]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 IPOs literature. See, for instance, Benveniste and Spindt (1989) or Sherman and Titman (2002).

[18]The condition $\epsilon > 0$ just serves to break indifference between participation to Stage 1 or 2 for experts.

the issue. In the mechanisms considered in Section 4, 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 that there is no cost of producing information, this payment can be arbitrarily close to zero.

In Section 6, 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 5, 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.

5 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 5.1). We then solve for the seller's optimal mechanism when information production is observable, so that only participation constraints apply (Section 5.2). This provides an upper bound on the seller's expected utility when information production is unobservable (Section 6).

5.1 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. An 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 may fail to find it with probability $(1 - \phi)$. When an expert does not find or does not search for 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 for information, he finds some with probability $\phi\pi$ and none with probability $(1-\phi\pi)$. In the former case, 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, $s = U$.[19] 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 the number of experts choosing to search for information: If K experts search information, at least one receives an informative signal with probability $\pi\left(1-(1-\phi)^K\right)$.

As in the baseline case, we assume that the seller cannot produce information about v.[20] This is a natural assumption since we want to analyze the trade-off between informativeness and illiquidity from the seller's viewpoint. If the seller could produce information, she would not need to incentivize information production in the first place.

We first consider the NIT and FP mechanisms when experts' signals are endogenous. If the seller uses the NIT mechanism (the price schedule in Equation (8) then it is a Nash equilibrium that (a) experts do not participate 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 seller's expected utility with the NIT mechanism is:

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

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 fixed price offering. We denote by p_{issue}^{FP*} the price sets by the seller 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:*

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

[20] 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.

- *The asset is sold at a price 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, that is, it solves the zero expected profit condition* $Q(\mathsf{E}(v) - p^*_{issue}(K^*_{FP})) = cK^*_{FP}$*.*

- *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, cK^*_{FP}. As experts' aggregate expected profits are equal to non-experts' adverse selection costs (see (36) in the proof of Proposition 2), the seller's expected proceeds from the asset sale are $\mathsf{E}(R(FP)) = Q\,\mathsf{E}(v) - cK^*_{FP}$. 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).[21]

5.2 Benchmark: Information Production is Observable

In the next section, we solve for the optimal mechanism when information production is endogenous and unobservable. Before doing so, 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 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

[21] 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 acquire information.

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 production 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 uses 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 the NIT mechanism if no information has been found in Stage 1.

When $\pi = \phi = 1$, the solution to the seller's problem is straightforward. 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 $Q\,\mathsf{E}(v) + \gamma\,\mathsf{Var}(v)$, 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 experts do not obtain information with certainty. The seller may therefore need to contact several experts before obtaining 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.[22] 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 $s = L$, because 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 $\pi_1 = \pi$ and π_i decreases with i (see Figure 2).[23] 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.[24] 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 in Stage 1. The total cost incurred by the seller in Stage 1 (the cost of obtaining information) is therefore:

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

[22]Contacting non-experts in Stage 1 is useless for the seller since they cannot produce information.

[23]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.

[24]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.

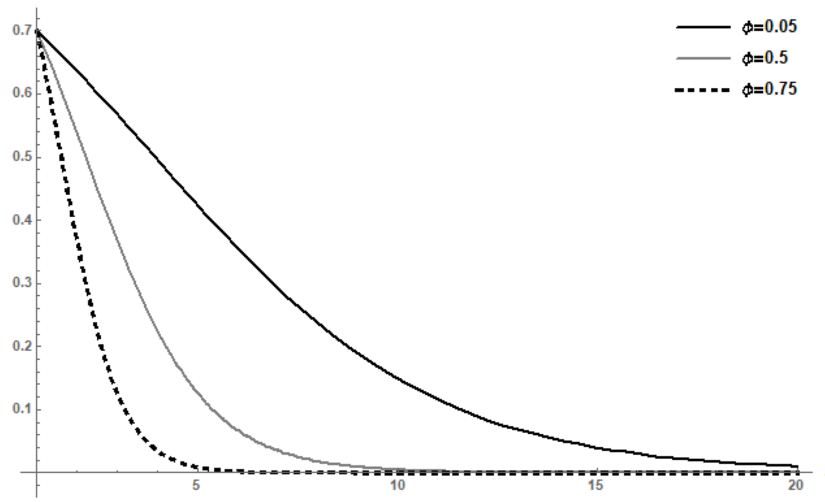

Figure 2. π_i (given by (13)) as a function of $i \in [1, 20]$ when $\pi = 0.7$.

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

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

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.[25] 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, using the NIT mechanism, is optimal after K^{max} failed attempts in Stage 1.[26]

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 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. Her*

[25] The seller may have to pay up to cK^{max} to buyers in Stage 1. Thus, the expected proceeds from the asset sale, $Q\,\mathsf{E}(v)$, must be large enough to cover the seller's liquidity needs plus cK^{max}. We assume that that v_L is large enough so that this constraint is always satisfied. If not, then the optimal value of K is the largest value of K such that this constraint binds. We omit this case for brevity, as it adds complexity without new insights.

[26] This is a difference with the case in which experts are exogenously informed. In this case, the seller must commit to use the NIT mechanism if no buyer buys a derivative in Stage 1. When experts must pay a cost to produce information, conditional on having contacted K^{max} experts, this is indeed optimal for the seller. Thus commitment is not necessary.

expected utility is:

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

If instead, $c \geq \pi\phi\gamma\,\mathsf{Var}(v)$*, 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 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. Thus, 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, buy-

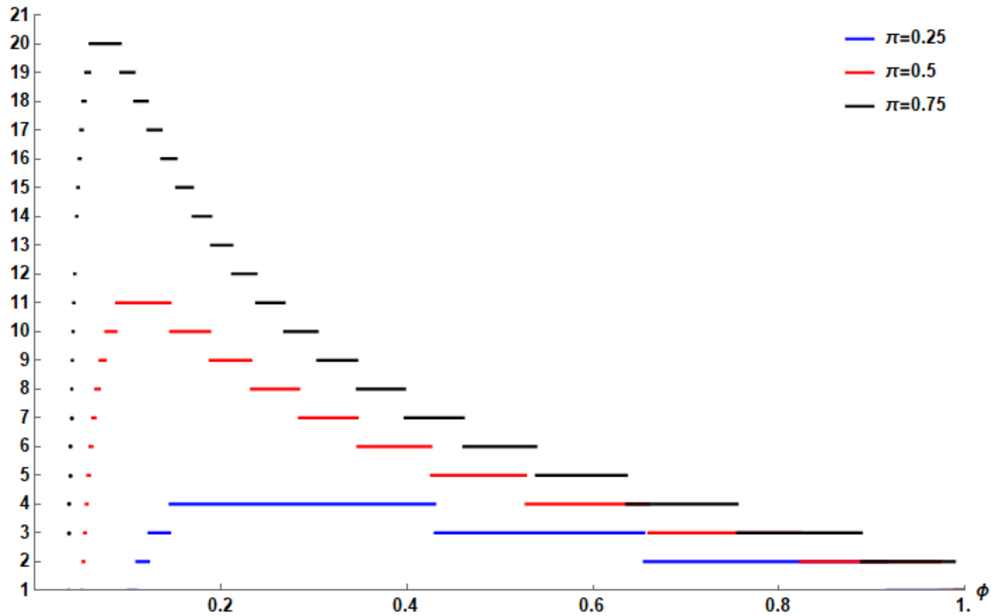

Figure 3. This figure shows $K_{\max}$ as a function of ϕ for $\pi = 0.75$ (black curve), $\pi = 0.5$ (red curve), and $\pi = 0.25$ (blue line). Other parameters are: $\gamma = 0.1$, $v_H = \$50$, $v_L = \$10$, $\mu = 0.5$, $c = \$1$.

ers' aggregate expected profits are zero (otherwise some buyers' participation constraints do not hold).[27] Now experts' expected aggregate cost of information production is minimized if experts are contacted sequentially one by one, because simultaneous elicitation 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 NIT 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.

[27]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.

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 6). 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}.

