Share Issues versus Share Repurchases

Philip Bond, Yue Yuan, Hongda Zhong*

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Abstract

Almost all firms repurchase shares through open-market repurchase programs. In contrast, issue methods are more diverse: at-the-market offerings, analogous to open-market repurchases, and SEOs, analogous to rarely used tender-offer repurchases, are both used by significant fractions of firms. Furthermore, average SEOs are larger than at-the-market offerings. We show that this asymmetry in the diversity of transaction methods in issuances and repurchases and the size-method relation in issuances are natural consequences of the single informational friction of a firm having superior information to investors. Moreover, while this friction always leads firms to issue inefficiently little, it leads firms to repurchase too little if they maximize long-term shareholder value, but too much if the primary goal is to boost short-term share prices.

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1 Introduction

Public firms often tap into equity markets, both issuing new shares to raise funds, and repurchasing existing shares to return cash to investors. Both issues and repurchases potentially yield transaction surplus: issues raise funds for investment, while repurchases disburse funds and avoid various costs associated with holding cash inside a firm. In many ways, issuing and repurchasing shares are mirror images of each other. Both types of transaction are subject to informational frictions arising from firms' superior knowledge. And for both types of transaction, firms choose transaction size and method. Conceptually, share repurchases are simply negative issuances.

In this paper, we analyze the two transactions side-by-side, under the assumption that firms have superior knowledge about their own prospects, and choose both transaction size and method. Although many papers analyze security transactions under asymmetric information, the comparison of issues and repurchases is new to the literature. Likewise, size and method are two of the main ways in which transactions differ in practice. Size corresponds to signaling via retention, while method directly affects transaction efficiency without impacting retention.[1] Our contribution is to analyze issues, repurchases, transaction size and transaction method in a unified framework, yielding new insights.

Specifically, we consider a firm with private information about its assets-in-place (Myers and Majluf, 1984), and with a surplus-creating "project" that requires an equity transaction to realize. If the project entails a positive investment, the firm needs to raise capital by issuing shares. In contrast, if the "investment" is negative, then the firm needs to pay out capital by repurchasing equity; here, surplus stems from tax savings and/or the avoidance of wasteful expenditures that would take place if cash were instead retained. In this context, the firm decides how much to invest or pay out, along with the method used for the transaction, where different methods differ in their efficiency levels.

We emphasize four points. First, and despite the conceptual symmetry between issue and repurchase transactions, their equilibrium *outcomes* are *not* mirror images. Repurchasing firms cannot signal via the efficiency of transaction method, while issuing firms can. Empirically, almost all firms repurchase via open-market transactions; while issuing firms use both seasoned equity offerings (henceforth, SEOs) and at-the-market offerings (henceforth, ATMs) with significant frequencies, though the latter has received limited academic attention. Our analysis rationalizes both patterns.

Repurchasing firms cannot separate via transaction method because such separation would entail worse firms repurchasing at lower prices using more inefficient methods—but then better firms would be attracted by the lower prices associated with these inefficient methods. In contrast, such separation is possible among issuing firms because better firms issue at higher prices, using more inefficient methods. Worse firms are deterred from issuing in the same way by the fact that the

[1] See the large literatures following, respectively, Leland and Pyle (1977) on signaling via retention, and Ross (1977) and Bhattacharya (1979) on signaling via transaction efficiency.

inefficiency cost represents a greater fraction of their value.[2]

Second, and in contrast, signaling by reducing transaction size is viable for both repurchasing and issuing firms. In equilibrium, worse firms repurchase less at lower prices, while better firms issue less at higher prices. The contrast between the first and second points highlights that while reducing repurchase size also reduces transaction surplus, doing so also has the separate effect of increasing a firm's total value, which is relatively more valuable for worse firms.

Third, we consider the case where firms care not only about long-term shareholder value but also the short-term share price. We establish that firms that attach high importance to short-term share prices repurchase more than the surplus-maximizing amount. Many commentators have claimed that firms engage in excessive buybacks to boost share prices, at the expense of real investment; but the existing academic literature lacks a coherent account of such behavior. In contrast, and regardless of the relative importance firms place on short- vs long-term share prices, issuing firms issue below the surplus-maximizing amount. Another interesting asymmetry therefore emerges: firms issue too little but repurchase too much.

The reason firms issue too little is standard: their direct preference for higher short-term prices coincides with their desire to increase long-term shareholder value. In contrast, repurchasing firms must balance their direct preference for higher short-term share prices with the fact that repurchasing at higher prices hurts long-term shareholders. If firms' direct preference for higher short-term prices dominates then the equilibrium outcome is that better firms repurchase excessive amounts. Although worse firms would increase short-term prices by mimicking these large repurchases, the cost to long-term shareholder value from overpaying for the shares is too large.

Fourth, and more conceptually, while the received wisdom is that transaction surplus (NPV) should dictate financial decisions, our analysis isolates a precise formal role for firm value, viz., for any equity transaction a manager should ask, "by what percent will this transaction affect firm value?" The point is starkest for repurchases, in which case larger repurchases decrease firm value but often increase transaction surplus. But even for issue decisions, a focus on firm value sheds light on firms' preferences for signaling-via-issue-size over signaling-via-issue-method, and operationalizes Viswanathan (1995)'s results on the ordering of signals in terms of standard financial quantities.

Relating our theoretical findings to empirical patterns requires placing structure on the determinants of the efficiency of different transaction methods. We argue that financial transactions are more efficient when the timing of the cash flows they generate matches that of the firm's "real" operations. In particular, one-off SEOs, which typically complete in 2–8 weeks (Gao and Ritter,

[2] Formally, this is a manifestation of the single-crossing property. An action needs to simultaneously satisfy two conditions to be a viable signal in equity transactions: it decreases surplus, and its effect relative to firm value is more favorable to the firms who want to distinguish their types relative to those who want to pool with others (the single-crossing property). For signaling via inefficient methods, the single-crossing property is violated in repurchase transactions, but holds in issue transactions.

2010), are more efficient than smoother ATMs, which often last a couple of years.[3] Since investment opportunities are typically lumpy, more timely SEOs allow immediate project implementation. In contrast, smooth open-market repurchases (henceforth, OMRs), which typically last several years (Stephens and Weisbach, 1998), are more efficient than tender offers (henceforth, TORs), which are often completed within a month (Masulis, 1980). This is because firms that use repurchases to distribute profits (for example, technology companies such as Apple or Google and banks such as JP Morgan and Bank of America) typically generate these cash flows gradually over time.

First, consider the prediction of asymmetry in transaction methods. In principle, similar transaction methods are available for issuing and repurchasing firms. Specifically, firms can raise equity through an SEO in a one-off transaction; or more smoothly through an ATM program over time. Likewise, repurchases can be carried out either one-off in TORs or smoothly via OMRs. Our asymmetry prediction gives an explanation for the prominent empirical feature that both SEOs and ATMs coexist as frequently observed issue methods, whereas OMR dominates the repurchase market (Section 4.)

Second, the prediction that transaction size reveals firm fundamentals in both issues and repurchases fits the data well: smaller issues and larger repurchases are both associated with higher prices.[4]

Third, our model's implication that issuing firms prefer to signal via smaller issues rather than via more inefficient methods implies the following pattern: The worst firms issue the surplus-maximizing amount using the most efficient method (SEO); better firms issue less, still using the most efficient method; and the best firms issue the minimum amount possible to fund the project, but use less efficient issue methods (ATM). This implies a size-method correlation: larger issues are carried out via SEOs, smaller issues are carried out via ATMs, consistent with Billett, Floros, and Garfinkel (2019)'s findings.[5]

Finally, the possibility that firms engage in excessive repurchases in order to push up the share price fits well with many anecdotal/informal accounts (see Section 5). This pattern does not typically emerge from a standard model with complete information, because the direct effect of an inefficiently large repurchase is a reduction in the share price.

Related Literature: There is a large literature on firms' capital transactions when they have an information advantage over investors. When selling securities, costly retention of unsold securities or broadly speaking, transaction size, can be informative signals about firms' hidden quality

[3] See Billett, Floros, and Garfinkel (2019) for an overview of ATMs, which are growing in popularity.

[4] Asquith and Mullins (1986) and Masulis and Korwar (1986) document negative relation between issue size and announcement return. For tender-offer repurchases, Vermaelen (1981) finds abnormal returns are positively related to target tender fractions.

[5] We calculate from Table 2 of Billett, Floros, and Garfinkel (2019) that the average proceeds per SEO are $256 million, whereas average proceeds per ATM program are $92 million. Even though the ratio of proceeds to market equity is roughly the same between the two methods (18% for SEO and 20% for ATM), it is significantly smaller for ATM than for SEO after controlling for other observable factors (see Table 4 of the same paper).

(see Leland and Pyle (1977), Myers and Majluf (1984), Krasker (1986), and DeMarzo and Duffie (1999)). When repurchasing securities, firms can similarly signal via different repurchase amounts (see Vermaelen (1984), Brennan and Kraus (1987), Ofer and Thakor (1987), Constantinides and Grundy (1989), Chowdhry and Nanda (1994), Lucas and McDonald (1998), and Bond and Zhong (2016)). In general, higher quality firms buy more or sell less (or even not sell at all). In addition to transaction-size signaling, these papers also show that firms can signal through tax-inefficient dividend payouts, or more generally via other forms of inefficiency (for example advertisements in Milgrom and Roberts (1986)), in exchange for more favorable transaction prices. We contribute to this literature by allowing both size- and efficiency-signaling simultaneously and by comparing the two directions of equity transactions (issues and repurchases). Novel to the literature is the insight that issuing firms use both transaction size and efficiency as signals, whereas repurchasing firms only signal via transaction size. We also establish that issuing firms prefer to signal via issuing less rather than via issuing with inefficient methods. We show that firms' different objectives to maximize long-term or short-term share prices lead to similar outcomes in issuance, but qualitatively different outcomes in repurchases.

Our analysis covers firms' actions that can be mapped into some combination of size- and efficiency-signaling. While this covers a large fraction of firms' decisions in equity transactions, we acknowledge that it doesn't cover everything. A notable case is Oded (2005), in which good firms announce a repurchase program that drives down medium-term prices because investors face adverse selection from trading against a more informed firm, but drives up long-term prices by the amount of the firm's trading profits; the net result is a redistribution away from shareholders hit by liquidity shocks and towards "patient" shareholders. Related, when shareholders are asymmetrically informed or liquidity constrained, the price formation method is also an interesting consideration, e.g., Comment and Jarrell (1991).[6] Our analysis abstracts away from these ingredients and emphasizes different forces, and is complementary.

Our analysis in Section 5, in which firms directly care about short-term share prices, raises the issue of conflicts of interest between short-term and long-term shareholders. This conflict of interest is present in Oded (2005) in the context of repurchase decisions, and is central to Babenko, Tserlukevich, and Wan (2020), who show that strategic market timing transactions by firms benefit long-term shareholders at the expense of short-term shareholders. Our analysis is complementary, in that we show firms may engage in excessive repurchases in order to boost short-term prices, thereby benefiting short-term shareholders at the expense of long-term shareholders.

Our paper is also related to the literature on firms' choice of equity transaction methods. Brennan and Thakor (1990) and Oded (2011) study firms' choice between tender-offer and open-market

[6] Comment and Jarrell (1991) hypothesize that Dutch-auction TORs and OMRs are weaker signals of undervaluation than fixed-price TORs, and find consistent evidence. We adopt competitive pricing of shares, a standard approach in the literature. In our model in which participating investors are equally uninformed and unconstrained, many alternative price formation methods are equivalent to competitive pricing.

repurchases. In contrast to our model, which studies firms' choice under private information, these papers consider the interaction between informed and uninformed shareholders in their tendering strategies, and emphasize the role of shareholders' endogenous decision to acquire information. For firms raising equity, Burkart and Zhong (2023) compare public offerings and rights offerings; the key driver in their paper is the wealth transfer between constrained and unconstrained shareholders, and there is no efficiency choice in their model. Chemmanur and Fulghieri (1994) model investment banks' endogenous acquisition of information as underwriters, and predict that firms choose underwritten issues over direct issues unless they face little information asymmetry or receive too low an evaluation from the bank to procure its services. In contrast, abstracting from the role of underwriters, we analyze firms' choices between one-off SEOs and smoother ATMs, emphasizing their differences in efficiency in funding corporate investment.

Our paper also speaks to the literature on multi-dimensional signaling/screening. We defer a fuller discussion of this point until Section 3.4.

2 The model

We model share issues and repurchases in a unified framework. Consider a firm with non-negative assets-in-place a and an opportunity to invest i in a new project. The value of assets-in-place, a, is the firm's private information, whereas others only commonly know a prior distribution of a, which admits a density with full support on $[a_{\min}, a_{\max}]$. We refer to a as the firm's type.

The firm plays either an issue game or a repurchase game. In both instances, the firm picks "project size" i. In an issue game, i corresponds to funds raised, and is positive: formally, $i \in [I_L, \infty)$ where $I_L \geq 0$ is a minimum project size. In a repurchase game, i corresponds to funds paid out, and is negative: formally, $i \in (-\infty, -I_L]$ where $I_L \geq 0$ is again a minimum project size. A strictly positive minimum project size $I_L > 0$ in the issue game corresponds to investment opportunities having a minimum viable scale. Similarly, a minimum project size in the repurchase game corresponds to a firm being compelled to pay out at least a minimum amount of cash; for example, if retaining cash above some level would lead to extremely wasteful spending.

(We have fully analyzed the case in which a firm also has the option of $i = 0$, i.e., $|i| \in \{0\} \cup [I_L, \infty)$. In particular, this specification is natural to consider for investment projects. The analysis of this case does not yield additional insights relative to $|i| \in [I_L, \infty)$, and so we focus on this latter case both for transparency, and to preserve symmetry across the analysis of issues and repurchases.)[7]

[7]Effectively, for the issue setting, we are assuming, in terms of formal objects defined below, that if $I_L > 0$, then

$$\Pi\left(a_{\max}, I_L, 1, a_{\min} + S\left(I_L, 1\right)\right) > a_{\max}, \tag{1}$$

i.e., the best firm prefers issuing I_L at full efficiency but at the most unfavorable price over the alternative of doing nothing; along with the analogous assumption for repurchases: if $I_L > 0$, then

$$\Pi\left(a_{\min}, -I_L, 1, a_{\max} + S\left(-I_L, 1\right)\right) > a_{\min}. \tag{2}$$

Both the issue and repurchase games entail equity transactions, specifically, share issues and share repurchases. For reasons outside the model, the firm prefers equity to other securities when raising funds and share repurchases to dividends when paying out cash.[8]

In addition to choosing transaction size i, the firm also chooses among equity transaction methods with different levels of efficiency, captured by the variable $\theta \in [0, 1]$, with efficiency increasing in θ. At an abstract level, the efficiency choice θ can be mapped to many decisions, including, for example, underwriter choice or lock-up provisions.[9] For some empirical applications we focus on a particular dimension of efficiency, namely whether a transaction method matches the need for investment capital or speed of cash flow generation. See Section 4 for full details.

A transaction i carried out with efficiency θ yields surplus $S(i, \theta)$. A firm's value V is the combination of its assets-in-place a, the funds raised or disbursed by the equity transaction i, and transaction surplus S:[10]

$$V(a, i, \theta) = a + i + S(i, \theta). \tag{3}$$

For share repurchases, positive surplus stems from cash being more valuable in the hands of shareholders than in those of the firm, potentially because of taxes, internal agency problems in the firm, or shareholders' liquidity needs.[11] Due to these reasons, a payout of $|i|$ reduces firm value by only $|i| - S(i, \theta)$, delivering (3). For use throughout, we define I^* as the efficiency-maximizing transaction size, $I^* = \arg\max_i S(i, 1)$; and assume $|I^*| > I_L$. A firm with assets-in-place a can only choose (i, θ) such that $V(a, i, \theta) > 0$, i.e., the firm value must be positive after equity transaction,

Under these conditions, results are invariant to adding $i = 0$ to firms' options (see Online Appendix B).

[8]For signaling effects of security design, see the large literature following Nachman and Noe (1994). Taxes are commonly invoked as a reason for firms' preference for share repurchases over dividends. For example, in the US dividends are tax-disadvantaged relative to paying out cash through share repurchases, even after the tax changes associated with the 2003 Jobs and Growth Tax Relief Reconciliation Act; see, for example Chetty and Saez (2005) and Blouin, Raedy, and Shackelford (2011). Allowing for dividends would serve to endogenize the lower boundary $a_{\min}$ of the support of firm types in the repurchase game. Firms at this boundary must be indifferent between paying out dividends, avoiding the costs of information asymmetry but incurring tax and other costs; and playing the equilibrium action characterized by our analysis. Similarly, the possibility of debt issues, rights offerings (Burkart and Zhong, 2023), etc. would endogenize the upper boundary $a_{\max}$ in the issue game.

[9]Choosing a more expensive underwriter reduces the issue proceeds and is less efficient. In contrast, the interpretation of a lock-up period is more intricate. The literature has proposed several reasons for lock-up periods (see, e.g., Brau, Lambson, and McQueen (2005) and Karpoff, Lee, and Masulis (2013)): they may directly impose illiquidity costs on the existing owners, thereby decreasing θ; or they may restrict insider trading and alleviate moral hazard problems, thereby increasing θ. Finally, both underwriter choice and lock-up periods may have their own unique signaling features (other than differences in efficiency) that are complementary to our analysis.

[10]In principle a firm's private information could be either about its assets-in-place a or the profitability of "investment" opportunities S. In the context of share issuance, Myers and Majluf (1984) show that if private information is solely about the investment opportunity then all firms issue and the announcement return is counterfactually 0. In a similar spirit, we analyze in an earlier draft of this paper (available upon request) a case in which all private information concerns investment opportunities, and establish the empirically counterfactual prediction that larger issues and smaller repurchases are associated with higher prices. So consistent with Myers and Majluf (1984), our results suggest that firms likely have private information about assets-in-place, the case we focus on in this paper. We also show that even if firms' private information is about investment opportunities, the central result in Section 3.2 that repurchasing firms do not separate via transaction efficiency remains robust.

[11]See Jensen (1986), Stulz (1990) and Chowdhry and Nanda (1994).

ruling out paying out more cash than the firm can afford even by liquidating all assets. We assume $V(a, I^*, 1) > 0$ for all a.

