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Wall Street and Silicon Valley: A Delicate Interaction

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Entrepreneurs and venture capitalists are concerned about investors' beliefs in asset markets because these beliefs shape the value of a potential IPO and the possibility to expand. Investors' beliefs, on the other hand, can be influenced by start-up activity insofar as the latter contains valuable information about eventual profitability. This two-way feedback is shown to generate excessive, non-fundamental, waves in start-up activity, IPOs, and asset prices. Policies that "lean against the wind" can improve welfare, without requiring an informational advantage by the government.

Key words: Beauty contests, IPO waves, Hot IPO effects, Mis-pricing, Heterogeneous beliefs, Information-driven complementarities, Volatility, Inefficiency

JEL Codes: C72, D62, D82

1. INTRODUCTION

The arrival of new, unfamiliar, technologies—e.g. e-commerce in the late 90s—is often associated with joint spikes in start-up activity, initial public offerings (IPOs), and asset prices. Do these spikes reflect the efficient response of the economy to available information about the likely profitability of the new technologies? Or are they symptoms of excessive waves of optimism and pessimism?

We study how the answer to this question depends on a particular two-way feedback between entrepreneurial activity ("Silicon Valley") and asset markets ("Wall Street"), which we expect to be particularly relevant in this context. On the one hand, Silicon Valley is concerned about investor sentiment in Wall Street because this determines the value of a possible IPO and the possibility to expand. On the other hand, Wall Street monitors start-up activity, venture capital, and other indicators of real investment because these variables may aggregate dispersed information about the underlying fundamentals. The first channel is the subject not only of the macro-finance literature at large but also of the literature on "IPO waves", with which we connect below. The second channel has received little attention in the specific context of interest but seems to find support in a large empirical literature, tracing back to Chen, Roll and Ross (1986) and

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Cutler, Poterba and Summers (1989), that documents the response of asset prices to news about real economic activity at both the macroeconomic and the sectorial level.

Our article shines the spotlight on the *interaction* of these two channels. We argue that this interaction can give rise to excessive, non-fundamental, waves of optimism and pessimism in start-up activity, IPOs, and asset prices. The amplification of "noise" or "animal spirits" and the associated inefficiency are largest when there is more uncertainty, less consensus, and more scope for social learning—which suggests that the arrival of new, unfamiliar, technologies may be especially conducive to such phenomena.

1.1. *Model preview*

Our "Silicon Valley" features a continuum of entrepreneurs, who move in two stages. In the first stage, they decide whether or not to start a project with a new technology, using internal funds and/or venture capital. We think of this stage as the start-up stage.[1] In the second stage, the entrepreneurs who started a project can expand its scale by raising funds in "Wall Street", by selling equity shares to a continuum of external investors. We think of this stage as the IPO stage. All agents are imperfectly informed about the long-run profitability of the new technology (the underlying "fundamental").

As anticipated above, at the core of the model is a two-way feedback between these two groups of agents. In the first stage, when an entrepreneur chooses whether or not to start a project, she bases this decision on her expectations about future IPO prices, which will determine her capacity to expand and her eventual payoff. In the second stage, investors base their demand for shares on, *inter alia*, the information they can extract from their observation of (a signal of) aggregate start-up activity. Through this information channel, start-up activity has a positive effect on investor demand and IPO prices.

1.2. *Main results*

In our model, aggregate start-up activity is driven by two shocks: the true fundamental and the entrepreneurs' "animal spirits". In the most literal interpretation of the model, animal spirits represent correlated noise in the entrepreneurs' information about the new technology; but, it is straightforward to recast this noise as a correlated bias in beliefs ("irrational exuberance"), or a correlated taste shock. Our first result shows how the aforementioned two-way feedback amplifies the effects of animal spirits, or noise, on start-up activity and IPO volume.

To understand this result, consider first the IPO stage. Investors are rational and understand that high start-up activity could be the product of either strong fundamentals or correlated entrepreneurial exuberance. But they cannot tell the two forces apart. It follows that, at the IPO stage, investors' demand and asset prices tend to increase with the entrepreneurs' animal spirits—and, by implication, so does the amount of capital that can be raised in the IPO market.

Next, consider the start-up stage. At this point, entrepreneurs face uncertainty about both the underlying fundamental and the likely IPO price. They understand that, in equilibrium, IPO prices tend to move in the same direction as the start-up activity of other entrepreneurs *conditional* on the fundamental. This means that the start-up stage reduces to a game of strategic complementarity:

1. We do not study the incentive problem between entrepreneurs and venture capitalists and, in fact, we do not even explicitly incorporate venture capitalists. However, we like to interpret the entrepreneur in our model as a "team" between an entrepreneur and a venture capitalist, with the former providing the relevant know-how, the later providing the funds for a start-up, and the two sharing information and payoffs. More generally, we think of the start-up decision as a proxy for a broad range of real investment decisions taking place before firms go public.

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for given beliefs about the fundamental, an entrepreneur is more willing to start a project (and subsequently enter the IPO market) when she expects other entrepreneurs to do the same. Similarly to the literature on beauty contests (Morris and Shin, 2002; Angeletos and Pavan, 2007), this complementarity amplifies the equilibrium effects of noise, or animal spirits, on start-up activity and, thereby, on IPO volume, too.

A complementary interpretation is that, because of the informational channel, entrepreneurs end up engaging in a form of speculation: whenever entrepreneurial spirits are high, the typical entrepreneur anticipates the investors to be bullish and her project to be overvalued (relative to her information), and this increases her incentive to start a project in these circumstances. This is despite the fact that investors themselves are fully rational and "leave no money on the table" in their own eyes (under their own information). Finally, because such speculative behaviour by the entrepreneurs ultimately reduces the precision of the information revealed to the investors, the non-fundamental movements in IPO prices and capital expansion are also amplified. In short, non-fundamental volatility is amplified across the board.

Our second result shows that these effects are excessive not only relative to a counterfactual world where our mechanism is absent (i.e. when the investors extract no information from start-up activity) but also relative to the following constrained-efficiency benchmark: a planner who does not have superior information over any private agent at any point of time but can nevertheless influence allocations, and in particular start-up activity, via subsidies/taxes contingent on public information. Such a planner can do better than the laissez-faire equilibrium because she internalizes two externalities, a pecuniary one and an informational one, both of which are tied to our mechanism.

The pecuniary externality relates to the aforementioned strategic complementarity in the start-up decisions. As explained above, this complementarity reflects a speculative motive, that is, the anticipation of a transfer from the investors to the entrepreneurs. Conditional on start-up activity and subsequent investment, such a transfer is of no welfare consequence. However, this also means that the anticipation of such a transfer should *not* drive start-up decisions in the first place. Translating this in the language of Angeletos and Pavan (2007), we have that the socially optimal degree of strategic complementarity is zero, whereas the equilibrium one is positive.

The informational externality, on the other hand, relates to the following. If entrepreneurs relied more on their idiosyncratic information about fundamentals and less on their collective optimism at the start-up stage, the aggregate start-up activity would reveal more information about the fundamentals, and this in turn would improve the efficiency of the investments made at the IPO stage.

Both externalities contribute in the same direction: relative to the planner's solution, equilibrium start-up decisions are driven too much by the entrepreneurs' collective optimism and too little by fundamentals. By the same token, a rationale emerges for policies that"lean against the wind", in the sense of penalizing start-ups/IPOs when prices are high and subsidizing them when prices are low (relative to the unconditional mean). These policies do not require the planner to detect any mis-pricing in real time, nor to ever have access to information other than the one in the public domain. Instead, it suffices to impose a price-contingent tax on the entrepreneurs, or a tax on financial traders. In our model, the former policy is strictly preferable because it is the entrepreneurs' choices and not the traders' ones that need to be corrected, but the latter strategy goes in the right direction, too.

1.3. *IPO waves*

As already alluded to, the idea of non-fundamental waves of optimism and pessimism connects our model to the large literature on IPO waves (Ritter and Welch, 2002; Lucas, 1972). Two key

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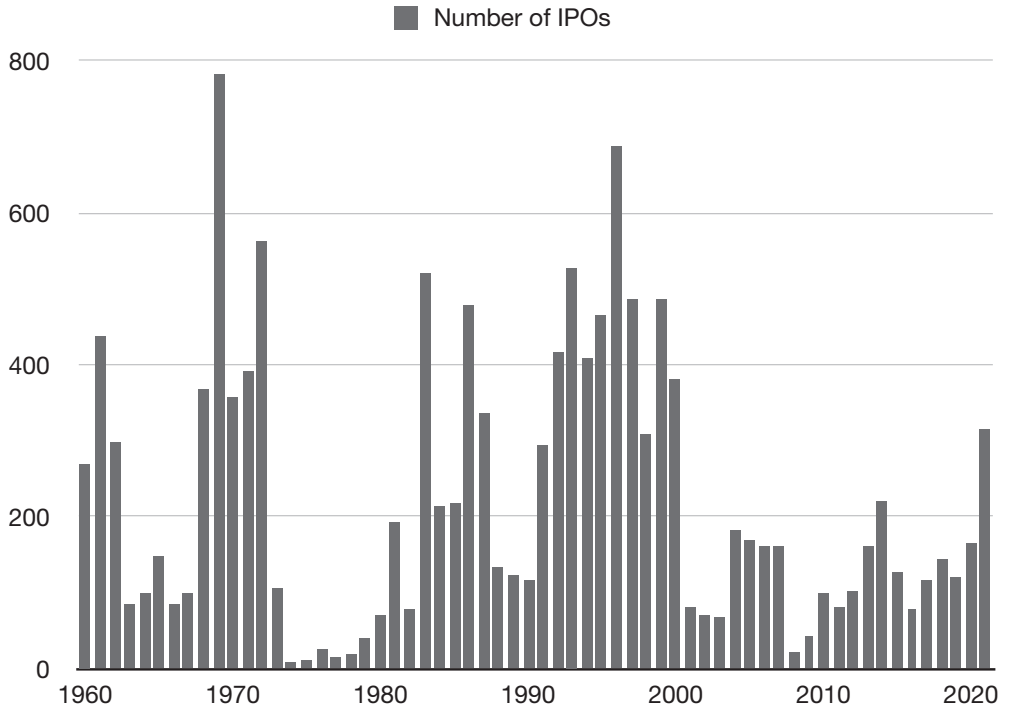

FIGURE 1
IPO waves

facts from this literature are particularly relevant for our analysis. First, IPO activity tends to be clustered in time: there are periods with very little action, and periods with large spikes. This is illustrated in Figure 1, which reports the number of IPOs per year in the US over the 1960–021 period.[2] Second, there seems to be a "hot IPO effect" (Ritter, 1984; Lowry and Schwert, 2002; Helwege and Liang, 2004): the presence of more IPO activity by firms in a particular sector tends to increase the price at which a given firm in that sector can do an IPO, holding constant both various proxies for sector-specific fundamentals and economy-wide IPO activity and asset prices.

Our model is broadly consistent with these facts and provides a new interpretation of them: a hot IPO market can reflect either fundamentals or noise, but the role of noise is both amplified and excessive from a welfare viewpoint. And while other explanations of IPO waves have already been proposed in the literature,[3] the following two implications distinguish our approach. First, we provide a theoretical justification for policies that lean against IPO waves even when all agents are fully rational and the planner has no informational advantage over the market. Second, we identify a new testable prediction: if our mechanism is at work, an econometrician should be able to detect a negative relation between IPO activity and realized IPO returns

2. This figure updates Figure 1 from Pástor and Veronesi (2005). Like the original one, it is based on data from Jay Ritter's webpage. Specifically, it plots the data from Column 2 in Table 8 from https://site.warrington.ufl.edu/ritter/files/IPO-Statistics.pdf.

3. Some authors emphasize rational factors (Pástor and Veronesi, 2005; He, 2007), others emphasize behavioural features (Shiller, 1990; Lee, Shleifer and Thaler, 1991; Ritter, 1991), but, to the best of our knowledge, none features our mechanism.

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conditional on subsequent information about fundamentals. We explain this point in more detail in Section 7.

1.4. *Beauty contests*

Another integral part of our contribution is to show how the two-way feedback under consideration gives rise to strategic complementarity in start-up activity and IPOs. This connects us to a literature that has sought to operationalize Keynes's famous beauty-contest metaphor for asset markets (Bacchetta and van Wincoop, 2005; Allen, Morris and Shin, 2006; Cespa and Vives, 2012; Kasa, Walker and Whiteman, 2014). Relative to this literature, we shift the focus from asset prices to real investment. More importantly, we justify the implicit suggestion that "beauty contests are bad" from a welfare standpoint, by showing that the strategic complementarity associated with our mechanism represents a wedge between private and social returns.

This property contrasts with the efficiency of another kind of beauty contest in real economic activity, that originating in pecuniary externalities in the textbook business-cycle framework (Angeletos and La'O, 2010, 2020). It also explains why our normative lessons extend to the variant model of Section 6, which lets start-ups compete for funds in the IPO stage. This "neoclassical" force naturally introduces strategic substitutability in start-up activity and IPO entry but does *not* introduce a wedge between the private and the social returns and hence it does not change our welfare analysis.[4]

1.5. *Other related literature*

Our article adds to a literature that studies the welfare implications of combining strategic interactions and informational externalities (Vives, 1997, 2017; Angeletos and Pavan, 2009; Amador and Weill, 2010, 2012). While these are typically treated as separate features, in our setting, they are tied together: the strategic complementarity is itself the product of an informational spillover.

Related in this regard are Benhabib, Wang and Wen (2015), Chahrour and Gaballo (2021), Gaballo (2018), and Goldstein, Ozdenoren and Yuan (2011). Common to all these papers and ours is the presence of a signal extraction problem that gives rise to some type of strategic complementarity. These papers, however, study different contexts than ours and do not contain the specific mechanism identified here.[5]

At a broad level, our article adds to the study of the nexus between asset prices and real investment. First, we borrow from macro-finance at large the feedback from asset markets to investment, but we add to it an informational feedback of the opposite direction. Second, we connect to the literature on speculation (Harrison and Kreps, 1978), but we let speculative

4. It is also worth clarifying that our mechanism allows but does not require strategic uncertainty among the entrepreneurs: the key is that the latter collectively shape IPO prices, not that they face uncertainty about one another's behaviour.

5. Benhabib *et al.* (2015) focus on the confusion of aggregate sunspots and idiosyncratic demand shocks, while Chahrour and Gaballo (2021) focus on confusion between idiosyncratic wealth shocks and aggregate housing supply shocks. Gaballo (2018) revisits Lucas (1972), shows how large private uncertainty may result from small primitive heterogeneity when firms learn from prices and uses this kind of near-discontinuity to argue that a small amount of uncertainty in fundamentals can rationalize a large degree of monetary non-neutrality. Finally, in work that was concurrent to the original version of our article, Goldstein *et al.* (2011) study a currency-attack setting where the speculators' actions become strategic complements when the central bank interprets a greater aggregate attack as a signal of poor economic fundamentals. At the abstract level, the last paper's mechanism is the closest to ours. However, both the context and the lessons are very different.

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motives operate in start-up activity as opposed to financial trading. Third, we complement a literature that studies how the information contained in asset prices helps guide real investment (Dow and Gorton, 1997; Subrahmanyam and Titman, 1999, 2001) by studying the opposite informational spillover, from real investment to asset prices.

Related are also Albagli, Hellwig and Tsyvinski (2017), which focuses on how information heterogeneity among traders impinge on financial market efficiency and thereby on firms' decisions, and Chari and Kehoe (2003) and Loisel, Portier and Pommeret (2012), which let an informational spillover—in the form of herding—generate "hot money" phenomena. None of these papers, however, features either the two-way feedback at the core of our model or the type of inefficiency discussed above.

Last but not least, our modelling of start-up decisions, and in particular their dependence on anticipated IPO returns, connects our work to the literature on short-termism in entrepreneurial decision making (e.g. Bebchuk and Stole, 1993). There are, however, important differences. In our model, the entrepreneurs' concern with the financial market's evaluation of their project is fully warranted from a normative standpoint because the reliance on the financial market is essential to the capital expansion that follows the launch of the firms. In this sense, short-termism is not a source of value destruction. What creates an inefficiency in our model is the fact that the collective signalling from the real sector to the financial market introduces a speculative motive that distorts the entrepreneurs' early decisions along with the information externality that such collective signalling induces on the firms' subsequent expansions.

1.6. *Layout*

The rest of the article is organized as follows. Section 2 introduces the model. Section 3 characterizes the equilibrium. Section 4 derives the main positive lesson. Section 5 formulates an appropriate efficiency benchmark and derives our policy implications. Section 6 discusses the robustness of our findings. Section 7 concludes by circling back to the literature on IPO waves and discussing possible venues for empirical work. All proofs are in the Appendix at the end of the document.

2. MODEL

There is a single perishable good, which can be used for either consumption or investment. There are three periods $t \in \{1,2,3\}$. There are two types of agents, entrepreneurs, and investors, each of measure one. Entrepreneurs are born at $t=1$, investors at $t=2$. At $t=1$, the entrepreneurs have the option to start new projects using internal funds, which can also be interpreted as funds provided by an un-modelled venture capitalist. We refer to this period as the "start-up stage". At $t=2$, those entrepreneurs who started a project at $t=1$ can expand it by selling shares to outside investors and using these funds to make an additional investment. We refer to this period as the "IPO stage". At $t=3$, the projects' profits are realized and distributed to the entrepreneurs and the outside investors.

2.1. *Technology.*

Starting a project requires an initial fixed investment of one unit of the perishable good at $t=1$. Once a project is started at $t=1$, it requires an additional investment at $t=2$. The size of this investment can vary. We denote by $k_i \in \mathbb{R}_+$ the stage-2 investment of entrepreneur i. At $t=3$, the

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output of an entrepreneur who started the project at $t=1$ and invested k_i at $t=2$ is equal to

$$q_i = \Theta f(k_i),$$

where $f(k)=k^\alpha$ and $\alpha \in (0,1)$ parametrizes the returns to scale. The profitability of all projects depends on the realization of the aggregate random variable Θ, which we interpret as the underlying "fundamental".

2.2. *Timing*

Before any agent moves, Nature draws the fundamental $\theta \equiv \log\Theta$ from a Normal distribution with mean 0 and variance $\sigma_\theta^2 = 1/\pi_\theta$. This distribution defines the common prior about θ, with π_θ parameterizing the precision of the prior. In addition, Nature draws a variety of private signals, some for the entrepreneurs and some for the investors; we specify the details of these signals in the sequel.

Start-up stage. At $t=1$, each entrepreneur is endowed with one unit of the perishable good, which he can either consume or invest into a start-up. Let $n_i \in \{0,1\}$ denote entrepreneur i's decision to start a project. We refer to the entrepreneurs who decide to start a project at $t=1$ as "active", and the rest as "inactive". Let N denote the measure of active entrepreneurs and, with some abuse of notation, let $[0,N]$ denote the set of active entrepreneurs.[6]

IPO stage. At $t=2$, the entire profile $(n_i)_{i\in[0,1]}$ of start-up decisions is publicly observed. Inactive entrepreneurs have no other source of income and take no further actions.[7] Active entrepreneurs have no income at $t=2$, so their investment k_i must be fully financed by outside investors. In particular, entrepreneurs finance their investment by selling shares in the IPO market implying that

$$k_i = p_i s_i, \tag{1}$$

where $s_i \in [0,1]$ is the amount of shares sold by entrepreneur i and p_i the price of such shares. The microstructure of the IPO market is described below.