6 Information Production is Unobservable

We now assume that information production is unobservable. 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, she cannot participate to Stage 2).[28] 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 $C_{i,H}$ that pays $F + f_{i,H}$ at date 2 if $v = v_H$ and zero otherwise. If he reports $\sigma_i = L$, he pays

[28]In fact this is the case in IPOs. Underwriters (who, as explained in the introduction can be interpreted as experts) cannot buy shares during the IPO process (they can only after the asset is publicly traded).

F to the seller and obtains a derivative contract $C_{i,L}$ that pays $F + f_{i,L}$ at date 2 if $v = v_L$ and zero otherwise.[29] 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 5.2), 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 the seller in Stage 1.

Stage 2 is organized as in the benchmark case. That is, if $\sigma_i = H$ then $p_{issue} = v_H$ in Stage 2 while if $\sigma_i = L$, then $p_{issue} = v_L$. If the seller stops Stage 1 without obtaining information (that is, if $\sigma_1 = ... = \sigma_K = U$), 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,

[29] 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's expected profit with this mechanism is:

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

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.[30] 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 the seller if he receives signal s_i and reports σ_i. The truth-telling constraints impose:[31]

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

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 the seller, the following incentive constraints must therefore be satisfied:

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

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,

[30] 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.

[31] 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.

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 the 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 1 must be better off reporting the signal than walking away, which imposes another 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, non-experts' expected profit from participation to Stage 1 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 $s = U$ for a non-expert and he can always report at no cost any message σ. 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, $R(U,U)$ must be nil as otherwise (24) cannot hold. This is the case because when a buyer reports $\sigma = U$, (a) there is no transfer between the seller and the buyer and (b) he cannot participate to Stage 2 (since those participating in Stage 1 are excluded from Stage 2).[32]

As $R(U,\sigma) \leq R(U,U)$ for $\sigma = H$ or $\sigma = L$ (truth-telling constraints (21)), it follows that

[32] 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).

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 1, (ii) each expert searches for information when he 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 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 $f = \{f_{i,H}, f_{i,L}\}_{i=1}^{i=K}$ 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 5.2*
- $f_{i,L} = f_{i,H} = \varepsilon + \frac{c}{\pi_i \phi}$ *with arbitrarily small $\varepsilon > 0$ and* $F > \max\left\{\frac{\mu}{1-\mu}, \frac{1-\mu}{\mu}\right\}\left(\varepsilon + \frac{c}{\phi \pi_{K^{max}}}\right)$;

With this specification of the DaC mechanism, the seller's expected utility is:

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

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 derivative contracts C_H and C_L and K, the seller can achieve an expected utility that is arbitrarily close to that in the first best. This implies that the DaC mechanism, with the specification in Proposition 4, is weakly dominant for the seller. As this 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.

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: $\phi\pi_i(\mu f_{i,H} + (1-\mu) f_{i,L}) - c = \epsilon > 0$.[33] To break indifference between participating or not (so that (23) holds strictly) ϵ must be strictly positive but it can be arbitrarily small. This profit for experts is realized only when one expert finds information in Stage 1, which happens with probability $\pi(1-(1-\phi)^{K^{max}})$.

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 1 from participation in Stage 2 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 DaC 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 ($\gamma(\mathsf{Var}(v) - \mathsf{E}(\mathsf{Var}(v \mid \Omega)))$) and the seller's expected utility when information production is endogenous with: (i) an optimally designed DaC mechanism (Proposition 4), (ii) the fixed price mechanism (Proposition 2) and (iii) the NIT mechanism in which the seller's expected utility is $Q\,\mathsf{E}(v)$ (the seller incurs no expected cost but does not gather information). In the FP mechanism, she obtains some information but there is either underinvestment of information (when π is small) or overinvestment (when π is large) relative to the efficient level cK^{max}. 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 ($\pi \approx 0.34$).

[33]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 $R(L,L) = f_{iL}$.

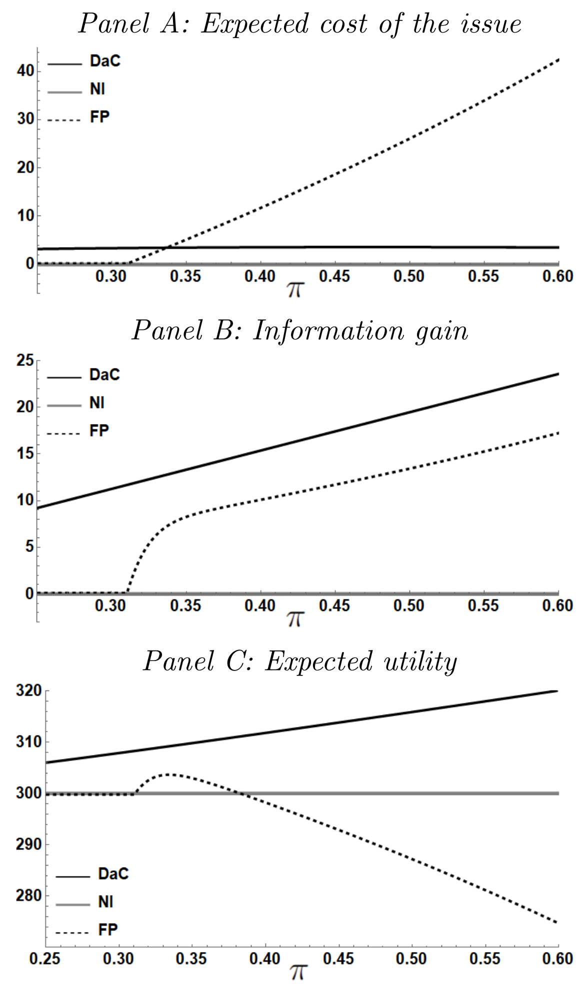

Figure 4. Expected cost, information gain and expected utilities.

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), NIT (gray line) and FP (dashed line). The parameters are as follows: $\gamma = 0.1$, $v_H = \$50$, $v_L = \$10$, $\mu = 0.5$, $\phi = 0.25$, $H = 15$, $Q = 10$.

7 Robustness

We now analyze the robustness of our conclusions regarding the efficiency of the DaC mechanisms by relaxing two assumptions. First, in Section 7.1, we consider a different information structure for experts, allowing experts to obtain noisy signals with certainty (rather than perfect signals with uncertainty). In this case, in contrast to the baseline case, the seller can never acquire perfect information about the asset payoff. Then, in Section 7.2, we analyze what happens when the seller cannot use the NIT mechanism in Stage 2 (e.g., because the seller does not know the exact number of potential market participants).

7.1 Noisy Signals.

In this section, we consider a different information structure for the signals received by experts. Specifically, we assume that each expert can produce a noisy binary signal about the asset payoff, v, at cost c. Specifically, we assume that experts' signals $s \in \{H, L\}$ are such that:

$$\Pr(s = H|v = v_H) = \Pr(s = L|v = v_L) = \lambda, \tag{25}$$

where $\lambda \in (0.5, 1)$. Thus, the higher is λ, the higher is the precision of an expert's signal.

As in previous sections, it is useful to first consider the benchmark case in which the seller can observe whether or not experts produce information and experts report their signal truthfully to the seller. In this way, we can derive the maximum expected utility that the seller can achieve when information production is costly. If there is a DaC mechanism that achieves this expected utility when information production is not observable then it is weakly dominant (no other mechanisms can do strictly better for the seller).

To establish this benchmark expected utility, we proceed as in Section 5. In Stage 1, the seller contacts experts sequentially and pays each expert c to produce information. In Stage 2, the seller announces the outcome of Stage 1 (that is, the signals reported in Stage 1) and sells the asset to non-experts at its expected payoff (in the benchmark case, the seller can distinguish experts from non-experts). As in Section 5, the seller faces a dynamic optimization problem in Stage 1. As she contacts new experts, she accumulates signals about the asset payoff and the key issue is when to stop contacting experts in Stage 1.