Surplus S is continuously differentiable, with partial derivatives with respect to i, θ denoted S_i, S_θ. We denote partial derivatives of V analogously. Surplus S satisfies the following mild assumption:

Assumption 1. *The surplus function S satisfies*

(i) $S(0, \theta) = 0$ *and* $S(i, 0) \leq 0$*;*

(ii) $S_\theta(i, \theta) > 0$ *for* $i \neq 0$ *and* $S(i, 1)$ *is single-peaked in* i*;*

(iii) $S_i > -1$*, that is,* $V_i > 0$*.*

Part (i) and the first half of part (ii) are normalizations: zero transaction size and zero efficiency both lead to zero surplus (or less), and surplus is increasing in efficiency. The second half of part (ii) is a mild regularity condition. Part (iii) says that a larger issue size leads to a higher firm value, and a larger repurchase size leads to a lower firm value. In other words: for issues, even if surplus is decreasing in i for some values, surplus is never so strongly decreasing as to offset the direct effect of adding resources i to the firm. Similarly, the surplus generated by increasing repurchases $|i|$ is never enough to offset the direct effect of paying out resources.

We normalize to 1 the number of shares outstanding before any issue or repurchase. Given a transaction price p, the firm needs to issue $\frac{i}{p}$ shares to raise capital i, or repurchase $\frac{|i|}{p}$ shares to disburse $|i|$. A firm's long-term investors' value after equity transaction (i, θ) at price p is

$$\Pi(a, i, \theta, p) = \frac{V(a, i, \theta)}{1 + \frac{i}{p}}. \tag{4}$$

Our baseline analysis covers the standard case in which firms seek to maximize the payoff of long-term investors, i.e., (4).[12] Under this assumption, firms don't have any direct preference over the short-term share price; instead, the price only matters insofar as it affects the revenue/cost of share issues/repurchases.[13] Ceteris paribus, a firm profits more from issuance when its share price is high; but conversely, a firm profits less from a repurchase when its share price is high. Section 5 extends the analysis to consider firms that care about both short- and long-term share prices.

[12] See, for example, Myers and Majluf (1984), Constantinides and Grundy (1989), and Chowdhry and Nanda (1994). When we interpret the surplus S as stemming from repurchases reducing a firm's internal agency problems, we have in mind either repurchase decisions as being made at the board level (in the US, board approval is typically required for repurchase programs) and agency problems occurring below the board and/or repurchase decisions being made by senior executives and agency problems occurring at levels below the firm's senior management.

[13] We assume that managers who make issue/repurchase decisions cannot trade their personal shares before their private information becomes public. For the information content of insider trading around share issues and repurchases, see Leland (1992), Buffa and Nicodano (2008), and Babenko, Tserlukevich, and Vedrashko (2012). We abstract from this aspect and focus on a firm's equity transactions.

For both intuition and formal analysis, it is convenient to take the logarithm of the firm's payoff,

$$\ln \Pi (a, i, \theta, p) = \ln V (a, i, \theta) - \ln \left(1 + \frac{i}{p}\right). \tag{5}$$

That is, firms trade off percentage changes in firm value V with percentage changes in the number of shares outstanding after the equity transaction. The fact that percentage changes are important stems from our focus on equity transactions.

Equity transactions are carried out at the competitively determined price $P(i, \theta)$. That is, after a firm announces its size and efficiency choices (i, θ), competitive investors update their beliefs about the firm type a, $\mu(i, \theta)$, and offer price $P(i, \theta)$ under which they expect to break even:

$$P(i, \theta) = E[\Pi(a, i, \theta, P(i, \theta)) | i, \theta], \tag{6}$$

where expectations are taken using beliefs $\mu(i, \theta)$. The assumption that transactions are carried at the competitively determined price directly implies that any firm that separates in equilibrium makes zero trading profits from the transaction; though the transaction typically yields some surplus via its effect on firm value. Equation (6) is equivalent to

$$P(i, \theta) = E[a|i, \theta] + S(i, \theta). \tag{7}$$

The firm chooses (i, θ) to maximize the payoff of its long-term investors, $\Pi(a, i, \theta, P(i, \theta))$ under the equilibrium price function P.

By design, this framework covers issue and repurchase decisions in a symmetric way. We refer to the case $i \geq I_L \geq 0$ as the *issue game*, and the to case $i \leq -I_L \leq 0$ as the *repurchase game*.

We focus on pure-strategy perfect Bayesian equilibria (PBEs), which consist of each firm type's choices of size and efficiency, $(i(a), \theta(a))$; investor beliefs $\mu(i, \theta)$ associated with each (i, θ); and competitive investors' price function, $P(i, \theta)$, that satisfy the following conditions:

1. Given $P(i, \theta)$, a firm's equilibrium strategy maximizes its long-term shareholders' payoff:

$$(i(a), \theta(a)) \in \arg\max_{i,\theta} \Pi(a, i, \theta, P(i, \theta)).$$

2. The price function $P(i, \theta)$ satisfies (7) with the expectation taken under beliefs $\mu(i, \theta)$.

3. Investor beliefs $\mu(i, \theta)$ satisfy Bayes' rule for any (i, θ) played in equilibrium.

As in many signaling models, the model admits multiple PBEs. In Section 3, we first construct a PBE strategy for each of the repurchase and issue games, and then employ the widely accepted D1 refinement criterion (Cho and Kreps, 1987) to show that the constructed PBE strategies are the only ones supported by "reasonable" off-equilibrium beliefs. Broadly speaking, the D1 refinement says that the off-equilibrium beliefs associated with transaction (i, θ) load on firm types that are most likely to gain by deviating to (i,θ), in the sense that the range of prices for which the deviation is beneficial is largest. Formally, let $\Pi^*(a)$ denote the equilibrium payoff of firm a, and define $D_a(i,\theta)$ as the range of prices p such that firm a prefers equity transaction (i,θ) at price p to $\Pi^*(a)$,

$$D_a(i,\theta) = \{p : \Pi(a,i,\theta,p) > \Pi^*(a)\}. \tag{8}$$

A belief $\mu(i,\theta)$ about an off-equilibrium choice (i,θ) satisfies D1 if its support consists solely of firms for which the corresponding set of supporting prices is as large as possible, i.e., firms a for which there is no $\tilde{a} \neq a$ such that $D_a(i,\theta) \subsetneq D_{\tilde{a}}(i,\theta)$. It is worth noting that one of our central results—the impossibility of separation-via-efficiency in repurchases—does not rely on equilibrium refinements.

Remark: Smooth transactions—that is, OMR and ATM programs—also entail the option of partial completion, since firms can transact smaller quantities than initially announced. As we verify in Online Appendix C, the equilibrium outcomes in Section 3 are robust to firms having this option.[14] For brevity, we abstract from this aspect, and assume that firms transact the full announced amount.

3 Equilibrium characterization

We fully characterize the equilibria of the repurchase and issue games. Specifically, for repurchases, separation-via-efficiency is impossible, while separation-via-size naturally arises: worse firms repurchase less at lower prices. For issues, firms separate by issuing different quantities, with better firms issuing less at higher prices, and the best firms further separating by issuing with inefficient methods at still higher prices. Figure 1 summarizes these results.

3.1 Full information benchmark

As a benchmark, consider the case of a firm's assets a being publicly observed. From (3), (4), (6),

$$P(i,\theta) = \Pi(a,i,\theta,p) = a + S(i,\theta).$$

In this benchmark, and as one would expect, firms choose transaction size $i = I^*$ and efficiency $\theta = 1$ to maximize transaction surplus $S(i,\theta)$. Firm value $V(a,i,\theta)$ is irrelevant to the decision.

[14]Specifically, the equilibrium outcomes in Propositions 2 and 4 are also equilibrium outcomes under the following perturbation of the model. Let $\Theta \subset [0,1]$ be the set of choices of θ that entail the option of partial completion. As in the main model, a firm publicly announces a transaction plan (i,θ), based on which investors price its shares. Different from the main model, if $\theta \in \Theta$ then the firm can privately choose an actual transaction size smaller than the announced size, viz., choose an actual transaction $\left|i^A\right| \in [I_L, |i|]$.

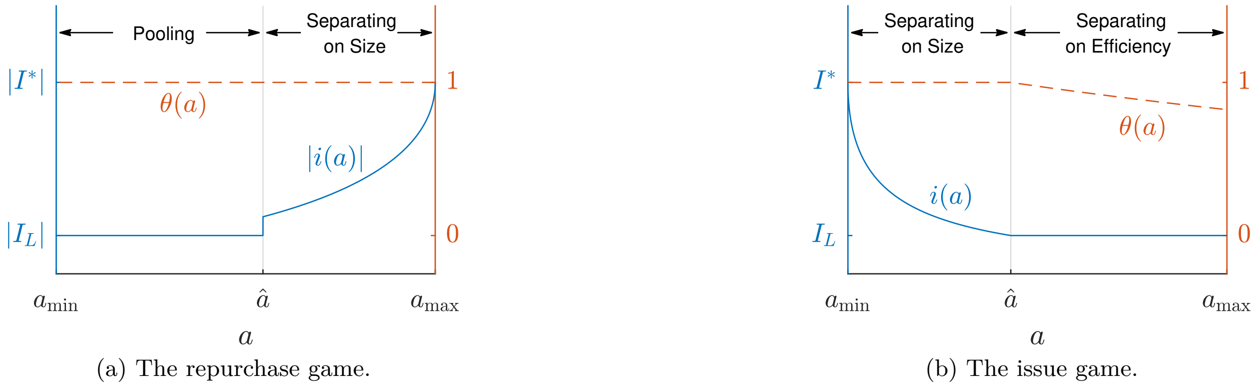

Figure 1: Equilibrium size (lefthand axis) and efficiency (righthand axis) in the repurchase and issue games.

3.2 Repurchases

We first analyze the behavior of firms wishing to pay out funds by repurchasing shares. We start by showing that repurchasing firms are unable to separate from each other by repurchasing with different efficiency levels. As we will see, this impossibility of separation-via-efficiency contrasts sharply with the possibility of such separation by issuing firms that seek to raise funds.

Proposition 1. *In the repurchase game, in any PBE, all firms that repurchase the same size i choose the same efficiency θ.*

To understand the economics behind Proposition 1, suppose to the contrary that there is an equilibrium in which worse firms repurchase at a lower price $P\left(i,\tilde{\theta}\right) < P\left(i,\theta\right)$, though at the cost of using a less efficient method $\tilde{\theta} < \theta$. On the one hand, the resulting sacrifice in firm value V, $S\left(i,\theta\right) - S\left(i,\tilde{\theta}\right)$, represents a smaller fraction of V for a better firm. On the other hand, the percentage change in the number of shares is independent of firm type. Consequently, the lower efficiency choice $\tilde{\theta}$ is more attractive for good firms than bad firms (see (5)), and so an equilibrium of this type cannot exist.

In contrast to Proposition 1's result that firms cannot separate via different efficiency levels, it *is* possible for different firms to repurchase different amounts at different prices. We first construct an equilibrium of this type, and then argue that it is the one most likely to be played.

In equilibrium, all firms repurchase as efficiently as possible, $\theta = 1$. The characterization of the size-separation schedule is standard (e.g., Mailath (1987)). There is no distortion at the "bottom," meaning here that the best firm $a_{\max}$ repurchases the surplus-maximizing amount I^*:

$$\hat{i}\left(a_{\max}\right) = I^*. \tag{9}$$

Worse firms separate by repurchasing less, that is,

$$\hat{i}\left(a\right) > I^* \text{ for } a < a_{\max}, \tag{10}$$

which has the advantage of reducing the repurchase price. Given separation, repurchases are fairly priced: $P(i(a),\theta(a)) = a + S(i(a),\theta(a))$. The equilibrium condition requires that firm a does not want to mimic neighboring firms, so that equilibrium strategy $\hat{i}(a)$ solves the differential equation

$$\frac{d}{d\tilde{a}}\Pi\left(a,\hat{i}(\tilde{a}),1,\tilde{a}+S\left(\hat{i}(\tilde{a}),1\right)\right)\Big|_{\tilde{a}=a} = 0. \tag{11}$$

By straightforward manipulation, (11) simplifies to

$$\frac{\partial\hat{i}(a)}{\partial a} = -\frac{\hat{i}(a)}{V\left(a,\hat{i}(a),1\right)S_i\left(\hat{i}(a),1\right)}. \tag{12}$$

The solution $\hat{i}(\cdot)$ to (9), (10), and (12) is strictly decreasing.

If $a_{\min}$ is close enough to $a_{\max}$ such that (9), (10), and (12) lead to repurchases above the minimum size, i.e., $\hat{i}(a) < -I_L$, for all firms a, then these repurchases constitute an equilibrium strategy.

Next we consider the case in which $a_{\min}$ is further from $a_{\max}$, so that there isn't room for firms to fully separate on repurchase size according to (9), (10), and (12). Instead, there must be a lower interval of firms that pool on the smallest repurchase size. Denote the boundary firm by $\hat{a}$; this firm must be indifferent between separating by repurchasing the amount $\hat{i}(\hat{a})$ determined by (9), (10), and (12), or pooling with firms $[a_{\min},\hat{a})$ and repurchasing the minimum amount, $i = -I_L$.

Formally, define $\hat{a}$ as follows, to encompass both cases. If $\left|\hat{i}(a_{\min})\right| \geq I_L$ then simply define $\hat{a} = a_{\min}$. Otherwise, there exists $a_0 > a_{\min}$ with $\left|\hat{i}(a_0)\right| = I_L$, and this firm strictly prefers repurchasing I_L at a price pooled with lower types to repurchasing $\left|\hat{i}(a_0)\right|$ at the fully revealing price:

$$\Pi(a_0,-I_L,1,E[a|a\leq a_0]+S(-I_L,1)) > a_0 + S\left(\hat{i}(a_0),1\right). \tag{13}$$

In this case, either there is a unique $\hat{a}\in(a_0,a_{\max})$ such that

$$\Pi(\hat{a},-I_L,1,E[a|a\leq\hat{a}]+S(-I_L,1)) = \hat{a} + S\left(\hat{i}(\hat{a}),1\right), \tag{14}$$

or there is no such $\hat{a}$, in which case define $\hat{a} = a_{\max}$.

It is worth highlighting that when the boundary firm $\hat{a}$ is interior it repurchases discretely more than the minimum repurchase size, $\left|\hat{i}(\hat{a})\right| > I_L$. This is because pooling at the minimum repurchase generates a discrete improvement in the repurchase price; firm $\hat{a}$ is therefore indifferent only if the repurchase amount also jumps discretely. Consequently, firms stop separating on size even before reaching the minimum repurchase size. See Figure 1a for an illustration of this case.

Proposition 2. *The repurchase game has a PBE with the following firm strategy: Firms $a > \hat{a}$ repurchase $\left|\hat{i}(a)\right|$ and firms $a < \hat{a}$ repurchase I_L, where $\hat{a}$ and $\hat{i}(\cdot)$ are as defined above; all firms repurchase in the most efficient way ($\theta = 1$).*

Why can repurchasing firms separate using size i even though they cannot separate using efficiency θ? The reason is that even though reducing repurchase size from the surplus-maximizing level I^* and reducing efficiency both reduce transaction surplus, the former increases firm value V while the latter decreases V (see Assumption 1). Consider the case of a worse firm repurchasing a smaller amount $|\tilde{i}| < |i|$, i.e., $\tilde{i} > i$, at a lower price $P\left(\tilde{i}, \theta\right) < P(i, \theta)$. While this smaller repurchase lowers transaction surplus by $S(i, \theta) - S\left(\tilde{i}, \theta\right)$, it increases firm value by $\tilde{i} + S\left(\tilde{i}, \theta\right) - i - S(i, \theta)$, because the firm retains more cash. This increase represents a larger fraction of total value for worse firms. So by (5), a smaller repurchase is more attractive to worse firms, making it a viable signal.

Propositions 1 and 2 represent the principle insights of this subsection. First, separation-via-efficiency is impossible for repurchasing firms. Second, and in contrast, separation-via-size is possible. Although scaling down a repurchase reduces the transaction surplus, just like adopting an inefficient method, doing so *increases* rather than decreases total firm value.

Proposition 2 constructs a particular equilibrium. Importantly, standard refinement arguments suggest it is the most plausible outcome; specifically, it is the unique outcome to satisfy D1:

Proposition 3. *A unique D1 equilibrium of the repurchase game exists, and features the strategy stated in Proposition 2.*

A key implication of the D1 refinement is that all firms that repurchase do so with maximal efficiency $\theta = 1$, which is a strengthening of the no-separation-via-efficiency result in Proposition 1. Similar to the reasoning behind Proposition 1, this follows from the observation that worse firms experience larger (percentage) effects from reducing efficiency. Suppose that, contrary to the claimed result, some firms repurchase using an inefficient method $\tilde{\theta} < 1$. Then these firms would like to deviate and repurchase more efficiently ($\theta = 1$), provided that doing so doesn't significantly increase the repurchase price. The D1 refinement ensures that this condition is met: the gain in firm value, $S(i, 1) - S\left(i, \tilde{\theta}\right)$, is a larger fraction of a worse firm; hence, D1 beliefs about a deviation to $\theta = 1$ are concentrated on worse firms, inducing a price decrease.

3.3 Issues

We now turn to firms that wish to raise funds by issuing shares ($i \geq I_L \geq 0$). We establish an asymmetry with respect to repurchases, namely that separation-via-efficiency is feasible for issuing firms, even though it is not for repurchasing firms. In fact, issuing firms separate via both size and efficiency. In isolation, the economic forces behind issuing firms' separation-via-size and separation-via-efficiency are standard in the literature. Better firms separate by retaining a larger fraction of equity, which is more valuable for them (Leland and Pyle, 1977). Better firms also separate by using inefficient transaction methods, which are less costly to them as a fraction of firm value.