At $t=3$, the fundamental θ is publicly revealed and the output of all projects is realized. Each active entrepreneur receives $(1-s_i)\Theta f(k_i)$ whereas outside investors receive $s_i\Theta f(k_i)$ from their investment in entrepreneur i's project.

2.3. *Payoffs.*

The lifetime utility of entrepreneur i is $U_i = c_{i1} + \beta c_{i2} + \beta^2 c_{i3}$, where $\beta \in (0,1)$ is the common discount factor. His consumption at $t=1$ is $c_{i1} = 1-n_i$, i.e., it is equal to the initial endowment of the perishable good if the entrepreneur does not start a project and is 0 otherwise. At $t=2$, each entrepreneur's consumption is equal to 0. At $t=3$, entrepreneur i's consumption is equal to 0 if he did not start a project and is equal to $c_{i3} = (1-s_i)\Theta f(k_i)$ otherwise. Combining the elements above, we have that the entrepreneur's lifetime utility is equal to

$$U_i = 1 - n_i + n_i\beta^2\Pi_i, \text{ where } \Pi_i \equiv (1-s_i)\Theta f(k_i). \tag{2}$$

All investors are identical, they behave as price takers, and are symmetrically informed. We thus represent this class of agents with a *representative investor*. For simplicity, we assume that

6. This amounts to a state-dependent re-ordering of the entrepreneurs so that the active ones are always listed first.

7. We studied the implications of relaxing such an assumption in an earlier version of the article, Angeletos, Lorenzoni and Pavan (2007), albeit under a simplified version of the model.

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the supply of funds in the IPO market is perfectly elastic, which can be micro-founded as follows. At $t=2$, the representative investor can produce the consumption good out of labour effort at a one-to-one rate. The representative investor's consumption levels at $t=2$ and $t=3$, respectively, are thus equal to

$$c_2 = l - \int_{i\in[0,N]} p_i s_i di \qquad \text{and} \qquad c_3 = \int_{i\in[0,N]} s_i \Theta f(k_i) di,$$

where l denotes the investor's labour effort at $t=2$, and where s_i denotes the quantity of shares bought from active entrepreneur $i\in[0,N]$. The investor's disutility of effort is linear so that his lifetime utility (from period 2's perspective), $V=c_2-l+\beta c_3$, can be expressed as follows

$$V = \int_{i\in[0,N]} \left[\beta\Theta f(k_i) - p_i\right] s_i di. \tag{3}$$

The above assumptions imply that the supply of external funds to each active entrepreneur is perfectly elastic at a price equal to the expected profit of the entrepreneur's project. In Section 6, we discuss the robustness of the results to the possibility of an imperfectly elastic supply of funds.

2.4. *Information*

At $t=1$, when choosing whether or not to a start a project, each entrepreneur has access to various sources of information (signals) that are not directly available to the investors. The noise in some of these signals may be mostly idiosyncratic, while, for other signals, the noise may be correlated across entrepreneurs. We capture such a possibility in the simplest possible way by assuming that each entrepreneur observes two signals. One has purely idiosyncratic noise and is given by $x_i=\theta+\xi_i$, with each ξ_i drawn from a Normal distribution with mean zero and variance $1/\pi_x$, independently of θ and independently across entrepreneurs. The other signal is given by $y=\theta+\varepsilon$, and its noise ε is perfectly correlated among the entrepreneurs and drawn from a Normal distribution with mean zero and variance $1/\pi_y$, independently from θ and $(\xi_i)_{i\in[0,1]}$.

As we show below, the key role of the correlated noise ε is to introduce a source of co-movement in start-up activity, financial prices, and Period-2 investment that can be interpreted as a rational form of "market sentiment" or "exuberance". Such a correlated noise can have various origins. It could originate in the entrepreneurs (a) attending common industry events such as fairs, forums and other networking venues (Ozgen and Baron, 2007), (b) being on a common social network (Robinson and Stubberud, 2011), or (c) sharing common venture capitalists or "angel investors" (Gompers and Lerner, 1997; Hochberg, Ljungqvist and Lu, 2007). Alternatively, one could embrace a behavioural interpretation of the model in which y is recasted as a biased signal or a taste shock.[8,9]

At $t=2$, the representative investor receives information about the fundamental θ which is not directly observed by the entrepreneurs and which is summarized in a private signal $\omega=\theta+\eta$,

8. For example, entrepreneurs in a given industry may come from experiences in a different industry. This may lead them to interpret preliminary data on the viability of a new technology using the same frame of reference.

9. Finally, as emphasized for example in Hellwig and Veldkamp (2009), strategic complementarities—like the ones that, as we will show below, emerge endogenously in our economy—by themselves generate an incentive for the entrepreneurs to learn from common sources of information or to rely on the same venture capitalists and consultants. See also Dow, Goldstein and Guembel (2017), Froot, Scharfstein and Stein (1992), and Veldkamp (2006) for complementary justifications.

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where η is drawn from a Normal distribution with mean zero and variance $1/\pi_\omega$, independently of θ, ε and $(\xi_i)_{i\in[0,1]}$.[10] It follows that the information set with which the representative investor enters the IPO markets in Period 2 is given by $\mathcal{I}=\{\omega,(n_j)_{j\in[0,1]}\}$, whereas the corresponding information set of each active entrepreneur i is given by $\mathcal{J}_i=\{x_i,y,(n_j)_{j\in[0,1]}\}$. The information sets with which these agents exit the IPO markets contain, in addition to the above signals, the prices, the shares, and the associated levels of investment in each of the IPO markets: that is, $\mathcal{I}'\equiv\mathcal{I}\cup\mathcal{M}$ and $\mathcal{J}_i'\equiv\mathcal{J}_i\cup\mathcal{M}$, where $\mathcal{M}\equiv\{(p_i,s_i,k_i)_{i\in[0,N]}\}$ represents the information generated in the IPO markets.

2.5. *IPO market structure*

The IPO market operates in a similar fashion as in Vives (2011, 2017).[11] Each entrepreneur i submits a supply correspondence $S_i^s((\tilde{p}_j)_{j\in[0,N]},(\tilde{k}_j)_{j\in[0,N]\setminus i}|\mathcal{J}_i)$, representing the amount of shares he is willing to sell at each price $\tilde{p}_i$, given the prices $(\tilde{p}_j)_{j\in[0,N]\setminus i}$ and investment levels $(\tilde{k}_j)_{j\in[0,N]\setminus i}$ in the other IPOs. The representative investor submits a collection of demand correspondences $\left(S_i^d(\cdot|\mathcal{I})\right)_{i\in[0,N]}$, one for each IPO market $i\in[0,N]$, with each $S_i^d((\tilde{p}_j)_{j\in[0,N]},(\tilde{k}_j)_{j\in[0,N]}|\mathcal{I})$ specifying the amount of firm i's shares he is willing to purchase at each price $\tilde{p}_i$, given firm i's investment $\tilde{k}_i$, and given the prices and investment levels $(\tilde{p}_j)_{j\in[0,N]\setminus i}$ and $(\tilde{k}_j)_{j\in[0,N]\setminus i}$ in the other IPO markets.[12] The auctioneer then selects a collection of triples $(p_i,s_i,k_i)_{i\in[0,N]}$, one for each IPO market $i\in[0,N]$, such that each IPO market clears. That is, for each market $i\in[0,N]$,

$$s_i\in S_i^s((p_j)_{j\in[0,N]},(k_j)_{j\in[0,N]\setminus i}|\mathcal{J}_i)\quad\text{and}\quad s_i\in S_i^d((p_j)_{j\in[0,N]},(k_j)_{j\in[0,N]}|\mathcal{I}),\tag{4}$$

and each investment k_i is consistent with the price p_i and shares s_i issued, that is,

$$k_i=p_i\cdot s_i.\tag{5}$$

By allowing the orders to be contingent on prices, the above structure allows the information of all market participants to be potentially revealed and used by other market participants. This is reminiscent of Grossman and Stiglitz (1980). However, here there is a continuum of assets and a continuum of markets, one for each active project $i\in[0,N]$. Furthermore, the dividend of each such asset is endogenous to the level of capital raised by the respective entrepreneur through the IPO, a property that both the entrepreneurs and the investors understand.

2.6. *Equilibrium definition*

An equilibrium is a collection of start-up rules $(n_i(\cdot))_{i\in[0,1]}$, demand and supply correspondences $\left(S_i^d(\cdot|\cdot)\right)_{i\in[0,N]}$ and $\left(S_i^s(\cdot|\cdot)\right)_{i\in[0,N]}$, and market outcomes $(p_i(\cdot),s_i(\cdot),k_i(\cdot))_{i\in[0,N]}$ that jointly satisfy the following five conditions:

10. While ω is modelled as an exogenous signal, it is straightforward to recast it as the outcome of the aggregation of information that may take place in the financial market when the investors themselves have dispersed private information about θ.

11. See also Malamud and Rostek (2017).

12. The conditioning of the schedules on the information sets $\mathcal{J}_i$ and $\mathcal{J}$ is mean to highlight that the submitted schedules depend on the entrepreneurs' and the investors' information at the beginning of the IPO stage.

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(i) For each $\mathcal{J}_i$, the supply correspondence $S_i^s(\cdot|\mathcal{J}_i)$ of each active entrepreneur $i \in [0,N]$ maximizes the entrepreneur's expectation of Π_i, as in (2), given the entrepreneur's information $\mathcal{J}_i$.
(ii) For each $\mathcal{J}$, the investor's demand correspondences $\left(S_i^d(\cdot|\mathcal{J})\right)_{i\in[0,N]}$ maximize the investor's expectation of V, as in (3), given the investor's information $\mathcal{J}$.
(iii) In each state of Nature $(\theta, \varepsilon, \eta, (\xi_i)_{i\in[0,1]})$, given the submitted demand and supply correspondences $\left(S_i^d(\cdot|\mathcal{J})\right)_{i\in[0,N]}$ and $\left(S_i^s(\cdot|\mathcal{J}_i)\right)_{i\in[0,N]}$, the prices, shares, and investments $(p_i, s_i, k_i)_{i\in[0,N]}$ selected by the auctioneer clear all markets and are budget feasible, that is, satisfy conditions (4) and (5).
(iv) For any (x_i, y), each entrepreneur's start-up decision $n_i(x_i, y)$ maximizes the entrepreneur's expectation of U_i.
(v) Expectations are rational.

In short, we study rational expectations equilibria. But, we also require that such equilibria satisfy the following three, standard refinements:

(vi) The equilibrium price in any given IPO market does not reveal any information not contained in the supply and demand schedules submitted by the relevant agents. This restriction is standard and requires the auctioneer to only use information coming from the submitted demand and supply schedules in choosing the outcome (p_i, s_i, k_i) in each market.
(vii) Each entrepreneur i is "informationally small". In particular, we require that the representative investor's posterior beliefs about θ be independent of the start-up decision n_i of any individual entrepreneur and of the outcome (p_i, s_i, k_i) of the entrepreneur's IPO. We allow the investor's beliefs to be influenced by the distribution $(n_i)_{i\in[0,1]}$ of start-up decisions and the distribution $(p_i, s_i, k_i)_{i\in[0,N]}$ of IPO market outcomes, and of course we allow any given entrepreneur to affect the outcome (p_i, s_i, k_i) of his own IPO via his choice of a supply schedule. What we rule out is only the possibility that the actions of a single entrepreneur move the representative investor's posterior beliefs about the aggregate fundamental θ.
(viii) The representative investor's posterior about the aggregate fundamental Θ is log-normal. Specifically, given $\mathcal{I}$, θ is normally distributed with a variance that is state-invariant; and the investor's posterior mean about θ, denoted by $\hat{\theta} \equiv \mathbb{E}[\theta|\mathcal{I}]$, is normally distributed with a variance that is invariant in $\mathcal{I}$. This restriction is also standard and is made for tractability, as it allows us to solve for the entrepreneurs' and the investor's inference problems in closed form.

3. EQUILIBRIUM CHARACTERIZATION

We characterize the equilibrium in four steps. First, we show how the investor's information determines share prices and investment levels in the IPO market. Second, we show how the entrepreneurs' expectations of share prices and fundamentals determine their start-up decisions. Third, we show how aggregate start-up activity conveys to the investor some of the entrepreneurs' information. In the fourth, and last, step, we close the loop by checking that the investor's information in the IPO stage is consistent with the endogenous signal contained in the start-up activity.

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3.1. *Step 1: IPOs*

Let us start from the IPO stage. Let

$$\hat{\Theta} \equiv \mathbb{E}\left[\Theta | \omega, (n_j)_{j\in[0,1]}, (p_j)_{j\in[0,N]}, (k_j)_{j\in[0,N]}\right]$$

denote the representative investor's equilibrium expectation of the fundamental. Because the investor is risk neutral, in equilibrium, it must be that the following relationship holds

$$p_i = \beta \hat{\Theta} f(k_i) \tag{6}$$

in each market $i \in [0,N]$.

Now consider the problem of each active entrepreneur. We proceed in two steps. First, we let the entrepreneur solve a relaxed problem. Next, we show that there exists a supply schedule S_i^s that implements the solution to such a problem.

The relaxed problem is one in which the entrepreneur knows $\hat{\Theta}$ and picks (p_i, s_i, k_i) to maximize his payoff subject to (6) and the budget constraint (5). Combining these two conditions, we have that

$$s_i = \frac{k_i}{\beta \hat{\Theta} f(k_i)}. \tag{7}$$

The entrepreneur's payoff can then be expressed as a function of Θ, $\hat{\Theta}$, and k_i, as follows:

$$(1-s_i)\Theta f(k_i) = \frac{\Theta}{\beta\hat{\Theta}}\left[\beta\hat{\Theta} f(k_i) - k_i\right]. \tag{8}$$

Because the entrepreneur is informationally small, he treats $\hat{\Theta}$ as invariant to his choices. As a consequence, the value of k_i that maximizes the right-hand side of (8) is given by

$$K(\hat{\Theta}) \equiv \arg\max_k \left\{\beta\hat{\Theta} f(k) - k\right\}. \tag{9}$$

The corresponding values of s_i and p_i are then given by (7) and (6), respectively. Note that, conditional on $\hat{\Theta}$, the solution (p_i, s_i, k_i) to the relaxed program is thus invariant to any private information entrepreneur i may have.

We now construct the entrepreneur's supply schedule that implements the above solution. Note that $K(\hat{\Theta})$ is strictly increasing in $\hat{\Theta}$ and that the expression on the right-hand side of (6) is strictly increasing in k_i. The following expression then defines a bijective relation between p_i and $\hat{\Theta}$:

$$p_i = P(\hat{\Theta}) \equiv \beta\hat{\Theta} f(K(\hat{\Theta})).$$

Given the above bijective relation, and using the fact that $s_i = k_i/p_i$, we have that the supply schedule that permits the entrepreneur to implement the allocation that solves the relaxed program is equal to

$$S_i^s((\tilde{p}_j)_{j\in[0,N]}, (\tilde{k}_j)_{j\in[0,N]\setminus i} | \mathcal{J}_i) = K(P^{-1}(\tilde{p}_i))/\tilde{p}_i. \tag{10}$$

We conclude that the equilibrium outcome of each market $i = [0,N]$ is given by

$$(p_i, s_i, k_i) = (P(\hat{\Theta}), K(\hat{\Theta})/P(\hat{\Theta}), K(\hat{\Theta})).$$

Because the latter are invariant in the entrepreneurs' private information, the restriction that the equilibrium price in any given IPO market not reveal any information not contained in the supply

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and demand schedules then implies that necessarily

$$\hat{\Theta} = \mathbb{E}\left[\Theta | \omega, (n_j)_{j\in[0,1]}\right] = \mathbb{E}[\Theta|\mathcal{I}].$$

That is, the representative investor does not learn anything about Θ after observing the prices $(p_j)_{j\in[0,N]}$ and the investments $(k_j)_{j\in[0,N]}$. This is a consequence of the entrepreneurs being cash-less at the IPO stage (an assumption we revisit in Section 6).

Thanks to the Cobb–Douglas specification, we can solve explicitly for the equilibrium investments, prices, and shares:

$$K(\hat{\Theta}) = (\alpha\beta\hat{\Theta})^{\frac{1}{1-\alpha}}, \qquad P(\hat{\Theta}) = \alpha^{\frac{\alpha}{1-\alpha}}(\beta\hat{\Theta})^{\frac{1}{1-\alpha}}, \qquad S(\hat{\Theta}) = \alpha. \tag{11}$$

Replacing the above into the entrepreneurs' supply schedules we then obtain that the latter are equal to

$$S_i^s((\tilde{p}_j)_{j\in[0,N]}, (\tilde{k}_j)_{j\in[0,N]\setminus i} | \mathcal{J}_i) = \alpha$$

for all $(\tilde{p}_j)_{j\in[0,N]}, (\tilde{k}_j)_{j\in[0,N]\setminus i}$, and no matter $\mathcal{J}_i$. That the amount of shares traded in equilibrium is equal to α in each state implies that, even though we have allowed entrepreneurs to post contingent supply schedules (aka generalized limit orders), the same equilibrium prices and allocations obtain if we assume a different market micro-structure whereby entrepreneurs commit to sell a fixed quantity of shares independently of the price (aka market orders).

3.2. *Step 2: Start-up stage*

We now turn to the start-up stage. From (2), entrepreneur i finds it optimal to start a project if and only if

$$\beta^2 \mathbb{E}_i[\Pi_i] \geq 1, \tag{12}$$

where $\mathbb{E}_i[\cdot]$ is a shortcut for $\mathbb{E}[\cdot|x_i, y]$ and $\Pi_i \equiv (1-s_i)\Theta f(k_i)$. From (11), the latter can be expressed as

$$\Pi_i = \Pi(\Theta, \hat{\Theta}) \equiv (1-\alpha)\Theta f(K(\hat{\Theta})) = (1-\alpha)\Theta(\alpha\beta\hat{\Theta})^{\frac{\alpha}{1-\alpha}}. \tag{13}$$

Combining these facts with the fact that $\hat{\theta} \equiv \mathbb{E}[\theta|\mathcal{I}]$ and $\theta|\mathcal{I}$ are normally distributed with deterministic variances, we conclude that entrepreneur i finds it optimal to start a project if and only if

$$\mathbb{E}_i\left[(1-\alpha)\theta + \alpha\hat{\theta}\right] \geq C, \tag{14}$$

where C is a deterministic scalar.[13]

Condition (14) captures the first direction of the feedback mechanism at the core of our article: when entrepreneurs expect a higher market valuation, they have a higher incentive to start a project. In particular, Condition (14) shows that it is optimal for an entrepreneur to start a project if and only if he is sufficiently optimistic about a weighted average of the fundamental and of the market's valuation of profitability. The intuition behind this condition is simple. The entrepreneur's decision depends on his expectation of θ because the latter directly affects his project's output. The entrepreneur's decision depends on his expectation of the market's valuation

13. See the proof of Proposition 1 for a detailed derivation of (14). Also note that $\hat{\theta} \equiv \mathbb{E}[\theta|\mathcal{I}]$ is different from $\log\hat{\Theta}$, where $\hat{\Theta} \equiv \mathbb{E}[\Theta|\mathcal{I}]$; the two differ by a constant that is derived in the Appendix. Finally, note that, to derive (14), we have also used the restriction that each entrepreneur is informationally small, that is, that the representative investor's information $\mathcal{I}$ is independent of entrepreneur i's individual start-up decision.