To solve this optimal stopping time problem, let $\mathbf{1}_{\{s=x\}}$ be an indicator variable equal to 1 if $s = x$ and zero otherwise and let $q(s_1, ..., s_i) = \sum_{j=1}^{j=i} \mathbf{1}_{\{s=s_H\}} - \sum_{j=1}^{j=i} \mathbf{1}_{\{s=s_L\}}$ be the difference between the number of signals $s = H$ and the number of signals $s = L$ reported by the i first contacted experts. This variable is a sufficient statistics for $(s_1, s_2, ...s_i)$ with respect to the posterior belief about v because:

$$\mu(q(s_1, ..., s_i)) \equiv \Pr(v = v_H|s_1, ..., s_i) = \frac{\lambda^q \mu}{\lambda^q \mu + (1-\lambda)^q (1-\mu)}, \tag{26}$$

Henceforth, to simplify notations, we therefore denote the seller's posterior probability that $v = v_H$ after contacting i experts by $\mu(q_i)$, where $\mu(q_i)$ is given by (26), with $q_0 = 0$. Note that $\mu(0) = \mu$ and as q increases, the seller assigns a larger likelihood to the value of the asset being large.[34] We also denote by $\mathsf{E}_{q_i}(v) = \mu(q_i)v_H + (1 - \mu(q_i)v_L)$ and $\mathsf{Var}_{q_i}(v) = \mu(q_i)(1 - \mu(q_i)(v_H - v_L)^2$, the expected payoff of the asset and the variance of this payoff conditional on q_i.

Belief q_i is the relevant state variable for the seller's decision to stop or continue contacting experts after she has contacted i experts. If the seller stops in this state, she announces q_i and sells the asset at $p_{issue}(q_i) = \mathsf{E}_{q_i}(v)$, with a residual uncertainty about this payoff equal to $\mathsf{Var}_{q_i}(v)$. If instead the seller contacts another expert, she expects q_i to increase by 1 with probability $\Psi(q_i) = \Pr(s = H \mid q_i) = \lambda\mu(q_i) + (1 - \lambda)(1 - \mu(q_i))$ and to decrease by 1 with probability $(1 - \Psi(q_i))$. By the law of iterated expectations, she expects the price of the asset in Stage 2 to remain unchanged. Moreover, she expects her residual uncertainty about the asset payoff to be:

$$\begin{aligned} \mathsf{E}\big(\mathsf{Var}_{q_{i+1}}(v) \mid q_i\big) &= \Psi(q_i)\ \mathsf{Var}_{q_i+1}(v) + \big(1 - \Psi(q_i)\big)\ \mathsf{Var}_{q_i-1}(v) \\ &= \frac{\lambda(1-\lambda)\mu(q_i)\big(1-\mu(q_i)\big)(v_H - v_L)^2}{\psi(q_i)\big(1-\psi(q_i)\big)}. \end{aligned} \tag{27}$$

Thus, if she contacts another expert, the gain in expected utility for the seller is positive if and only if:

$$\begin{aligned} &\gamma\Big(\mathsf{E}\big(\mathsf{Var}_{q_{i+1}}(v) \mid q_i\big) - \mathsf{Var}_{q_i}(v)\Big) - c = \\ &\qquad \gamma\left(\frac{\mu(q_i)^2\big(1-\mu(q_i)\big)^2\big(1-4\lambda(1-\lambda)\big)}{\psi(q_i)\big(1-\psi(q_i)\big)}\right)(v_H - v_L)^2 - c \geq 0. \end{aligned} \tag{28}$$

Let $\bar{c} = \gamma\frac{\mu^2(1-\mu)^2(1-4\lambda(1-\lambda))}{\Psi(0)(1-\Psi(0))}\gamma(v_H - v_L)^2$, be the largest value of c for which Condition (28) is satisfied for $i = 0$, that is for $q_0 = 0$. If $c \leq \bar{c}$, then it is optimal for the seller to contact at least one expert in Stage 1. Otherwise, the seller optimally sells the asset at its expected payoff to non-experts without contacting any experts in Stage 1.

When $c \leq \bar{c}$, the R.H.S of Condition (28) decreases as $|q_i|$ increases and becomes negative

[34] The likelihood $\mu(q)$ goes to 1 when q goes to ∞ and goes to zero when q goes to $-\infty$.

for $\mid q_i \mid$ large. Hence, let $q^+ > 0$ and $q^- < 0$ denote respectively the largest and smallest values of q_i such that Condition (28) is satisfied. After contacting i experts, it is optimal for the seller to contact another expert if and only if $q_i \in [q^-, q^+]$. The seller therefore stops at the (random) stopping time

$$\tau_{stop} = \inf\{i : q_i \notin [q^-, q^+]\},$$

at which point $q_{\tau_{stop}} \in \{q^+ + 1, q^- - 1\}$. These observations yield the following result.

Proposition 5. *Suppose $c \leq \bar{c}$. When information production is observable, the seller maximizes her expected utility by contacting experts sequentially until $q_i = q_{\tau_{stop}}$ and then sells the asset to non-experts at $p_{issue} = \mathsf{E}_{q_{\tau_{stop}}}(v)$. With this mechanism, the seller's expected utility is:*

$$\Pi^*_{\text{bench}} = Q\ \mathsf{E}(v) - c\ \mathsf{E}(\tau_{\text{stop}}) + \gamma\Big(\mu(1-\mu) - \mathsf{E}\big[\mu(q_{\tau_{\text{stop}}})\big(1-\mu(q_{\tau_{\text{stop}}})\big)\big]\Big)(v_H - v_L)^2, \quad (29)$$

where the expectation is taken with respect to the distribution of the random stopping boundary $q_{\tau_{\text{stop}}}$. If instead, $c > \bar{c}$, the seller does not contact experts and sells the asset to non-experts at $p_{issue} = \mathsf{E}(v)$. Her expected utility is then equal to $Q\,\mathsf{E}(v)$. Closed-form solutions for $\mathsf{E}(\tau_{\text{stop}})$ and $\mathsf{E}\big[\mu(q_{\tau_{\text{stop}}})\big(1-\mu(q_{\tau_{\text{stop}}})\big)\big]$ are given in the proof of the proposition.

Now we turn to the environment in which information production is unobservable. In this case, the seller cannot (i) distinguish experts from non-experts, (ii) verify whether an expert exerts effort to acquire information, or (iii) check whether experts report the outcome of their search honestly. Therefore, to replicate the outcome obtained when information is observable, the seller must design Stages 1 and 2 of the DaC mechanism so that (a) participation in Stage 1 is attractive to experts but not to non-experts, (b) experts optimally choose to acquire information in Stage 1 rather than report a signal without searching, and (c) experts have incentives to report their signals truthfully. The next proposition shows that the seller can achieve this with a properly designed DaC mechanism.

In particular, as in the baseline case, investors who choose to participate in Stage 1 are contacted sequentially by the seller and can buy one of two derivatives contracts, C_H or C_L. More specifically, when the i^{th} investor is contacted, the seller discloses q_{i-1} to the seller and asks the investor to report his signal. If the investor reports $\sigma_i = H$, he pays $F_H(q_{i-1})$ to the seller and receives a derivative contract C_H that pays $F_H + f_H(q_{i-1})$ if $v = v_H$ and zero otherwise. If instead the investor reports $\sigma_i = L$, he pays $F_L(q_{i-1})$ to the seller and obtains a derivative contract C_L that pays $F_L + f_L(q_{i-1})$ if $v = v_L$ and zero otherwise.