Parallel to the repurchase case, we construct a particular equilibrium (see Figure 1b), and then argue that it is the one most likely to be played. As standard, there is no distortion at the bottom:

the worst firm $a_{\min}$ issues the surplus-maximizing amount I^*:

$$\hat{i}\left(a_{\min}\right) = I^*, \tag{15}$$

using the most efficient method $\theta = 1$. An interval of firms better than $a_{\min}$ separate by scaling down the project, while keeping maximal issue efficiency $\theta = 1$. The construction is the same as for the equilibrium of the repurchase game, with the exception that it starts from the worst firm $a_{\min}$ rather than the best firm $a_{\max}$. Writing $\hat{i}(a)$ for firm a's issue strategy, the function $\hat{i}\left(\cdot\right)$ solves the differential equation (11), which is equivalent to (12), subject to the boundary condition (15) and that

$$\hat{i}\left(a\right) < I^* \text{ for } a > a_{\min}. \tag{16}$$

Note that although repurchase and issue sizes share the same differential equation (12), the prediction on transaction size is reversed across the two cases, with better firms repurchasing more (in absolute values) but issuing less.

Separation on issue size according to (12) continues as long as there is room. Specifically, if $\hat{i}\left(a_{\max}\right) \geq I_L$, all firms separate on issue size; for use below, define $\hat{a} = a_{\max}$. Otherwise, define $\hat{a}$ by $\hat{i}\left(\hat{a}\right) = I_L$. Firms better than $\hat{a}$ issue the minimum amount I_L, and separate by adopting less efficient methods. Specifically, a firm $a > \hat{a}$ adopts efficiency level $\hat{\theta}\left(a\right)$, determined by the differential equation

$$\frac{d}{d\tilde{a}}\Pi\left(a, I_L, \hat{\theta}\left(\tilde{a}\right), \tilde{a} + S\left(I_L, \hat{\theta}\left(\tilde{a}\right)\right)\right)\Big|_{\tilde{a}=a} = 0, \tag{17}$$

subject to the boundary condition

$$\hat{\theta}\left(\hat{a}\right) = 1. \tag{18}$$

Equation (17) simplifies to

$$\frac{\partial\hat{\theta}\left(a\right)}{\partial a} = -\frac{I_L}{V\left(a, I_L, \hat{\theta}\left(a\right)\right) S_\theta\left(I_L, \hat{\theta}\left(a\right)\right)}. \tag{19}$$

Recall that we assume the best firm prefers issuing I_L with efficiency $\theta = 1$ under the worst belief rather than doing nothing (footnote 7). It follows that there is enough room in efficiency choices for all firms above $\hat{a}$ to fully separate, i.e., $\hat{\theta}\left(a\right)$ remains positive for all a.

Proposition 4. *The issue game has a PBE with the following firm strategy: Firms $a \leq \hat{a}$ issue $\hat{i}\left(a\right)$ in the most efficient way ($\theta = 1$), and firms $a > \hat{a}$ issue I_L at efficiency $\hat{\theta}\left(a\right)$, where $\hat{a}$, $\hat{i}\left(\cdot\right)$, and $\hat{\theta}\left(\cdot\right)$ are as defined above.*

In particular, whenever $a_{\min}$ and $a_{\max}$ are far apart that $\hat{a} < a_{\max}$, firms $a \in [\hat{a}, a_{\max}]$ adopt different efficiency levels, in contrast to the impossibility of separation-via-efficiency in the repurchase game.

We conclude this subsection by arguing that the equilibrium outcome described in Proposition 4 is the most plausible one, in the sense that it is the only outcome to satisfy D1. A first step in this argument is that firms separate via size "before" separating via efficiency:

Lemma 1. *In any D1 equilibrium of the issue game, if a firm issues $i > I_L$ then it uses the most efficient method $\theta = 1$.*

The economic intuition for an issuing firm's preference to separate via size is as follows. Suppose to the contrary that in a D1 equilibrium some firm a issues more than the minimum amount, $i > I_L$, but uses an inefficient method $\theta < 1$. By issuing less but transacting more efficiently, the firm can both increase transaction surplus S and reduce its total value V. That is, there exists a deviation to $\tilde{i} < i$ and $\tilde{\theta} > \theta$ such that

$$S\left(\tilde{i}, \tilde{\theta}\right) > S(i, \theta), \tag{20}$$

$$\tilde{i} + S\left(\tilde{i}, \tilde{\theta}\right) < i + S(i, \theta). \tag{21}$$

The economic principle that makes the combination of (20) and (21) possible is that increasing efficiency θ raises transaction surplus and firm value by the same amount; while issuing less leads to a larger reduction in firm value than in surplus.

The percentage reduction in firm value associated with (21) is smaller for better firms. From (5), it follows from D1 that the beliefs associated with this deviation are supported on firms at least as good as a, so the deviation is at least fairly priced for firm a. And since it raises transaction surplus, it raises firm a's payoff.

Lemma 1 establishes a necessary condition for firms to separate using transaction efficiency, that is, the possibilities from size-separation are exhausted. Proposition 5 shows that this condition is also sufficient: once separation-via-size is exhausted, issuing firms indeed switch to separation-via-efficiency. We therefore have a full characterization of the unique D1 equilibrium.

Proposition 5. *A unique D1 equilibrium of the issue game exists, and features the strategy stated in Proposition 4.*

3.4 Relation to Viswanathan (1995)

Lemma 1's ordering of signaling-via-size versus signaling-via-efficiency can be understood as operationalizing Viswanathan (1995)'s "benefit-cost criterion." When multiple signaling devices are available, Viswanathan establishes that the Pareto-optimal separating equilibrium uses the signal with the highest "benefit-cost ratio." Formally, define $\pi(a, i, \theta, \tilde{a}) = \ln \Pi(a, i, \theta, \tilde{a} + S(i, \theta))$. Viswanathan's benefit-cost ratios for issue size and efficiency are, respectively, $\left.\frac{-\pi_{ai}}{\pi_i}\right|_{\tilde{a}=a}$ and $\left.\frac{-\pi_{a\theta}}{\pi_\theta}\right|_{\tilde{a}=a}$.

At first sight, the comparison of these benefit-cost ratios appears opaque. However, this comparison can be expressed entirely in terms of a signal's effect on firm value and transaction surplus:

Lemma 2. *The ordering of* $\left.\frac{-\pi_{ai}}{\pi_i}\right|_{\tilde{a}=a}$ *and* $\left.\frac{-\pi_{a\theta}}{\pi_\theta}\right|_{\tilde{a}=a}$ *matches the ordering of* $\frac{V_i}{S_i}$ *and* $\frac{V_\theta}{S_\theta}$.

In particular, Lemma 2 formalizes the distinct roles of firm value and transaction surplus in determining a signal's attractiveness. Precisely because transaction size i affects firm value not only via transaction surplus S but also directly, it is immediate that transaction size has the more attractive benefit-cost ratio in the issue game, $\frac{V_i}{S_i} = \frac{1+S_i}{S_i} > 1 = \frac{V_\theta}{S_\theta}$, consistent with Lemma 1.

Viswanathan (1995) characterizes Pareto-optimal separating equilibria. Abstract papers such as Engers (1987), Cho and Sobel (1990), and Ramey (1996) in turn show that the D1 refinement typically selects such equilibria.[15]

4 Empirical implications

In this section, we explore the empirical implications of our model. Broadly speaking, there are two ways in which public firms issue seasoned equity in practice. The first method is a one-off SEO, which is typically completed within several weeks.[16] A lesser known but increasingly popular method is an at-the-market offering (ATM). Billett, Floros, and Garfinkel (2019) provide a nice review of ATMs. In an ATM, the firm first registers new shares with the Securities and Exchange Commission (SEC), and then anonymously sells these shares in the secondary market. Compared to SEOs, ATMs take much longer to complete, on average 6.2 quarters. Similarly, firms can repurchase equity in a one-off fashion through a tender-offer repurchase (TOR) within a month.[17] Alternatively, they can carry out an open-market repurchase program (OMR) over a horizon of several years.[18]

The starkest prediction to emerge from our analysis (see Propositions 2 and 4) is:

Prediction 1: A greater variety of transaction methods is used in share issues than in repurchases.

When firms repurchase shares, Proposition 2 shows that they cannot separate by the efficiency of transaction methods. In contrast, when firms issue shares, Proposition 4 shows that firms may adopt both different transaction methods in equilibrium.

Consistent with this prediction, significant amounts of issuance occur via both SEOs and ATMs. Billett, Floros, and Garfinkel (2019) document that ATMs represented 63% incidences and 26% issue proceeds of those for SEOs in 2016. In addition, economically important quantities of equity

[15]For other uses of Pareto-optimality to select among signals in corporate finance settings, see John and Williams (1985), Ambarish, John, and Williams (1987), Besanko and Thakor (1987), Ofer and Thakor (1987), and Williams (1988). Williams (2021) analyzes a seller's choice between signalling via retention and illiquidity in a competitive search model; his results emphasize the role of participation costs of potential investors, which is a dimension that we do not pursue in this paper.

[16]A non-shelf bookbuilt SEO, which accounts for 91% of all SEOs, often takes 2-8 weeks, while an accelerated bookbuilt SEO often takes 2 days from announcement to completion (Gao and Ritter, 2010; Huang and Zhang, 2011).

[17]It takes 25 days on average from announcement of an TOR to the expiration of the offer (Masulis, 1980).

[18]On average, 46.2%, 66.9%, and 73.9% of the target amount is completed by the end of the first, second, and third years, respectively (Stephens and Weisbach, 1998).

are issued via employee stock option grants, restricted stock grants, and in mergers and acquisitions (see Fama and French (2005) and McLean (2011)).

In contrast, an overwhelming fraction of repurchases are OMRs, with only a very small fraction being TORs. For example, in 2004, there were 466 cases of OMR with a total size of $223 billion, while tender offers and Dutch auctions only accounted for 18 and 10 cases, and $1.3 billion and $3.9 billion proceeds respectively (see Banyi, Dyl, and Kahle (2008), and similar patterns documented by Grullon and Ikenberry (2000)). There are also other repurchase methods, including accelerated share repurchase (ASR) or privately negotiated repurchases. King and Teague (2022) show that the dollar amount of ASRs as a fraction of total annual repurchases is consistently less than or around 10%. Furthermore, Bargeron, Kulchania, and Thomas (2011) document that other repurchase methods, such as privately negotiated repurchases, are empirically even rarer than ASRs.

Prediction 1 is independent of which equity transaction method is more efficient (i.e., the mapping between θ and methods). More specific predictions about transaction methods, and their correlation with transaction size and future outcomes, require us to take a stand on how the efficiency parameter θ in the model maps to different methods. While different assumptions are possible here (for example, see Oded (2011)), we argue that efficiency is enhanced by matching the timing of cash inflows and outflows. Specifically, firms typically generate smooth operating cash flows while investment needs are discrete and lumpy. Hence, a one-off SEO is more efficient because it leads to cash inflows that match the lumpiness of capital expenditure outflows; while a smoother ATM is less efficient because the gradual inflow of issuance proceeds is mismatched to investment expenditure outflows, thereby delaying a firm's investment. In contrast, a smoother OMR is more efficient than a one-off TOR precisely because the smooth OMR generates cash outflows that better match the smooth inflow of earnings; while a one-off TOR results in a timing mismatch, leading to an inefficient build-up of cash inside the firm.[19]

We microfound the efficiency gains from matching inflows and outflows as follows. For the issue setting, consider a firm that encounters an investment opportunity at time 0, but lacks funds to undertake it. The project requires minimum investment I_L and exhibits decreasing returns to scale. The firm chooses both an investment amount i, i.e., project scale; and a time t to start the project. The project can only start after the firm has raised funds i. If implemented at time 0, the project generates payoff $f(i)$, which is increasing and concave. As time passes, the project becomes more obsolete (for example, due to the entry of competitors), and the payoff decreases at the rate of α.

[19] Prominent examples of firms using repurchases to distribute smoothly arriving earnings include large technology companies (e.g., Apple, Amazon, Facebook, and Google) and profitable banks (Goldman Sachs, JP Morgan, and Bank of America), among many other companies. Another motive to carry out share repurchases is to distribute one-off cash windfalls, such as lump-sum damage awards from legal disputes, spinoff proceeds, sudden capital structure adjustment, and so on. But these are rare events, and we believe our model captures the majority of repurchase activities. Moreover, Blanchard, Lopez-de-Silanes, and Shleifer (1994) document that for firms receiving cash windfalls "repurchases are generally not open-market, but targeted at large outside shareholders of the firm"; this is consistent with our analysis, in that repurchase efficiency is achieved by matching the timing of cash inflows and outflows.

Defining $\theta(t) = e^{-\alpha t}$, the project's payoff is $f(i)\,\theta(t)$. As such, an immediate SEO corresponds to the highest efficiency level $\theta = 1$, while smoother ATMs correspond to lower efficiency levels.

For the repurchase setting, consider a firm that generates free cash flows at continuous rate λ over a time interval $[0, T]$. Holding cash inside the firm is costly, either because of internal agency problems or due to tax inefficiencies, and generates a rate of return strictly lower than investors' opportunity cost of funds. The firm chooses a total amount to repurchase, $|i|$, and how many dates to spread these repurchases over, $n \leq N$; that is, under payout policy $(|i|, n)$ the firm spends $\frac{|i|}{n}$ on repurchases at dates $\frac{T}{n}, 2\frac{T}{n}, \ldots, T$. At a payout date, divestment from the bad project incurs adjustment cost $\kappa\left(\frac{|i|}{n}\right)^{\gamma}$, where $\kappa > 0$ and $\gamma > 1$ are constants. Hence repurchases create surplus by avoiding the wasteful holding of cash in the firm, while larger repurchases $|i|$ carry larger adjustment costs, dissipating the surplus; and more frequent repurchases (higher n) are more efficient because they better match the arrival of cash inflows, thereby allowing the firm to reduce the costs of accumulated cash balances.[20] In terms of our notation, efficiency θ is simply a (scaled) transformation of the number of repurchase dates n. For more details of this microfoundation see Appendix B.

This formalization allows us to replace Prediction 1 with the more specific:

Prediction 1': Firms issue equity using both SEOs and ATMs, while firms repurchase equity via OMRs.

Relative to Prediction 1, the incremental insight of Prediction 1' is that firms repurchase using OMRs. Empirically, this is overwhelmingly the case, as discussed above.

Proposition 5 also delivers the cross-sectional prediction that a firm carries out larger issues using efficient methods, which in our interpretation corresponds to SEOs. In contrast, for smaller issues a firm sometimes uses more inefficient methods, corresponding to ATM programs. As illustrated in Figure 1b, worse firms separate on size between I^* and I_L, but maintain the most efficient transaction method (SEO). ATMs with varying degrees of efficiency (corresponding to transaction speed) only occur for small-sized issues at I_L. Hence, we have

Prediction 2: SEOs are larger than ATM programs.

Empirically, Billett, Floros, and Garfinkel (2019) document average SEO proceeds of $256 million, which is significantly larger than the average ATM program proceeds of $92 million. The result remains robust after controlling for additional observable factors, including size of the issuing firm.[21]

Since worse firms issue more efficiently (SEO), Proposition 5 (Figure 1b) also implies

Prediction 3: Firms with better unobservable qualities are more likely to use ATM issues.

Consistent with Prediction 3, Hartzell et al. (2019) show in a dataset of REITs that the announce-

[20]In addition, more frequent repurchases reduce the total impact of convex adjustment costs.

[21]See Tables 2 and 4 in Billett, Floros, and Garfinkel (2019) for details.

		Issues		Repurchases	
Method		SEO	ATM	OMR	TOR
	Frequency	One-off	Gradual	Gradual	One-off
	Efficiency	High	Low	High	Low
Predictions 1 and 1'	Used?	Yes	Yes	Yes	No
Prediction 2	Size	Larger	Smaller		
Prediction 3	Firm quality	Worse	Better		
Prediction 4	Info friction	Low	High		

Table 1: Summary of efficiency ranking and empirical predictions for issue and repurchase transactions. Note that the cross method comparisons (Predictions 2-4) only exist between issue transactions, because all repurchase firms in the model use the more efficient method OMR.

ment returns of ATMs are less negative than of SEOs.[22] Billett, Floros, and Garfinkel (2019) use *future* analyst recommendation updates as their proxy for firm quality unobservable to the market at the time of issuance. Their Table 4 shows that ATM firms receive better future analyst recommendation updates than SEO firms.

In our model, the degree of the informational friction is captured by the dispersion of firm types, $a_{\max} - a_{\min}$. Proposition 5 predicts that separation-via-transaction-efficiency arises only when the dispersion of firm types is large ($a_{\max} > \hat{a}$, see Figure 1b). Otherwise, all firms use SEO and separate by issue size. Hence, we have

Prediction 4: Firms facing larger informational frictions are more likely to use ATM issues.

Consistent with Prediction 4, Billett, Floros, and Garfinkel (2019) show that higher levels of information asymmetry, proxied by unexplained current accruals, are indeed associated with the choice of ATM over SEO.

Table 1 summarizes the empirical predictions of our model.

We close this section with a brief discussion of an implication that superficially appears more testable than we believe it is, viz., the prediction of pooling at the minimum transaction size I_L. The difficulty of testing this prediction is that I_L—in common with all parameters of the model—is common knowledge, and so should be understood as being a function of observable firm characteristics. As such, the prediction of pooling at I_L could only be tested by an econometrician who knows how I_L varies with firm characteristics.

[22] That both ATMs and SEOs are followed by negative returns can be generated in our model by relaxing the assumptions of footnote 7 to allow for the possibility that the best firms do not issue any shares.

5 Direct preferences for higher short-term share prices

Many commentators suggest that when public firms repurchase shares they are motivated primarily by a desire to boost their short-term share prices, and that inefficiently excessive repurchases are commonplace.[23] The existing academic literature lacks a coherent account of such behavior. In particular, the direct effect of an inefficiently large repurchase is to decrease a firm's share price (in our notation, see (7)),[24] and any explanation for how an excessive repurchase ends up boosting share prices must overcome this direct effect.

In this section, we show that price-motivated inefficiently large repurchases emerge if we perturb our model to one in which firms have a significant direct preference for higher short-term share prices. In this case, better firms signal quality to investors by excessive repurchases; the information conveyed by the signal dominates the direct cost of the inefficient repurchase. This outcome contrasts with the inefficiently small repurchases in our baseline model. At the same time, and in line with our findings on the asymmetry between repurchases and issues, regardless of the weight firms put on short-term share prices, firms issue inefficiently small amounts, just as in the baseline model.

In addition, we show that regardless of the weight that firms place on short- vs long-term share prices, repurchasing firms pool on transaction efficiency θ, while issuing firms separate along this dimension.