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$\hat{\theta}$ because that variable determines the cost of raising capital in the IPO market: the higher $\hat{\theta}$ is, the higher the IPO stock price, and hence the higher the amount of capital that the entrepreneur raises and invests at the IPO stage.

The relative importance of θ and $\hat{\theta}$ is determined by α, which parameterizes the decreasing returns to the Period-2 investment. A higher α implies that profits are more sensitive to the entrepreneur's capacity to raise capital in the IPO stage and hence that they are more sensitive to variations in share prices.

Given that θ, $\hat{\theta}$ and the available signals are jointly normal, condition (14) is equivalent to

$$(1-b)x_i + by \geq c, \tag{15}$$

for some constants b and c to be determined. This condition gives us the entrepreneur's strategy in the start-up stage, that is, it characterizes the start-up decision as a function of the entrepreneur's information. Using (15), we can derive the aggregate level of start-up activity:

$$N = \Pr((1-b)x_i + by \geq c|\theta, y) = \Phi\left(\sqrt{\pi_x}\frac{(1-b)\theta + by - c}{1-b}\right), \tag{16}$$

where Φ is the standard-normal cumulative distribution function. The second equality follows from the definitions of the signal x_i and from the symmetry of the normal distribution. Because strategies, and hence the scalars b and c, are commonly known in equilibrium, the above implies that the observation of N conveys to the representative investor the same information as the signal

$$z \equiv (1-b)\theta + by = \theta + b\varepsilon. \tag{17}$$

The level of start-up activity N is a noisy indicator of θ because the investor cannot tell apart whether, for example, a high value of N is driven by a high realization of the fundamental θ or by a high realization of the correlated noise in the entrepreneurs' beliefs.

The precision of the signal z can be derived using the last expression in (17) and is equal to

$$\pi_z = \pi_y / b^2.$$

This is endogenous to the entrepreneurs' strategy: the signal-to-noise ratio decreases with the coefficient b, which measures the relative response of the entrepreneurs' start-up decision to the two signals x_i and y. This is a key property, whose positive and normative implications we study in the sequel.

Note that, here, N reveals θ perfectly to the entrepreneurs. This is a consequence of the assumption that *all* the correlated noise in the entrepreneurs' information originates in the common signal y. However, this property, which is not important to our results, does not extend to richer information structures, for example, by adding idiosyncratic noise to the entrepreneurs' observations of y.

3.3. *Step 3: Market valuation*

We now derive the investors' valuations when entering the IPO market. Investors have two sources of information, the exogenous signal ω and the distribution of start-up decisions $(n_j)_{j\in[0,1]}$. The restriction that individual start-up decisions do not have a direct effect on the investor's expectation of Θ implies that $(n_j)_{j\in[0,1]}$ contains the same information as N. We thus have that

$$\hat{\Theta} = \mathbb{E}[\Theta|\mathcal{I}] = \mathbb{E}[\Theta|\omega, N].$$

This captures the second direction of our feedback mechanism: a high level of start-up activity increases the market's valuation of firms' profitability at the IPO stage. Using the fact that the

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information in N is equivalent to the information in z, we can verify that the equilibrium we are constructing satisfies our distributional restrictions on θ and $\hat{\theta}$. First, we verify that $\theta|\mathcal{I}$ is normally distributed with mean

$$\hat{\theta} = \mathbb{E}[\theta|z,\omega] = \frac{\pi_\omega}{\pi}\omega + \frac{\pi_z}{\pi}z, \tag{18}$$

and (state-invariant) variance $1/\pi$, where $\pi = \pi_\theta + \pi_\omega + \pi_z$ is the posterior precision, as assumed. Second, using (18), we verify that $\hat{\theta}$ is normally distributed with a variance that is state-invariant, as assumed .

3.4. *Step 4: Fixed point*

Now that we have an explicit expression for the investors' valuation $\hat{\theta}$ we can go back to the entrepreneurs' optimality condition (14) and use it to derive explicitly the coefficients defining their start-up decisions, as assumed in (15).

Given (17) and (18), each entrepreneur's forecast of $\hat{\theta}$ is given by

$$\mathbb{E}_i[\hat{\theta}] = \frac{\pi_\omega + \pi_z(1-b)}{\pi}\mathbb{E}_i[\theta] + \frac{\pi_z}{\pi}by.$$

Substituting $\mathbb{E}_i[\hat{\theta}]$ into the optimality condition (14), we have that each entrepreneur finds it optimal to start a project if and only if

$$\left(1-\alpha+\alpha\frac{\pi_\omega + \pi_z(1-b)}{\pi}\right)\mathbb{E}_i[\theta] + \alpha\frac{\pi_z}{\pi}by \geq C. \tag{19}$$

Bayesian updating implies that

$$\mathbb{E}_i[\theta] = \delta_x x_i + \delta_y y, \tag{20}$$

where

$$\delta_x \equiv \frac{\pi_x}{\pi_\theta + \pi_x + \pi_y} \quad \text{and} \quad \delta_y \equiv \frac{\pi_y}{\pi_\theta + \pi_x + \pi_y}.$$

Substituting δ_x and δ_y into (19), we conclude that $n_i = 1$ if and only if

$$(1-b')x_i + b'y \geq c', \tag{21}$$

where the coefficients b' and c' depend only on b and exogenous parameters (see the Appendix for the details). So, the problem of finding an equilibrium boils down to finding a fixed point to a known function Γ that maps $b \in \mathbb{R}$ to some $b' \in \mathbb{R}$. This function, which is defined explicitly in the Appendix, has a simple interpretation: when the investors believe that the distribution of start-up decisions contains the same information as the signal $z = \theta + b\varepsilon$, for some $b \in \mathbb{R}$, the entrepreneurs respond by following a start-up rule that amounts to sending to the investors a signal $z' = \theta + b'\varepsilon$ with $b' = \Gamma(b)$. In equilibrium, the signal received by the investors must coincide with the signal sent by the entrepreneurs. We then have the following result:

Proposition 1. *There are two functions $\Gamma : \mathbb{R} \to \mathbb{R}$ and $\Lambda : \mathbb{R} \to \mathbb{R}$ such that if b^* is a fixed point of Γ and $c^* = \Lambda(b^*)$, then there is an equilibrium in which each entrepreneur i starts a project if and only if*

$$(1-b^*)x_i + b^*y \geq c^*. \tag{22}$$

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Closed-form expressions for Γ and Λ are derived in the Appendix. Studying these functions permits us to reach the following existence and uniqueness results:

Proposition 2. *(i) There exists an equilibrium in which all entrepreneurs follow the start-up decision rule in (22) with $b^* \in (0,1)$. In this equilibrium, start-up investment N, the market valuation of profitability $\hat{\Theta}$, and the share price $p = P(\hat{\Theta})$ are all increasing in the fundamental θ and in the noise ε. (ii) For any parametrization of the information structure, there exists a cutoff value $\bar{\alpha} > 0$ for the capital share in production, such that the equilibrium is unique for all $\alpha \leq \bar{\alpha}$. (iii) If $\alpha > \bar{\alpha}$, multiple equilibria are possible.*

The intuition for part (i) is as follows. When $b^* \in (0,1)$, each entrepreneur's start-up activity responds positively to both signals x_i and y. This implies that aggregate start-up activity responds positively to both the fundamental θ and the noise ε. Whenever this is the case, the investors' expectation of θ, and by implication the equilibrium asset prices, also respond positively to both θ and ε. This is because the investors correctly perceive high aggregate activity as "good news" about profitability but cannot distinguish between increases in activity driven by θ from those driven by ε.

Part (ii) guarantees that the equilibrium is unique if α is small enough, in which case the sensitivity of start-up activity to the expected market valuation is not too high. When, instead, α is high, multiple equilibria can emerge. The possibility of multiple equilibria does not interfere with the main message of the article—it only reinforces it by opening the door to sunspot volatility. At the same time, the positive and normative implications of the informational spillovers at the core of our article are most cleanly isolated by ruling out multiple equilibria. With this in mind, in the sequel, we restrict attention to the region of the parameter space that guarantees equilibrium uniqueness.

4. POSITIVE ANALYSIS

In this section, we show how our mechanism gives rise to amplification of non-fundamental volatility; discuss the sense in which it represents a form of speculation and a form of beauty contest; and highlight how its potency is likely to be highest in sectors with high growth potential and/or high finance dependence.

4.1. *Amplification role of information spillovers*

To gain more insight, it is worth contrasting the equilibrium outcomes of our economy to variants in which there is no informational spillover from the real sector to the financial sector. To this purpose, suppose that investors do not learn from the observation of N. This could be either because investors do not observe N, or because their exogenous signal ω is already perfectly informative of θ, which obtains when $\pi_\omega \to \infty$. We consider both cases to emphasize that the positive results in Proposition 3 below do not depend on the amount of information in the investors' hands. What matters for the result is whether or not investors learn about aggregate profitability by looking at the entrepreneurs' activity.

When investors do not learn from N, their valuation $\hat{\theta}$ is just a linear function of their exogenous signal $\omega = \theta + \eta$. Since entrepreneurs do not possess any information about η at the start-up stage, their expectation of $\hat{\theta}$ is simply a linear transformation of their expectation of the fundamental θ. It follows that, in the absence of informational spillovers, the entrepreneurs' start-up Condition (14) reduces to $\mathbb{E}_i[\theta] \geq C$, for some constant C. Using (20), we then have that each entrepreneur

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starts a project at $t=1$ if and only if

$$(1-\delta)x_i+\delta y\geq c,$$

where $\delta=\delta_y/(\delta_x+\delta_y)$ and where c is a scalar that depends on all exogenous parameters.

The following result compares the entrepreneurs' start-up decisions in the model with investment spillovers to their counterparts in the absence of informational spillovers.

Lemma 1. *In the equilibrium in part (i) of Proposition 2, $b^*>\delta$.*

The result shows that the two-way feedback between real activity and financial prices raises the relative sensitivity of the entrepreneurs' start-up activity to the correlated component of their private information, here captured by the signal y.

We provide more intuition for this result in the next subsection. First, we look at the aggregate implications of this result for investment and asset price volatility. Recall that, when the entrepreneur follows a strategy of the form in (15), aggregate start-up activity is given by

$$N=\Phi\left(\sqrt{\pi_x}\left(\frac{\theta+b\varepsilon-c}{1-b}\right)\right).$$

It follows that

$$\frac{\partial N/\partial\varepsilon}{\partial N/\partial\theta}=b.$$

That is, a higher value of b implies a higher sensitivity of aggregate start-up activity to the non-fundamental noise ε relative to the fundamental θ. By the same token, if an econometrician were to observe data generated by our model and run a regression of aggregate start-up activity on the fundamental θ, the R-squared of this regression—which measures the contribution of the fundamental θ to the volatility of aggregate start-up activity—will be smaller the higher b is.[14] In what follows, we thus refer to b interchangeably as the sensitivity of the entrepreneurs' start-up activity to y relative to x, and as a measure of the contribution of noise to aggregate volatility.

Based on the preceding observations, we reach the following conclusion:

Proposition 3. *The informational spillovers from the real to the financial sector amplify the contribution of noise to aggregate volatility.*

4.2. *Mis-pricing and speculation (or lack thereof)*

Consider the realized difference between the price of a share and the discount value of its dividend, namely $p-\beta d$ where $d\equiv\Theta f(K)$. Recall that the equilibrium price satisfies

$$p=\beta\hat{\Theta}f(K)=\mathbb{E}\left[\beta\Theta f(K)|\mathcal{I}\right],$$

where $\mathcal{I}$ is the investors' information. It is immediate that there is no mis-pricing in the eyes of the investors (i.e. conditional on their information):

$$\mathbb{E}\left[p-\beta d|\mathcal{I}\right]=0.$$

14. To be precise, for a linear regression to be valid, one needs to regress the transformation $\Phi^{-1}(N)$ on θ.

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Furthermore, because $\mathcal{I}$ contains N, p, and K, there is no mis-pricing conditional on an IPO boom either.[15]

However, the same IPO boom can be the product of two different states of nature: one in which the true fundamentals are strong (Θ is high), and one in which entrepreneurs are collectively over-optimistic (the error in z is high). No investor in the model can tell part these two states—and neither can any outside observer who only has access to data that are publicly available at the IPO stage. But the average entrepreneur has *some* information that can help her disentangle these two states, for she knows something about the sources of variation behind N.

In particular, entrepreneurs expect the IPO to be overpriced when they are collectively optimistic, and to be underpriced otherwise, in the following sense: $\mathbb{E}\left[p-\beta d|\mathcal{I}_i\right]>0$, whenever z is high relative to θ, and $\mathbb{E}\left[p-\beta d|\mathcal{I}_i\right]<0$ otherwise.[16] The typical entrepreneur cannot profit from this kind of informational advantage during the IPO stage, because she cannot herself speculate in the IPO market, nor can she divert some of the funds through the IPO to private consumption. But she can use this informational advantage to fine-tune the states of Nature in which she starts up a project. In particular, she has a higher incentive to enter when $\mathbb{E}\left[p-\beta d|\mathcal{I}_i\right]>0$, because, in these states, she expects to be able to finance the project's subsequent expansion at a relatively low cost. (The converse is true when $\mathbb{E}\left[p-\beta d|\mathcal{I}_i\right]<0$.)

This clarifies the sense in which there is mis-pricing and speculation in our model: there is no arbitrage opportunity at the IPO stage, nor any predictable mis-pricing in the eyes of an outside observer who only has access to publicly available information, but there is an opportunity for entrepreneurs to "time" their entry. We expand on this point below.

4.3. *Speculative entry and amplification*

Rewrite condition (14), which characterizes the entrepreneurs' start-up decisions, as follows:

$$\mathbb{E}_i[\theta]+\alpha\mathbb{E}_i[\hat{\theta}-\theta]\geq C. \tag{23}$$

Recall that $\hat{\theta}$ captures the market valuation of capital during the IPO stage, while θ identifies the true underlying profitability of capital. Therefore, the gap $\hat{\theta}-\theta$ reflects the log difference between the price, p, and the discounted dividend, βd. Following our discussion above, we can therefore interpret $\mathbb{E}_i[\hat{\theta}-\theta]$ as the expected mis-pricing in the eyes of an entrepreneur at the entry stage.

Condition (23) then says that the decision of each entrepreneur to start a project depends not only on his forecast of the underlying fundamental profitability of the project but also on his forecast of the pricing error. This is because an inflated IPO price e translates into a lower cost of raising capital and, therefore, to a higher overall profit for any start-up. In this sense, the term $\hat{\theta}-\theta$ in (23) also captures a form of speculation that is reminiscent of the dot-com bubble: a higher start-up activity obtains when entrepreneurs expect financial markets to overvalue their businesses. (Keep in mind, though, that there is no mis-pricing in the eyes of investors at any stage.)

The result that $b^*>\delta$ can then be interpreted as follows. Recall that the representative investor's forecast of θ is $\hat{\theta}=\frac{\pi_\omega}{\pi}\omega+\frac{\pi_z}{\pi}z$, where $z=\theta+b^*\varepsilon$ is the endogenous signal contained in the

15. This point seems broadly consistent with the empirical literature which has found limited support for the claim that IPO issues are systematically mis-priced relative to similar stocks already in the market, given publicly available information (see e.g. the discussion in Wang and Yung (2018)).

16. These possibilities must of course average to zero, because $\mathbb{E}\left[\mathbb{E}\left[p-\beta d|\mathcal{I}_i\right]\right]=\mathbb{E}\left[p-\beta d\right]=\mathbb{E}\left[\mathbb{E}\left[p-\beta d|\mathcal{I}\right]\right]=0$; the first two equations follow from the Law of Iterated Expectations, the last from the absence of mis-pricing in the eyes of the investors.

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aggregate start-up activity. To simplify, consider the limit case of an uninformative prior, which corresponds to $\pi_\theta \to 0$. In this case, $\frac{\pi_\omega}{\pi} + \frac{\pi_z}{\pi} = 1$, which implies that the pricing error can be rewritten as

$$\hat{\theta} - \theta = \frac{\pi_\omega}{\pi}\eta + \frac{\pi_z}{\pi}b^*\varepsilon,$$

where η is the noise in the investor's exogenous signal ω, whereas $b^*\varepsilon$ is the noise in the endogenous signal z. A high value of the common noise ε in the entrepreneurs' signals then leads to a high level of start-up activity, which is perceived by the investors as a favourable signal of underlying profitability θ thus leading to overpricing.

Now consider the entrepreneurs' decision at the start-up stage. The entrepreneurs receive no information about η, so their expectation of η is zero. On the other hand, they possess information about ε through their correlated signal y. Their expectation of ε is given by

$$\mathbb{E}_i[\varepsilon] = y - \mathbb{E}_i[\theta] = (1 - \delta_y)y - \delta_x x_i.$$

The y signal contains information both about θ and about ε. A high value of y thus contributes positively to the entrepreneurs' expectation of both the primitive profitability θ of their start-up activity and of the pricing error at the IPO stage. By contrast, a high value of x_i contributes positively to the entrepreneurs' expectation of θ but negatively to their expectation of the pricing error. This explains why, in equilibrium, $b^* > \delta$, that is, the relative sensitivity of the entrepreneurs' start-up activity to sources of information with correlated noise is higher than what warranted by the relative informativeness of such sources vis-a-vis the fundamental.

The argument above uses the specific signal structure assumed here. The result, however, is more general. When an entrepreneur is *idiosyncratically* optimistic about the profitability of his project (which is the case here when x_i is high relative to y), he expects the financial market to receive only a modest signal from the aggregate start-up activity and hence the cost of raising capital to be relatively high, which dampens his incentive to start the project. By contrast, when the entrepreneurs are *collectively* optimistic about the profitability of their projects (which is the case here when y is high), they expect the financial market to receive a strong positive signal from aggregate start-up activity and thereby the IPO prices to be high, which boosts their incentives to start a project. It is this spillover from the collective optimism of the entrepreneurs to the exuberance of the financial markets that crowds out private information and amplifies non-fundamental volatility.

Notice that the mere fact that the equilibrium start-up activity responds to the expectation of financial prices is not *per se* a symptom of inefficiency. To the extent that the cost of financing (and, related, the social cost of expanding the existing projects) depend on the market valuation $\hat{\theta}$, there are efficiency gains from having the initial start-up decision respond to expectations of market valuation. We postpone addressing the efficiency properties of the equilibrium to Section 5.

4.4. *A beauty contest interpretation*

We now offer an alternative interpretation of our result, which builds a bridge to the literature on "beauty contests" (see, among others, Morris and Shin (2002), and Allen *et al.* (2006)).