In the next proposition, we show that one can design these securities (set $F_H(q_{i-1})$, $F_L(q_{i-1})$, $f_H(q_{i-1})$ and $f_L(q_{i-1})$) in such a way that conditions (a), (b), and (c) are satisfied and the seller obtains an expected utility arbitrarily close to that in the benchmark case (eq.(29)). The proof provides more details regarding the construction of the DaC mechanism in this case. Remember that $\mathsf{E}_{q_i}(v) = \mu(q_i)v_H + (1 - \mu(q_i)v_L)$

Proposition 6. *Suppose $c < \bar{c}$. With the DaC mechanism, the seller can achieve an expected utility arbitrarily close to $\bar{\Pi}^*_{bench}$ by designing the mechanism as follows:*

- *In Stage 1, she contacts investors who applied to this stage sequentially until $q_i = q^+ + 1$ or $q_i = q^- - 1$, where q^+ and q^- are as defined in (28) and she designs the derivatives C_H and C_l for the i^{th} investor in such a way that $f_L(q_{i-1}) = \varepsilon + \frac{c}{\lambda} + F_L\left[\frac{(1-\lambda)}{\lambda}\frac{\mu(q_{i-1})}{(1-\mu(q_{i-1}))}\right]$, $f_H(q_{i-1}) = \varepsilon + \frac{c}{\lambda} + F_H\left[\frac{(1-\lambda)}{\lambda}\frac{(1-\mu(q_{i-1}))}{\mu(q_{i-1})}\right]$ with arbitrarily small $\varepsilon > 0$ and*

$$F_L(q_{i-1}) > \left(\varepsilon + \frac{c}{\lambda}\right)\frac{\lambda}{(2\lambda-1)}\frac{(1-\mu(q_{i-1}))}{\mu(q_{i-1})}, \quad F_H(q_{i-1}) > \left(\varepsilon + \frac{c}{\lambda}\right)\frac{\lambda}{(2\lambda-1)}\frac{\mu(q_{i-1})}{(1-\mu(q_{i-1}))};$$

- *In Stage 2, the seller sells the asset with the NIT mechanism at price $p_{issue} = \mathsf{E}_{q_{\tau_{stop}}}(v)$ with $q_{\tau_{stop}} \in \{q^+ + 1, q^- - 1\}$.*

With this specification of the DaC mechanism, the seller's expected utility is:

$$\Pi^*_{DaC} = \Pi^*_{\text{bench}} - \lambda\varepsilon. \tag{30}$$

Thus, as in the baseline case, the seller can achieve an expected utility arbitrarily close to the benchmark case without informational frictions by using a properly designed DaC mechanism even though experts' signals are never perfect.

7.2 Inability to use the NIT mechanism.

In Stage 2 of the DaC mechanism, the seller uses the NIT mechanism. Hence, an expert anticipates that he will obtain zero expected profits in Stage 2, if instead of participating to Stage 1, he chooses to exploit private information only in Stage 2, even when the payoff of the asset is not discovered at the end of Stage 1. Intuitively, this feature reduces the cost of providing incentives to experts both for participating to Stage 1 and truthfully reporting their signals. The NIT mechanism however requires the seller to know J, the number of non experts. In this section, we study the conditions under which Proposition 4 still holds when the seller cannot use the NIT mechanism in Stage 2.

To do so, we consider the conditions under which the actions described in Proposition 4 still form an equilibrium when the seller just offers to sell the asset at its expected value given the information revealed in Stage 1, using a fixed price offering (with pro-rata rationing in case of excess demand). In this equilibrium, all non-experts participate to Stage 2 in which they expect a zero expected profit. Following the same steps as those used to obtain Proposition 4, it is straightforward to show that this is still a best response for non-experts, even though the seller uses a fixed price offering.

Furthermore, in equilibrium, each expert must find optimal to participate to Stage 1, in which he expects a profit (net of information production cost) of ϵ (see Equation (55) in the proof of Proposition 4). This implies that ϵ must be larger than the largest expected profit that an expert can obtain by participating to Stage 2. This deviation can be profitable only if the asset payoff is not revealed in Stage 1, which happens with probability $\big(1 - \pi(1 - (1 - \phi)^{K^{max}}\big))$. The expert can then attempt to produce information and buys the asset at $p_{issue} = \mathsf{E}(v)$ if he discovers that $v = v_H$. Otherwise, if the expert discovers that $v = v_L$ or does not find information, he is better off not trading (in which cases, he loses the cost of producing information). Thus, the largest expected profit that an expert can book by deviating is:

$$\begin{aligned}\bar{\Pi}_2^{expert,\, deviation} &= \frac{Q}{J+1}(1 - \pi\big(1 - (1 - \phi)^{K^{max}}\big))\big[\pi_{K^{max}}\phi\mu(v_H - \mathsf{E}(v)) - c\big] \\ &= \frac{Q}{J+1}(1 - \pi\big(1 - (1 - \phi)^{K^{max}}\big))\big(\pi_{K^{max}}\phi\mu(1-\mu)(v_H - v_L) - c\big),\end{aligned} \tag{31}$$

where the factor $\frac{Q}{J+1}$ reflects pro-rata rationing. Hence, deviating is not optimal iff:

$$\epsilon > \frac{Q}{J+1}(1-\pi(1-(1-\phi)^{K^{max}}))(\pi_{K^{max}}\phi\mu(1-\mu)(v_H-v_L)-c). \tag{32}$$

This no-deviation condition is always satisfied for ϵ arbitrarily small if $c > \pi_{K^{max}}\phi\mu(1-\mu)(v_H-v_L)$ and therefore if K^{max} is large enough, since π_K goes to zero when K increases. Intuitively, the reason is that even if experts fail to discover v in Stage 1, they produce information about whether information is available or not. This information affects an expert's incentive to search for information in order to buy the asset in Stage 2. Indeed, if the posterior likelihood that information is available, $\pi_{K^{max}}$, is low enough, the expected trading profit from producing information (which is zero if no information about v is found) is too small relative to the cost, and an expert is better off not searching for information and not trading in Stage 2.

In this case, Proposition 4 still holds, even though the seller cannot use the NIT mechanism. In particular, the seller achieves an expected utility arbitrarily close to the case in which information production is observable with the DaC mechanism described in Section 6. Observe that this is always the case if the seller's preference for information, γ, is large enough. Indeed, from (18), we know that K^{max} increases with γ. Therefore, for any parameter values, there is always a value of γ large enough such that Condition (32) holds.

In addition, even if $c < \pi_{K^{max}}\phi\mu(1-\mu)(v_H-v_L)$, Condition (32) holds for arbitrarily small ϵ if J grows large. This suggests that the seller can implement the DaC mechanism described in Proposition 4 by encouraging participation of uninformed investors in Stage 2.

We have so far considered the information structure used in Section 5. However, the same logic applies when experts received noisy signals, as in Section 7.1. In this case, the no deviation Condition (32) becomes

$$\epsilon > \frac{Q}{J+1}(\mu(q^-)(1-\mu(q^-))(2\lambda-1)(v_H-v_L)-c), \tag{33}$$

which is satisfied for ϵ arbitrarily small if $c > \mu(q^-)(1-\mu(q^-))(2\lambda-1)(v_H-v_L)$. The economic intuition is the same as in the previous case. Indeed, $\mu(q^-)(1-\mu(q^-))$ is low when Stage 1 results in a large decrease in uncertainty about the asset payoff, making the acquisition of private information in Stage 2 not profitable enough to justify the cost. As q^- is the smallest value such that (32) holds, we deduce that it decreases with γ and that therefore $\mu(q^-)(1 - \mu(q^-)$ decreases with γ.

8 Conclusion

The Grossman–Stiglitz paradox highlights a fundamental tension between liquidity and informativeness: prices cannot be informative unless informed investors earn rents at the expense of uninformed investors. Anticipating such losses, uninformed investors rationally require a discount relative to expected value. Informativeness therefore comes at the expense of liquidity. We show that this conclusion depends critically on market design.

In our setting, the seller can induce information production without sacrificing liquidity by separating the market for information from the market for liquidity through a Divide and Conquer (DaC) mechanism. In Stage 1 (the information market), the seller elicits information production and disclosure by selling derivative securities to informed investors (experts). After publicly announcing the outcome of Stage 1, the seller then sells the asset in Stage 2 at its expected value conditional on the information revealed in Stage 1.

The derivative securities are designed to induce optimal information acquisition and truthful revelation. They leave experts with arbitrarily small informational rents—just enough to cover their information costs—and ensure that the seller's investment in information is efficient, in the sense that the expected marginal benefit of an additional expert equals the marginal cost of information production. Consequently, the DaC mechanism delivers the same expected utility to the seller as in the benchmark without informational frictions.

In this environment, there is no trade-off between liquidity and informativeness. However, as explained in the previous section, this conclusion may fail if experts can earn sufficiently large profits by producing information and participating in Stage 2. This deviation does not arise when the seller's gains from pricing accuracy are sufficiently large, but it may otherwise. Whether the DaC mechanism remains optimal in such cases is an open question for future research.