Concretely, in this section we analyze an extension of our baseline model in which firms have Cobb-Douglas preferences over short-term and long-term share prices, i.e.,

$$\Pi(a, i, \theta, p) = p^{\epsilon} \left(\frac{V(a, i, \theta)}{1 + \frac{i}{p}} \right)^{1-\epsilon}, \tag{22}$$

where the weight $\epsilon \in [0, 1)$ reflects the degree to which firms care about their share prices directly.[25]

[23]See, for example, "Are Stock Buybacks Starving the Economy?" (Lowrey, The Atlantic, 2018); "End Stock Buybacks, Save the Economy" (Lazonick and Jacobson, New York Times, 2018); and "Profits Without Prosperity" (Lazonick, Harvard Business Review, 2014), which asserts that "[c]orporate profitability is not translating into widespread economic prosperity. The allocation of corporate profits to stock buybacks deserves much of the blame."

[24]The mechanism that at least some commentators appear to have in mind through which repurchases boost share prices is that repurchases increase earnings-per-share (EPS). For example, the aforementioned article in the Harvard Business Review states that repurchases "enable [a] company to hit quarterly earnings per share (EPS) targets," while Eisen and Otani (the Wall Street Journal, 2018) state "Share repurchases can play a key role in supporting stock prices because they lower the number of shares outstanding—driving up per-share earnings even without overall profit growth." Related, Almeida, Fos, and Kronlund (2016) present evidence that firms indeed distort decisions in order to meet analysts' EPS forecasts.

[25]The specific Cobb-Douglas form of preferences in (22) is unimportant, and most results extend to linear preferences

$$\Pi(a, i, \theta, p) = \epsilon p + (1 - \epsilon) \left(\frac{V(a, i, \theta)}{1 + \frac{i}{p}} \right). \tag{23}$$

Specifically, under linear preferences, our central result that repurchasing firms don't separate via the efficiency of transaction methods continues to hold; moreover, under the assumptions that S is concave in i and the extent of asymmetric information $a_{\max} - a_{\min}$ isn't too large, the equilibria we characterize in Propositions 6 and 7 remain

The case $\epsilon = 0$ corresponds to our baseline analysis where firms act in the interest of long-term shareholders. In contrast, in cases $\epsilon > 0$ firms have a direct preference for higher short-term share prices.

5.1 Repurchases

We first consider the repurchase game. We establish that, regardless of firms' weight on short-term share prices, firms pool on transaction efficiency, and partially separate by repurchase size. For separating firms, equilibrium repurchase decisions satisfy the differential equation (11), which rewrites to

$$\frac{\partial \hat{i}(a)}{\partial a} = -\frac{\epsilon V\left(a, \hat{i}(a), 1\right) + (1-\epsilon)\,\hat{i}(a)}{V\left(a, \hat{i}(a), 1\right) S_i\left(\hat{i}(a), 1\right)}, \tag{24}$$

thereby generalizing (12).

Equation (24) might appear to suggest that the relative weight ϵ that firms place on short- and long-term share prices doesn't qualitatively affect the equilibrium, but this is not the case. Instead, if firms place little weight on short-term prices then, as in our baseline analysis, firms separate by repurchasing inefficiently small amounts. In contrast, if firms heavily weight short-term share prices then firms separate by repurchasing inefficiently large amounts, $|i| > |I^*|$. Formally, for $\underline{\epsilon} = \min_{i \in [I^*, -I_L]} \frac{-i}{a_{\max} + S(i,1)}$ and $\bar{\epsilon} = \frac{-I^*}{a_{\min} + S(I^*,1)}$, which satisfy $0 < \underline{\epsilon} < \bar{\epsilon} < 1$ if $I_L > 0$:[26]

Proposition 6. *In the repurchase game:*

(i) For $\epsilon \in [0,1)$, in any D1 equilibrium, all repurchasing firms choose maximal efficiency $\theta = 1$.

(ii) If $\epsilon \in [0, \underline{\epsilon})$, there is a unique D1 equilibrium, in which a firm's strategy takes the same form as in the case of $\epsilon = 0$ except that ODE (12) generalizes to (24); In particular, $|i(a)| < |I^*|$ for all $a < a_{\max}$.

(iii) If $\epsilon \in (\bar{\epsilon}, 1)$, there is a unique D1 equilibrium, in which firms separate on repurchase sizes according to (24), the boundary condition $\hat{i}(a_{\min}) = I^*$, and the condition that $|i(a)| > |I^*|$ for $a > a_{\min}$.

To understand the economics behind the contrast between Proposition 6(ii) and (iii), it is easiest to first return to the baseline case of $\epsilon = 0$, and see why separation on transaction size doesn't entail inefficiently large repurchases. Separation of this kind would entail better firms repurchasing more than worse firms, and hence suffering more inefficiency than worse firms. But this cannot be

equilibria. The main drawback to adopting linear preferences is that characterizing the unique equilibrium via use of the D1 refinement becomes intractable. Formal results are presented in a prior draft that is available on request.

[26] Analogous to footnote 7, we make simplifying assumptions to ensure all types participate: In the issue game, if $I_L > 0$, we assume condition (1) holds; In the repurchase game, if $I_L > 0$, then

$$\Pi\left(a_{\min}, -I_L, 1, a_{\max} + S\left(-I_L, 1\right)\right) > \Pi\left(a_{\min}, 0, 1, a_{\max}\right). \tag{25}$$

an equilibrium outcome, because better firms would gain from reducing their repurchase amounts and mimicking worse firms; doing so both increases efficiency (higher transaction surplus S) and results in a lower and hence more favorable repurchase price. This logic extends straightforwardly to the case of small positive weights ϵ on the short-term price.

In contrast, consider next the case of firms that heavily weight (large ϵ) short-term prices. Here, firms' net preference is for a higher short-term price; the direct preference for a high price dominates the cost that high repurchase prices impose on long-term value. So the question becomes: if better firms separate by issuing inefficiently large amounts, why don't worse firms mimic them? Analogous to arguments from our baseline analysis, the reason is that an inefficiently large repurchase is proportionally more costly (as a fraction of firm value) for worse firms than for better firms.

As noted, Proposition 6(iii) fits well with anecdotal and informal accounts of firms repurchasing inefficiently large amounts in order to boost short-term prices. But these informal accounts skirt over the mechanism by which excessive repurchases actually increase short-term prices, which is far from obvious: after all, a fairly-priced repurchase affects the price only through transaction surplus S, and if this is negative, as alleged, then prices would fall rather than rise.

One possible way to empirically determine whether part (ii) or (iii) of Proposition 6 applies is to examine the effect of repurchases on the firm's marginal value of cash, i.e., marginal q. That is, part (ii) predicts a low marginal value of cash ($q<1$) after a repurchase, while part (iii) predicts a high marginal value ($q>1$.) Wang, Yin, and Yu (2021) give cross-country evidence that repurchases boost stock prices at the expense of lowering profitability, growth, and innovation, all of which are broadly consistent with firms heavily cutting investment (and thereby increasing the marginal value of cash), and hence with part (iii), viz., a high weight on short-term share prices. Gala, Gomes, and Liu (Forthcoming) estimate that the marginal q of US firms has increased from below 1 in the past to above 1 in the present; and a cross-sectional version of their analysis has the potential to shed light on whether Proposition 6(ii) or (iii) applies.[27]

A more nuanced aspect of the result is that, for large weights ϵ on short-term prices, a good firm could alternatively separate by adopting an inefficient repurchase method (low θ). But the D1 refinement implies that firms separate via inefficiently large repurchases instead of via inefficient methods. The argument is again analogous to those in our baseline analysis. If a firm adopts an inefficient repurchase method, then consider a deviation by that firm to a more efficient method but a larger (and hence more inefficient) repurchase, with the net effect being an increase in transaction surplus but a decrease in firm value. This deviation is proportionally more costly for worse firms, and so by D1 investors interpret such a deviation as coming from good firms, thereby ensuring that the deviation is indeed attractive. Moreover, in this case, firms never "run out of room" to separate

[27] Wang, Yin, and Yu (2021) also find that repurchases are associated with a lower long-run Tobin's Q. The question of whether Tobin's Q is a good proxy for marginal q is a long-standing one; again, see Gala, Gomes, and Liu (Forthcoming).

on repurchase size, because as repurchases grow larger, the marginal cost of further repurchases grows large, and so even small incremental repurchases carry substantial signaling power.[28]

5.2 Issues

In the issue game, outcomes under the baseline case of $\epsilon = 0$ remain qualitatively unchanged if instead firms directly care about short-term share prices ($\epsilon > 0$). The reason is that issuing firms prefer to issue at a high price even in the baseline case, and introducing a direct preference for short-term prices only strengthens this desire.

Proposition 7. *In the issue game, for any $\epsilon \in [0, 1)$, there is a unique D1 equilibrium, in which a firm's strategy takes the same form as in the case of $\epsilon = 0$ except that ODE (12) generalizes to (24) and ODE (19) generalizes to*

$$\frac{\partial \hat{\theta}(a)}{\partial a} = -\frac{\epsilon V\left(a, I_L, \hat{\theta}(a)\right) + (1-\epsilon) I_L}{V\left(a, I_L, \hat{\theta}(a)\right) S_\theta\left(I_L, \hat{\theta}(a)\right)}. \tag{26}$$

In particular, Proposition 7 establishes that firms' equilibrium issuance decisions are too small, in contrast to the finding for repurchases in the large-ϵ case. Concretely, better firms are unable to separate from worse firms by issuing inefficiently large amounts. This is a consequence of Assumption 1(iii), which states that firm value V is increasing in the issuance amount, even though transaction surplus drops for issues $i > I^*$. Consequently, if a good firm a prefers to issue a larger amount over a smaller amount then the same is true for every firm of lower quality $\tilde{a} < a$, for which the increase in firm value is proportionally larger.

6 Discussion

6.1 Transaction fees

One of our key theoretical insights is that when firms issue or repurchase equity, signaling through inefficient transaction methods is fundamentally different from signaling through reduction in transaction size. Some other actions can be modeled as combinations of these two signals, and hence can be incorporated and understood in our framework. For example, a firm paying a transaction fee c out of the amount of a payout $|i|$ can be interpreted as simultaneously reducing repurchase surplus to $S - c$ and repurchase size to $|i| - c$. If firms can choose the amount of transaction fee c (with i and θ fixed), they may separate on different transaction fees in equilibrium due to the

[28] Economically, it is increasingly costly for worse firms to mimic better firms. Formally, the numerator in the ODE (24) becomes small as $\hat{i}$ becomes more negative and V correspondingly decreases. In contrast, in our main analysis issuing firms may run out of room to separate on transaction size because many projects have a natural minimum scale (Propositions 4 and 5).

effect of c on repurchase sizes. But when firms can directly choose different repurchase sizes, they separate only on repurchase sizes and pool on these other dimensions such as transaction fees.

6.2 Policy implications

ATM offerings were rarely used until regulatory changes in 2005 and 2008 made them more accessible.[29] Since then, the use of ATMs has risen sharply (Billett, Floros, and Garfinkel, 2019). The regulatory changes reflected the SEC's intention to "allow more companies to benefit from the greater flexibility and efficiency in accessing the public securities market" (Securities and Exchange Commission, 2007). In line with this intention, Gustafson and Iliev (2017) find that after the 2008 deregulation, treated firms (listed firms with public floats under \$75 million) raised more public equity and increased capital expenditure.

Our model implies that even though lifting the barriers to ATMs may allow firms to invest more by issuing more equity, total surplus (welfare) may decrease.[30] To show this, here we consider an "SEO-only" issue game where $\theta = 1$ is the only available issue method (following our interpretation in Section 4), and compare it to our baseline results in Section 3.3, corresponding to the case where the barriers to ATMs are lifted.

Let $\hat{a}$ be the cutoff firm type in the baseline model (see page 13), above which firms separate on issue sizes and use method $\theta = 1$, and below which firms issue I_L and separate on different methods $\theta < 1$. If $\hat{a} = a_{\max}$, then the baseline model and the SEO-only game generate the same outcomes: all firms issue different sizes with SEOs. If $\hat{a} < a_{\max}$, then in the SEO-only game, there is a cutoff firm type $\check{a} < \hat{a}$ such that firms below $\check{a}$ take the same actions as in the baseline model, using SEOs and separating on different issue sizes; whereas types above $\check{a}$ act differently from the baseline model, pooling on issuing the minimum size I_L using SEOs. See Online Appendix D.

Compared with the SEO-only game, when ATMs are allowed, intermediate firms $a \in (\check{a}, \hat{a})$ issue and invest more, which increases surplus. This is consistent with the above empirical findings of Gustafson and Iliev (2017). On the other hand, the best firms $a > \hat{a}$ use less efficient issue methods. Consequently, the net effect of allowing ATMs on total surplus is ambiguous.[31]

[29] In 2005, the SEC Securities Offering Reform liberalized the filing requirements when firms "take securities down" from a shelf registration of equity offerings, allowing takedowns without review or delay by the SEC. This opened the door to ATMs, which involve frequent takedowns off a shelf. In 2008, the SEC expanded the eligibility of shelf offerings including ATMs to firms with public floats under \$75 million.

[30] Beyond making ATMs practically feasible, the 2005 and 2008 SEC rules also relaxed restrictions on shelf offerings in general, including shelf SEOs. Our discussion here is restricted to the effects of allowing ATMs.

[31] Our analysis assumes that all firms prefer issuing shares over doing nothing even under the worst market belief (see footnote 7). In general, allowing ATMs could also lead to additional share issuance and investment by firms who would otherwise forgo the investment opportunity.

7 Conclusion

We analyze issue and repurchase transactions side-by-side, under the assumption that firms have superior knowledge about their values, and choose both transaction size and method. The comparison of issues and repurchases is new to the literature, and yields fresh insights. First, despite the conceptual symmetry between issue and repurchase transactions, their equilibrium outcomes aren't mirror images of each other. In particular, repurchasing firms do not signal via the efficiency of transaction methods while issuing firms do. Second, and in contrast, reducing repurchase size is a viable signal for repurchasing firms, just as reducing issue size is a viable signal for issuing firms. These implications fit well with empirical evidence. Third, managers' short- v.s. long-term objectives lead to similar outcomes for share issues but qualitatively different outcomes for repurchases; specifically, short-term oriented firms engage in excessive repurchases. Fourth, and more conceptually, our analysis isolates a precise formal role for firm value in equity transactions.

While our model covers many aspects of firms' issue and repurchase decisions (in particular, we make only mild assumptions on the surplus function S, and the efficiency choice θ can be interpreted in a wide range of ways), it nonetheless omits important topics that would be interesting for future research. One promising avenue is to embed our analysis of firms' payout and funding costs into a setting in which future investment needs are uncertain and both carrying cash and raising financing are costly; see, e.g., Bolton, Chen, and Wang (2011) and Décamps et al. (2017) for settings of this type with exogenously specified costs.

Another interesting direction to consider is firms' strategic disclosure of information. In this paper, we focus on signaling through equity transactions and abstract away from firms' direct information disclosures. For instance, firms may strategically disclose good (bad) information before issuing (repurchasing) shares. How do these activities interact with firms' choices about transaction size and method? We look forward to future work that can speak to these questions.

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Appendix

A Proofs of results stated in main text

Proofs of Lemmas stated in this Appendix are relegated to Online Appendix A.

Some of the Lemmas and Corollaries below are established for the generalized firm's objective function (22) with $\epsilon \in [0, 1)$. Note that they also applies to the objective function (4), which is the special case of (22) with $\epsilon = 0$.

Lemma A1. *Under the generalized firm's objective function (22) with $\epsilon \in [0, 1)$, in both issue and repurchase games, the ratio*

$$\frac{\Pi(a, i_1, \theta_1, p_1)}{\Pi(a, i_2, \theta_2, p_2)}$$

is strictly increasing (constant) in a if

$$i_1 + S(i_1, \theta_1) < (=) i_2 + S(i_2, \theta_2).$$

Proof of Proposition 1: Fix an equilibrium. We show: There cannot exist sets of firms A and $\tilde{A}$ such that firms in A play (i, θ) and firms in $\tilde{A}$ play $\left(i, \tilde{\theta}\right)$ where $\tilde{\theta} < \theta$. The proof is by contradiction; suppose to the contrary that sets A and $\tilde{A}$ exist.

Firms in $\tilde{A}$ prefer $\left(i, \tilde{\theta}\right)$ to (i, θ). By Lemma A1, it follows that any firm $a > \inf \tilde{A}$ strictly prefers $\left(i, \tilde{\theta}\right)$ to (i, θ). Since firms in A prefer (i, θ) to $\left(i, \tilde{\theta}\right)$, it follows that $\sup A \leq \inf \tilde{A}$. Consequently,

$$P(i, \theta) \leq \inf \tilde{A} + S(i, \theta). \tag{A1}$$

$$P\left(i, \tilde{\theta}\right) \geq \inf \tilde{A} + S\left(i, \tilde{\theta}\right). \tag{A2}$$

Consider an arbitrary firm $\tilde{a} \in \tilde{A}$. Because repurchasing firms prefer lower transaction prices,

$$\Pi(\tilde{a}, i, \theta, P(i, \theta)) \geq \Pi(\tilde{a}, i, \theta, \tilde{a} + S(i, \theta)) = \tilde{a} + S(i, \theta) > \tilde{a} + S\left(i, \tilde{\theta}\right) = \Pi\left(\tilde{a}, i, \tilde{\theta}, \tilde{a} + S\left(i, \tilde{\theta}\right)\right), \tag{A3}$$

where the inequalities follow from (A1) and $\theta > \tilde{\theta}$. To complete the proof, choose $\tilde{a} \in \tilde{A}$ such that

$$\Pi(\tilde{a}, i, \theta, P(i, \theta)) - \Pi\left(\tilde{a}, i, \tilde{\theta}, \tilde{a} + S\left(i, \tilde{\theta}\right)\right) > \Pi\left(\tilde{a}, i, \tilde{\theta}, P\left(i, \tilde{\theta}\right)\right) - \Pi\left(\tilde{a}, i, \tilde{\theta}, \tilde{a} + S\left(i, \tilde{\theta}\right)\right). \tag{A4}$$

Such a choice is possible because by (A3) the LHS of (A4) is at least $S(i, \theta) - S\left(i, \tilde{\theta}\right) > 0$, and by (A2) the RHS of (A4) can either be made weakly negative (if $\min \tilde{A}$ exists, or if (A2) holds strictly), or else can be made arbitrarily small. Inequality (A4) says that firm $\tilde{a}$ prefers (i, θ) to $\left(i, \tilde{\theta}\right)$, a contradiction. This completes the proof.