Recall that the market valuation $\hat{\theta}$ is a linear function of the endogenous signal z that the real sector sends to the financial market, and that this signal is itself a monotone transformation of the aggregate start-up activity N. Using these facts, we can express the expected payoff of starting a project as a monotone function of θ and N, which yields the following result:

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Proposition 4. *There exists scalars* $r, c^{\#} > 0$ *such that, in equilibrium, each entrepreneur starts a project if and only if*

$$\mathbb{E}_i[(1-r)\theta + r\Phi^{-1}(N)] \geq c^{\#}. \tag{24}$$

The equilibrium start-up activity in our model can therefore be represented as the PBE of a binary-action coordination game among the entrepreneurs in which the best response is given by (24). This best response is akin to the best response function in the beauty contest games studied by, *inter alia*, Morris and Shin (2002) and Angeletos and Pavan (2007). It follows that the amplified effect of the y signal on non-fundamental volatility in our model is akin to the amplified effect of public information in those games: in both cases, the amplification effect can be traced to strategic complementarity.

What distinguishes our framework from this other work is that the strategic complementarity is here endogenous, originating in the information spillovers from the real to the financial sector. Although each entrepreneur alone is too small to have any impact on either aggregate start-up activity or on the investors' beliefs, the entrepreneurs as a group can influence the investors' beliefs and hence the price in the financial market. This leads to a complementarity in the entrepreneurs' actions: the higher the aggregate start-up activity, the higher the market valuation of the new projects, and hence the lower the cost of raising capital at the IPO stage. This explains why strategic complementarity in the entrepreneurs' decisions (i.e. $r > 0$) emerges whenever a high aggregate level of start-up activity is interpreted by the financial maker as "good news". By contrast, strategic complementarity vanishes (i.e. $r = 0$) when the financial market does not extract any information from the real sector's activity, as in the benchmark without spillovers considered above.

In Section 5, we explain that this type of complementarity represents a form of inefficiency. This is in contrast to the *efficient* beauty contest that emerges from aggregate demand externalities in the textbook business-cycle paradigm (Angeletos and La'O, 2010, 2020) or, more generally, from the kind of strategic complementarities or substitutabilities that emerge from pecuniary externalities in the Arrow–Debreu framework. Importantly, our mechanism remains the only source of inefficiency even when such neoclassical effects are added to the analysis (see Section 6). Finally, because starting a project is linked to doing an IPO, the strategic complementarities identified above square well with the "hot IPO effect" mentioned in Section 1.

4.5. *The impact of* α

So far, we have shown that informational spillovers lead to the amplification of non-fundamental shocks. We now show that the strength of these effects depends on the parameter α. The parameter α plays a double role in our model: it captures the growth potential of the real sector, as a larger α means a lower degree of decreasing returns; it also captures the real sector's dependence on funding from the financial market, as a larger α implies that the entrepreneurs' Period-2 investments k are more sensitive to financial market valuations. In equilibrium, a larger value of α increases the entrepreneurs' incentives to rely on the correlated signal y to predict the mis-pricing in the IPO stage. Formally, a higher value of α shifts the Γ function in Proposition 1 upwards. As long as Γ admits a unique fixed point ($\alpha < \bar{\alpha}$),[17] this implies a higher sensitivity b^* of the entrepreneurs' start-up activity to sources of information with correlated noise. We thus have the following result:

17. Relaxing the restriction that $\alpha < \bar{\alpha}$ only reinforces the result in Proposition 5 by adding sunspot volatility.

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Proposition 5. *A higher value of α implies a higher contribution of correlated noise to aggregate volatility—but only through the information spillover.*

Our theory thus predicts that sectors with high growth potential and/or high finance dependence are those most prone to non-fundamental volatility and our kind of strategic complementarity ("hot IPO effect"), and that this effect is especially salient in the early stages of a new sector's life, when there is still significant uncertainty about its eventual profitability (small π_θ). The prediction seems consistent with historical experiences such as the dot-com bubble as well as the evidence reported in Jain and Kini (2006) that IPO clustering tends to occur in fragmented, high growth, R&D-intensive industries.

5. NORMATIVE ANALYSIS AND POLICY

The analysis in the previous section focuses on the positive properties of the equilibrium and shows that information spillovers increase the contribution of correlated noise to non-fundamental volatility of start-up activity, IPO prices, and capital investments. We now turn to the normative implications of the mechanism identified above. The questions that we address are the following: Are the positive properties derived so far a symptom of inefficiency? And, if so, how should policy influence entrepreneurial decisions? To address these questions, we proceed in two steps. We start by studying the problem of a social planner who can dictate to the entrepreneurs the strategy that they should follow at the start-up stage. This planning problem bypasses the details of the available policy instruments and identifies directly the normative content of the aforementioned positive properties. Once the solution to the planner's problem is at hands, we discuss policies that implement the planner's optimum as well as policies that, while not the ideal ones within our model, have received attention in the policy debate.

5.1. *Constrained efficiency*

Consider a social planner who can choose a linear start-up rule of the form

$$n_i = 1 \quad \text{if and only if} \quad (1-b)x_i + by \geq c, \tag{25}$$

for some scalars $b, c \in \mathbb{R}$ and can choose investment k_i in Period 2 as a function of the signal ω of the representative investor and of aggregate start-up activity N. By setting up the planner's problem this way, we constrain the planner to use the same information as the market economy. Requiring linearity of the start-up rule is a restriction which we make for tractability. Suppose that the planner's objective is to maximize a utilitarian welfare function assigning equal weights to the entrepreneurs' and the investors' utilities. Because of the linearity of individual payoffs in consumption, social welfare is given by the present value of aggregate output, net of all investment costs:

$$\int_0^1 \left\{ n_i \left(\beta^2 \Theta f(k_i) - \beta k_i \right) + (1-n_i) \right\} di = 1 + N \left(\beta^2 \Theta f(k) - \beta k - 1 \right).$$

Note that in writing the welfare function above we use the fact that, because of concavity of f, it is optimal to dictate the same level of investment to all entrepreneurs who are active in Period 2. Given the start-up rule (25), aggregate start-up activity is given by

$$N = \Phi \left(\tfrac{\sqrt{\pi_x}}{1-b} (z-c) \right),$$

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where z is the endogenous signal $z=\theta+b\varepsilon$. Since the planner can condition the choice of k on (ω,N), and observing N is equivalent to observing z, the planner's problem can be written as

$$\max_{(b,c)\in\mathbb{R}^2,\mathcal{K}\in\mathbf{C}} \mathbb{E}\Big[N(z)\Big(\beta^2\Theta f(\mathcal{K}(\omega,z))-\beta\mathcal{K}(\omega,z)-1\Big)\Big]$$

$$s.t. \quad z=\theta+b\varepsilon, \quad N(z)=\Phi\Big(\tfrac{\sqrt{\pi_x}}{1-b}(z-c)\Big),$$

where $\mathbf{C}$ denotes the set of continuous functions $\mathcal{K}:\mathbb{R}^2\to\mathbb{R}$.

Consider first the choice of $\mathcal{K}$. For almost every (ω,z), $\mathcal{K}(\omega,z)$ must maximize the expected output net of investment costs:

$$\mathcal{K}(\omega,z)\in\arg\max_k\Big\{\beta\hat{\Theta}f(k)-k\Big\},$$

where $\hat{\Theta}=\mathbb{E}[\Theta|\omega,z]$. Recall that the same maximization problem determines investment in the market equilibrium, therefore,

$$\mathcal{K}(\omega,z)=K(\hat{\Theta})=(\alpha\beta\hat{\Theta})^{\frac{1}{1-\alpha}}. \tag{26}$$

This proves that the equilibrium level of investment is efficient conditional on the information available to the investors at the IPO stage. Notice, however, that the signal z may be different from the analogous signal in the market equilibrium, if the planner chooses a different start-up strategy, reflecting the informational externality that aggregate start-up activity exerts on the subsequent capital expansions.

Thus consider next the optimal start-up strategy. Given (26), the social value of a project, net of investment costs at $t=2$, is given by

$$Q(\Theta,\hat{\Theta})\equiv\beta\Theta f(K(\hat{\Theta}))-K(\hat{\Theta})=\beta(\Theta-\alpha\hat{\Theta})(\alpha\beta\hat{\Theta})^{\frac{\alpha}{1-\alpha}}.$$

The planner's objective at the start-up stage can thus be written as

$$\mathbb{E}\Big[n(x,y)\Big(\beta Q(\Theta,\hat{\Theta})-1\Big)\Big], \tag{27}$$

where $n(x,y)$ denotes the start-up rule (25). The following proposition characterizes the optimal start-up rule for the planner.

Proposition 6. *Let $(b^\diamond,c^\diamond)$ denote the coefficients of the start-up rule that maximizes social welfare (27). When the equilibrium is unique (which is always the case for $\alpha<\bar{\alpha}$), $b^\diamond<b^*$, meaning that the equilibrium sensitivity of start-up decisions to the signal with correlated noise is too high from a welfare perspective. Consequently, the contribution of correlated noise to aggregate volatility is inefficiently high.*

There are two reasons why the planner's start-up rule differs from the market equilibrium one. First, comparing (12) and (27), one can see that the private return to start-up activity is $\beta^2\mathbb{E}[\Pi(\Theta,\hat{\Theta})|x,y]$, while the social return is $\beta\mathbb{E}[Q(\Theta,\hat{\Theta})|x,y]$. Second, the planner internalizes the fact that different start-up rules imply different informativeness of the endogenous signal upon which the subsequent expansions at $t=2$ are made. The proof of Proposition 6 in the Appendix

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shows that both forces go in the direction of choosing a smaller b. We now discuss the two parts of this argument separately.

First, consider the wedge between the private and the social benefit of starting a project. To isolate this effect, consider a planner who can choose the start-up rule, but only that of entrepreneur i, in which case the information revealed by N continues to be the same as in the market equilibrium. Note that

$$\begin{aligned} Q(\Theta,\hat{\Theta}) &\equiv \beta\Theta f(K(\hat{\Theta})) - K(\hat{\Theta}) \\ &= \beta\Pi(\Theta,\hat{\Theta}) + \alpha\beta(\Theta-\hat{\Theta})f(K(\hat{\Theta})). \end{aligned} \tag{28}$$

The last term in (28) is the difference between the true value of the shares sold to the investors at the IPO (i.e. the associated cash flow) and the investors' valuation of these shares, given the information available to them.[18] Therefore, as long as the entrepreneur's expectation $\mathbb{E}[\hat{\Theta}|x,y]$ of the investors' expectation of Θ differs from the entrepreneur's own expectation $\mathbb{E}[\Theta|x,y]$ of Θ, the social and private benefits differ:

$$\beta\mathbb{E}[Q(\Theta,\hat{\Theta})|x,y] - \beta^2\mathbb{E}[\Pi(\Theta,\hat{\Theta})|x,y] \neq 0.$$

This difference is related to the mis-pricing discussed in the previous section. In particular, when the entrepreneur expects $\hat{\Theta}$ to be higher than Θ, he expects his shares to be overvalued at the IPO stage, i.e. he expects to make a gain at the expenses of the outside investors. Because this speculative gain is a zero-sum transfer from the investors to the entrepreneur, it does not enter the planner's objective. As argued in the previous section, a high value of the signal y relative to x tends to increase the entrepreneur's expectation of $\hat{\Theta}$ relative to Θ and thus increases the entrepreneur's incentive to start the project for speculative reasons. It follows that the planner, who is not driven by speculative motives, would like the entrepreneur to put less weight on y relative to x, which means a lower b.

Next, consider the informational effects of choosing a smaller value of b, when the planner can choose the start-up rule for *all* entrepreneurs and thus affects the precision of the endogenous signal z at the IPO stage. The precision of z is decreasing in b and more precision is welfare improving, because it increases the efficiency of the second-period investment decisions. Formally, the *ex ante* expectation of $Q(\Theta,\hat{\Theta})$ is increasing in π_z. This informational effect adds to the social benefit of reducing b to mitigate the entrepreneurs' speculative entry decisions and thus reinforces the conclusion that $b^{\diamond} < b^*$.

To recap, there are two reasons why the equilibrium sensitivity of start-up decisions to the signal with correlated noise is inefficiently high. The first one is that the entrepreneurs can predict the difference between fundamental profitability and its market valuation, and this predictability generates a speculative wedge between their private incentives and social welfare. The second one is that there is an informational externality associated with the endogeneity of the information upon which second-period investment decisions are made. Conceptually, these sources of inefficiency are distinct. In our setting, however, they are tied together, as they both emerge from the information spillover from the real to the financial sector.

Finally, note that there also exists an inefficiency in the *level* of start-up decisions. That is, even if $b^{\diamond} = b^*$, in general $c^{\diamond} \neq c^*$. This is akin to the holdup problem. The private surplus from starting a project is $\beta^2(1-\alpha)\Theta f(K)$, while the social surplus is $\beta^2\Theta f(K) - \beta K$. Under complete information, the two coincide, but with informational frictions, their expected values may differ.

18. Recall that, in equilibrium, the shares sold by entrepreneur i are $s_i = \alpha$ and their price is $p_i = \hat{\Theta} f(k)$, so that $s_i \cdot \Theta f(k) = \alpha\Theta f(k)$ and $p_i \cdot s_i = \alpha\hat{\Theta} f(k)$.

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5.2. *Policy*

What kind of policies could help improve the equilibrium use of information? We have identified two types of inefficiency: one regarding the entrepreneurs' excessive concern about the market's valuation of their projects; the other regarding the informational externality from initial investment, N, to subsequent expansion, K. Below, we show that *both* inefficiencies can be corrected by introducing a subsidy/tax to entry that is contingent on the realized asset price, even if this subsidy cannot be contingent on the realized fundamental.[19]

Let us start with the first inefficiency, which is more central to our theory. To simplify the exposition, assume momentarily that $\beta=1$. As explained above, this inefficiency boils down to a discrepancy between the private return to entry, given by $\mathbb{E}_i[\Pi(\Theta,\hat{\Theta})]-1$, and the social return to entry, given by $\mathbb{E}_i[Q(\Theta,\hat{\Theta})]-1$. Denote the aforementioned subsidy by $\sigma(p)$, with p representing the average price in the market.[20] Each entrepreneur's net payoff from entry is then given by $\mathbb{E}_i\left[\Pi(\Theta,\hat{\Theta})+\sigma(p)-1\right]$. Now suppose that the subsidy takes the form

$$\sigma(p)\equiv 1-(1-\alpha)(1+\alpha p).$$

Recall that, in equilibrium,

$$K(\hat{\Theta})=\alpha p \qquad \text{and} \qquad p=\hat{\Theta}f(K(\hat{\Theta})).$$

It follows that the subsidy satisfied $\sigma(p)=1-(1-\alpha)(1+K(\hat{\Theta}))$ and, by implication, the entrepreneur's net payoff satisfies

$$\begin{aligned}\mathbb{E}_i\left[\Pi(\Theta,\hat{\Theta})+\sigma(p)-1\right]&=\mathbb{E}_i\left[(1-\alpha)\Theta f(K(\hat{\Theta}))-(1-\alpha)(1+K(\hat{\Theta}))\right]\\&=(1-\alpha)\mathbb{E}_i\left[\Theta f(K(\hat{\Theta}))-K(\hat{\Theta})-1\right]\\&=(1-\alpha)\mathbb{E}_i\left[Q(\Theta,\hat{\Theta})-1\right].\end{aligned}$$

The above subsidy thus aligns the private return to entry to the social return.

To understand the nature of this subsidy, it is useful to rewrite it as

$$\sigma(p)=-b(p-p^{\#})$$

where $b\equiv\alpha(1-\alpha)$ and $p^{\#}\equiv 1/(1-\alpha)$. By making the subsidy decrease with the realized price, the planner "penalizes" the entrepreneurs for conditioning their entry decisions too much on their expectations of asset prices and, thereby, tilt their *relative* use of information. At the same time, by choosing appropriately $p^{\#}$, or the intercept of the subsidy, the planner can regulate the level of entry. Together, these properties allow the planner to correct the inefficiency in the entry decisions caused by the speculative motive identified earlier.[21]

19. One can think of this policy in two ways: (i) the subsidy is paid in Stage 3, at which point both p and Θ are publicly known, but is restricted to depend only on p; (ii) the subsidy is paid at the end of Period 2 after the IPO is completed and the capital expansion k is finalized, at which point p is publicly known but Θ is still uncertain. In either case, in those states in which the subsidy takes on negative values (i.e. is a tax), for simplicity one can think of the entrepreneurs paying it by exerting effort, with the latter generating the consumption good at a 1–1 rate.

20. Conditioning the subsidy on the average IPO price instead of the *firm-specific* price guarantees that the entrepreneur cannot manipulate the subsidy through her choice of a supply schedule.

21. The specific value of $p^{\#}$ given above may look mysterious at first, but it has a natural interpretation. Consider the full-information benchmark. Note that in this case the social (and also the private) return to entry satisfies $Q(\Theta,\Theta)=$

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So far, we have shown how to correct the main inefficiency of interest. What about the second inefficiency, that regarding the informational externality? Because a subsidy that declines with p induces the entrepreneurs to rely more on their idiosyncratic sources of information (i.e. on x_i relative to y), such a subsidy can also improve the aggregation of information via N. This suggests that the same type of policy can correct both inefficiencies. The next proposition verifies that this intuition is correct.

Proposition 7. *The socially optimal start-up rule of Proposition 6 can be implemented as an equilibrium by giving to those entrepreneurs who started a project at $t=1$ and completed their IPO at $t=2$ a (possibly negative) subsidy equal to*

$$\sigma^*(p)=\frac{1}{\beta}(1-\exp\{B\ln p-C)\})$$

for some $B>0$ and $C\in\mathbb{R}$.

The subsidy in Proposition 7 shares with the simpler one described above the latter's key monotonicity: it is decreasing in p. However, it has a different functional form, to induce a Gaussian equilibrium (which we impose in Proposition 6 to characterize the informational externality and pin down the optimal linear start-up rule). While the slope of the simple subsidy described above with respect to p is pinned down by α alone, the slope of the subsidy in Proposition 7 also depends on the "details" of the information structure. This is because the latter details determine the extent of the informational externality. Notwithstanding these subtleties, the main take-home message is that a policy that "leans against the wind" can help improve the efficiency of the equilibrium decisions at all stages and reduce the magnitude of noise-driven IPO waves.

Needless to say, the policy described above is not the unique way to "lean against the wind". For instance, if one takes our model "as is", it is possible to implement the socially optimal entry rule by replacing the contingency on p with one on N in the subsidy described above or with a tax/subsidy in Stage 3 that is contingent on Θ. However, if we think of stage 3 as something sufficiently remote in the future, at which point the firm has matured but its original founders have possibly exited, the anticipation of a subsidy/tax levied at that point may have a more limited, or even a muted, effect on entry decisions. For this reason, we find the "real-time" policy described above, as well as the policies described next, more appealing.