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Appendix

A. Proofs.

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 $F > \max\left\{\frac{(1-\mu)}{\mu}, \frac{\mu}{1-\mu}\right\}\epsilon$, not trading in Stage 1 is a best response for non-experts.

Finally, due to full revelation of v in Stage 1, all buyers are indifferent between trading at $p_{issue} = v$ and not trading in Stage 2. Thus, trading at $p_{issue} = v$ is a best response. □

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:

$$(J+I-k)q_u(v) + kq_i(v) = Q \quad \text{for} \quad \forall k \in [0, K] \text{ and } \forall v \in \{v_H, v_L\}. \tag{34}$$

Thus, uninformed buyers' aggregate expected profit is:

$$\mathsf{E}((J+I-k)q_u(v)(v - p^*_{issue})) = Q(\mathsf{E}(v - p^*_{issue}) - \underbrace{\mathsf{E}(kq_i(v)(v - p^*_{issue}))}_{\text{Adverse Selection Cost}}, \tag{35}$$

As this aggregate expected profit is zero in equilibrium (so that uninformed buyers' participation constraint binds), we deduce from (35) that:

$$Q(\mathsf{E}(v - p^*_{issue})) = \underbrace{\mathsf{E}(kq_i(v)(v - p^*_{issue}))}_{\text{Adverse Selection Cost}}. \tag{36}$$

Therefore

$$p^*_{issue}(K_{FP}) = \frac{\mathsf{E}(v)Q}{Q - \mathsf{E}(kq_i(v))} - \frac{\mathsf{E}(kq_i(v)v)}{Q - \mathsf{E}(kq_i(v))}. \tag{37}$$

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:

$$\mathsf{E}(\tilde{\tau}(k)) = \pi \sum_{k=1}^{K_{FP}} \binom{K_{FP}}{k} (1-\phi)^{K_{FP}-k} \phi^k \left(\frac{k}{k+J}\right). \tag{38}$$

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

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

We deduce that

$$p^*_{issue}(K_{FP}) = \beta v_H + (1-\beta)v_L \tag{39}$$

with $\beta = \frac{\mu(1-\mathsf{E}(\tilde{\tau}(k)))}{1-\mathsf{E}(\tilde{\tau}(k))\mu}$. Observe that $0 < \beta < \mu < 1$ if $\mathsf{E}(\tau(k)) > 0$. 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 this step, we derive the equilibrium number of experts K^*_{FP} who choose to produce information. An expert who searches for information expects a profit of

$$\Pi_i(K_{FP}) \equiv \frac{\mathsf{E}(kq_i(v)(v - p^*_{issue}(K_{FP})))}{K_{FP}} = \frac{Q(\mathsf{E}(v) - p^*_{issue}(K_{FP}))}{K_{FP}}, \tag{40}$$

where the second equality follows from (36). 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 (40) and ignoring the integer constraint, we deduce that this zero expected profit condition for experts is equivalent to

$$Q(E(v) - p^*_{issue}(K^*_{FP})) = K^*_{FP} \times c, \tag{41}$$

where $p^*_{issue}(K^*_{FP})$ is given by (37). This proves the second claim in the proposition.

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

As in the exogenous information case, 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:

$$\mu(D=J+I) = \frac{\Pr(D=J+I\mid v=v_H)Pr(v=v_H)}{\Pr(D=J+I\,|\,v=v_H)\Pr(v=v_H)+\Pr(D=J+I\mid v=v_L)\Pr(v=v_L)}$$
$$= \frac{\mu\times 1}{\mu\times 1+(1-\mu)\Pr(k=0)} = \frac{\mu}{\mu+(1-\mu)(1-\pi+\pi(1-\phi)^{K_{FP}})}. \quad (42)$$

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

$$Var(v\,|\,D=J+I) = \mu(D=J+I)(1-\mu(D=J+I))(v_H-v_L)^2 \quad (43)$$
$$=\frac{\mu(1-\mu)\left(1-\pi+\pi(1-\phi)^{K^*_{FP}}\right)(v_H-v_L)^2}{\left(\mu+(1-\mu)\left(1-\pi+\pi(1-\phi)^{K^*_{FP}}\right)\right)^2} = \frac{\mathsf{Var}(v)\left(1-\pi+\pi(1-\phi)^{K^*_{FP}}\right)}{\left(\mu+(1-\mu)\left(1-\pi+\pi(1-\phi)^{K^*_{FP}}\right)\right)^2},$$

$$\mathsf{E}(\mathsf{Var}(v\,|D)) = \mathsf{Var}(v\mid D=J+I)\Pr(D=J+I) \quad (44)$$
$$= \mu(D=J+I)(1-\mu(D=J+I)(v_H-v_L)^2 = \frac{\mathsf{Var}(v)\left(1-\pi+\pi(1-\phi)^{K^*_{FP}}\right)}{\mu+(1-\mu)\left(1-\pi+\pi(1-\phi)^{K^*_{FP}}\right)}.$$

The expected informational gain of the seller if she uses the FP mechanism is:

$$\mathsf{Var}(v)-\mathsf{E}(\mathsf{Var}(v\mid\Omega)) = \frac{\gamma\mu\pi\left(1-(1-\phi)^{K^*_{FP}}\right)\mathsf{Var}(v)}{\mu+(1-\mu)\left(1-\pi+\pi(1-\phi)^{K^*_{FP}}\right)}. \quad (45)$$

Now, from (36), we deduce that the seller's expected proceeds from the issue is:

$$Qp^*_{issue}(K^*_{FP}) = Q\,\mathsf{E}(v)-\mathsf{E}(kq_i(v)(v-p^*_{issue}(K^*_{FP}))) = Q\,\mathsf{E}(v)-K^*_{FP}\times c, \quad (46)$$

where the last equality follows from (41). Combining (45) and (46), we deduce that

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

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

$$\begin{aligned}
& \Pi^*_{FP} - \Pi(K^*) \leq \Pi^*_{FP} - \Pi(K^*_{FP}) \\
= \;& cK^*_{FP}(1-\pi) + \frac{c\pi(1-(1-\phi)^{K^*_{FP}})}{\phi} - \gamma\pi\left(1-(1-\phi)^{K^*_{FP}}\right)Var(v) \\
- \;& cK^*_{FP} + \frac{\gamma\mu\pi\left(1-(1-\phi)^{K^*_{FP}}\right)Var(v)}{\mu+(1-\mu)\left(1-\pi+\pi(1-\phi)^{K^*_{FP}}\right)} \\
< \;& -cK^*_{FP}\pi + \frac{c\pi(1-(1-\phi)^{K^*_{FP}})}{\phi} \\
+ \;& \gamma\pi\left(1-(1-\phi)^{K^*_{FP}}\right)Var(v) - \gamma\pi\left(1-(1-\phi)^{K^*_{FP}}\right)Var(v) \\
= \;& \frac{c\pi}{\phi}\left(1-(1-\phi)^{K^*_{FP}} - K^*_{FP}\phi\right) < 0.
\end{aligned} \tag{47}$$

□

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:

$$\mathsf{E}(C_{issue}(K)) = c \times K(1-\pi) + \frac{\pi(1-(1-\phi)^K)}{\phi}. \tag{48}$$

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:

$$\Pi(K,i) = \phi\pi_i(Q\,\mathsf{E}(v) + \gamma\,\mathsf{Var}(v)) - c + (1-\phi\pi_i)\Pi(K,i+1), \tag{49}$$

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

Equation (50) 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 $QE(v) + \gamma\,\mathsf{Var}(v)$ 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 $i \leq K$, (50) is equivalent to:

$$\Pi(K,i) - Q\,\mathsf{E}(v) = \phi\pi_i\gamma\,\mathsf{Var}(v) - c + (1-\phi\pi_i)(\Pi(K,i+1) - Q\,\mathsf{E}(v)). \tag{50}$$