Lemma A2. *Under the generalikzed firm's objective function (22) with $\epsilon \in [0, \underline{\epsilon})$, in the repurchase game, there is $a_0 < a_{\max}$ such that conditions (9), (10) and (24) (which reduces to (12) when*

$\epsilon = 0$) determine a unique $\hat{i}(a) \in [I^*, -I_L]$ for each $a \in [a_0, a_{\max}]$, with a_0 satisfying $a_0 = a_{\min}$ or $\hat{i}(a_0) = -I_L$. Moreover, $\frac{\partial \hat{i}(a)}{\partial a} < 0$.

Lemma A3. *Under the generalized firm's objective function (22) with $\epsilon \in [0,1)$, in both issue game and repurchase game, an interval of firm types A do not benefit from mimicking each other if all the following conditions are satisfied: $i(a)$ is continuous on A; $\frac{\partial i(a)}{\partial a} \leq 0$ for $a \in A$ except for countable points; for a in the interior of A,*

$$\frac{dS(i(a), \theta(a))}{da} = -\frac{\epsilon V(a, i(a), \theta(a)) + (1-\epsilon) i(a)}{V(a, i(a), \theta(a))}, \tag{A5}$$

which in the case $\epsilon = 0$ reduces to

$$\frac{dS(i(a), \theta(a))}{da} = -\frac{i(a)}{V(a, i(a), \theta(a))}; \tag{A6}$$

$P(i(a), \theta(a)) = a + S(i(a), \theta(a))$ for $a \in A$; and if the game is a repurchase game then $\theta(a)$ is a constant on A.

Proof of Proposition 2: By Lemma A2, the firm's strategy $\hat{i}(\cdot)$ is well defined.

To complete the description of the PBE, we specify off-equilibrium beliefs. Consider an off-equilibrium action $\left(\tilde{i}, \tilde{\theta}\right)$. If $\tilde{i} + S\left(\tilde{i}, \tilde{\theta}\right) = \hat{i}(a) + S\left(\hat{i}(a), 1\right)$ for some firm type $a \geq \hat{a}$ then the associated off-equilibrium belief loads on type a. If $\tilde{i} + S\left(\tilde{i}, \tilde{\theta}\right) > \sup_{a \geq \hat{a}} \hat{i}(a) + S\left(\hat{i}(a), 1\right)$ then the associated off-equilibrium belief loads on type $\hat{a}$. If $\tilde{i} + S\left(\tilde{i}, \tilde{\theta}\right) < \inf_{a \geq \hat{a}} \hat{i}(a) + S\left(\hat{i}(a), 1\right)$ then the associated off-equilibrium belief loads on type $a_{\max}$.

Step 1. No firm has the incentive to deviate to an in-equilibrium action.

From Lemma A3, types $a \geq \hat{a}$ do not gain by deviating to $\hat{i}(\tilde{a})$ for $\tilde{a} \geq \hat{a}$. This step then follows immediately if $\hat{a} = a_{\min}$. If $\hat{a} = a_{\max}$ then all firms play $-I_L$ and there is nothing to prove. So it remains to deal with the case $\hat{a} \in (a_{\min}, a_{\max})$. For any $a > \hat{a}$, $\hat{i}(a) < \hat{i}(\hat{a}) < -I_L$, and Assumption 1(iii) implies

$$\hat{i}(a) + S\left(\hat{i}(a), 1\right) < \hat{i}(\hat{a}) + S\left(\hat{i}(\hat{a}), 1\right) < -I_L + S(-I_L, 1).$$

By construction, firm $\hat{a}$ is indifferent between transactions $\hat{i}(\hat{a})$ and $-I_L$:

$$\frac{\Pi\left(\hat{a}, \hat{i}(\hat{a}), 1, \hat{a} + S\left(\hat{i}(\hat{a}), 1\right)\right)}{\Pi(\hat{a}, -I_L, 1, E[a|a \leq \hat{a}] + S(-I_L, 1))} = 1. \tag{A7}$$

By Lemmas A1 and A3, it follows that for $a > \hat{a}$

$$\frac{\Pi^*(a)}{\Pi\left(a, \hat{i}(\hat{a}), 1, \hat{a} + S\left(\hat{i}(\hat{a}), 1\right)\right)} \frac{\Pi\left(a, \hat{i}(\hat{a}), 1, \hat{a} + S\left(\hat{i}(\hat{a}), 1\right)\right)}{\Pi(a, -I_L, 1, E[a|a \leq \hat{a}] + S(-I_L, 1))} > 1,$$

i.e., firms $a > \hat{a}$ prefer their equilibrium payoff to repurchasing $-I_L$. Similarly, for any $\tilde{a} < \hat{a}$ and $a > \hat{a}$, (A7) and Lemma A3 implies firm $\hat{a}$ weakly prefers repurchasing $-I_L$ to repurchasing $\hat{i}(a)$:

$$\frac{\Pi\left(\hat{a}, -I_L, 1, E\left[a|a \leq \hat{a}\right] + S\left(-I_L, 1\right)\right)}{\Pi\left(\hat{a}, \hat{i}\left(a\right), 1, a + S\left(\hat{i}\left(a\right), 1\right)\right)} \geq 1,$$

and A1 implies

$$\frac{\Pi\left(\tilde{a}, -I_L, 1, E\left[a|a \leq \hat{a}\right] + S\left(-I_L, 1\right)\right)}{\Pi\left(\tilde{a}, \hat{i}\left(a\right), 1, a + S\left(\hat{i}\left(a\right), 1\right)\right)} > 1,$$

i.e., firms $\tilde{a} < \hat{a}$ prefer transaction$-I_L$ to any transaction in $\left\{\hat{i}\left(a\right) : a \geq \hat{a}\right\}$.

Step 2. No firm has the incentive to deviate to an off-equilibrium action.

Consider an off-equilibrium action $\left(\tilde{i}, \tilde{\theta}\right)$.

Case: $\tilde{i} + S\left(\tilde{i}, \tilde{\theta}\right) = \hat{i}\left(a\right) + S\left(\hat{i}\left(a\right), 1\right)$ for some firm type $a \geq \hat{a}$. Note that $\tilde{\theta} < 1$, since otherwise the action is in-equilibrium. Note moreover that $\tilde{i} > \hat{i}\left(a\right)$, since otherwise Assumption 1(ii), (iii) implies $\tilde{i} + S\left(\tilde{i}, \tilde{\theta}\right) < \hat{i}\left(a\right) + S\left(\hat{i}\left(a\right), 1\right)$. Since $\hat{i}\left(a\right) \geq I^*$, Assumption 1(ii) further implies $S\left(\tilde{i}, \tilde{\theta}\right) < S\left(\hat{i}\left(a\right), 1\right)$. Under the stated off-equilibrium beliefs, both $\left(\hat{i}\left(a\right), 1\right)$ and $\left(\tilde{i}, \tilde{\theta}\right)$ are fairly priced from firm a's perspective, and so firm a strictly prefers $\left(\hat{i}\left(a\right), 1\right)$ because it generates greater surplus. By Lemma A1, it follows that all firm types strictly prefer $\left(\hat{i}\left(a\right), 1\right)$ to $\left(\tilde{i}, \tilde{\theta}\right)$. Step 1 and transitivity together imply that all firm types strictly lose by deviating to $\left(\tilde{i}, \tilde{\theta}\right)$.

Case: $\tilde{i} + S\left(\tilde{i}, \tilde{\theta}\right) > \sup_{a \geq \hat{a}} \hat{i}\left(a\right) + S\left(\hat{i}\left(a\right), 1\right)$. Assumption 1(ii),(iii) implies $\tilde{i} > \hat{i}\left(\hat{a}\right)$. Consequently $S\left(\tilde{i}, \tilde{\theta}\right) < S\left(\hat{i}\left(a\right), 1\right)$. Under the stated off-equilibrium beliefs, both $\left(\hat{i}\left(\hat{a}\right), 1\right)$ and $\left(\tilde{i}, \tilde{\theta}\right)$ are fairly priced from firm $\hat{a}$'s perspective, and so firm $\hat{a}$ strictly prefers $\left(\hat{i}\left(\hat{a}\right), 1\right)$ because it generates greater surplus. By Lemma A1, it follows that all firm types $a \geq \hat{a}$ strictly prefer $\left(\hat{i}\left(\hat{a}\right), 1\right)$ to $\left(\tilde{i}, \tilde{\theta}\right)$. Step 1 and transitivity together imply that all firm types $a \geq \hat{a}$ strictly lose by deviating to $\left(\tilde{i}, \tilde{\theta}\right)$.

If $\hat{a} = a_{\min}$ this case is complete. If instead $\hat{a} > a_{\min}$ then (14) holds with $\leq$, i.e., type $\hat{a}$ weakly prefers $\left(-I_L, 1\right)$ to $\left(\hat{i}\left(\hat{a}\right), 1\right)$. From above, it follows that $\hat{a}$ prefers $\left(I_L, 1\right)$ to $\left(\tilde{i}, \tilde{\theta}\right)$. By Assumption 1(ii),(iii), $\tilde{i} + S\left(\tilde{i}, \tilde{\theta}\right) < -I_L + S\left(-I_L, 1\right)$. By Lemma A1, types $a < \hat{a}$ also prefer $\left(-I_L, 1\right)$ to $\left(\tilde{i}, \tilde{\theta}\right)$, completing this case.

Case: $\tilde{i} + S\left(\tilde{i}, \tilde{\theta}\right) < \inf_{a \geq \hat{a}} \hat{i}\left(a\right) + S\left(\hat{i}\left(a\right), 1\right)$.

Under the stated off-equilibrium beliefs the deviation $\left(\tilde{i}, \tilde{\theta}\right)$ is fairly priced for firm $a_{\max}$, and so

$$\Pi\left(a_{\max}, \tilde{i}, \tilde{\theta}, P\left(\tilde{i}, \tilde{\theta}\right)\right) = a_{\max} + S\left(\tilde{i}, \tilde{\theta}\right) \leq a_{\max} + S\left(I^*, 1\right), \tag{A8}$$

where the inequality follows from the definition of I^*.

Subcase: $\hat{a} = a_{\max}$. By construction

$$a_{\max} + S(I^*, 1) \leq \Pi(a_{\max}, -I_L, 1, E[a] + S(-I_L, 1)).$$

Combined with (A8), it follows that firm $a_{\max}$ strictly prefers $(-I_L, 1)$ to $(\tilde{i}, \tilde{\theta})$. By Lemma A1, the same is true for all firms $a < a_{\max}$.

Subcase: $\hat{a} < a_{\max}$: Firm $a_{\max}$ is the only firm repurchasing $(I^*, 1)$, and so the transaction is fairly priced and $\Pi(a_{\max}, I^*, 1, P(I^*, 1)) = a_{\max} + S(I^*, 1)$. From (A8), firm $a_{\max}$ prefers $(I^*, 1)$ to $(\tilde{i}, \tilde{\theta})$. By Assumption 1(iii), $\inf_{a \geq \hat{a}} \hat{i}(a) + S(\hat{i}(a), 1) = I^* + S(I^*, 1)$; hence Lemma A1 implies that firms $a < a_{\max}$ strictly prefer $(I^*, 1)$ to $(\tilde{i}, \tilde{\theta})$. Step 1 and transitivity together imply that all firm types a strictly lose by deviating to $(\tilde{i}, \tilde{\theta})$. This completes the proof.

Lemma A4. *Under the generalized firm's objective function (22) with $\epsilon \in [0, 1)$, in an equilibrium of the issue or repurchase game, the price of an off-equilibrium action $(\tilde{i}, \tilde{\theta})$ satisfies D1 if and only if both the following conditions are met:*

For any firm type a whose equilibrium choice $(i(a), \theta(a))$ satisfies

$$\tilde{i} + S(\tilde{i}, \tilde{\theta}) < i(a) + S(i(a), \theta(a)), \tag{A9}$$

$P(\tilde{i}, \tilde{\theta})$ satisfies

$$P(\tilde{i}, \tilde{\theta}) \geq a + S(\tilde{i}, \tilde{\theta}); \tag{A10}$$

For any firm type a whose equilibrium choice $(i(a), \theta(a))$ satisfies

$$\tilde{i} + S(\tilde{i}, \tilde{\theta}) > i(a) + S(i(a), \theta(a)), \tag{A11}$$

$P(\tilde{i}, \tilde{\theta})$ satisfies

$$P(\tilde{i}, \tilde{\theta}) \leq a + S(\tilde{i}, \tilde{\theta}). \tag{A12}$$

Lemma A1 implies:

Corollary 1. *Under the generalized firm's objective function (22) with $\epsilon \in [0, 1)$, in any equilibrium of the issue or repurchase game, $i(a) + S(i(a), \theta(a))$ is weakly decreasing in a.*

Lemma A5. *Under the generalized firm's objective function (22) with $\epsilon \in [0, 1)$, in an equilibrium of the issue or repurchase game, if there is an interval of firm types A on which size and efficiency choices $i(a)$ and $\theta(a)$ are continuous, and the choices fully reveal a firm's type, then (A5) holds on A. If $\epsilon = 0$, then (A5) reduces to (A6).*

Proof of Proposition 3: First, we show that the PBE specified in Proposition 2 (with off-equilibrium beliefs as specified at the start of its proof) satisfies D1. To do so, it suffices to show that the conditions of Lemma A4 hold. Consider an off-equilibrium action $\left(\tilde{i},\tilde{\theta}\right)$. Let a be a firm such that (A9) holds. We know $i(a)+S(i(a),\theta(a))$ is weakly decreasing in a from Corollary 1; it follows that the beliefs associated with $\left(\tilde{i},\tilde{\theta}\right)$ load on some $\tilde{a}\geq a$, implying $P\left(\tilde{i},\tilde{\theta}\right)=\tilde{a}+S\left(\tilde{i},\tilde{\theta}\right)$, and so (A10) is satisfied. Similarly, if a is a firm such that (A11) holds then the beliefs associated with $\left(\tilde{i},\tilde{\theta}\right)$ load on some $\tilde{a}\leq a$ and (A12) is satisfied. Hence the conditions of Lemma A4 indeed hold.

The second and harder part of the proof is to show that this is the unique D1 equilibrium. To do so, we establish the following claims:

Claim 1: In a D1 equilibrium of the repurchase game, all repurchasing firms choose the maximal efficiency $\theta=1$.

Proof of Claim 1: Suppose to the contrary that transaction (i,θ) with $\theta<1$ is chosen by a non-empty set of firms A in a D1 equilibrium. Then there is firm $a\in A$ with $P(i,\theta)\geq a+S(i,\theta)$. Since $\Pi(a,i,\theta,p)$ decreases in p in the repurchase game,

$$\Pi^{*}(a)\leq\Pi(a,i,\theta,a+S(i,\theta))=a+S(i,\theta).$$

Note that $i+S(i,\theta)<i+S(i,1)$. By Proposition 1, the action $(i,1)$ is off-equilibrium. By Lemma A4, the associated price is $P(i,1)\leq a+S(i,1)$. So firm a's payoff from deviating to $(i,1)$ is

$$\Pi(a,i,1,P(i,1))\geq\Pi(a,i,1,a+S(i,1))=a+S(i,1)>a+S(i,\theta)\geq\Pi^{*}(a),$$

contradicting the equilibrium condition and establishing the claim.

Claim 2: In a D1 equilibrium of the repurchase game, there is a firm type $\hat{a}\in[a_{\min},a_{\max}]$ such that firms $a>\hat{a}$ play $-I_L$ and firms $a<\hat{a}$ separate on different sizes $i(a)<-I_L$ with $i(a)$ continuous and strictly decreasing.

Proof of Claim 2: From Claim 1, all repurchasing firms adopt efficiency $\theta=1$. Hence $i(a)+S(i(a),1)$ is weakly decreasing in a by Corollary 1. From Assumption 1(iii) it follows that $i(a)$ is weakly decreasing in a. Hence there exists $\hat{a}\in[a_{\min},a_{\max}]$ such that firms $a<\hat{a}$ play $-I_L$ and firms $a>\hat{a}$ play $i(a)<-I_L$ with $i(a)$ weakly decreasing.

Subclaim 2.1: $i(a)$ is strictly decreasing for $a>\hat{a}$.

Proof of Subclaim 2.1: Suppose to the contrary that $i<-I_L$ is chosen by a non-degenerate interval A of firms. Then $P(i,1)>\inf A+S(i,1)$. So for any $a\in A$,

$$\Pi^{*}(a)=\Pi(a,i,1,P(i,1))<\Pi(a,i,1,\inf A+S(i,1)).\tag{A13}$$

Consider an alternative repurchase $\left(\tilde{i},1\right)$ where $\tilde{i}>i$. If $\left(\tilde{i},1\right)$ is in-equilibrium then the fact that

$i(a)$ is weakly decreasing implies

$$P\left(\tilde{i},1\right) \leq \inf A + S\left(\tilde{i},1\right); \tag{A14}$$

while if $\left(\tilde{i},1\right)$ is out-of-equilibrium this same inequality follows from $\tilde{i} + S\left(\tilde{i},1\right) > i + S(i,1)$ (Assumption 1(iii)) and Lemma A4. Inequality (A14) in turn implies

$$\Pi\left(a,\tilde{i},1,\inf A + S\left(\tilde{i},1\right)\right) \leq \Pi\left(a,\tilde{i},1,P\left(\tilde{i},1\right)\right).$$

The LHS is continuous in $\tilde{i}$. Consequently, from (A13) there exists $\tilde{i} > i$ such that

$$\Pi^*(a) < \Pi\left(a,\tilde{i},1,\inf A + S\left(\tilde{i},1\right)\right) \leq \Pi\left(a,\tilde{i},1,P\left(\tilde{i},1\right)\right),$$

contradicting the equilibrium condition and establishing Subclaim 2.1.

Subclaim 2.2: $i(a)$ is continuous for $a > \hat{a}$.