Consider now a tax on financial trades collected from the investors in Period 2. Proposals for such taxes have received a lot of attention in recent years; here, we study their merits within the confounds of our analysis. When an investor buys s shares, her total cost is $(1+\tau)ps$, where τ is the tax rate. By letting τ itself be a function of the average price p, the planner can influence how asset prices vary with $\hat{\Theta}$, the investors' expectation of the fundamental, and, thereby, also influence the entrepreneurs' entry decisions. In particular, the more steeply τ increases with p, the less p itself varies with $\hat{\Theta}$ and, therefore, the less sensitive the entrepreneurs' entry decisions to the "speculative" motives. In this respect, this policy achieves the same goal as the subsidy described above. However, such a policy comes at a cost: by dampening the response of p to $\hat{\Theta}$, it distorts the investment at stage 2.[22] That is, the planner now faces a trade-off between improving

$\max_k\{\Theta f(k)-k\}$, which is strictly increasing in Θ. Let $\Theta^{\#}$ be the unique solution to $Q(\Theta^{\#},\Theta^{\#})=1$, which means that $\Theta^{\#}$ is the fundamental threshold above which entry is optimal under full information. Then, $p^{\#}=\Theta^{\#}f(K(\Theta^{\#}))$, which allows us to interpret $p^{\#}$ as the price threshold for entry under complete information. When $\Theta=\Theta^{\#}$, and hence $p=p^{\#}$, the subsidy ought to be zero, or else it would distort entry under full information and, by extension, it would not be optimal under incomplete information either.

22. Indeed, whenever $\tau\neq 0$, we have that $p\neq\hat{\Theta}f(k)$ and, as a result, $K(\hat{\Theta})\neq\arg\max_k\{\hat{\Theta}f(k)-k\}$.

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entry decisions and distorting firms' subsequent expansions, and the "unrestricted" optimum of Proposition 6 is no longer attainable. Nonetheless, this policy shares with the one described above both the spirit of "leaning against the wind" and the function of improving entry decisions.

Next, consider a cap on the shares that the entrepreneurs can sell to the stock market, which is another policy that has received some attention in the policy debate. To see how such a policy can improve over the laissez-faire equilibrium, one needs to adjust the framework by making the realistic assumption that not all entrepreneurs get to do an IPO. In particular, let each entrepreneur have the opportunity to access the stock market and undertake the kind of expansion described above with probability $\lambda \in (0,1)$; with the complementary probability $(1-\lambda)$, the entrepreneur, instead, is excluded from the IPO market in which case the return to her project is given by $q\Theta$, for some $q>0$. Consider then a policy that constrains each entrepreneur to sell no more than $\bar{s} \in (0,1)$ shares, where $\bar{s}$ is the cap on the sale of IPO shares. It is straightforward to check (i) that the cap is binding if and only if $\bar{s}<\alpha$ and (ii) such a cap tilt the use of information in the direction of increasing the sensitivity of entry decisions to fundamentals. Intuitively, requiring the entrepreneurs to keep more "skin in the game" reduces the extent to which their decisions are driven by speculative motives and can therefore improve the efficiency of their entry decisions.

The common thread of all the policies described above is that they help ease the bite of speculative motives on entry decisions and IPO activity: entrepreneurs (and the venture capitalists behind) are induced to think more about fundamentals and less about (speculative) IPO returns. The analysis above provides a precise rationale for this kind of policy interventions.

6. ROBUSTNESS AND ENRICHMENTS

Our analysis identifies an informational mechanism that induces strategic complementarity in entrepreneurial decisions. It abstracts from the standard "neoclassical" mechanism that can contribute in the opposite direction: when the supply of capital in the financial market is imperfectly elastic (that is, when entrepreneurs "compete for limited funding"), more aggregate entry in Stage 1 raises the expected cost of funding in stage 2, thus discouraging individual entry. In the first part of this section, we show how this traditional mechanism contributes to strategic substitutability, without however changing the essence of our mechanism or its normative/policy implications: entry and IPO waves remain over-responsive to "noise." In the second part, we then discuss a few possible re-interpretations of such "noise" and additional dimensions of robustness.

6.1. *Information complementarity meets neoclassical substitutability*

To accommodate for the aforementioned neoclassical channel, it suffices to introduce convexity in the investors' opportunity cost of investing in IPOs. We do so by letting investors consume only in the last period and by introducing convexity in their disutility of labour, so that their utility is now given by

$$V = -\tfrac{1}{1+\epsilon} l^{1+\epsilon} + c_3,$$

where $\epsilon \geq 0$. (The baseline model corresponds to $\epsilon = 0$.)

It is straightforward to show that the following properties hold in equilibrium:[23] (i) each entrepreneur starting a project at $t=1$ continues to issue $s_i = \alpha$ shares at the IPO stage and uses the proceeds to invest $k_i = k$; and (ii) the level of investment, k, now solves

$$\alpha \hat{\Theta} k^{\alpha-1} = (Nk)^{\epsilon}. \tag{29}$$

23. The formal arguments are included in the proof of Proposition 8 in the Appendix.

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The left-hand side of (29) captures the marginal product of capital whereas the right-hand side captures the marginal cost of investment (or the marginal cost of funding). Clearly, the latter is an increasing function of the aggregate level of investment N if and only if $\epsilon > 0$, which verifies that the modelling role of $\epsilon > 0$ is precisely to introduce convexity in the investors' opportunity cost of investing.[24]

The next proposition translates these observations in terms of the "entry game" played at $t = 1$:

Proposition 8. *In equilibrium, each entrepreneur starts a project if and only if*

$$\mathbb{E}_i\left[\exp\left\{\tfrac{1+\epsilon}{1-\alpha+\epsilon}\left[(1-a)\theta + a\hat{\theta} - \psi \ln N\right]\right\}\right] \geq \chi, \tag{30}$$

where χ is a constant, $a \equiv \alpha/(1+\epsilon) > 0$, $\psi \equiv \epsilon a > 0$, and $\hat{\theta} \equiv \ln \hat{\Theta}$.[25]

When $\epsilon = 0$, (30) reduces to (14), that is, to the entry condition in the baseline model. Relative to it, there are two changes. First, α is replaced with a; this changes the quantitative magnitude but not the qualitative nature of our mechanism. Second, the entry condition now contains the new term $-\psi \ln N$; this term encapsulates the neoclassical mechanism anticipated above.

Clearly, while the neoclassical mechanism contributes to strategic substitutability, ours contributes to strategic complementarity. To the extent that our model applies to a specific sector, rather than the entire economy, we expect the supply of funds to be quite elastic and, therefore, entry decision to remain strategic complements. However, regardless of which mechanism dominates on the positive front, it is only our mechanism that operates on the normative front: the convexity in the opportunity cost of investment is not a source of inefficiency.

Proposition 9. *Regardless of the magnitude of ϵ (equivalently, the magnitude of the elasticity of the investors' supply of funds and of the resulting substitutability in the entrepreneurs' entry decisions), inefficiency emerges because, and only because, of the two mechanisms identified in the baseline model: the speculative motive in the entrepreneurs' start-up decisions, and the informational externality.*

To see this, abstract momentarily from the informational externality (namely, the endogeneity of $\hat{\Theta}$, the investors' posterior expectations) and focus on the remaining wedge between the social and the private return to entry. In the Appendix, we show that this wedge is given by the entrepreneurs' expectation of

$$\alpha\left(\Theta - \hat{\Theta}\right) f(k),$$

exactly as in the baseline model. Therefore, as one varies the convexity ϵ in the investors' cost of funds, one also varies the strength ψ of the aforementioned neoclassical form of strategic substitutability in entry decisions, but with no effect on the "speculative" motive for entry. Along with the fact that the informational externality continues to operate as in the baseline model (it's

24. The same can be achieved by adding concavity in the utility of c^3. We considered this alternative in an earlier draft and showed that Proposition 8 below readily extends, modulo (i) an adjustment in the coefficients a and ψ and (ii) the replacement of the risk-neutral expectation $\hat{\theta} \equiv \mathbb{E}_2[\theta]$ with an appropriate risk-adjustment counterpart.

25. Note the slight change in the definition of $\hat{\theta}$. In the baseline model, $\hat{\theta} \equiv \mathbb{E}[\theta|\mathcal{I}] = \mathbb{E}[\ln\Theta|\mathcal{I}]$; but this is the same as $\ln\mathbb{E}[\Theta|\mathcal{I}] = \ln\hat{\Theta}$ up to a constant, thanks to the fact that investors' posterior beliefs at $t = 2$ are Gaussian. Here, the last property is lost, because N is no longer log-Normally distributed, so it is more appropriate to define $\hat{\theta} \equiv \ln\hat{\Theta}$.

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valuable to generate more information about Θ via N in order to guide k), the above observations suggest that our policy implications remain intact: It is still optimal to lean against the wind.[26]

6.2. *Reinterpretations and additional robustness*

We now discuss a few reinterpretations of our mechanism and its likely robustness to richer specifications of the IPO stage.[27]

6.2.1. Noise. By assuming that all agents are rational and by abstracting from the possibility of sunspot fluctuations, we have imposed that all the non-fundamental variation in investment and asset prices is the product of correlated noise in dispersed private information. This has made clear that our amplification mechanism and its normative implications do not depend on a departure from rational expectations. Nevertheless, our insights are relevant more broadly. In particular, the non-fundamental waves in beliefs, investment, and asset prices, we have documented here can readily be recast as the product of "irrational exuberance" by replacing the correlated error in the entrepreneurs' information either with a correlated bias or a correlated taste for starting up a firm. Provided that investors cannot tell apart these drivers of entrepreneurial activity from fundamentals, our mechanism amplifies the noise.

6.2.2. Investor sentiment. We have interpreted ω as the investors' unbiased signal about θ and have precluded the entrepreneurs from having any information about ω other than the one contained in their information about θ. Suppose, instead, that ω represents a biased signal and that entrepreneurs receive a correlated private signal about ω or, equivalently, about the *error* in ω. Denote this signal by $z^\omega \equiv \omega + u^\omega$, where u^ω is a new noise term. Naturally, a positive realization for u^ω triggers an increase in start-up activity, because it makes entrepreneurs expect more optimism in asset markets. Perhaps more interestingly, because z^ω is not directly observed by the investors, the increase in start-up activity will appear in their eyes as positive news for profitability. Our mechanism is thus switched on again, causing this kind of noise, too, to be amplified.

6.2.3. Secondary markets. Our analysis has abstracted from the possibility of trade after the IPO stage. However, this is without any loss of generality, because there is no arbitrage opportunity in the eyes of the investors. To see this, suppose that we introduce a "secondary" market between $t=2$ (the IPO stage) and $t=3$ (the final fruition of the project), say at $t=2.5$. Continue to denote by p the price in the primary market and let p' denote the price of the asset in the secondary market. Suppose next that only investors participate in this market, let ω' denote any new public information made available at $t=2.5$, and, for simplicity, abstract from

26. We say that "the above observations suggest" instead of "prove" because a closed-form characterization of either the equilibrium or the planner's solution is not possible in the enriched model. However, the logic seems clear. Also, our normative lesson extends to the scenario mentioned in footnote 24 above, subject to the following qualification. When the utility of c_3 is concave, there is a social value for insurance between the investors and the entrepreneurs, but there are no markets for it. If group-specific transfers are not possible either, the planner may wish to manipulate entrepreneurial investment decisions and/or IPO outcomes in an attempt to mimic the missing transfers. Risk aversion thus introduces another channel which, however, is orthogonal to the one investigated in the article.

27. The first two of the extensions mentioned below are straightforward. The remaining four are more complicated, either because they break the linear-Gaussian specification or because they involve richer dynamics; but the intuition seems clear.

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discounting (i.e. set $\beta = 1$). Then, clearly, the equilibrium price in the secondary market is given by $p' = \mathbb{E}_{2.5}[\Theta f(K)]$, where $\mathbb{E}_{2.5}$ is the rational expectation conditional on the union of $\mathcal{I}$, the investors' information at $t = 2$, and ω', the additional information made available to the investors at $t = 2.5$. By the Law of Iterated Expectations, we have that $\mathbb{E}_2[\Theta f(K)] = \mathbb{E}_{2.5}[p']$, which verifies that the equilibrium IPO prices in the primary market in the baseline model are the same as in the extended model—and therefore all the results extend verbatim.

Note that the above property is true even if ω' reveals not only θ but also y (the true fundamental and the entrepreneurs' optimism), which in turn means that the following is also true: our results are robust not only to letting the entrepreneurs participate in the secondary market but also to letting all their information be perfectly revealed at $t = 2.5$. In short, the presence of secondary markets and of additional information revealed after the primary market is completely inconsequential for our results. What is essential is only that the entrepreneurs' information no being perfectly revealed at the IPO stage. We already highlighted this point on the onset of our analysis, but let us now expand on it.

6.2.4. Information revelation at the IPO stage. Although IPOs are mis-priced in the entrepreneurs' eyes, entrepreneurs cannot take advantage of this during the IPO stage. This is because they do not have funds of their own at this point, nor can they borrow or short-sell. Along with the property that the optimal amount of shares they sell is invariant to the entrepreneurs' private information, this guarantees that there is no revelation of the entrepreneurs' information at the IPO stage.

Suppose now that we modify the model so as to let the optimal supply of shares be sensitive to the entrepreneurs' private information, or let the entrepreneurs directly trade in the primary market. This may naturally allow some of the entrepreneurs' information to be revealed to the investors. But as long as such a revelation is not perfect (because of noise traders, unobserved wealth, or liquidity shocks, etc.), the entrepreneurs will retain, on average, an information advantage about the source of variation behind N vis-a-vis the investors, and our mechanism will remain active. We verified this idea in an earlier draft (Angeletos *et al.*, 2007), in a variant model without investment at the IPO stage. One can also capture the essence of information aggregation at the IPO stage in the present model by re-interpreting ω as the product of such an imperfect revelation. It is only in the knife-edge case in which ω reveals perfectly θ, or at least y, that our mechanism disappears.

6.2.5. Decoupling IPOs from start-ups. Our model has equated the number of IPOs with the number of start-ups, N. The most trivial way to decouple the two is to let an exogenous random fraction of entrepreneurs get access to the IPO market. More interestingly, one could endogenize the IPO margin along similar lines as those described above: like the decision of how many shares to sell, the decision to do any IPO in the first place could be sensitive to entrepreneurs' private information, implying that IPO volume could contain additional information over start-up activity. But as long as IPO volume does not perfectly reveal y to the investors, our mechanism remains active. What is more, if the private return to an IPO inherits the monotonicity properties of the private return to a start-up (i.e. it increases with the expectations of both θ and p), our mechanism is bound to give rise to strategic complementarily not only at the start-up margin but also at the IPO margin. This helps bring our theory even closer to the facts about IPO waves we discuss in the next section.

6.2.6. Richer dynamics. So far, we have assumed that all start-ups take place simultaneously in stage 1, and similarly that all IPOs take place simultaneously in Stage 2.

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Suppose, instead, that each stage has two phases, an early one and a late one, and that entrepreneurs are randomly selected to be "early movers" or "late movers" in both stages. Late movers may naturally have an informational advantage, but this does not change the essence of our message. To illustrate, consider the most extreme scenario in which early and late movers receive the same correlated signal y, but late movers also get to see the start-up activity of the early movers. Then, late movers will learn perfectly θ and will face no uncertainty about N and its subcomponents. But as long as the investors get to see either a possibly perfect signal of N or two noisy signals of the early and late start-up activities, neither y nor θ will be perfectly revealed to them. As a result, all entrepreneurs—both the early ones and the late ones—will be able to forecast the asset market mis-pricing when making their start-up decisions, as in our baseline model.

Also note that, under the assumptions made thus far, there is *no* revelation of information between the early and the late IPO phases. This is because both the selection of who goes first and the number of shares sold is independent of the entrepreneurs' private information. One could of course relax these assumptions, but for the reasons already explained above we do not expect this to overturn the message.

These points clarify that our results do not rely on the following two simplifying assumptions: that all start-up decisions take place with symmetric information; and that entrepreneurs face uncertainty about each others' decisions. Instead, our results are driven by the following two key properties: that a larger start-up/IPO activity is interpreted by financial markets as a positive signal about profitability; and that entrepreneurs naturally have some private information relative to financial markets (but not necessarily relative to one another) about the drivers of their start-up decisions. We expect these properties to extend to models that tackle more seriously the dynamics of both start-up and IPO activity.[28]

6.2.7. Endogenous collection of information. Our analysis takes for granted the presence of correlated noise in the entrepreneurs' information. As already noted, such noise could be a proxy for irrational impulses. But the following point is also relevant. Suppose that entrepreneurs can choose what information to collect, or pay attention to.[29] In such an extension, the two-way feedback we have identified is likely to increase the entrepreneurs' incentives not only to react to sources of information with correlated noise but also to collect such information in the first place—e.g. to rely on common consultants, participate in the same conferences, business fairs, social events, etc. This hints at possible empirical proxies for the "noise" in our model, a point we return to in the next section.

7. DISCUSSION AND CONCLUSION

Our article offers a new perspective on the interaction between real investment and asset markets, focusing on periods of fast technological change and intense start-up activity. Because higher start-up activity may signal stronger fundamentals (higher eventual profitability), external investors' willingness to provide funds to any given start-up may increase with aggregate start-up activity, inducing a strategic complementarity, or a "beauty contest", in start-up activity and IPO entry. This mechanism amplifies the non-fundamental waves in real investment, IPO volume, and IPO prices. It also creates a wedge between private and social incentives, offering in turn a rationale for policies of "leaning against the wind."

28. See also Altı (2005) for information spillovers from early IPOs to later ones.

29. See, among others, Hellwig and Veldkamp (2009), Myatt and Wallace (2012), Colombo, Femminis and Pavan (2014), Chahrour (2014), and Pavan (2016).

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As mentioned in Section 1, this mechanism seems broadly consistent with the phenomena studied in the literature on IPO waves and hot IPO effects. In the rest of this section, we expand on this connection and discuss possible new venues for empirical work.

The aforementioned literature has documented that IPOs tend to be clustered in time, both at the aggregate and the sectoral level, as indicated in Figure 1 in Section 1. The interpretation of this clustering through the lens of our model is that a high volume of start-up activity and IPOs in a given sector sends a positive signal to the financial market about the sector's profitability. Such a signal boosts IPO prices and induces more start-up activity and more IPOs, thus reinforcing the wave. In our model, the decision to go public follows mechanically that of starting a firm and there is no decision of "when" to go public. However, the endogenous complementarity uncovered by our mechanism appears broadly consistent with the empirical evidence that aggregate market conditions matter for the decision to go public and that IPO prices tend to be positively correlated with various measures of start-up activity and IPO volume (see Loughran *et al.*, 1994 for an early paper showing that IPO volume tends to be higher when the level of the stock market is higher).

This finding is subject to many interpretations as a high stock market value could reflect high expected returns for the entrepreneurs thus reflecting an increase in investment opportunities and in the demand for capital, rather than the entrepreneurs' response to outside investors' supply of funds. For this reason, the empirical literature has tried to identify variations in stock valuations that are more likely to be driven purely by investors' optimism. Pagano and Zingales (1998) show that companies are more likely to go public when the market-to-book ratios of public companies in the same industry are high. Lowry (2003) uses various proxies for investor sentiment, in particular the discount on closed-end funds and post-IPO market returns and concludes that "firms seem to successfully go public when a broad class of firms, often the entire market, is valued especially highly".