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 $\Pi(K^*, K^*) - Q\,\mathsf{E}(v) = \gamma\phi\pi_{K^*}Var(v) - c > 0$ since $\Pi(K^*, K^*{+}1) = Q\,\mathsf{E}(v)$. Thus, K^* cannot be larger than K^{max}, the largest value of K for which

$$\frac{c}{\gamma\,\mathsf{Var}(v)\phi} < \pi_K. \tag{51}$$

The threshold $K^{max} \geq 1$ if and only if $\frac{c}{\gamma\,\mathsf{Var}(v)\phi} < \pi$. 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:

$$\Pi(K^*, K^*+1) - Q\,\mathsf{E}(v) = \phi\pi_i\gamma\,\mathsf{Var}(v) - c + (1-\phi\pi_i)(\Pi(K^*, K^*+1) - Q\,\mathsf{E}(v)) > 0, \tag{52}$$

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 $\frac{c}{\gamma\,\mathsf{Var}(v)\phi} > \pi$, 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 3 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:

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

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

Suppose now that expert i receives $s_i = U$. If he deviates and reports $s_i = H$, he obtains:

$$R(U,H) = \mu\left(\varepsilon + \frac{c}{\phi\pi_i}\right) - (1-\mu)F < R(U,U), \tag{53}$$

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:

$$R(U,L) = (1-\mu)\left(\varepsilon + \frac{c}{\phi\pi_i}\right) - \mu F < R(U,U), \tag{54}$$

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) holds. It imposes:

$$\pi_i\phi(\mu R(H,H) + (1-\mu)R(L,L)) + (1-\pi_i\phi)R(U,U) \geq c, \quad \forall i \leq K. \tag{55}$$

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 buyer number K^*_{DaC} in Stage 1 where K^*_{DaC} is the largest K such that $\gamma\phi\pi_{K^*_{DaC}}\mathsf{Var}(v) - c - \epsilon > 0$. 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 6, 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

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

where $\mathsf{E}(C^{bench}_{issue})$ is the expected cost of the issue in the benchmark given in (48).

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 informational benefit is as in the benchmark case. We deduce from these observations that:

$$\begin{aligned}\Pi^*_{\text{DaC}} &= Q\ \mathsf{E}(v) - cK^{max}(1-\pi) - \frac{c\pi\big(1-(1-\phi)^{K^{\max}}\big)}{\phi} \\ &\quad - \gamma\pi\big(1-(1-\phi)^{K^{max}}\big)\,\mathsf{Var}(v) - \epsilon\pi\big(1-(1-\phi)^{K^{max}-1}\big) \\ &= \Pi^*_{\text{bench}} - \gamma\pi\big(1-(1-\phi)^{K^{max}}\big)\,\mathsf{Var}(v) - \pi\big(1-(1-\phi)^{K^{\max}-1}\big)\,\epsilon. \end{aligned} \tag{56}$$

□

Proof of Proposition 5. Consider first the case in which $c \leq \bar{c}$ first. We use the definitions of τ_{stop} and $q_{\tau_{stop}}$ introduced in the main text where τ_{stop} is the stopping time chosen by the seller in Stage 1. Each time an expert is contacted in Stage 1, the seller pays a cost c to cover the expert's information cost. Thus, the total payment in Stage 1 to experts by the seller is $C_{\text{issue}} = \sum_{i=1}^{\tau_{stop}} c = c\,\tau_{stop}$ and therefore the expected payment by the seller to experts in Stage 1 is:

$$\mathsf{E}(C_{\text{issue}}) = c\ \mathsf{E}(\tau_{stop}).$$

As explained in the text, after reaching the stopping time τ_{stop} in Stage 1, the expert sells the asset to non-experts at price $p_{issue}(q_{\tau_{stop}}) = \mathsf{E}_{q_{\tau_{stop}}}(v)$. By the law of iterated expectations $\mathsf{E}\big[p_{issue}(q_{\tau_{stop}})\big] = \mathsf{E}\Big[\mathsf{E}_{q_{\tau_{stop}}}(v)\Big] = \mathsf{E}(v)$. Thus, the total expected revenues earned by the seller is $\mathsf{E}(v) - c\ \mathsf{E}(\tau_{stop})$ and her ex-ante expected utility in the benchmark case is:

$$\begin{aligned}\Pi_{\text{bench}}(\tau) &= Q\ \mathsf{E}(v) - c\ \mathsf{E}(\tau_{stop}) + \gamma\left(\mathsf{Var}(v) - \mathsf{E}[\mathsf{Var}(v \mid q_\tau)]\right. \\ &= Q\ \mathsf{E}(v) - c\ \mathsf{E}(\tau_{stop}) + \gamma\ \Big(\mu(1-\mu) - \mathsf{E}\big[\mu(q_{\tau_{stop}})\big(1-\mu(q_{\tau_{stop}})\big)\big]\Big)\,(v_H - v_L)^2.\end{aligned}$$

One can further compute $\mathsf{E}\big[\mu(q_{\tau_{\text{stop}}})\big(1-\mu(q_{\tau_{\text{stop}}})\big)\big]$. Indeed:

$$\begin{aligned}\mathsf{E}\big[\mu(q_{\tau_{stop}+1})\,\big(1-\mu(q_{\tau_{stop}})\big)\big] &= \Pr(q_{\tau_{stop}} = q^+ + 1)\,\mu(q^+ + 1)\,\big(1-\mu(q^+ + 1)\big) \\ &\quad + \Pr(q_{\tau_{stop}} = q^- - 1)\,\mu(q^- - 1)\,\big(1-\mu(q^- - 1)\big)\,. \end{aligned} \tag{57}$$

To make (57) explicit, set

$$a = q_0 - (q^- - 1), \qquad N = (q^+ + 1) - (q^- - 1) = 2 + q^+ - q^-, \qquad \rho = \frac{1-\lambda}{\lambda} \in (0,1),$$

(with $q_0 = 0$). Conditional on the true state, the process $\{q_i\}$ is a biased random walk. The standard gambler's ruin formulas imply, for $\lambda \neq \frac{1}{2}$,

$$\Pr(q_{\tau_{stop}} = q^+ + 1 \mid v = v_H) = \frac{1-\rho^a}{1-\rho^N}, \tag{58}$$

$$\Pr(q_{\tau_{stop}} = q^+ + 1 \mid v = v_L) = \frac{1-\rho^{-a}}{1-\rho^{-N}}. \tag{59}$$

Hence, we have

$$\Pr(q_{\tau_{stop}} = q^+ + 1) = \mu \frac{1-\rho^a}{1-\rho^N} + (1-\mu) \frac{1-\rho^{-a}}{1-\rho^{-N}}, \quad \text{and} \tag{60}$$

$$\Pr(q_{\tau_{stop}} = q^- - 1) = 1 - \Pr(q_{\tau_{stop}} = q^+ + 1). \tag{61}$$

Finally, $\mathsf{E}(\tau_{stop})$ can also be written in closed form. Let T be the absorption time of a biased random walk on $\{0, 1, \ldots, N\}$ starting at a, with up-probability $p \in (0,1)$ and down-probability $1 - p$. For $p \neq \frac{1}{2}$, it is a known result that:

$$\mathsf{E}[T \mid p] = \frac{a}{1-2p} - \frac{N}{1-2p} \cdot \frac{1 - \left(\frac{1-p}{p}\right)^a}{1 - \left(\frac{1-p}{p}\right)^N}. \tag{62}$$

In our case, conditional on $v = v_H$ we have $p = \lambda$, while conditional on $v = v_L$ we have $p = 1 - \lambda$. Thus,

$$\mathsf{E}[\tau_{stop} \mid v = v_H] = \frac{a}{1-2\lambda} - \frac{N}{1-2\lambda} \cdot \frac{1-\rho^a}{1-\rho^N}, \tag{63}$$

$$\mathsf{E}[\tau_{stop} \mid v = v_L] = \frac{a}{2\lambda-1} - \frac{N}{2\lambda-1} \cdot \frac{1-\rho^{-a}}{1-\rho^{-N}}. \tag{64}$$

Therefore,

$$\mathsf{E}[\tau_{stop}] = \mu \, \mathsf{E}[\tau_{stop} \mid v = v_H] + (1-\mu) \, \mathsf{E}[\tau_{stop} \mid v = v_L]. \tag{65}$$

Substituting (57)–(65) into the expression for Π^*_{bench} yields a fully explicit closed-form representation of the benchmark expected utility.