Proof of Subclaim 2.2: Since $i(a)$ is weakly decreasing, left and right limits exist everywhere. Suppose to the contrary there is $\tilde{a} > \hat{a}$ such that

$$\bar{i} \equiv \lim_{a\uparrow\tilde{a}} i(a) > \underline{i} \equiv \lim_{a\downarrow\tilde{a}} i(a).$$

Since $i(a)$ is strictly decreasing for $a > \hat{a}$, prices are fully revealing for $i(a) < -I_L$, and so these repurchases are fairly priced, i.e., $P(i(a),1) = a + S(i(a),1)$.

By Assumption 1(ii), there exists some $\tilde{i} \in \left(\underline{i},\bar{i}\right)$ that strictly increases transaction surplus relative to at least one of $\underline{i}$ and $\bar{i}$, i.e.,

$$S\left(\tilde{i},1\right) > \min\left\{S\left(\underline{i},1\right), S\left(\bar{i},1\right)\right\}. \tag{A15}$$

To establish the Subclaim, it suffices to show that repurchase $\left(\tilde{i},1\right)$ is priced as if it is issued by firm $\tilde{a}$, i.e.,

$$P\left(\tilde{i},1\right) = \tilde{a} + S\left(\tilde{i},1\right). \tag{A16}$$

The Subclaim follows from (A16) because continuity, fair pricing and (A15) together imply that there exists some firm a in the neighborhood of $\tilde{a}$ that would strictly gain from repurchasing $\left(\tilde{i},1\right)$ instead of $(i(a),1)$, contradicting the equilibrium condition.

It remains to establish (A16). The equality is immediate from full revelation if $i(\tilde{a}) = \tilde{i}$. If instead $i(\tilde{a}) \neq \tilde{i}$ then for every $a < \tilde{a}$, $\tilde{i} + S\left(\tilde{i},1\right) < i(a) + S(i(a),1)$, and so Lemma A4 implies $P\left(\tilde{i},1\right) \geq \tilde{a} + S\left(\tilde{i},1\right)$; similarly, for every $a > \tilde{a}$, $\tilde{i} + S\left(\tilde{i},1\right) > i(a) + S(i(a),1)$, and so Lemma A4 implies $P\left(\tilde{i},1\right) \leq \tilde{a} + S\left(\tilde{i},1\right)$. Consequently, equality (A16) holds, establishing Subclaim 2.2, and hence Claim 2 also.

Claim 3: In a D1 equilibrium of the repurchase game, if firm $a_{\max}$ plays $i(a_{\max}) < -I_L$, then $i(a_{\max}) = I^*$.

Proof of Claim 3: Suppose to the contrary that firm $a_{\max}$ plays $i < -I_L$ with $i \neq I^*$. By Claims 1 and 2, the repurchase is conducted at efficiency $\theta = 1$ and is fairly priced, so that firm $a_{\max}$'s equilibrium payoff is $a_{\max} + S(i, 1)$. The price associated with repurchase $(I^*, 1)$ is bounded above by $a_{\max} + S(I^*, 1)$, and hence firm $a_{\max}$'s payoff from deviating to $(I^*, 1)$ is bounded below by

$$\Pi(a_{\max}, I^*, 1, a_{\max} + S(I^*, 1)) = a_{\max} + S(I^*, 1) > a_{\max} + S(i, 1) = \Pi^*(a_{\max}).$$

This contradicts the equilibrium condition, thereby establishing Claim 3.

By Claims 1, 2, and 3 above, together with Lemma A5, in any D1 equilibrium firms follow the strategy stated in Proposition 2 for some $\hat{a} \in [a_{\min}, a_{\max}]$.

Claim 4: The cutoff $\hat{a}$ that supports a D1 equilibrium of the repurchase game is unique.

Proof of Claim 4: Let $\hat{i}(a)$ be determined by (9), (10), and (12). Note that, if a cutoff $\hat{a}$ that supports a D1 equilibrium is interior, then by continuity firm $\hat{a}$ is indifferent between repurchases $\left(\hat{i}(\hat{a}), 1\right)$ and $(-I_L, 1)$, i.e.,

$$\hat{a} + S\left(\hat{i}(\hat{a}), 1\right) = \Pi(\hat{a}, -I_L, 1, E[a|a \leq \hat{a}] + S(-I_L, 1)). \tag{A17}$$

Also note that if cutoff $\hat{a} = a_{\max}$ (i.e., full pooling at $(-I_L, 1)$) is a D1 equilibrium then

$$a_{\max} + S(I^*, 1) \leq \Pi(a_{\max}, -I_L, 1, E[a] + S(-I_L, 1)), \tag{A18}$$

since otherwise, by continuity and the price of $(I^*, 1)$ characterized by Lemma A4, some types around $a_{\max}$ benefit from deviating to $(I^*, 1)$.

Subclaim 4.1: Let $a_1 < a_2$ with $\hat{i}(a_2) < \hat{i}(a_1) \leq -I_L$. If firm a_1 weakly prefers $\left(\hat{i}(a_1), 1\right)$ at price $a_1 + S\left(\hat{i}(a_1), 1\right)$ to $(-I_L, 1)$ at price $E[a|a \leq a_1] + S(-I_L, 1)$, then firm a_2 strictly prefers $\left(\hat{i}(a_2), 1\right)$ at price $a_2 + S\left(\hat{i}(a_2), 1\right)$ to $(-I_L, 1)$ at price $E[a|a \leq a_2] + S(-I_L, 1)$.

Proof of Subclaim 4.1: Let the conditions of the claim be satisfied. By Assumption 1(iii), $\hat{i}(a_1) + S\left(\hat{i}(a_1), 1\right) \leq -I_L + S(-I_L, 1)$. So by Lemma A1, firm a_2 weakly prefers $\left(\hat{i}(a_1), 1\right)$ at price $a_1 + S\left(\hat{i}(a_1), 1\right)$ to $(-I_L, 1)$ at price $E[a|a \leq a_1] + S(-I_L, 1)$, and hence strictly prefers the former to $(-I_L, 1)$ at price $E[a|a \leq a_2] + S(-I_L, 1)$. By Lemma A3, firm a_2 weakly prefers $\left(\hat{i}(a_2), 1\right)$ at price $a_2 + S\left(\hat{i}(a_2), 1\right)$ to $\hat{i}(a_1)$ at price $a_1 + S\left(\hat{i}(a_1), 1\right)$. The conclusion of Subclaim 4.1 then follows transitivity.

Continuing the proof of Claim 4:

Case: $\hat{i}(a_{\min}) \leq -I_L$. In this case, the cutoff must be $\hat{a} = a_{\min}$. This follows because $S\left(\hat{i}(a_{\min}), 1\right) \geq$

$S(-I_L, 1)$ (Assumption 1(ii)), so firm $a_{\min}$ certainly weakly prefers $\left(\hat{i}(a_{\min}), 1\right)$ at price $a_{\min} + S\left(\hat{i}(a_{\min}), 1\right)$ to $(-I_L, 1)$ at price $E[a|a \leq a_{\min}] + S(-I_L, 1) = a_{\min} + S(-I_L, 1)$; and Subclaim 4.1 then implies that any firm $\tilde{a} > a_{\min}$ strictly prefers $\left(\hat{i}(\tilde{a}), 1\right)$ at price $\tilde{a} + S\left(\hat{i}(\tilde{a}), 1\right)$ to $(-I_L, 1)$ at price $E[a|a \leq \tilde{a}] + S(-I_L, 1)$. So neither (A17) nor (A18) can hold, ruling out both $\hat{a} \in (a_{\min}, a_{\max})$ and $\hat{a} = a_{\max}$, implying $\hat{a}$ is unique.

Case: $\hat{i}(a_{\min}) > -I_L$. Define $a_0 \in (a_{\min}, a_{\max})$ by $\hat{i}(a_0) = -I_L$. Then by definition of $\hat{a}$, $\hat{i}(\hat{a}) \leq -I_L$ so $\hat{a}$ must be in $[a_0, a_{\max}]$. Note that

$$a_0 + S\left(\hat{i}(a_0), 1\right) < \Pi\left(a_0, -I_L, E[a|a \leq a_0] + S(-I_L, 1)\right)$$

because the LHS corresponds to firm a_0's payoff from repurchase $\left(\hat{i}(a_0), 1\right) = (-I_L, 1)$ at price $a_0 + S\left(\hat{i}(a_0), 1\right)$, while the RHS corresponds to the same transaction but at a strictly lower price. By continuity, either

$$\tilde{a} + S\left(\hat{i}(\tilde{a}), 1\right) < \Pi\left(\tilde{a}, -I_L, E[a|a \leq \tilde{a}] + S(-I_L, 1)\right)$$

holds strictly for all $\tilde{a} \in [a_0, a_{\max})$, in which case (A17) cannot hold for any $\tilde{a} \in [a_0, a_{\max})$ and the cutoff must uniquely be $\hat{a} = a_{\max}$; or (A18) holds with equality for a unique $\tilde{a} \in (a_0, a_{\max}]$ and (A18) holds only if $\tilde{a} = a_{\max}$, where uniqueness and "only if" both follow from Subclaim 4.1. Hence the cutoff $\hat{a}$ must uniquely be $\tilde{a}$. This completes the proof of Claim 4, and hence the proof of the Proposition.

Lemma A6. *Under the generalized firm's objective function (22) with $\epsilon \in [0, 1)$, in the issue game, there is a unique $\hat{a} > a_{\min}$ such that conditions (15), (16), and (24) determine a unique $\hat{i}(a) \in [I_L, I^*]$ for each $a \in [a_{\min}, \hat{a}]$, with $\hat{a}$ satisfying either $\hat{a} = a_{\max}$ and $\hat{i}(a_{\max}) > 0$ or $\hat{i}(\hat{a}) = I_L > 0$. If $\hat{a} < a_{\max}$, then there is a unique function $\hat{\theta}(a) \in (0, 1]$ for $a \in [\hat{a}, a_{\max}]$ that satisfies (18) and (26). If $\epsilon = 0$, conditions (24) and (26) reduce to (12) and (19), respectively.*

Proof of Proposition 4: By Lemma A6, $\hat{i}(a)$ is well defined for $a \leq \hat{a}$ and $\hat{\theta}(a)$ is well defined for $a > \hat{a}$. The equilibrium firm strategy $i(a)$ and $\theta(a)$ extend $\hat{i}$ and $\hat{\theta}$ to all firm types with $i(a) = I_L$ for $a > \hat{a}$ and $\theta(a) = 1$ for $a \leq \hat{a}$.

To complete the description of the PBE, we specify off-equilibrium beliefs. Consider an off-equilibrium action $\left(\tilde{i}, \tilde{\theta}\right)$. If $\tilde{i} + S\left(\tilde{i}, \tilde{\theta}\right) = i(a) + S(i(a), \theta(a))$ for some firm type a then the associated off-equilibrium belief loads on type a. If $\tilde{i} + S\left(\tilde{i}, \tilde{\theta}\right) > \sup_a i(a) + S(i(a), \theta(a))$ then the associated off-equilibrium belief loads on type $a_{\min}$. If $\tilde{i} + S\left(\tilde{i}, \tilde{\theta}\right) < \inf_a i(a) + S(i(a), \theta(a))$ then the associated off-equilibrium belief loads on type $a_{\max}$.

It is immediate from Lemma A3 that no firm has the incentive to deviate to an in-equilibrium action. It remains to show that no firm has the incentive to deviate to an off-equilibrium action. For use below, note that the conjectured equilibrium features full separation, so that all in-equilibrium issues are fairly priced and $\Pi(a, i(a), \theta(a), P(i(a), \theta(a))) = a + S(i(a), \theta(a))$. Also note $i(a) + S(i(a), \theta(a))$ strictly decreases in a.

Consider an off-equilibrium action $\left(\tilde{i}, \tilde{\theta}\right)$.

Case: $\tilde{i} + S\left(\tilde{i}, \tilde{\theta}\right) = i(a) + S(i(a), \theta(a))$ for some firm type a. Under the stated off-equilibrium beliefs the deviation $\left(\tilde{i}, \tilde{\theta}\right)$ is fairly priced for firm a. It suffices to show $S\left(\tilde{i}, \tilde{\theta}\right) \leq S(i(a), \theta(a))$; if this inequality holds, then neither firm a nor (by Lemma A1) any other firm gains by deviating to $\left(\tilde{i}, \tilde{\theta}\right)$. Suppose to the contrary that $S\left(\tilde{i}, \tilde{\theta}\right) > S(i(a), \theta(a))$ and $\tilde{i} < i(a)$. Hence $I_L < i(a) \leq I^*$, and so by construction, $\theta(a) = 1$. But then by Assumption 1(ii) $S\left(\tilde{i}, \tilde{\theta}\right) < S(i(a), \theta(a))$, establishing a contradiction and completing this case.

Case: $\tilde{i} + S\left(\tilde{i}, \tilde{\theta}\right) < \inf_a i(a) + S(i(a), \theta(a))$. By Assumption 1(ii),(iii), $i(a) + S(i(a), \theta(a))$ achieves its minimum value at $a_{\max}$. Under the stated off-equilibrium beliefs the deviation $\left(\tilde{i}, \tilde{\theta}\right)$ is fairly priced for firm $a_{\max}$. By an exactly parallel argument to the prior case, $S\left(\tilde{i}, \tilde{\theta}\right) \leq S(i(a_{\max}), \theta(a_{\max}))$. Consequently, both firm $a_{\max}$ and all firms $a < a_{\max}$ (by Lemma A1) weakly prefer $(i(a_{\max}), \theta(a_{\max}))$ to $\left(\tilde{i}, \tilde{\theta}\right)$. Since all firms a weakly prefer $(i(a), \theta(a))$ to $(i(a_{\max}), \theta(a_{\max}))$, they weakly prefer $(i(a), \theta(a))$ to $\left(\tilde{i}, \tilde{\theta}\right)$, completing this case.

Case: $\tilde{i} + S\left(\tilde{i}, \tilde{\theta}\right) > \sup_a i(a) + S(i(a), \theta(a))$. Under the stated off-equilibrium beliefs the deviation $\left(\tilde{i}, \tilde{\theta}\right)$ is fairly priced for firm $a_{\min}$. By construction, $(i(a_{\min}), \theta(a_{\min})) = (I^*, 1)$ and $S(I^*, 1) > S\left(\tilde{i}, \tilde{\theta}\right)$. Certainly firm $a_{\min}$ strictly prefers $(I^*, 1)$ to $\left(\tilde{i}, \tilde{\theta}\right)$. By Lemma A1, all firms $a > a_{\min}$ also prefer $(I^*, 1)$ to $\left(\tilde{i}, \tilde{\theta}\right)$, and it follows that they prefer $(i(a), \theta(a))$ to $\left(\tilde{i}, \tilde{\theta}\right)$, completing the proof.

Proof of Lemma 1: Suppose to the contrary that in a D1 equilibrium some firm chooses (i, θ) with $i > I_L$ and $\theta < 1$. We first establish the following Claim:

Claim: It is always possible to find $\left(\tilde{i}, \tilde{\theta}\right)$ *that satisfies (20) and (21).*

Proof of the Claim:

Case: There exists $\tilde{i} \in [I_L, i)$ with $S\left(\tilde{i}, \theta\right) \geq S(i, \theta)$. By Assumption 1(iii), $\tilde{i} + S\left(\tilde{i}, \theta\right) < i + S(i, \theta)$. By Assumption 1(ii) and continuity, there is $\tilde{\theta} > \theta$ such that (20) and (21) are satisfied.

Case: $S(I_L, \theta) < S(i, \theta) < S(I_L, 1)$. By Assumption 1(iii), $I_L + S(I_L, \theta) < i + S(i, \theta)$. By continuity there exists $\theta' \in (\theta, 1)$ such that $S(I_L, \theta') = S(i, \theta)$. Note that $I_L + S(I_L, \theta') < i + S(i, \theta)$. By Assumption 1(ii) and continuity, there is $\tilde{\theta} > \theta$ such that (20) and (21) are satisfied with $\tilde{i} = I_L$.

Case: $S(I_L, 1) \leq S(i, \theta)$. So by Assumption 1(ii), $S(I_L, 1) \leq S(i, \theta) < S(i, 1)$; and by continuity, there exists $i' \in [I_L, i)$ with $S(i', 1) = S(i, \theta)$. Note that $i' \neq I^*$. By Assumption 1(iii), $i' + S(i', 1) < i + S(i, \theta)$. By continuity, there is $\tilde{i}$ near i' such that (20) and (21) are satisfied with $\tilde{\theta} = 1$, completing the proof of the Claim.

Given the existence of such an $\left(\tilde{i}, \tilde{\theta}\right)$, we obtain a contradiction as follows. By supposition, (i, θ) is chosen by some firm a such that, $P(i,\theta) \leq a + S(i,\theta)$, and since $\Pi(a,i,\theta,p)$ strictly increases in p in the issue game,

$$\Pi(a,i,\theta,P(i,\theta)) \leq a + S(i,\theta).$$

If $\left(\tilde{i},\tilde{\theta}\right)$ is in-equilibrium then (21) and the fact that $i(a) + S(i(a),\theta(a))$ is weakly decreasing in a (Corollary 1) imply

$$P\left(\tilde{i},\tilde{\theta}\right) \geq a + S\left(\tilde{i},\tilde{\theta}\right). \tag{A19}$$

If $\left(\tilde{i},\tilde{\theta}\right)$ is off-equilibrium then (21) and Lemma A4 imply (A19). So for both cases,

$$\Pi\left(a,\tilde{i},\tilde{\theta},P\left(\tilde{i},\tilde{\theta}\right)\right) \geq a + S\left(\tilde{i},\tilde{\theta}\right) > a + S(i,\theta) \geq \Pi(a,i,\theta,P(i,\theta)),$$

contradicting the equilibrium condition. This completes the proof.

Proof of Proposition 5: First, the PBE specified in Proposition 4 (with off-equilibrium beliefs as specified at the start of its proof) satisfies D1; the proof of this statement is the same as for the repurchase game, given at the beginning of the proof of Proposition 3.

The second and harder part of the proof is to show that this is the unique D1 equilibrium. To do so, we establish the following claims:

As preliminaries: By Lemma 1, a firm chooses either $(i,1)$ for some i or (I_L,θ) for some θ. We know $i(a)+S(i(a),\theta(a))$ is weakly decreasing in a (Corollary 1). Assumption 1 implies that there is a firm $\hat{a}$ such that firms $a < \hat{a}$ choose $(i(a),1)$ with weakly decreasing $i(a) > I_L$ and firms $a > \hat{a}$ choose $(I_L,\theta(a))$, and if $I_L > 0$, then $\theta(a)$ is weakly decreasing.