In our model, firms go public to raise funds to invest in the firm. This also seems consistent with what documented in the IPO literature. For example, the same study by Lowry (2003) shows that IPO volume is higher when firms' demands for capital (as proxied by changes in output or investment) is higher.

An early strand of the IPO literature focused on whether IPOs systematically under-perform (Ritter, 1991; Shiller, 1990; Lee, Shleifer and Thaler, 1991). There is a controversy on whether such an under-performance is empirically significant. Furthermore, Pástor and Veronesi (2005) and others have criticized this literature for assuming that investors cannot detect mis-pricing that entrepreneurs can detect and has provided an alternative explanation of the clustering of IPOs based on time-varying risk premia. In our model, the entrepreneurs' advantage vis-a-vis the investors stems from the fact that part of the latter's overoptimism originates in the observation of the former's activity thus providing the entrepreneurs with an informational advantage when it comes to interpreting the drivers of such an optimism. Our theory thus hinges on the inability of markets to fully aggregate all available information but does not require one to take a strong stand on investors' rationality, nor does it predict systematic mis-pricing of IPOs, based on public information.

So far, we have discussed how our theory is broadly consistent with existing evidence. But how could one test more directly for our mechanism? And does our theory suggest new empirical explorations?

First, one could test for a specific kind of *conditional* mis-pricing. Our model predicts that, when controlling for fundamentals, a higher level of aggregate start-up activity leads to more underperformance following the IPO. Indeed, in our model, the return $\Theta f(k) - P$ on IPO stocks is negatively correlated with aggregate start-up activity N, when controlling for fundamentals Θ. To test this prediction, one could use the same measures of stock overvaluation used in the IPO literature (e.g. post-IPO market returns) at the sectoral level and look at their correlation

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with pre-IPO start-up activity, the aggregate volume of IPOs in the same time window, and real investment in the same sector. The two main challenges with such an approach are the following: (i) first, one needs to find reasonable proxies for the "fundamental" value of firms' stocks $\Theta f(k)$;[30] (ii) second, one needs measures of pre-IPO start-up activity and investment that are comparable across different sectors and that can be used to build a sample that includes sectors that did not experience significant IPO activity, to get around obvious selection issues. In this respect, it is worth highlighting an important difference between this approach and the one in the literature on hot IPO issues and their long-term underperformance. That literature focuses on *unconditional* mis-pricing. It documents a negative relation between the volume of IPOs and the return to IPO stocks after a certain number of years. Without conditioning on proxies for Θ, our theory predicts no underperformance and zero correlation between aggregate start-up activity (or IPO volume) and the long-term return on IPO stocks.

It would also be interesting to test empirically for some of the comparative statics that the model delivers. Our mechanism is likely to be more relevant in sectors where (i) firms rely intensively on external funding (in the model, this is captured by a high level of the parameter α), (ii) there is more uncertainty about the profitability of new technologies (higher σ_θ^2), and (iii) entrepreneurs are exposed to more correlated noise (larger σ_ϵ^2). Provided that one can identify appropriate measures of long-term fundamental profitability to address the issue of conditional underperformance discussed above, it would be interesting to study how the correlation between long-term underperformance and IPO volume (or early start-up activity as proxied by venture-capital investment) varies across industries and time. As mentioned above, the evidence in Jain and Kini (2006) that IPO clustering tends to occur prevalently in fragmented, high growth, R&D-intensive industries seems to provide some support to the comparative statics of our mechanism but more work in this direction is needed. The main challenge here, in addition to those discussed above, is in finding reasonable proxies for the degree to which investors rely on IPO finance (α) and for their exposure to correlated noise. The latter could be captured in part by the extent to which entrepreneurs in a given sector rely on common venture capitalists and common consultants, or, alternatively, by their network connections (e.g. the schools they attended, and the participation to similar industry events such as fairs, forums, and other venues for business networking).

We conclude with the following observation. While we focused on IPO waves and the associated "hot IPO effect" as a natural context for our theory, we expect our mechanism to extend to the broader real-financial nexus and to find an application at the business-cycle level, too. This would bring our theory closer to the literature, also mentioned in Section 1, that documents the response of asset prices to news about real economic activity (Chen *et al.* (1986); Cutler *et al.* (1989)). As usual, the higher the level of aggregation, the lesser the hope for clean identification. This suggests that the empirical exercises mentioned above may prove useful not only in the IPO context but also for a micro-to-macro application of our theory at the business-cycle level.

APPENDIX: PROOFS

Proof of Proposition 1. In this proof, we fill in the details of the equilibrium characterization in Section 3 and provide explicit expressions for the functions Γ and Λ.

First, let us derive the optimality condition (14), which we rewrite here for convenience:

$$\mathbb{E}_i[(1-\alpha)\theta+\alpha\hat{\theta}] \geq C \tag{A.1}$$

30. One could perhaps follow the prevalent approach in the literature on underperformance and look at post-IPO market returns over some fixed horizon, taking the value of the firm at longer horizons after the IPO as a proxy for its fundamental value.

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and provide an explicit expression for the constant C. In the text, we argued that an entrepreneur will start-up the project if and only if

$$\beta^2(1-\alpha)(\alpha\beta)^{\frac{\alpha}{1-\alpha}}\mathbb{E}_i[\Theta\cdot\hat{\Theta}^{\frac{\alpha}{1-\alpha}}]\geq 1. \tag{A.2}$$

As argued in the text, conditional on the investors' information $\mathcal{I}$, θ is normally distributed with mean

$$\hat{\theta}=\frac{\pi_\omega}{\pi}\omega+\frac{\pi_z}{\pi}z \tag{A.3}$$

(which corresponds to (18) in the text) and variance π^{-1}, so we can compute

$$\hat{\Theta}=\mathbb{E}[e^\theta|\mathcal{I}]=\exp\left\{\hat{\theta}+\frac{1}{2}\pi^{-1}\right\}. \tag{A.4}$$

We can then compute the expression $\mathbb{E}_i[\Theta\cdot\hat{\Theta}^{\frac{\alpha}{1-\alpha}}]$ in (A.2) as follows

$$\begin{aligned}\mathbb{E}_i\left[\Theta\cdot\hat{\Theta}^{\frac{\alpha}{1-\alpha}}\right]&=\mathbb{E}_i\left[\exp\left\{\frac{(1-\alpha)\theta+\alpha\hat{\theta}}{1-\alpha}+\frac{\alpha}{1-\alpha}\frac{1}{2}\pi^{-1}\right\}\right]\\&=\exp\left\{\mathbb{E}_i\left[\frac{(1-\alpha)\theta+\alpha\hat{\theta}}{1-\alpha}\right]+\frac{\alpha}{1-\alpha}\frac{1}{2}\pi^{-1}+\frac{1}{2}\mathrm{Var}_i\left[\frac{(1-\alpha)\theta+\alpha\hat{\theta}}{1-\alpha}\right]\right\}.\end{aligned}$$

Substituting into (A.2), we obtain condition (A.1), where

$$C=-(1-\alpha)\ln\left(\beta^2(1-\alpha)(\alpha\beta)^{\frac{\alpha}{1-\alpha}}\right)-\frac{\alpha}{2}\pi^{-1}-\frac{1}{2(1-\alpha)}\mathrm{Var}_i\left[(1-\alpha)\theta+\alpha\hat{\theta}\right]. \tag{A.5}$$

Joint normality of $(1-\alpha)\theta+\alpha\hat{\theta}$ and of the signals (x_i,y) imply that the conditional variance in the last term is a constant independent of the realization of (x_i,y).

Next, let us solve the Bayesian updating problem of entrepreneurs at the start-up stage. Substituting $z=(1-b)\theta+by$ (which corresponds to (17) in the text) in (A.3), we have

$$\hat{\theta}=\frac{\pi_\omega}{\pi}(\theta+\eta)+\frac{\pi_z}{\pi}\left[(1-b)\theta+by\right],$$

so

$$(1-\alpha)\theta+\alpha\hat{\theta}=\left(1-\alpha+\alpha\frac{\pi_\omega+\pi_z(1-b)}{\pi}\right)\theta+\alpha\frac{\pi_z}{\pi}by+\alpha\frac{\pi_\omega}{\pi}\eta.$$

Conditional on (x_i,y), the posterior distribution of θ has mean

$$\mathbb{E}_i[\theta]=\delta_x x_i+\delta_y y,$$

with

$$\delta_x=\frac{\pi_x}{\pi_\theta+\pi_x+\pi_y}\quad\delta_y=\frac{\pi_y}{\pi_\theta+\pi_x+\pi_y},$$

and variance $(\pi_\theta+\pi_x+\pi_y)^{-1}$. Moreover, (x_i,y) contains perfect information on y and no information on η. Therefore, the posterior mean and variance of $(1-\alpha)\theta+\alpha\hat{\theta}$ are

$$\mathbb{E}_i\left[(1-\alpha)\theta+\alpha\hat{\theta}\right]=\left(1-\alpha+\alpha\frac{\pi_\omega+\pi_z(1-b)}{\pi}\right)\left(\delta_x x_i+\delta_y y\right)+\alpha\frac{\pi_z}{\pi}by, \tag{A.6}$$

$$\mathrm{Var}_i\left[(1-\alpha)\theta+\alpha\hat{\theta}\right]=\left(1-\alpha+\alpha\frac{\pi_\omega+\pi_z(1-b)}{\pi}\right)^2\frac{1}{\pi_\theta+\pi_x+\pi_y}+\left(\alpha\frac{\pi_\omega}{\pi}\right)^2\frac{1}{\pi_\omega}. \tag{A.7}$$

We can now go back to the optimality condition (A.1), substitute (A.6) and obtain

$$\left(1-\alpha+\alpha\frac{\pi_\omega+\pi_z(1-b)}{\pi}\right)\left(\delta_x x_i+\delta_y y\right)+\alpha\frac{\pi_z}{\pi}by\geq C.$$

Matching the coefficients of this condition to the coefficients of the entrepreneur's strategy (15), we obtain

$$b=\frac{\left(1-\alpha+\alpha\frac{\pi_\omega+\pi_z(1-b)}{\pi}\right)\delta_y+\alpha\frac{\pi_z}{\pi}b}{\left(1-\alpha+\alpha\frac{\pi_\omega+\pi_z(1-b)}{\pi}\right)\left(\delta_x+\delta_y\right)+\alpha\frac{\pi_z}{\pi}b}, \tag{A.8}$$

and

$$c=\frac{C}{\left(1-\alpha+\alpha\frac{\pi_\omega+\pi_z(1-b)}{\pi}\right)\left(\delta_x+\delta_y\right)+\alpha\frac{\pi_z}{\pi}b}. \tag{A.9}$$

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Substituting $\pi=\pi_\theta+\pi_\omega+\pi_z$ and $\pi_z=\pi_y/b^2$, we can rewrite the right-hand side of (A.8) as

$$\frac{\left[(1-\alpha)\left(\pi_\theta+\pi_\omega+\frac{\pi_y}{b^2}\right)+\alpha\left(\pi_\omega+\frac{\pi_y}{b^2}(1-b)\right)\right]\delta_y+\alpha\frac{\pi_y}{b^2}b}{\left[(1-\alpha)\left(\pi_\theta+\pi_\omega+\frac{\pi_y}{b^2}\right)+\alpha\left(\pi_\omega+\frac{\pi_y}{b^2}(1-b)\right)\right](\delta_x+\delta_y)+\alpha\frac{\pi_y}{b^2}b},$$

which can be rearranged to yield

$$\Gamma(b)\equiv\frac{\left[((1-\alpha)\pi_\theta+\pi_\omega)b^2+\pi_y-\alpha\pi_y b\right]\delta_y+\alpha\pi_y b}{\left[((1-\alpha)\pi_\theta+\pi_\omega)b^2+\pi_y-\alpha\pi_y b)\right](\delta_x+\delta_y)+\alpha\pi_y b}. \tag{A.10}$$

This shows that the equilibrium value of b can be found finding a fixed point of the function Γ, which only involves known parameters of the model.

The mapping $\Lambda(b)$ is given by the right-hand side of (A.9), after substituting C from (A.5), substituting $\mathrm{Var}_i\left[(1-\alpha)\theta+\alpha\hat{\theta}\right]$ from (A.7), and finally substituting $\pi=\pi_\theta+\pi_\omega+\pi_z$ and $\pi_z=\pi_y/b^2$, so as to obtain an expression that only involves known parameters and b. This shows that the equilibrium value of c can be computed by simple algebra after having found a b that solves $b=\Gamma(b)$. Q.E.D.

Proof of Proposition 2. *Part (i): Existence.* First, notice that $\Gamma(1)<1$ so there is no equilibrium with $b=1$. Now define $B\equiv b/(1-b)$ for any $b\neq 1$. Using the definition of Γ, we then have that $b=B/(1+B)$, corresponds to an equilibrium if and only if

$$\begin{aligned}B\;&\equiv\;\frac{b}{1-b}=\frac{\Gamma(b)}{1-\Gamma(b)}=\frac{\alpha\pi_y b+\left[(1-\alpha)b^2\pi_\theta+b^2\pi_\omega+\pi_y-\alpha\pi_y b\right]\delta_y}{\left[(1-\alpha)b^2\pi_\theta+b^2\pi_\omega+\pi_y-\alpha\pi_y b\right]\delta_x}\\&=\frac{\pi_y+\frac{B^2}{(1+B)^2}(\pi_\theta+\pi_\omega)+\alpha\frac{B}{1+B}\left(\pi_x+\frac{1}{1+B}\pi_\theta\right)}{\pi_y+\frac{B^2}{(1+B)^2}(\pi_\theta+\pi_\omega)-\alpha\frac{B}{1+B}\left(\pi_y+\frac{B}{1+B}\pi_\theta\right)}\frac{\delta_y}{\delta_x}.\end{aligned}$$

Letting

$$F(B)\equiv\frac{\delta_y}{\delta_x}\left\{1+\frac{\alpha(1+B)B}{[(1-\alpha)(1-\delta_x)+\Omega]B^2+(2-\alpha)\delta_y B+\delta_y}\right\} \tag{A.11}$$

with $\Omega\equiv\frac{\pi_\omega}{\pi_x+\pi_y+\pi_\theta}>0$, and noting that B is a one-to-one transformation of b, we then have that the solutions to the equations $B=F(B)$ identify the solutions to the equation $b=\Gamma(b)$ and vice versa.

It is easy to see that F is well defined and continuous over $\mathbb{R}_+$, with $F\left(\delta_y/\delta_x\right)>\delta_y/\delta_x$ and $\lim_{B\to+\infty}F(B)$ finite. It follows that F has at least one fixed point $B>\delta_y/\delta_x$. Given this value of B, existence of an equilibrium then follows by letting $b=B/(1+B)$. That $B>\delta_y/\delta_x$ in turn implies that

$$b>\frac{\delta_y}{\delta_x+\delta_y}=\frac{\pi_y}{\pi_x+\pi_y}\equiv\delta.$$

That $B>0$ in turn implies that $b<1$. We conclude that a solution $b\in(\delta,1)$ to $\Gamma(b)=b$ always exists, as claimed in the proposition. The implications for N, P, and $\hat{\Theta}$ follow directly from the arguments in the main text.

Part (ii): Uniqueness. To prove uniqueness, note that all equilibria must correspond to a fixed point of the mapping F defined in (A.11). Next, note there exists $\alpha'>0$ such that, for any $\alpha\in[0,\alpha']$ the denominator in the fraction in the right-hand side of (A.11) is strictly positive, for any $B\in\mathbb{R}$. This implies that, when $\alpha\in[0,\alpha']$, the function F is defined and continuously differentiable over the entire real line, with

$$F'(B)=\alpha\frac{\delta_y}{\delta_x}\frac{\left[\delta_y-(1-\alpha)(1-\delta_x-\delta_y)-\Omega\right]B^2+2\delta_y B+\delta_y}{\left\{[(1-\alpha)(1-\delta_x)+\Omega]B^2+(2-\alpha)\delta_y B+\delta_y\right\}^2}.$$

Moreover,

$$\lim_{B\to-\infty}F(B)=\lim_{B\to+\infty}F(B)=F_\infty\equiv\frac{\delta_y}{\delta_x}\left[1+\frac{\alpha}{(1-\alpha)(1-\delta_x)+\Omega}\right]>\frac{\delta_y}{\delta_x}.$$

Thus, from now on, restrict attention to $\alpha<\alpha'$. We now need to consider two cases. First, suppose $\delta_y=(1-\alpha)(1-\delta_x)+\Omega$. The function F then has a global minimum at $B=-1/2$. In this case, F is bounded from below and above, respectively, by $\underline{F}\equiv F(-1/2)$ and $\overline{F}\equiv F_\infty$. Second, suppose $\delta_y\neq(1-\alpha)(1-\delta_x)+\Omega$. Then, $F'(B)$ has two zeros, respectively at $B=B_1$ and at $B=B_2$, where

$$B_1\equiv\frac{-\delta_y-\sqrt{[(1-\alpha)(1-\delta_x-\delta_y)+\Omega]\delta_y}}{\delta_y-(1-\alpha)(1-\delta_x-\delta_y)-\Omega}\text{ and }B_2\equiv\frac{-\delta_y+\sqrt{[(1-\alpha)(1-\delta_x-\delta_y)+\Omega]\delta_y}}{\delta_y-(1-\alpha)(1-\delta_x-\delta_y)-\Omega}.$$

When $\delta_y\neq(1-\alpha)\delta_0+\Omega$, the function F then has a global minimum at $\underline{F}\equiv F(B_2)$ and a global maximum at $\overline{F}\equiv F(B_1)$. It is easy to check that in all the cases considered both $\underline{F}$ and $\overline{F}$ converge to δ_y/δ_x as $\alpha\to 0$. But then F converges uniformly

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to δ_y/δ_x as $\alpha \to 0$. It follows that for any $\varepsilon > 0$, there exists a $\hat{\alpha} \leq \alpha'$ so that, whenever $\alpha < \hat{\alpha}$, F has no fixed point outside the interval $[\delta_y/\delta_x - \varepsilon, \delta_y/\delta_x + \varepsilon]$.

Now, with a slight abuse of notation, replace $F(B)$ with $F(B;\alpha)$, to highlight the dependence of F on α. Notice that $\partial F(B;\alpha)/\partial B$ is continuous in B at $(B;\alpha) = (\delta_y/\delta_x, 0)$ and $\partial F(\delta_y/\delta_x; 0)/\partial B = 0$. It follows that there exist $\tilde{\varepsilon} > 0$ and $\tilde{\alpha} \in (0, \hat{\alpha}]$ such that $\partial F(B;\alpha)/\partial B < 1$ for all $B \in [\delta_y/\delta_x - \tilde{\varepsilon}, \delta_y/\delta_x + \tilde{\varepsilon}]$ and $\alpha \in [0, \tilde{\alpha}]$. Combining these results with the continuity of $F(\cdot;\alpha)$, we have that there exist $\bar{\varepsilon} > 0$ and $\bar{\alpha} > 0$ such that, for all $\bar{\alpha} \in [0, \bar{\alpha}]$, the following are true: for any $B \notin [\delta_y/\delta_x - \bar{\varepsilon}, \delta_y/\delta_x + \bar{\varepsilon}]$, $F(B;\alpha) \neq B$; for $B \in [\delta_y/\delta_x - \bar{\varepsilon}, \delta_y/\delta_x + \bar{\varepsilon}]$, F is continuous and differentiable in B, with $\partial F(B;\alpha)/\partial B < 1$. It follows that, if $\alpha \leq \bar{\alpha}$, F has at most one fixed point, which establishes the result.