Finally consider the case $c > \bar{c}$. Then in this case, as explained in the text, the seller does not contact any experts and sells the asset at price $p_{issue} = \mathsf{E}(v)$. Then, the expected utility of the seller is just $Q\ \mathsf{E}(v)$. $\square$

Proof of Proposition 6. Step 1. We first verify that given the specification of the derivatives contracts in Proposition 6 and the fact that the seller uses a NIT mechanism in Stage 2, only experts apply to Stage 1 and report truthfully the signal they obtain after producing formation. As in the baseline case, this requires checking that all incentives and participation constraints are satisfied. we denote by $R(s_i, \sigma_i; q_{i-1})$ the expected profit of the i^{th} investor contacted by the seller when observes signal s_i and report σ_i. Remember that q_i is the likelihood that $v = v_H$ conditional on the signals reported to the seller up to the moment he contacts the i^{th} investor, under the conjecture (verified below) that investors report their signals truthfully.

First, conditional on producing information and observing signal $s_i \in \{H, L\}$, each expert must be better off reporting $\sigma_i = s_i$ rather than the opposite signal. That is, the following truth-telling conditions must hold for each investor i:

$$R(H, H; q_{i-1}) \geq R(H, L; q_{i-1}). \tag{66}$$

$$R(L, L; q_{i-1}) \geq R(L, H; q_{i-1}). \tag{67}$$

Consider first the case in which $s = H$. We have:

$$R(H, H; q_{i-1}) = \mu(q_{i-1} + 1)(f_H(q_{i-1}) + F_H(q_{i-1}) - F_H(q_{i-1})) - (1 - \mu(q_{i-1} - 1)F_H(q_{i-1})$$

As $\mu(q_{i-1} + 1) = \frac{\lambda\mu(q_{i-1})}{\Psi(q_{i-1})}$, we deduce that:

$$R(H, H; q_{i-1}) = \frac{f_H(q_{i-1})\lambda\mu(q_{i-1})}{\Psi(q_{i-1})} - \frac{F_H(q_{i-1})(1 - \lambda)(1 - \mu(q_{i-1}))}{\Psi(q_{i-1})}.$$

If instead, the buyer who receives signal $s_i = H$ in state q_{i-1} reports $\sigma_i = L$, he obtains:

$$\begin{aligned} R(H, L; q_{i-1}) &= (1 - \mu(q_{i-1} - 1))(f_L(q_{i-1})) - \mu(q_{i-1} + 1)F_L(q_{i-1}), \\ &= \frac{f_L(q_{i-1})(1-\lambda)(1-\mu(q_{i-1}))}{\Psi(q_{i-1})} - \frac{F_L(q_{i-1})\lambda\mu(q_{i-1})}{\Psi(q_{i-1})}. \end{aligned}$$

Now:

$$\begin{aligned} &\Psi(q_{i-1})(R(H,H;q_{i-1}) - R(H,L;q_{i-1})) = f_H\lambda\mu(q_{i-1}) - f_L(1-\lambda)(1-\mu(q_{i-1})) \\ &- F_H(1-\lambda)(1-\mu(q_{i-1})) + F_L(\lambda\mu(q_{i-1})) \\ &> \lambda\mu(q_{i-1})\left(\frac{c}{\lambda} + \varepsilon\right) - (1-\lambda)(1-\mu(q_{i-1}))\left(\frac{c}{\lambda} + \varepsilon\right) + F_L\frac{\mu(q_{i-1})(1-\lambda)^2}{\lambda} - F_L(\mu(q_{i-1})\lambda) \\ &= (\lambda\mu(q_{i-1}) - (1-\lambda)(1-\mu(q_{i-1})))\left(\frac{c}{\lambda} + \varepsilon\right) + F_L\frac{\mu(q_{i-1})(2\lambda - 1)}{\lambda} \\ &> (\lambda\mu(q_{i-1}) - (1-\lambda)(1-\mu(q_{i-1})))\left(\frac{c}{\lambda} + \varepsilon\right) + \left(\frac{c}{\lambda} + \varepsilon\right) > 0. \end{aligned}$$

Thus, $R(H, H; q_{i-1}) > R(H, L; q_{i-1})$. Similar calculations yield:

$$R(L, L; q_{i-1}) = \frac{f_L(q_{i-1})\lambda(1-\mu(q_{i-1}))}{1 - \Psi(q_{i-1})} - \frac{F_L(q_{i-1})(1-\lambda)\mu(q_{i-1})}{1 - \Psi(q_{i-1})}.$$

Similarly,

$$R(L, H; q_{i-1}) = \frac{f_H(1-\lambda)\mu(q_{i-1})}{1 - \Psi(q_{i-1})} - \frac{F_H\lambda(1-\mu(q_{i-1}))}{1 - \Psi(q_{i-1})},$$

Therefore,

$$\begin{aligned} &(1 - \Psi(q_{i-1}))(R(L,L;q_{i-1}) - R(L,H)) = f_L\lambda(1-\mu(q_{i-1})) - f_H(1-\lambda)\mu(q_{i-1}) \\ &- F_L(1-\lambda)\mu(q_{i-1}) + F_H\lambda(1-\mu(q_{i-1})) \\ &> \lambda(1-\mu(q_{i-1}))\left(\frac{c}{\lambda} + \varepsilon\right) - (1-\lambda)\mu(q_{i-1})\left(\frac{c}{\lambda} + \varepsilon\right) + F_H\frac{(1-\mu(q_{i-1}))(1-\lambda)^2}{\lambda} - F_H(1-\mu(q_{i-1}))\lambda \\ &= (\lambda(1-\mu(q_{i-1})) - (1-\lambda)\mu(q_{i-1}))\left(\frac{c}{\lambda} + \varepsilon\right) + F_H\frac{(1-\mu(q_{i-1}))(2\lambda-1)}{\lambda} \\ &> (\lambda(1-\mu(q_{i-1})) - (1-\lambda)\mu(q_{i-1}))\left(\frac{c}{\lambda} + \varepsilon\right) + \left(\frac{c}{\lambda} + \varepsilon\right) > 0. \end{aligned}$$

Thus, $R(H, H; q_{i-1}) > R(H, L; q_{i-1})$.

Moreover, as each investor can always abstain from participating to Stage 1, she must at least obtain a positive expected profit when she reports truthfully, that is, the participation constraints $R(H,H;q_{i-1}) \geq 0$ and $R(L,L;q_{i-1}) \geq 0$ must be satisfied. This is the case since:

$$f_H(q_{i-1}) = \frac{c}{\lambda} + \varepsilon + F_H(q_{i-1})\frac{(1-\lambda)}{\lambda}\frac{(1-\mu(q_{i-1}))}{\mu(q_{i-1})} > F_H(q_{i-1})\frac{(1-\lambda)}{\lambda}\frac{(1-\mu(q_{i-1}))}{\mu(q_{i-1})},$$

$$f_L(q_{i-1}) = \frac{c}{\lambda} + \varepsilon + F_L(q_{i-1})\frac{(1-\lambda)}{\lambda}\frac{\mu(q_{i-1})}{(1-\mu(q_{i-1}))} > F_L(q_{i-1})\frac{(1-\lambda)}{\lambda}\frac{\mu(q_{i-1})}{(1-\mu(q_{i-1}))}.$$