Claim 1: If $I_L > 0$, no firm chooses $(I_L,0)$ in equilibrium.

Proof of Claim 1: By Assumption (1) of Footnote 7, firm $a_{\max}$ strictly prefers $(I_L,1)$ to $(0,1)$ (doing nothing). Moreover, Assumption 1(i) and $P(I_L,0) \leq a_{\max} + S(I_L,0)$ imply that

$$a_{\max} \geq a_{\max} + S(I_L,0) = \Pi(a_{\max},I_L,0,a_{\max}+S(I_L,0)) \geq \Pi(a_{\max},I_L,0,P(I_L,0)).$$

Hence, firm $a_{\max}$ strictly prefers $(I_L,1)$ to $(I_L,0)$ under any prices. By Lemma A1, all firms have the same preference, thereby establishing Claim 1.

Claim 2: In any D1 equilibrium, if $I_L > 0$ then there is full separation and hence $i(a)+S(i(a),\theta(a))$ is strictly decreasing in a; if $I_L = 0$ then $i(a)$ is strictly decreasing on $[a_{\min},\hat{a})$.

Proof of Claim 2: Suppose to the contrary that there is a non-degenerate interval A of firms that pool on some (i,θ) with $i > 0$. Hence $P(i,\theta) < \sup A + S(i,\theta)$. By Claim 1, if $i = I_L$ then $\theta > 0$, and so there exists $\left(\tilde{i},\tilde{\theta}\right)$ satisfying $\tilde{i} + S\left(\tilde{i},\tilde{\theta}\right) < i + S(i,\theta)$. If $\left(\tilde{i},\tilde{\theta}\right)$ is in-equilibrium then $P\left(\tilde{i},\tilde{\theta}\right) \geq \sup A + S\left(\tilde{i},\tilde{\theta}\right)$; if instead $\left(\tilde{i},\tilde{\theta}\right)$ is off-equilibrium then Lemma A4 delivers the same inequality. By continuity of Π, there exists some $\left(\tilde{i},\tilde{\theta}\right)$ in the neighborhood of (i,θ) such that any firm in A strictly prefers $\left(\tilde{i},\tilde{\theta}\right)$ to (i,θ) because $\left(\tilde{i},\tilde{\theta}\right)$ delivers a discrete increase in the issue price. The contradiction establishes Claim 2.

Claim 3: In any D1 equilibrium, if $I_L > 0$ then $i(a)$ and $\theta(a)$ are continuous; if $I_L = 0$ then $i(a)$ is continuous on $[a_{\min}, \hat{a})$.

Proof of Claim 3: We know that $i(a)$ and $\theta(a)$ are weakly decreasing. Suppose to the contrary that in the case $I_L > 0$ there is $\tilde{a} \in (a_{\min}, a_{\max})$ such that either

$$\bar{i} \equiv \inf_{a<\tilde{a}} i(a) > \sup_{a>\tilde{a}} i(a) \equiv \underline{i} \tag{A20}$$

or

$$\bar{\theta} \equiv \inf_{a<\tilde{a}} \theta(a) > \sup_{a>\tilde{a}} \theta(a) \equiv \underline{\theta},$$

or in the case $I_L = 0$ there is $\tilde{a} \in (a_{\min}, \hat{a})$ that satisfies (A20) (and in this case $\bar{\theta} = \underline{\theta} = 1$). By Assumption 1, $S\left(\bar{i},\bar{\theta}\right) > S\left(\underline{i},\underline{\theta}\right)$ and $\bar{i} + S\left(\bar{i},\bar{\theta}\right) > \underline{i} + S\left(\underline{i},\underline{\theta}\right)$. By Claim 2 and Lemma A4, $\left(\bar{i},\bar{\theta}\right)$ is priced as if it is issued by firm $\tilde{a}$, i.e., $P\left(\bar{i},\bar{\theta}\right) = \tilde{a} + S\left(\bar{i},\bar{\theta}\right)$. Hence as a approaches $\tilde{a}$, firm a's payoff from $\left(\bar{i},\bar{\theta}\right)$ approaches $\tilde{a} + S\left(\bar{i},\bar{\theta}\right)$. By Claim 2, the equilibrium payoff of any firm a is $a + S(i(a),\theta(a))$, and so as a approaches $\tilde{a}$ from above, firm a's equilibrium payoff approaches $\tilde{a} + S\left(\underline{i},\underline{\theta}\right) < \tilde{a} + S\left(\bar{i},\bar{\theta}\right)$. Consequently, firms in the righthand neighboorhood of $\tilde{a}$ would strictly benefit from deviating to $\left(\bar{i},\bar{\theta}\right)$, contradicting the equilibrium condition and establishing Claim 3.

Claim 4: Firm $a_{\min}$ chooses $(I^*,1)$ in equilibrium.

Proof of Claim 4: Suppose to the contrary that firm $a_{\min}$ chooses $(i,\theta) \neq (I^*,1)$. If $i > 0$, (i,θ) is fairly-priced for firm $a_{\min}$ by Claim 2, so

$$\Pi^*(a_{\min}) = a_{\min} + S(i,\theta). \tag{A21}$$

If $i = 0$, then (A21) holds again since $S(0,\theta) = 0$. But $(I^*,1)$ is at fairly-priced or better for firm $a_{\min}$, i.e., $P(I^*,1) \geq a_{\min} + S(I^*,1)$, and since it generates strictly more surplus than (i,θ) (Assumption 1(ii)), firm $a_{\min}$ strictly prefers it. The contradiction establishes Claim 4.

Claim 5: If $I_L = 0$, then $\hat{a} = a_{\max}$.

Proof of Claim 5: Suppose $I_L = 0$, and suppose to the contrary of the Claim that $\hat{a} < a_{\max}$. By Claims 2 and 3, for firm types $a \in [a_{\min}, \hat{a})$, Lemma A5 applies and hence $i(a)$ satisfies ODE (12), and by Claims 2 and 4, conditions (15) and (16) are also satisfied. Let $\tilde{i} \equiv \inf_{a<\hat{a}} i(a)$, then $\tilde{i} > 0$ by Lemma A6. Moreover, regardless of whether type $\hat{a}$ chooses $\left(\hat{i}(\hat{a}),1\right)$ or $(0,\theta)$ for some θ, $P\left(\tilde{i},1\right) = \hat{a} + S\left(\tilde{i},1\right)$ by Lemma A4. By continuity of Π, for firms $a > \hat{a}$ in a neighbourhood of $\hat{a}$, their payoff from deviating to $\left(\tilde{i},1\right)$ is in a neighbourhood of

$$\Pi\left(\hat{a},\tilde{i},1,P\left(\tilde{i},1\right)\right) = \hat{a} + S\left(\tilde{i},1\right) > \hat{a}.$$

On the other hand, firms $a > \hat{a}$ have equilibrium payoff $\Pi^* (a) = a$, so for firms $a > \hat{a}$ in a neighbourhood of $\hat{a}$, their equilibrium payoff is in a neighbourhood of $\hat{a}$. Hence there exist firms above $\hat{a}$ in a neighbourhood of $\hat{a}$ that benefit from deviating to $\left(\tilde{i}, 1\right)$. The contradiction establishes Claim 5.

Completing the proof: By Claim 2, 3, and 5, Lemma A5 applies to $[a_{\min}, a_{\max}]$. Hence $i(a)$ satisfies ODE (12) for types $a \leq \hat{a}$, and Claim 4 gives the boundary condition. Similarly, $\theta(a)$ satisfies ODE (19) for $a > \hat{a}$; and both $\hat{a}$ and the boundary condition for (19) are determined by the fact that both $i(a)$ and $\theta(a)$ are continuous (Claim 3 again). This completes the proof.

Proof of Lemma 2: Differentiation yields

$$\begin{aligned}
\pi_a (a, i, \theta, \tilde{a}) &= \frac{V_a (a, i, \theta)}{V (a, i, \theta)} = \frac{1}{V (a, i, \theta)} \\
\pi_{ai} (a, i, \theta, \tilde{a}) &= \frac{-V_i (a, i, \theta)}{V (a, i, \theta)^2}.
\end{aligned}$$

Moreover,

$$\pi_i (a, i, \theta, a) = \frac{\partial}{\partial i} \ln (a + S (i, \theta)) = \frac{S_i (i, \theta)}{a + S (i, \theta)}.$$

Hence,

$$\left. \frac{-\pi_{ai} (a, i, \theta, \tilde{a})}{\pi_i (a, i, \theta, \tilde{a})} \right|_{\tilde{a}=a} = \frac{V_i (a, i, \theta)}{S_i (i, \theta)} \cdot \frac{a + S (i, \theta)}{V (a, i, \theta)^2}.$$

Similarly,

$$\left. \frac{-\pi_{a\theta} (a, i, \theta, \tilde{a})}{\pi_\theta (a, i, \theta, \tilde{a})} \right|_{\tilde{a}=a} = \frac{V_\theta (a, i, \theta)}{S_\theta (i, \theta)} \cdot \frac{a + S (i, \theta)}{V (a, i, \theta)^2}.$$

Since $a + S (i, \theta) > 0$,

$$\left. \frac{-\pi_{ai} (a, i, \theta, \tilde{a})}{\pi_i (a, i, \theta, \tilde{a})} \right|_{\tilde{a}=a} - \left. \frac{-\pi_{a\theta} (a, i, \theta, \tilde{a})}{\pi_\theta (a, i, \theta, \tilde{a})} \right|_{\tilde{a}=a}$$

has the same sign as

$$\frac{V_i (a, i, \theta)}{S_i (i, \theta)} - \frac{V_\theta (a, i, \theta)}{S_\theta (i, \theta)},$$

completing the proof.

Lemma A7. *Under the generalized firm's objective function (22) with $\epsilon \in [0, 1)$, in the issue game or the repurchase game, type-a firm's overall preference for price satisfies*

$$\frac{\partial \Pi (a, i, \theta, p)}{\partial p} \gtrless 0 \quad \text{if} \quad \epsilon p + i \gtrless 0. \tag{A22}$$

In particular,

(i) In the issue game, $\Pi (a, i, \theta, p)$ strictly increases in p for all a, i, θ, p with $i > 0$;

(ii) In the repurchase game with $\epsilon \in [0, \underline{\epsilon})$, $\Pi (a, i, \theta, p)$ strictly decreases in p for any a, i, θ, p with

$i \leq -I_L$ and $p \leq a_{\max} + S(i,\theta)$.

Proof of Proposition 6(i): Suppose to the countrary that (i,θ) with $\theta < 1$ is chosen by a non-empty set of firms A in a D1 equilibrium. Then there is $\bar{a} \in [\inf A, \sup A]$ such that $P(i,\theta) = \bar{a} + S(i,\theta)$.

Case: $\epsilon P(i,\theta) + i < 0$. Consider type $\tilde{a} \in A$ with $\tilde{a} \leq \bar{a}$. For $p \in [\tilde{a} + S(i,\theta), P(i,\theta)]$, $\Pi_p(a,i,\theta,p) < 0$ by Lemma A7, so

$$\Pi^*(\tilde{a}) \leq \Pi(\tilde{a},i,\theta,\tilde{a} + S(i,\theta)) = \tilde{a} + S(i,\theta). \tag{A23}$$

By continuity of S, there is $\theta' > \theta$ such that

$$\epsilon\bar{a} + \epsilon S(i,\theta') + i < 0. \tag{A24}$$

By Assumption 1(ii),

$$i + S(i,\theta') > i + S(i,\theta). \tag{A25}$$

By Corollary 1 and Lemma A4, the price of (i,θ') satisfies $P(i,\theta') \leq \tilde{a} + S(i,\theta')$. For $p \in [P(i,\theta'), \tilde{a} + S(i,\theta')]$, (A24) implies $\epsilon p + i < 0$, and by Lemma A7, $\Pi_p(a,i,\theta',p) < 0$. Hence

$$\Pi(\tilde{a},i,\theta',P(i,\theta')) \geq \Pi(\tilde{a},i,\theta',\tilde{a} + S(i,\theta')) = \tilde{a} + S(i,\theta'). \tag{A26}$$

Since $S(i,\theta') > S(i,\theta)$, A23 and (A26) together implies $\Pi(\tilde{a},i,\theta',P(i,\theta')) > \Pi^*(\tilde{a})$, that is, type $\tilde{a}$ benefits from deviates to (i,θ'), contradicting the equilibrium condition.

Case: $\epsilon P(i,\theta) + i = 0$. Consider $\theta' > \theta$. For $p \gtreqless P(i,\theta)$, $\epsilon p + i \gtreqless 0$, and hence $\Pi_p(a,i,\theta',p) \gtreqless 0$ by Lemma A7. Then for $a \in A$,

$$\Pi(a,i,\theta',P(i,\theta')) \geq \Pi(a,i,\theta',P(i,\theta)) = P(i,\theta)^{\epsilon}\left(\frac{V(a,i,\theta')}{1 + \frac{i}{P(i,\theta)}}\right)^{1-\epsilon}$$

whereas

$$\Pi^*(a) = \Pi(a,i,\theta,P(i,\theta)) = P(i,\theta)^{\epsilon}\left(\frac{V(a,i,\theta)}{1 + \frac{i}{P(i,\theta)}}\right)^{1-\epsilon}.$$

By Assumption 1, $V(a,i,\theta') > V(a,i,\theta)$, so $\Pi(a,i,\theta',P(i,\theta')) > \Pi^*(a)$, implying type $\tilde{a}$ benefits from deviating to (i,θ'), contradicting the equilibrium condition.

Case: $\epsilon P(i,\theta) + i > 0$. Consider firm $\tilde{a} \in A$ with $\tilde{a} \geq \bar{a}$. By Lemma A7, $\Pi_p(\tilde{a},i,\theta,p) > 0$ for $p \geq P(i,\theta)$, so

$$\Pi^*(\tilde{a}) \leq \Pi(\tilde{a},i,\theta,\tilde{a} + S(i,\theta)) = \tilde{a} + S(i,\theta). \tag{A27}$$

By definition of $\tilde{a}$, $\epsilon\tilde{a} + \epsilon S(i, \theta) + i > 0$, so

$$\epsilon\tilde{a} + \epsilon S(i', \theta') + i' > 0 \tag{A28}$$

holds for (i', θ') in a neighbourhood of (i, θ). Consider a subset of this neighbourhood:

$$B = \left\{(i', \theta') : \text{the distance between } (i, \theta) \text{ and } (i', \theta') \text{ is } \delta\right\}.$$

Since $(i, \theta + \delta)$ and $(i - \delta, \theta)$ belong to B with

$$i - \delta + S(i - \delta, \theta) < i + S(i, \theta) < i + S(i, \theta + \delta),$$

by continuity there is $\left(\bar{i}, \bar{\theta}\right) \in B$ with $\bar{\theta} > \theta$ and $\bar{i} < i$ that satisfies

$$\bar{i} + S\left(\bar{i}, \bar{\theta}\right) = i + S(i, \theta). \tag{A29}$$

This implies $S\left(\bar{i}, \bar{\theta}\right) > S(i, \theta)$. By continuity, there is $(i', \theta') \in B$ with $i' \in \left(i - \delta, \bar{i}\right)$ and $\theta' \in \left(\theta, \bar{\theta}\right)$ with

$$S(i', \theta') > S(i, \theta). \tag{A30}$$

By construction, $i' + S(i', \theta') < \bar{i} + S\left(\bar{i}, \bar{\theta}\right)$. Combined with (A29) this implies

$$i' + S(i', \theta') < i + S(i, \theta). \tag{A31}$$

Since (A28) implies $V(\tilde{a}, i', \theta') > 0$, (i', θ') is a feasible choice for firm $\tilde{a}$. By (A31), Corollary 1 and Lemma A4, a D1 price of (i', θ') satisfies $P(i', \theta') \geq \tilde{a} + S(i', \theta')$. For $p \in (\tilde{a} + S(i', \theta'), P(i', \theta'))$, $\epsilon p + i > 0$ by (A28), so $\Pi_p(\tilde{a}, i', \theta', p) > 0$ by Lemma A7, implying

$$\Pi(\tilde{a}, i', \theta', P(i', \theta')) \geq \Pi(\tilde{a}, i', \theta', \tilde{a} + S(i', \theta')) = \tilde{a} + S(i', \theta').$$

By (A27) and (A30), $\Pi(\tilde{a}, i', \theta', P(i', \theta')) > \Pi^*(\tilde{a})$, implying $\tilde{a}$ benefits from deviating to (i', θ'), contradicting the equilibrium condition. This completes the proof of Proposition 6(i).

Lemma A8. *Under the generalized firm's objective function (22) with $\epsilon \in [0, 1)$, in a D1 equilibrium of the repurchase game, there is a firm type $\hat{a} \in [a_{\min}, a_{\max}]$ such that firms $a > \hat{a}$ play $-I_L$ and firms $a < \hat{a}$ separate on different sizes $i(a) < -I_L$ with $i(a)$ continuous and strictly decreasing.*

Proof of Proposition 6(ii): Note that in the repurchase game with $\epsilon \in [0, \underline{\epsilon})$, $\Pi(a, i, \theta, p)$ strictly decreases in p by Lemma A7. Then that the described firm strategy constitutes a PBE follows proof identical to that of Proposition 2. That this firm strategy and the belief described in the proof of Proposition 2 constitute a D1 equilibrium follows proof identical to that of Proposition 3. The proof of the uniqueness of the D1 equilibrium is identical to the proof of Proposition 3 with Claim 1 substituted by Proposition 6(i), Claim 2 substituted by Lemma A8, ODE (12) substituted by (24).