Part (iii): Multiplicity. Consider the function $F\left(B;\alpha,\delta_x,\delta_y,\Omega\right)$ introduced in the proof of part (ii). For convenience, we are highlighting here the dependence on all parameters, with $\Omega \equiv \frac{\pi_\omega}{\pi_x+\pi_y+\pi_\theta}$. Take the parameters $\left(\alpha,\delta_x,\delta_y,\Omega\right) = (.75,.2,.1,.1)$. With these parameters, the function F is defined and continuous over the entire real line and $B_2 < B_1$, where B_1 and B_2 are as defined in the proof of part (ii). Moreover, at the point B_2, we have that $F\left(B_2;\alpha,\delta_x,\delta_y,\Omega\right) < B_2 < 0$. These properties, together with the properties that $F\left(0;\alpha,\delta_x,\delta_y,\Omega\right) > 0$ and $\lim_{b\to-\infty} F\left(B;\alpha,\delta_x,\delta_y,\Omega\right) > 0 > -\infty$, ensure that, in addition to a fixed point in $\left(\delta_y/\delta_x, +\infty\right)$, F admits at least one fixed point in $(-\infty, B_2)$ and one in $(B_2, 0)$. Furthermore, each of these three fixed point is "strict" in the sense that $F(B) - B$ changes sign around them. Because F is continuous in $\left(B;\alpha,\delta_x,\delta_y,\Omega\right)$ in an open neighbourhood of $\left(\alpha,\delta_x,\delta_y,\Omega\right) = (.75,.2,.1,.1)$, there necessarily exists an open set $D \subset (0,1)^3 \times \mathbb{R}$ such that F admits at least three fixed points whenever $\left(\alpha,\delta_x,\delta_y,\Omega\right) \in D$. The result then follows by noting that for any $\left(\alpha,\delta_x,\delta_y,\Omega\right) \in D$, there corresponds a unique set of parameters $(\alpha,\pi_\theta,\pi_x,\pi_y,\pi_\omega) \in \mathbb{R}^5$. Q.E.D.

Proof of Lemma 1. The result is proved in the proof of part (i) of Proposition 2. Q.E.D.

Proof of Proposition 4. Using

$$N = \Phi\left(\tfrac{\sqrt{\pi_x}}{1-b^*}\left[(1-b^*)\theta + b^* y - c^*\right]\right),$$

we have that the endogenous signal z can be written as

$$z = \frac{1-b^*}{\sqrt{\pi_x}}\Phi^{-1}(N) + c^*$$

The investors' forecast of the fundamentals can then be expressed as follows

$$\hat{\theta} = \tfrac{\pi_\omega}{\pi_\theta+\pi_\omega+\pi_z}\omega + \tfrac{\pi_z}{\pi_\theta+\pi_\omega+\pi_z}\left(\frac{1-b^*}{\sqrt{\pi_x}}\Phi^{-1}(N) + c^*\right) \tag{A.12}$$

with $\pi_z = \pi_y/(b^*)^2$. Replacing (A.12) into (14), we have that the entrepreneurs' optimality condition can be written as

$$n_i = 1 \iff \mathbb{E}_i\left[(1-r)\theta + r\Phi^{-1}(N)\right] \geq c^{\#},$$

where

$$r \equiv \frac{\alpha\pi_y(1-b^*)}{\alpha\pi_y(1-b^*) + \left[(1-\alpha)\left(\pi_\theta(b^*)^2 + \pi_y\right) + (b^*)^2\pi_\omega\right]\sqrt{\pi_x}} \tag{A.13}$$

and

$$c^{\#} \equiv \frac{\left[(\pi_\theta+\pi_\omega)(b^*)^2 + \pi_y\right]C - \alpha\pi_y c^*}{\frac{\alpha\pi_y(1-b^*)}{\sqrt{\pi_x}} + (1-\alpha)\left(\pi_\theta(b^*)^2 + \pi_y\right) + \pi_\omega(b^*)^2}$$

with C as defined in (A.5). From (A.13), we then have that $r > 0$ whenever $b < 1$, i.e. whenever N is increasing in θ, which is always the case when the equilibrium is unique, for in this case $b \in (\delta, 1)$ as shown in the proof of Propositions 1 and 2. Q.E.D.

Proof of Proposition 5. Consider the function $F(B;\alpha)$ introduced in the proof of Propositions 1 and 2. For any $\alpha \in [0, \bar{\alpha})$, the function $F(\cdot;\alpha)$ is continuously differentiable over $\mathbb{R}$. Take any pair $\alpha', \alpha'' \in [0, \bar{\alpha})$ with $\alpha'' > \alpha'$, and let B' and B'' be the unique solutions to $F(B;\alpha) = B$, respectively for $\alpha = \alpha'$ and $\alpha = \alpha''$ (existence and uniqueness of such solutions follows directly from Proposition 2). Furthermore, as shown in the proof of Propositions 1 and 2, $F\left(B;\alpha'\right) - B > 0$ for all $B \in [0, B')$. Simple algebra then shows that $\partial F(B;\alpha)/\partial\alpha \geq 0$ for any $B \geq 0$, with strict inequality if $B > 0$. It follows that $B'' > B'$. The result in the proposition then follows from the fact that $b \equiv B/(1+B)$ along with the fact that the contribution of noise to volatility is increasing in b. Q.E.D.

Proof of Proposition 6. Aggregate welfare is given by

$$W\left(b,\tilde{b},c\right) \equiv \mathbb{E}\left[n(x,y)\left(\beta Q\left(\Theta,\hat{\Theta}\right) - 1\right)\right],$$

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where

$$Q\left(\Theta,\hat{\Theta}\right)=\beta(\Theta-\alpha\hat{\Theta})(\alpha\beta\hat{\Theta})^{\frac{\alpha}{1-\alpha}},$$

$$\hat{\Theta}=e^{\hat{\theta}+\frac{1}{2}\pi^{-1}},\quad \hat{\theta}=\frac{\pi_\omega}{\pi}(\theta+\eta)+\frac{\pi_z}{\pi}z,\quad z=\theta+b\varepsilon, \tag{A.14}$$

$$\pi=\pi_\theta+\pi_\omega+\pi_z,\quad \pi_z=\pi_y/b^2, \tag{A.15}$$

and with the start-up rule given by

$$n(x,y)=1 \text{ iff } (1-\tilde{b})x+\tilde{b}y\geq c.$$

For convenience, we are introducing two different coefficients b and $\tilde{b}$: b captures the informativeness of the signal z, $\tilde{b}$ is the coefficient in the start-up rule. Of course, for consistency, the planner must choose $b=\tilde{b}$. Therefore, the planner's optimization problem is

$$\max_{b,c} W(b,b,c).$$

We want to show that it is optimal to choose a $b<b^*$, where b^* is the coefficient in the market equilibrium (recall that the latter is unique when α is small enough). The argument is by contradiction. Suppose, it is optimal to choose a pair (b,c) with $b\geq b^*$. Then we want to show that there is a (b',c'), with $b'<b$, that delivers higher welfare. We do it in two steps. First, we show that there is a pair (b',c'), with $b'<b$, such that $W\left(b,b',c'\right)>W(b,b,c)$. That is, fixing the precision of the endogenous public signal, it is optimal to choose a start-up rule less sensitive to the signal with correlated noise. Second, we show that a more informative endogenous signal increases welfare, that is, $W\left(b',b',c'\right)>W\left(b,b',c'\right)$. Combining the two inequalities, we have

$$W\left(b',b',c'\right)>W(b,b,c),$$

a contradiction.

Step 1. Define expected social surplus conditional on x,y as

$$S(x,y)\equiv\mathbb{E}[\beta Q(\Theta,\hat{\Theta})-1|x,y]=\beta^2(\alpha\beta)^{\frac{\alpha}{1-\alpha}}\mathbb{E}[\Theta\hat{\Theta}^{\frac{\alpha}{1-\alpha}}|x,y]-\beta(\alpha\beta)^{\frac{1}{1-\alpha}}\mathbb{E}[\hat{\Theta}^{\frac{1}{1-\alpha}}|x,y]-1.$$

In the proof of Proposition 1, we showed that

$$\mathbb{E}[\Theta\cdot\hat{\Theta}^{\frac{\alpha}{1-\alpha}}|x,y]=\exp\left\{\begin{array}{c}\frac{1}{1-\alpha}\mathbb{E}[(1-\alpha)\theta+\alpha\hat{\theta}|x,y]\\+\frac{\alpha}{2(1-\alpha)}\pi^{-1}+\frac{1}{2(1-\alpha)^2}\mathrm{Var}\left((1-\alpha)\theta+\alpha\hat{\theta}|x,y\right)\end{array}\right\},$$

where

$$\frac{1}{1-\alpha}\mathbb{E}[(1-\alpha)\theta+\alpha\hat{\theta}|x,y]=q_x x+q_y y,$$

with

$$q_x\equiv\frac{1}{1-\alpha}\left(1-\alpha+\alpha\frac{\pi_\omega+\pi_z(1-b)}{\pi}\right)\delta_x,$$

$$q_y\equiv\frac{1}{1-\alpha}\left(1-\alpha+\alpha\frac{\pi_\omega+\pi_z(1-b)}{\pi}\right)\delta_y+\frac{1}{1-\alpha}\alpha\frac{\pi_z}{\pi}b$$

and where $\mathrm{Var}\left((1-\alpha)\theta+\alpha\hat{\theta}|x,y\right)$ is invariant in (x,y), as shown in (A.7).

Following similar steps, we can derive

$$\mathbb{E}[\hat{\Theta}^{\frac{1}{1-\alpha}}|x,y]=\exp\left\{\frac{1}{1-\alpha}\mathbb{E}[\hat{\theta}|x,y]+\frac{\pi^{-1}}{2(1-\alpha)}+\frac{1}{2(1-\alpha)^2}\mathrm{Var}(\hat{\theta}|x,y)\right\},$$

where

$$\frac{1}{1-\alpha}\mathbb{E}[\hat{\theta}|x,y]=\hat{q}_x x+\hat{q}_y y,$$

with

$$\hat{q}_x\equiv\frac{1}{1-\alpha}\left(\frac{\pi_\omega+\pi_z(1-b)}{\pi}\right)\delta_x,$$

$$\hat{q}_y\equiv\frac{1}{1-\alpha}\left(\frac{\pi_\omega+\pi_z(1-b)}{\pi}\right)\delta_y+\frac{1}{1-\alpha}\frac{\pi_z}{\pi}b$$

and where $\mathrm{Var}(\hat{\theta}|x,y)$ is invariant in (x,y).

It follows that we can write expected surplus as

$$S(x,y)=Q_1 e^{q_x x+q_y y}-Q_2 e^{\hat{q}_x x+\hat{q}_y y}-1,$$

where Q_1 and Q_2 are positive constant terms.

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It will be useful to derive some properties of the coefficients $q_x, q_y, \hat{q}_x, \hat{q}_y$. The coefficients are all positive and satisfy the inequalities $\hat{q}_x < q_x$ and $\hat{q}_y/\hat{q}_x > q_y/q_x$. The first inequality follows immediately from $(\pi_\omega + \pi_z(1-b))/\pi < 1$. The second inequality follows from the fact that the expression

$$\frac{\left(1-\tilde{\alpha}+\tilde{\alpha}\frac{\pi_\omega+\pi_z(1-b)}{\pi}\right)\delta_y+\tilde{\alpha}\frac{\pi_z}{\pi}b}{\left(1-\tilde{\alpha}+\tilde{\alpha}\frac{\pi_\omega+\pi_z(1-b)}{\pi}\right)\delta_x}=\frac{\delta_y}{\delta_x}+\frac{\frac{\pi_z}{\pi}b}{\left(1/\tilde{\alpha}-1+\frac{\pi_\omega+\pi_z(1-b)}{\pi}\right)\delta_x}$$

is an increasing function of $\tilde{\alpha}$, is equal to q_y/q_x when $\tilde{\alpha}=\alpha$, and is equal to $\hat{q}_y/\hat{q}_x$ when $\tilde{\alpha}=1$. Finally, we can prove that

$$\frac{q_y}{q_x}=F\left(\frac{b}{1-b}\right)<\frac{b}{1-b},$$

where the function F is defined in the proof of Proposition 2. The equality can be proved comparing the expressions for q_x and q_y above with the definition of F in that proof. The inequality follows from the fact that the equilibrium is unique, so the F function can only cross the 45 degree line once, from above, at $\frac{b^*}{1-b^*}$, and from the fact that, by hypothesis, we have $b > b^*$.

We can now prove two lemmas.

Lemma 2. *For each y there is a unique x such that $S(x,y)=0$, $S(x',y)>0$ if $x'>x$ and $S(x',y)<0$ if $x'<x$.*

Proof of Lemma 2. Existence: Fix any $y\in(-\infty,\infty)$. Notice that $\lim_{x\to-\infty}S(x,y)=-1$. Rewrite

$$S(x,y)=e^{q_x x+q_y y}\left[Q_1-Q_2 e^{(\hat{q}_x-q_x)x+(\hat{q}_y-q_y)y}\right]-1,$$

and notice that $\hat{q}_x-q_x<0$, so the term in square brackets converges to Q_1 as $x\to\infty$, so $\lim_{x\to\infty}S(x,y)=\infty$. By continuity, there exists an x such that $S(x,y)=0$. Uniqueness: Differentiating, we have

$$S_x(x,y)=q_xQ_1e^{q_xx+q_yy}-\hat{q}_xQ_2e^{\hat{q}_xx+\hat{q}_yy},$$

so at a (x,y) such that $S(x,y)=0$ we have

$$S_x(x,y)=q_x-\hat{q}_xw>0,$$

where

$$w\equiv\frac{Q_2e^{\hat{q}_xx+\hat{q}_yy}}{1+Q_2e^{\hat{q}_xx+\hat{q}_yy}}\in(0,1). \tag{A.16}$$

An index argument implies a unique solution and a continuity argument implies the inequalities.

Lemma 3. *The slope of the locus $\{(x,y):S(x,y)=0\}$ satisfies*

$$\frac{dx}{dy}>-\frac{q_y}{q_x},$$

everywhere.

Proof of Lemma 3. Differentiating, we have

$$S_y(x,y)=q_yQ_1e^{q_xx+q_yy}-\hat{q}_yQ_2e^{\hat{q}_xx+\hat{q}_yy}.$$

Therefore, the slope is given by

$$\frac{dx}{dy}=-\frac{S_y}{S_x}=-\frac{q_y-\hat{q}_yw}{q_x-\hat{q}_xw}>-\frac{q_y}{q_x},$$

where w is given in (A.16). The last inequality follows from $w>0$, $q_x-\hat{q}_xw>0$ and $\hat{q}_y/\hat{q}_x>q_y/q_x$.

To complete this step, we use a graphical argument. In Figure A1, the locus $S(x,y)=0$ is represented by the solid line. For values to the right of the solid line, we have $S(x,y)>0$, and for values to the left $S(x,y)<0$. Suppose that the planner is using the conjectured optimal start-up rule with $\tilde{b}=b>b^*$. Such a rule is represented by the dashed line, which represents the points where $(1-b)x+by=c$. The dashed line must cross the locus $S(x,y)=0$ at least at one point or it would be optimal to change c and shift the dashed line. Moreover, it can only cross it at one point, from below, given the result in Lemma 3 and the fact that $q_y/q_x<b/(1-b)$ as shown above. Consider an alternative start-up rule, given by the dotted line, which has $b'<b$ and a c' such that the two rules cross the locus $S(x,y)=0$ in the same point. This rule delivers a higher expected welfare given that (i) it reduces the size of the region in which $n=0$ is chosen and $S(x,y)>0$, (ii) it

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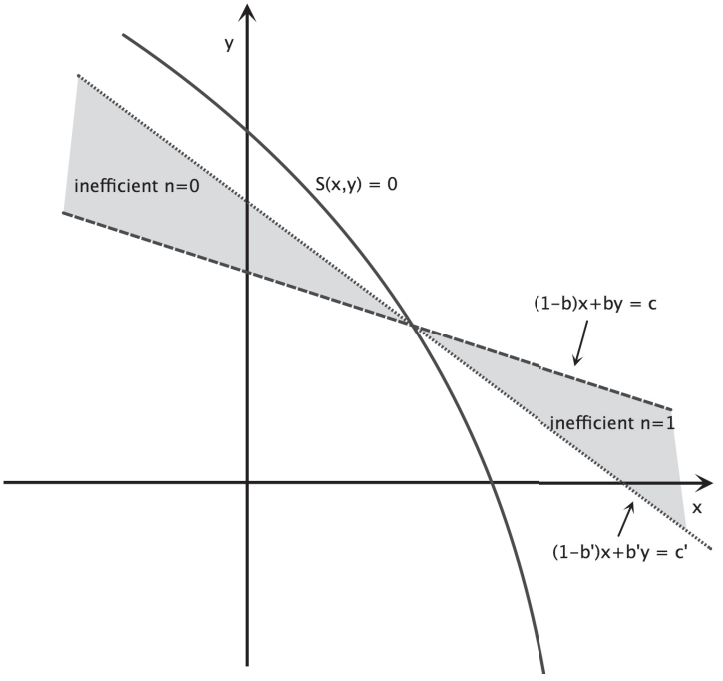

FIGURE A1
Improving the start-up rule

reduces the size of the region in which $n=1$ is chosen and $S(x,y)<0$, and (iii) leaves all other choices of n unchanged. We conclude that

$$W\left(b,b',c'\right)>W\left(b,b,c\right).$$

Step 2. We want to prove that

$$W\left(b',b',c'\right)>W\left(b,b',c'\right).$$

Let us first establish a result on the benefits of basing investment decisions on a more informative signal. Let

$$z_1=\theta+b_1\varepsilon,\quad z_2=\theta+b_2\varepsilon$$

and assume $b_2>b_1$. Similarly, define the random variable $\hat{\Theta}_j$ and the parameters $\pi_{z,j}$ and π_j using (A.14)–(A.15) with $b=b_j$, for $j=1,2$. The unconditional version of the next lemma is just Blackwell's theorem. For our argument, however, we need to prove the conditional version stated below.