In addition, an investor who does not produce information (e.g., a non-expert) must be worse off than participating in Stage 2, in which he obtains a zero expected profit since the seller uses the NIT mechanism and sells the asset at its expected value given the information obtained in Stage 1. Thus, we must have $R(U,H;q_{i-1}) < 0$ and $R(U,L;q_{i-1}) < 0$. This is the case since

$$\begin{aligned}
R(U,H;q_{i-1}) &= \mu f_H - (1-\mu(q_{i-1}))F_H \\
&= \mu(q_{i-1})\left(\frac{c}{\lambda}+\varepsilon\right) + \mu(q_{i-1})\frac{(1-\lambda)}{\lambda}\frac{(1-\mu(q_{i-1}))}{\mu(q_{i-1})}F_H - (1-\mu(q_{i-1}))F_H \\
&= \mu(q_{i-1})\left(\frac{c}{\lambda}+\varepsilon\right) - F_H(1-\mu(q_{i-1}))\frac{(2\lambda-1)}{\lambda} \\
&< \mu(q_{i-1})\left(\frac{c}{\lambda}+\varepsilon\right) - \mu(q_{i-1})\left(\frac{c}{\lambda}+\varepsilon\right) = 0.
\end{aligned}$$

and

$$\begin{aligned}
R(U,L;q_{i-1}) &= (1-\mu(q_{i-1}))f_L - \mu(q_{i-1})F_L(q_{i-1}) \\
&= (1-\mu(q_{i-1}))\left(\frac{c}{\lambda}+\varepsilon\right) + (1-\mu(q_{i-1}))\frac{(1-\lambda)}{\lambda}\frac{\mu(q_{i-1})}{(1-\mu(q_{i-1}))}F_L(q_{i-1}) - \mu(q_{i-1})F_L(q_{i-1}) \\
&= (1-\mu(q_{i-1}))\left(\frac{c}{\lambda}+\varepsilon\right) - F_L(q_{i-1})\mu(q_{i-1})\frac{(2\lambda-1)}{\lambda} \\
&< (1-\mu(q_{i-1}))\left(\frac{c}{\lambda}+\varepsilon\right) - (1-\mu(q_{i-1}))\left(\frac{c}{\lambda}+\varepsilon\right) = 0.
\end{aligned}$$

Furthermore, when she is contacted, each expert participating to Stage 1 is better off paying the cost of producing information than abstaining from participating (and obtain zero expected profit). That is,

$$\Psi(q_{i-1})R(H,H;q_{i-1}) + (1-\Psi(q_{i-1}))R(L,L;q_{i-1}) \geq c. \tag{68}$$

Substituting expressions for $R(H, H; q_{i-1})$ and $R(L, L; q_{i-1})$ yields

$$\begin{aligned}
& \Psi(q_{i-1})R(H,H;q_{i-1}) + (1-\Psi(q_{i-1}))R(L,L;q_{i-1}) \\
= \; & f_H(q_{i-1})\lambda\mu(q_{i-1}) - F_H(q_{i-1})(1-\lambda)(1-\mu(q_{i-1})) + f_L(q_{i-1})\lambda(1-\mu(q_{i-1})) - F_L(q_{i-1})(1-\lambda)\mu(q_{i-1}) \\
= \; & \lambda\mu(q_{i-1})\left(\frac{c}{\lambda}+\varepsilon\right) + \lambda\mu(q_{i-1})F_H(q_{i-1})\frac{(1-\lambda)}{\lambda}\frac{(1-\mu(q_{i-1}))}{\mu(q_{i-1})} - F_H(q_{i-1})(1-\lambda)(1-\mu(q_{i-1})) \\
+ \; & \lambda(1-\mu(q_{i-1}))\left(\frac{c}{\lambda}+\varepsilon\right) + \lambda(1-\mu(q_{i-1}))F_L(q_{i-1})\frac{(1-\lambda)}{\lambda}\frac{\mu(q_{i-1})}{(1-\mu(q_{i-1}))} - F_L(q_{i-1})(1-\lambda)\mu(q_{i-1}) \\
= \; & \lambda\left(\frac{c}{\lambda}+\varepsilon\right) = c + \lambda\varepsilon > c.
\end{aligned}$$

Observe that this implies that an expert participating to Stage 1 obtains a strictly positive expected profit equal to $\lambda\varepsilon > 0$. Thus, all experts should be better off participating to Stage 1 rather than to Stage 2 or abstaining to participate at all. Indeed, if she abstains from participating, an expert obtains zero profit and if he participates to Stage 2, he obtains at best a zero expected profit since the seller sells the asset at its expected payoff with the NIT mechanism given the information produced in Stage 1.

Step 2. In a second step, we present the NIT mechanism that the seller uses in Stage 2 and show that it deters experts from producing information in Stage 2. If the seller stops in Stage 1, she announces all the signals collected in Stage 1 (reports q_{stop}). She then offers to sell the asset at $\mathsf{E}_{q_{\tau_{stop}}}(v)$ if $D \leq J$ and at $v_H + \varepsilon$ if $D > J$. As in the baseline case, under this mechanism, it is a best response for only non-experts to participate in Stage 2.

Step 3. Finally we compute the ex-ante expected utility of the seller. As in the benchmark case, the expected selling price is $\mathsf{E}(v)$ and therefore the expected proceeds from the sale of the asset at date 1 is $Q\,\mathsf{E}(v)$. Now consider the expected cost from selling derivatives to the i^{th} expert in Stage 1, that we denote $\mathsf{E}(\text{Cost}_{issue} \mid q_{i-1})$ since upon contacting the i^{th} expert, q_{i-1} is a summary statistics for the seller's belief about the distribution of the payoff of the asset. This expected cost is the expert's expected profit on the derivative purchased by the expert. As each expert is incentivized to report its signal truthfully, we deduce that:

$$\mathsf{E}[\text{Cost}_{issue} \mid v = v_H, q_{i-1}] = \lambda f_H(q_{i-1}) + (1-\lambda)(-F_L(q_{i-1})) = \lambda f_H(q_{i-1}) - (1-\lambda)F_L(q_{i-1}),$$

$$\mathsf{E}[\text{Cost} \mid v = v_L, q_{i-1}] = (1-\lambda)(-F_H(q_{i-1})) + \lambda f_L(q_{i-1}) = \lambda f_L(q_{i-1}) - (1-\lambda)F_H((q_{i-1})).$$

Therefore, taking expectation over v, we obtain:

$$
\begin{aligned}
\mathsf{E}[\text{Cost}_{issue} \mid q_{i-1}] &= \lambda\mu(q_{i-1}) f_H(q_{i-1}) + \lambda(1-\mu(q_{i-1})) f_L(q_{i-1}) \\
&\quad - \mu(q_{i-1})(1-\lambda)F_L(q_{i-1}) - (1-\mu(q_{i-1}))(1-\lambda)F_H(q_{i-1}) \\
&= \lambda\mu(q_{i-1}) \left(\varepsilon + \frac{c}{\lambda} + F_H(q_{i-1})\frac{(1-\lambda)}{\lambda}\frac{(1-\mu(q_{i-1}))}{\mu(q_{i-1})}\right) \\
&\quad + \lambda(1-\mu(q_{i-1})) \left(\varepsilon + \frac{c}{\lambda} + F_L(q_{i-1})\frac{(1-\lambda)}{\lambda}\frac{\mu(q_{i-1})}{(1-\mu(q_{i-1}))}\right) \\
&\quad - \mu(q_{i-1})(1-\lambda)F_L(q_{i-1}) - (1-\mu(q_{i-1}))(1-\lambda)F_H(q_{i-1}) \\
&= \mu(q_{i-1})(\lambda\varepsilon + c) + (1-\lambda)(1-\mu(q_{i-1}))F_H(q_{i-1}) \\
&\quad + (1-\mu(q_{i-1}))(\lambda\varepsilon + c) + (1-\lambda)\mu(q_{i-1})F_L(q_{i-1}) \\
&\quad - \mu(q_{i-1})(1-\lambda)F_L(q_{i-1}) - (1-\mu(q_{i-1}))(1-\lambda)F_H(q_{i-1}) \\
&= c + \lambda\varepsilon.
\end{aligned}
$$

Therefore, the expected cost borne by the seller from selling derivative to each expert in Stage 1 is $c + \lambda\varepsilon$ for each expert. We deduce that the expected total cost for the seller is:

$$\mathsf{E}[C_{issue}] = (c + \lambda\varepsilon)\ \mathsf{E}[\tau_{stop}],$$

where $\mathsf{E}[\tau_{stop}]$ is given by (65).

Hence, the expected revenues for the seller is $Q\,\mathsf{E}(v) - (c + \lambda\varepsilon)\ \mathsf{E}[\tau_{stop}]$. Moreover the expected benefit from the information generated in Stage 1 is identical to that in the benchmark case since the seller behaves exactly in the same way as in the benchmark case (same stopping rule) and experts truthfully reveal their signals in equilibrium, as in the benchmark case. We deduce that the expected utility of the seller is as given in (30).

□