Lemma A9. *Under the generalized firm's objective function (22) with* $\epsilon \in (\bar{\epsilon}, 1)$*, in the repurchase game, Conditions (24),*

$$\hat{i}\left(a_{\min}\right) = I^*, \tag{A32}$$

$$\hat{i}\left(a\right) < I^* \quad \textit{for} \quad a > a_{\min} \tag{A33}$$

determine a unique strategy $\hat{i}\left(a\right)$ *for each type* $a \in [a_{\min}, a_{\max}]$*. Moreover, for* $a > a_{\min}$*,*

$$\epsilon V\left(a, \hat{i}\left(a\right), 1\right) + (1-\epsilon)\,\hat{i}\left(a\right) > 0, \tag{A34}$$

and

$$V\left(a, \hat{i}\left(a\right), 1\right) > 0, \quad \frac{\partial \hat{i}\left(a\right)}{\partial a} < 0. \tag{A35}$$

Proof of Proposition 6(iii): *Step 1. We prove the existence of a D1 equilibrium with the strategy specified in the proposition.*

By Lemma A9, the firm strategy is well defined and feasible, and $i\left(a\right) + S\left(i\left(a\right), 1\right)$ is continuous and strictly decreasing in a by Assumption 1(iii).

To complete the description of the D1 equilibrium, we specify off-equilibrium beliefs. Consider an off-equilibrium action (i, θ). If

$$i\left(a_{\max}\right) + S\left(i\left(a_{\max}\right), 1\right) < i + S\left(i, \theta\right) < I^* + S\left(I^*, 1\right), \tag{A36}$$

then by continuity of $i\left(a\right) + S\left(i\left(a\right), 1\right)$, there is a unique $a \in (a_{\min}, a_{\max})$ with

$$i + S\left(i, \theta\right) = i\left(a\right) + S\left(i\left(a\right), 1\right), \tag{A37}$$

and let the associated off-equilibrium belief load on type a. If

$$i + S\left(i, \theta\right) \geq I^* + S\left(I^*, 1\right), \tag{A38}$$

let the associated off-equilibrium belief load on type $a_{\min}$. If

$$i + S\left(i, \theta\right) \leq i\left(a_{\max}\right) + S\left(i\left(a_{\max}\right), 1\right), \tag{A39}$$

let the associated off-equilibrium belief load on type $a_{\max}$.

This belief satisfies D1 from Lemma A4. By Lemma A3, no firm benefits from mimicking another type. We show no firm has the incentive to deviate to an off-equilibrium action (i, θ).

Case: (i, θ) satisfies (A38). Then firm $a_{\min}$ is fairly priced under both (i, θ) and its equilibrium choice $(I^*, 1)$. By Assumption 1(ii), $S\left(i, \theta\right) < S\left(I^*, 1\right)$. Hence, type $a_{\min}$ prefers its equilibrium choice $(I^*, 1)$ to (i, θ). By (A38) and Lemma A1, all firm types also prefer $(I^*, 1)$ to (i, θ). Since no type benefits from mimicking type $a_{\min}$, no type benefits from deviating to (i, θ).

Case: (i, θ) satisfies (A39). Then we know $S(i, \theta) \leq S\left(\hat{i}(a_{\max}), 1\right)$, since if to the contrary $S(i, \theta) > S\left(\hat{i}(a_{\max}), 1\right)$, then by (A39), $i < \hat{i}(a_{\max})$, and by Assumption 1(ii), $S(i, \theta) < S\left(\hat{i}(a_{\max}), 1\right)$, leading to contradiction. Since firm $a_{\max}$ is fairly priced under both (i, θ) and its equilibrium choice $\left(\hat{i}(a_{\max}), 1\right)$, it weakly prefers $\left(\hat{i}(a_{\max}), 1\right)$ because it generates weakly higher surplus. By (A39) and Lemma A1, all firm types also prefer $\left(\hat{i}(a_{\max}), 1\right)$ to (i, θ). Since no type benefits from mimicking type $a_{\max}$, no type benefits from deviating to (i, θ).

Case: (i, θ) satisfies (A37) for some $a \in (a_{\min}, a_{\max})$. Then we know $S(i, \theta) \leq S\left(\hat{i}(a), 1\right)$, since if to the contrary $S(i, \theta) > S\left(\hat{i}(a), 1\right)$, then by (A37), $i < \hat{i}(a)$, and by Assumption 1, part (ii), $S(i, \theta) < S\left(\hat{i}(a), 1\right)$, leading to contradiction. Since firm a is fairly priced under both (i, θ) and its equilibrium choice $\left(\hat{i}(a), 1\right)$, it prefers $\left(\hat{i}(a), 1\right)$ since it generates weakly higher surplus. By (A37) and Lemma A1, all firm types also prefer $\left(\hat{i}(a), 1\right)$ to (i, θ). Since no type benefits from mimicking type a, no type benefits from deviating to (i, θ). This completes step 1.

Step 2. We prove the uniqueness of the D1 equilibrium strategy.

By Proposition 6(i), all firms repurchase with the efficient method $\theta = 1$.

Claim 1: Every firm type a repurchases $i(a) \leq I^*$.

Proof of Claim 1: Since $\epsilon > \bar{\epsilon}$,

$$\epsilon V(a_{\min}, I^*, 1) + (1 - \epsilon) I^* > 0.$$

For $i \geq I^*$, it follows Assumption 1(iii) that

$$\epsilon V(a_{\min}, i, 1) + (1 - \epsilon) i > 0,$$

and hence $\epsilon p + i > 0$ for any $p \geq a_{\min} + S(i, 1)$, implying

$$\Pi_p(a, i, 1, p) > 0 \tag{A40}$$

by Lemma A7.

Suppose to the contrary of the Claim that a non-empty set of firm types A choose $\left(\tilde{i}, 1\right)$ with $\tilde{i} > I^*$. Then there is $a \in A$ with $P\left(\tilde{i}, 1\right) \leq a + S\left(\tilde{i}, 1\right)$. Then (A40) implies

$$\Pi^*(a) = \Pi\left(a, \tilde{i}, 1, P\left(\tilde{i}, 1\right)\right) \leq \Pi\left(a, \tilde{i}, 1, a + S\left(\tilde{i}, 1\right)\right) = a + S\left(\tilde{i}, 1\right).$$

Since $\tilde{i} + S\left(\tilde{i}, 1\right) > I^* + S(I^*, 1)$ by Assumption 1(iii), by Lemma A4 and Corollary 1, regardless of whether $(I^*,1)$ is on-path or off-path, $P(I^*,1) \geq a + S(I^*,1)$. (A40) then implies

$$\Pi(a, I^*, 1, P(I^*,1)) \geq \Pi(a, I^*, 1, a + S(I^*,1)) = a + S(I^*,1).$$

By Assumption 1(ii), $S(I^*,1) > S\left(\tilde{i},1\right)$, and hence $\Pi(a, I^*, 1, P(I^*,1)) > \Pi^*(a)$, implying type a benefits from deviating to $(I^*,1)$. This contradicts the equilibrium condition and completes the proof of Claim 1.

Following Claim 1, by Lemmas A8 and A5, $i(a)$ is continuous and strictly decreasing, and satisfies ODE (24). This implies $i(a) < I^*$ for $a > a_{\min}$.

What remains to show is that firm $a_{\min}$ repurchases I^*. Suppose to the contrary, $i(a_{\min}) < I^*$. Then $(I^*,1)$ is an off-equilibrium action, and since

$$I^* + S(I^*,1) > i(a_{\min}) + S(i(a_{\min}),1)$$

by Assumption 1(iii), the belief about $(I^*,1)$ loads on type $a_{\min}$ by Lemma A4. Since $i(a)$ is strictly decreasing, firm $a_{\min}$ is also fairly priced under its equilibrium action $(i(a_{\min}),1)$. Since $S(I^*,1) > S(i(a_{\min}),1)$ by Assumption 1(ii), firm $a_{\min}$ benefits from deviating to $(I^*,1)$, leading to a contradiction. This completes the proof.

Proof of Proposition 7: By Lemma A7, $\Pi(a,i,\theta,p)$ is strictly increasing in p in the issue game. That there is a PBE with the strategy described in the Proposition with beliefs specified in the proof of 4 then follows arguments identical to the proof of Proposition 4.

Moreover, Lemma 1 generalizes to the firm's objective function (22) with identical proof. The existence and uniqueness of the D1 equilibrium then follows arguments identical to the proof of Proposition 5 with the following exceptions: condition (12) is substituted by (24), condition (19) is substituted by (26), and the proofs of Claims 4 and 5 change as follows. We first establish Claim 0:

Claim 0: If $I_L = 0$, then conditions (15), (16), and (24) determine a unique $\hat{i}(a) \in (0, I^*]$ for each $a \in [a_{\min}, a_{\max}]$, and each type a strictly prefers $\left(\hat{i}(a),1\right)$ at price $a + S\left(\hat{i}(a),1\right)$ to action $(0,\theta)$ with any θ and any price.

Proof of Claim 0: That conditions (15), (16), and (24) determine a unique $\hat{i}(a) \in (0, I^*]$ for each a follows Lemma A6. For any θ, since $\hat{i}(a_{\max}) \in (0, I^*]$, $S\left(\hat{i}(a_{\max}),1\right) > S(0,\theta)$ by Assumption 1(ii). Hence firm $a_{\max}$ strictly prefers action $\left(\hat{i}(a_{\max}),1\right)$ at price $a_{\max} + S\left(\hat{i}(a_{\max}),1\right)$ to action $(0,\theta)$ at any price $P(0,\theta)$, since the latter choice leads to strictly lower surplus and fair price or underpricing:

$$\Pi\left(a_{\max}, \hat{i}(a_{\max}), 1, a_{\max} + S\left(\hat{i}(a_{\max}),1\right)\right) > \Pi(a_{\max}, 0, \theta, P(0,\theta)).$$

By Lemma A1, all firm types a have the same preference:

$$\Pi\left(a, \hat{i}\left(a_{\max}\right), 1, a_{\max}+S\left(\hat{i}\left(a_{\max}\right), 1\right)\right)>\Pi\left(a, 0, \theta, P\left(0, \theta\right)\right).$$

By Lemma A3, firm a weakly prefers $\left(\hat{i}\left(a\right), 1\right)$ at price $a+S\left(\hat{i}\left(a\right), 1\right)$ to action $\left(\hat{i}\left(a_{\max}\right), 1\right)$ at price $a_{\max}+S\left(\hat{i}\left(a_{\max}\right), 1\right)$:

$$\Pi\left(a, \hat{i}\left(a\right), 1, a+S\left(\hat{i}\left(a\right), 1\right)\right) \geq \Pi\left(a, \hat{i}\left(a_{\max}\right), 1, a_{\max}+S\left(\hat{i}\left(a_{\max}\right), 1\right)\right).$$

Combined with the previous inequality, this implies firm a strictly prefers $\left(\hat{i}\left(a\right), 1\right)$ at price $a+S\left(\hat{i}\left(a\right), 1\right)$ to action $\left(0, \theta\right)$ at any price $P\left(0, \theta\right)$. This establishes Claim 0.

Claim 4: Firm $a_{\min}$ chooses $\left(I^{*}, 1\right)$ in equilibrium.

Proof of Claim 4: The case that firm $a_{\min}$ chooses $\left(i, \theta\right) \neq \left(I^{*}, 1\right)$ with $i>0$ is ruled out by arguments identical to those in the proof of Proposition 5. We here change the proof for that firm $a_{\min}$ doesn't choose $\left(0, \theta\right)$ for any θ. Suppose to the contrary that firm $a_{\min}$ chooses $\left(0, \theta\right)$. If firm $a_{\min}$ deviates to $\left(I^{*}, 1\right)$, it can only be fairly priced or over priced, so the deviation payoff satisfies

$$\Pi\left(a_{\min}, I^{*}, 1, P\left(I^{*}, 1\right)\right) \geq \Pi\left(a_{\min}, I^{*}, 1, a_{\min}+S\left(I^{*}, 1\right)\right).$$

That $\left(0, \theta\right)$ is a feasible choice implies $I_{L}=0$. By Claim 0, firm $a_{\min}$ strictly prefers $\left(I^{*}, 1\right)$ at price $a_{\min}+S\left(I^{*}, 1\right)$ to action $\left(0, \theta\right)$ with any price $P\left(0, \theta\right)$:

$$\Pi\left(a_{\min}, I^{*}, 1, a_{\min}+S\left(I^{*}, 1\right)\right)>\Pi\left(a_{\min}, 0, \theta, P\left(0, \theta\right)\right).$$

These two inequalities together imply

$$\Pi\left(a_{\min}, I^{*}, 1, P\left(I^{*}, 1\right)\right)>\Pi\left(a_{\min}, 0, \theta, P\left(0, \theta\right)\right),$$

that is, firm $a_{\min}$ benefits from deviating to $\left(I^{*}, 1\right)$, contradicting the equilibrium condition and establishes Claim 4.

Claim 5: If $I_{L}=0$, then $\hat{a}=a_{\max}$.

Proof of Claim 5: Suppose $I_{L}=0$, and suppose to the contrary of the Claim that $\hat{a}<a_{\max}$. By Claims 2 and 3, for firm types $a<\hat{a}$, Lemma A5 applies and hence $i\left(a\right)$ satisfies ODE (24), and by Claims 2 and 4, conditions (15) and (16) are also satisfied, so $i\left(a\right)=\hat{i}\left(a\right)$ as specified in Claim 0 with $\hat{i}\left(\hat{a}\right)>0$. Let $\tilde{i}=\hat{i}\left(\hat{a}\right)$. Then regardless of whether type $\hat{a}$ chooses $\left(\tilde{i}, 1\right)$ or $\left(0, \theta\right)$ for some θ, $P\left(\tilde{i}, 1\right)=\hat{a}+S\left(\tilde{i}, 1\right)$ by Lemma A4. By continuity of Π, for firms $a>\hat{a}$ in a neighbourhood of

$\hat{a}$, their payoff from deviating to $\left(\tilde{i},1\right)$ is in a neighbourhood of

$$\Pi\left(\hat{a},\tilde{i},1,P\left(\tilde{i},1\right)\right)=\hat{a}+S\left(\tilde{i},1\right).$$

On the other hand, firms $a>\hat{a}$ have equilibrium payoff

$$\Pi^{*}\left(a\right)=P\left(0,\theta\left(a\right)\right)^{\epsilon}a^{1-\epsilon}=\max_{\theta}P\left(0,\theta\right)^{\epsilon}a^{1-\epsilon},$$

where the second equality follows the equilibrium condition that type a doesn't deviate to other θ. Hence for firms $a>\hat{a}$ in a neighbourhood of $\hat{a}$, their equilibrium payoff is in a neighbourhood of $\max_{\theta}P\left(0,\theta\right)^{\epsilon}\hat{a}^{1-\epsilon}$. By Claim 0,

$$\hat{a}+S\left(\tilde{i},1\right)=\Pi\left(\hat{a},\hat{i}\left(\hat{a}\right),1,\hat{a}+S\left(\hat{i}\left(\hat{a}\right),1\right)\right)>\max_{\theta}\Pi\left(\hat{a},0,\theta,P\left(0,\theta\right)\right)=\max_{\theta}P\left(0,\theta\right)^{\epsilon}\hat{a}^{1-\epsilon}.$$

Hence there exist firms above $\hat{a}$ in a neighbourhood of $\hat{a}$ that benefit from deviating to $\left(\tilde{i},1\right)$. The contradiction establishes Claim 5.

B Details for the repurchase microfoundation in Section 4

We assume that holding cash inside the firm is costly and generates a negative rate of return $-\beta<0$ (relative to investors' opportunity cost of funds, which is normalized to 0). Hence if no payouts are made over an arbitrary time interval $[0,t]$, the free cash flows accumulate to a date-t value of

$$\int_{0}^{t}\lambda e^{-\beta(t-s)}ds=\frac{\lambda}{\beta}\left(1-e^{-\beta t}\right).$$

Under payout policy $\left(\left|i\right|,n\right)$, the firm's date-$T$ cash balance is[32]

$$\sum_{m=1}^{n}\left(\frac{\lambda}{\beta}\left(1-e^{-\beta\frac{T}{n}}\right)-\frac{\left|i\right|}{n}-\kappa\left(\frac{\left|i\right|}{n}\right)^{\gamma}\right)e^{-\beta\left(T-m\frac{T}{n}\right)}. \tag{A41}$$

Let a_{IL} denote the firm's illiquid assets-in-place, which do not incur the negative return $-\beta$. The firm knows the value of a_{IL} but investors don't. By straightforward evaluation of (A41),[33] the firm's value under the above payout policy is

$$V=a_{IL}+\frac{\lambda}{\beta}\left(1-e^{-\beta T}\right)-\left(\frac{\left|i\right|}{n}+\kappa\left(\frac{\left|i\right|}{n}\right)^{\gamma}\right)\frac{1-e^{-\beta T}}{1-e^{-\beta\frac{T}{n}}}. \tag{A42}$$

[32]The cash flows between dates $(m-1)\frac{T}{n}$ and $m\frac{T}{n}$ accumulate to $\frac{\lambda}{\beta}\left(1-e^{-\beta\frac{T}{n}}\right)$ at date $m\frac{T}{n}$, and become $\frac{\lambda}{\beta}\left(1-e^{-\beta\frac{T}{n}}\right)-\frac{|i|}{n}-\kappa\left(\frac{|i|}{n}\right)^{\gamma}$ after divesting and paying out $\frac{|i|}{n}$ at date $m\frac{T}{n}$. This amount of cash kept in the firm becomes $\left(\frac{\lambda}{\beta}\left(1-e^{-\beta\frac{T}{n}}\right)-\frac{|i|}{n}-\kappa\left(\frac{|i|}{n}\right)^{\gamma}\right)e^{-\beta\left(T-m\frac{T}{n}\right)}$ at date T.

[33]The evaluation uses the fact that $\sum_{m=1}^{n}e^{-\beta\left(T-m\frac{T}{n}\right)}=\frac{1-e^{-\beta T}}{1-e^{-\beta\frac{T}{n}}}$.

Defining $a = a_{IL} + \frac{\lambda}{\beta}\left(1 - e^{-\beta T}\right)$, $\theta\left(n\right) = \frac{1-\frac{1}{n}}{1-\frac{1}{N}}$, and

$$S = |i| - \left(\frac{|i|}{n} + \kappa\left(\frac{|i|}{n}\right)^{\gamma}\right)\frac{1-e^{-\beta T}}{1-e^{-\beta\frac{T}{n}}}, \tag{A43}$$

firm value (A42) maps to our general specification of firm value (3). θ increases monotonically from 0 to 1 as n increases from 1 to N. As such, smoother repurchases correspond to higher efficiency levels θ. We show in Online Appendix E that (A42) satisfies Assumption 1.