Lemma 4. *For all* (ω,z_1), *the following is true:*

$$\mathbb{E}[Q(\Theta,\hat{\Theta}_1)|z_1,\omega]>\mathbb{E}[Q(\Theta,\hat{\Theta}_2)|z_1,\omega].$$

Proof of Lemma 4. Recall that

$$Q(\Theta,\hat{\Theta}_j)=\beta\Theta f(K(\hat{\Theta}_j))-K(\hat{\Theta}_j)$$

for $j=1,2$, and notice that the function $\Theta f(k)-k$ is concave in k. Then, we have

$$\mathbb{E}[Q(\Theta,\hat{\Theta}_2)|z_1,\omega]\leq\mathbb{E}[Q(\Theta,\hat{\Theta}_1)|z_1,\omega]+\mathbb{E}[(\beta\Theta f'(K(\hat{\Theta}_1))-1)(K(\hat{\Theta}_2)-K(\hat{\Theta}_1))|z_1,\omega],\tag{A.17}$$

and to prove our claim we need to show that the last term on the right-hand side is negative. Recall the optimality condition for $K(\hat{\Theta}_1)$

$$\beta\hat{\Theta}_1 f'(K(\hat{\Theta}_1))=1.$$

Using this condition, the last term on the right-hand side of (A.17) simplifies to

$$(\alpha\beta)^{\frac{1}{1-\alpha}}\mathbb{E}[(\Theta/\hat{\Theta}_1-1)\hat{\Theta}_2^{\frac{1}{1-\alpha}}|z_1,\omega],$$

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and to prove that this expression is smaller than 0 we need to prove the inequality

$$\mathbb{E}[\Theta\hat{\Theta}_2^{\frac{1}{1-\alpha}}|z_1,\omega]<\mathbb{E}[\hat{\Theta}_2^{\frac{1}{1-\alpha}}|z_1,\omega]\mathbb{E}[\Theta|z_1,\omega].$$

Because of the normality of the underlying shocks, this condition is equivalent to $\mathrm{Cov}[\theta,\hat{\theta}_2|z_1,\omega]<0$, which in turn is equivalent to $\mathrm{Cov}[\theta,z_2|z_1,\omega]<0$, given that $\hat{\theta}_2=\frac{\pi_\omega}{\pi_2}\omega+\frac{\pi_{z,2}}{\pi_2}z_2$. The following step completes the argument

$$\mathrm{Cov}[\theta,z_2|z_1,\omega]=\mathrm{Cov}[\theta,(1-b_2/b_1)\theta+(b_2/b_1)z_1|z_1,\omega]=-(b_2/b_1-1)\mathrm{Var}[\theta|z_1,\omega]<0.$$

Given the start-up rule (b',c'), we can define

$$N(z')=\Phi\left(\tfrac{\sqrt{\pi_x}}{1-b'}(z'-c')\right),$$

where $z'=\theta+b'\varepsilon$, and write social welfare under the two information sets for investment as

$$W(b,b',c')=\mathbb{E}[N(z')(Q(\Theta,\hat{\Theta})-1)],\quad W(b',b',c')=\mathbb{E}[N(z')(Q(\Theta,\hat{\Theta}')-1)].$$

Since in the previous step, we have chosen $b'<b$, we can use Lemma 4 to obtain

$$N(z')\mathbb{E}[(Q(\Theta,\hat{\Theta})-1)|z',\omega]<N(z')\mathbb{E}[(Q(\Theta,\hat{\Theta}')-1)|z',\omega].$$

Taking expectations on both sides completes the proof. Q.E.D.

Proof of Proposition 7. Consider the following broader class of subsidies/taxes contingent on period-2 information which includes the one in the proposition as a special case. Each entrepreneur $i\in[0,N]$ who started a project receives a subsidy (alternatively, is asked to pay a tax) at the end of period 2 (i.e. after his IPO is completed and the capital investment k_i is finalized) equal to

$$\sigma(p,N)=\frac{1}{\beta}\left(1-\exp\left\{A\Phi^{-1}(N)+B\ln(p)+C\right\}\right),$$

where $A,B,C\in\mathbb{R}$ and where p denotes the average IPO price. Below we show that, by selecting A, B, and C appropriately, the planner can induce the entrepreneurs to follow the socially optimal start-up of Proposition 6. Because the subsidy/tax is paid at the end of Period 2 once k_i is sunk and does not depend on the outcome (k_i,s_i,p_i) of entrepreneur i's individual IPO, it does not affect the expansion made at $t=2$ (i.e. it has no impact on the supply and demand schedules submitted at the IPO stage). Furthermore, because, given the investors' information, the Period-2 investments are efficient in the absence of policy interventions, that the proposed policies induce efficiency in the start-up decisions also guarantees that they induce efficiency in the subsequent investment decisions.

Under the proposed policy, each entrepreneur starts a project if and only if $\mathbb{E}_i[\beta^2(1-\alpha)\Theta f(K(\hat{\Theta}))+\beta\sigma]\geq 1$ or, equivalently,

$$\beta^2(1-\alpha)(\alpha\beta)^{\frac{\alpha}{1-\alpha}}\mathbb{E}_i[\Theta\cdot\hat{\Theta}^{\frac{\alpha}{1-\alpha}}]+\beta\mathbb{E}_i[\sigma]\geq 1. \tag{A.18}$$

When all entrepreneurs $j\neq i$ follow the efficient linear start-up rule, that is, start a project if and only if $(1-b^\diamond)x_j+b^\diamond y\geq c^\diamond$, the information contained in the aggregate start-up activity

$$N=\Phi\left(\tfrac{\sqrt{\pi_x}}{1-b^\diamond}\left[(1-b^\diamond)\theta+b^\diamond y-c^\diamond\right]\right) \tag{A.19}$$

is the same as the one contained in the endogenous signal $z=\theta+b^\diamond\varepsilon$ with precision $\pi_z=\pi_y/(b^\diamond)^2$. Furthermore, because the investors' expected value of θ, which is given by

$$\hat{\theta}=\tfrac{\pi_\omega}{\pi_\theta+\pi_\omega+\pi_z}\omega+\tfrac{\pi_z}{\pi_\theta+\pi_\omega+\pi_z}z,$$

is normally distributed, then

$$\mathbb{E}_i\left[\Theta\cdot\hat{\Theta}^{\frac{\alpha}{1-\alpha}}\right]=\exp\left\{\mathbb{E}_i\left[\frac{(1-\alpha)\theta+\alpha\hat{\theta}}{1-\alpha}\right]+\frac{\alpha}{1-\alpha}\frac{1}{2}\pi^{-1}+\frac{1}{2}\mathrm{Var}_i\left[\frac{(1-\alpha)\theta+\alpha\hat{\theta}}{1-\alpha}\right]\right\}$$

where $\pi=\pi_\theta+\pi_\omega+\pi_z$ and where $\mathrm{Var}_i\left[\frac{(1-\alpha)\theta+\alpha\hat{\theta}}{1-\alpha}\right]$ is invariant to entrepreneur i's information (x_i,y).

Now suppose that $1-\beta\sigma$ is log-normally distributed, meaning that $1-\beta\sigma=\exp\{g\}$ with g normally distributed with a variance that is invariant to entrepreneur i's information (x_i,y). Then,

$$\mathbb{E}_i[1-\beta\sigma]=\exp\left\{\mathbb{E}_i[g]+\frac{1}{2}Var_i[g]\right\}.$$

It follows that entrepreneur i's start-up rule (A.18) can be rewritten as

$$\beta^2(1-\alpha)(\alpha\beta)^{\frac{\alpha}{1-\alpha}}\exp\left\{\mathbb{E}_i\left[\tfrac{(1-\alpha)\theta+\alpha\hat{\theta}}{1-\alpha}\right]+\tfrac{\alpha}{1-\alpha}\tfrac{1}{2}\pi^{-1}+\tfrac{1}{2}\mathrm{Var}_i\left[\tfrac{(1-\alpha)\theta+\alpha\hat{\theta}}{1-\alpha}\right]\right\}\geq \exp\left\{\mathbb{E}_i[g]+\tfrac{1}{2}\mathrm{Var}_i[g]\right\},$$

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which is equivalent to

$$\mathbb{E}_i\Big[(1-\alpha)\theta+\alpha\hat{\theta}-(1-\alpha)g\Big]\geq M$$

where

$$M\equiv\frac{1-\alpha}{2}\mathrm{Var}_i\big[g\big]-\frac{1-\alpha}{2}\mathrm{Var}_i\left[\frac{(1-\alpha)\theta+\alpha\hat{\theta}}{1-\alpha}\right]-(1-\alpha)\ln\left\{\beta^2(1-\alpha)(\alpha\beta)^{\frac{\alpha}{1-\alpha}}\right\}-\frac{\alpha}{2}\pi^{-1}.$$

Now use (A.19) along with the fact that

$$p=P(\hat{\Theta})=\alpha^{\frac{\alpha}{1-\alpha}}(\beta\hat{\Theta})^{\frac{1}{1-\alpha}}$$

with

$$\hat{\Theta}=\exp\left\{\hat{\theta}+\frac{1}{2}\pi^{-1}\right\}$$

to observe that, for any $(A,B,C)\in\mathbb{R}^3$,

$$A\Phi^{-1}(N)+B\ln(p)+C=\sqrt{\pi_x}A\theta+\frac{Ab^\diamond\sqrt{\pi_x}}{1-b^\diamond}y+\frac{B}{1-\alpha}\hat{\theta}+\left\{\frac{B}{1-\alpha}\left(\ln\left(\alpha^\alpha\beta\right)+\frac{\pi^{-1}}{2}\right)-\frac{Ac^\diamond\sqrt{\pi_x}}{1-b^\diamond}+C\right\}.$$

This means that when

$$g=A\Phi^{-1}(N)+B\ln(p)+C$$

then g is indeed normally distributed with a variance that is invariant to (x_i,y).

Furthermore, when g takes the form above

$$\mathbb{E}_i\Big[(1-\alpha)\theta+\alpha\hat{\theta}-(1-\alpha)g\Big]=\mathbb{E}_i\left[(1-\alpha)\left(1-\sqrt{\pi_x}A\right)\theta+(\alpha-B)\hat{\theta}-(1-\alpha)\frac{Ab^\diamond\sqrt{\pi_x}}{1-b^\diamond}y\right]-D,$$

where

$$D\equiv(1-\alpha)\left\{\frac{B}{1-\alpha}\left(\ln\left(\alpha^\alpha\beta\right)+\frac{\pi^{-1}}{2}\right)-\frac{Ac^\diamond\sqrt{\pi_x}}{1-b^\diamond}+C\right\}.$$

Next recall that

$$\mathbb{E}_i[\theta]=\delta_x x_i+\delta_y,$$

and that

$$\mathbb{E}_i\left[\hat{\theta}\right]=\left(\frac{\pi_\omega+\pi_z(1-b^\diamond)}{\pi}\right)\left(\delta_x x_i+\delta_y y\right)+\frac{\pi_z}{\pi}b^\diamond y,$$

where

$$\delta_x=\frac{\pi_x}{\pi_\theta+\pi_x+\pi_y}\quad\text{and}\quad\delta_y=\frac{\pi_y}{\pi_\theta+\pi_x+\pi_y}.$$

This means that

$$\mathbb{E}_i\Big[(1-\alpha)\theta+\alpha\hat{\theta}-(1-\alpha)g\Big]=S_x x_i+S_y y-D,$$

where

$$S_x=\left\{(1-\alpha)\left(1-\sqrt{\pi_x}A\right)+(\alpha-B)\left(\frac{\pi_\omega+\pi_z(1-b^\diamond)}{\pi}\right)\right\}\delta_x$$

and

$$S_y=\left\{(1-\alpha)\left(1-\sqrt{\pi_x}A\right)+(\alpha-B)\left(\frac{\pi_\omega+\pi_z(1-b^\diamond)}{\pi}\right)\right\}\delta_y+(\alpha-B)\frac{\pi_z}{\pi}b^\diamond-(1-\alpha)\frac{Ab^\diamond\sqrt{\pi_x}}{1-b^\diamond}.$$

It follows that, under the proposed policy, each entrepreneur starts a project if and only if

$$(1-b^\#)x_i+b^\# y\geq c^\#,$$

where

$$b^\#=\frac{\left\{(1-\alpha)\left(1-\sqrt{\pi_x}A\right)+(\alpha-B)\left(\frac{\pi_\omega+\pi_z(1-b^\diamond)}{\pi}\right)\right\}\delta_y+(\alpha-B)\frac{\pi_z}{\pi}b^\diamond-(1-\alpha)\frac{Ab^\diamond\sqrt{\pi_x}}{1-b^\diamond}}{\left\{(1-\alpha)\left(1-\sqrt{\pi_x}A\right)+(\alpha-B)\left(\frac{\pi_\omega+\pi_z(1-b^\diamond)}{\pi}\right)\right\}\left(\delta_x+\delta_y\right)+(\alpha-B)\frac{\pi_z}{\pi}b^\diamond-(1-\alpha)\frac{Ab^\diamond\sqrt{\pi_x}}{1-b^\diamond}}$$

and

$$c^\#=\frac{M+D}{\left\{(1-\alpha)\left(1-\sqrt{\pi_x}A\right)+(\alpha-B)\left(\frac{\pi_\omega+\pi_z(1-b^\diamond)}{\pi}\right)\right\}\left(\delta_x+\delta_y\right)+(\alpha-B)\frac{\pi_z}{\pi}b^\diamond-(1-\alpha)\frac{Ab^\diamond\sqrt{\pi_x}}{1-b^\diamond}}.$$

Note that, given A and B, $\mathrm{Var}_i\big[g\big]$ is invariant to C. This means that, given A and B, there always exists C such that $c^\#=c^\diamond$. It is also easy to see that there exist infinitely many combinations of A and B such that $b^\#=b^\diamond$.

The result in the proposition then follows from specializing the subsidy/tax above to the case where $A=0$. Q.E.D.

Proof of Proposition 8. The proof is in two steps. Step 1 verifies the two equilibrium properties mentioned in the main text right before the proposition: for all entrepreneurs i who start a project, $s_i=\alpha$ and $k_i=k$, with k satisfying Condition (29). Step 2 uses these properties to show that the equilibrium entry rule satisfies the condition in the proposition.

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Step 1. Using the fact that

$$l=\int_{i\in[0,N]} p_i s_i di \qquad \text{and} \qquad c_3=\int_{i\in[0,N]} s_i \Theta f(k_i) di,$$

we have that the investor's expected payoff is equal to

$$V=\int_{i\in[0,N]} s_i \hat{\Theta} f(k_i) di - \frac{1}{1+\epsilon}\left(\int_{i\in[0,N]} p_i s_i di\right)^{1+\epsilon},$$

where $\hat{\Theta}\equiv\mathbb{E}_2[\Theta]$ is as in the baseline model.

As in the baseline model, the investor takes $(p_i,k_i)_{i\in[0,N]}$ as given and chooses $(s_i)_{i\in[0,N]}$ to maximize V. The FOCs for the above problem give

$$p_i\left(\int_{j\in[0,N]} p_j s_j dj\right)^{\epsilon}=\hat{\Theta} f(k_i) \tag{A.20}$$

for all $i\in[0,N]$. Combining the above conditions with the expansion-feasibility condition

$$k_i=p_i s_i, \tag{A.21}$$

we conclude that each entrepreneur i's profit when selling s_i shares is given by

$$\Pi_i=(1-s_i)\Theta f(k_i)=\frac{\Theta}{\hat{\Theta}}\left\{\hat{\Theta} f(k_i)-\left(\int_{j\in[0,N]} k_j dj\right)^{\epsilon} k_i\right\}$$

and hence that the value of k_i that maximizes Π_i now solves

$$\hat{\Theta} f'(k_i)=\left(\int_{j\in[0,N]} k_j dj\right)^{\epsilon} \tag{A.22}$$

for all $i\in[0,N]$, where the right-hand side of (A.22) is the investor's marginal cost of investment. With Cobb–Douglas, the above gives $\alpha\hat{\Theta}k_i^{\alpha-1}=\left(\int_{j\in[0,N]} k_j dj\right)^{\epsilon}$. Using the fact that $k_i=k$ for all $i\in[0,N]$, we thus conclude that the equilibrium k satisfies $\alpha\hat{\Theta}k^{\alpha-1}=(Nk)^{\epsilon}$, which coincides with the expression in (29).

Combining $\alpha\hat{\Theta}k_i^{\alpha-1}=\left(\int_{j\in[0,N]} k_j dj\right)^{\epsilon}$ with (A.20) and (A.21), we can also verify that

$$s_i=\alpha,$$

as in the baseline model.

Step 2. Using (29), we have that the equilibrium level of investment is given by

$$k=K(\hat{\Theta},N)\equiv\left(\alpha\hat{\Theta}N^{-\epsilon}\right)^{\frac{1}{1-\alpha+\epsilon}}.$$

It follows that the entrepreneur's payoff from starting a project is given by

$$\Pi=\Pi\left(\Theta,\hat{\Theta},N\right)\equiv(1-\alpha)\Theta(\alpha\hat{\Theta})^{\frac{\alpha}{1-\alpha+\epsilon}}N^{-\frac{\epsilon\alpha}{1-\alpha+\epsilon}},$$

and therefore that each entrepreneur starts up if and only if

$$\mathbb{E}_i\left[\Theta\hat{\Theta}^{\frac{\alpha}{1-\alpha+\epsilon}}N^{-\frac{\alpha\epsilon}{1-\alpha+\epsilon}}\right]\geq\chi,$$

where $\chi\equiv\left((1-\alpha)(\alpha)^{\frac{\alpha}{1-\alpha+\epsilon}}\right)^{-1}$. Redefining $\hat{\theta}\equiv\log\hat{\Theta}$, and letting $a\equiv\alpha/(1+\epsilon)$ and $\psi\equiv\alpha\epsilon/(1+\epsilon)$, we have that the above condition is equivalent to that stated in the proposition. Q.E.D.

Proof of Proposition 9. Welfare is given by the *ex ante* expectation of aggregate output net of entry and investment costs:

$$W\equiv\mathbb{E}\left[\int n_i\Theta f(k_i)di-\int n_i di-\frac{1}{1+\epsilon}\left(\int n_i k_i di\right)^{1+\epsilon}\right].$$

Clearly, it is optimal for the planner to equalize the level of investment at the IPO stage: $k_i=k$ for all i such that $n_i=1$ (and $k_i=0$ otherwise). It follows that welfare reduces to

$$W\equiv\mathbb{E}\left[(\Theta f(k)-1)\left(\int n_i di\right)-\frac{1}{1+\epsilon}k^{1+\epsilon}\left(\int n_i di\right)^{1+\epsilon}\right] \tag{A.23}$$

Finally, the planner chooses k and $\{n_i\}_{i\in[0,1]}$ subject to two measurability constraints: that n_i is a function of x_i and z; and that k is a function of ω and $N=\int n_i di$.

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The planner's choice of k satisfies the following FOC:

$$(kN)^{\epsilon} = \mathbb{E}_2[\Theta]f'(k) = \hat{\Theta}f'(k), \tag{A.24}$$

where $\hat{\Theta} \equiv \mathbb{E}_2[\Theta]$. This verifies that the equilibrium level of investment is *ex post* efficient (i.e. efficient, conditional on $\hat{\Theta}$ and N), regardless of ϵ. By the same token, the "neoclassical" element we have introduced in this extension is not a source of inefficiency at the IPO stage.

The same applies to the start-up stage. The endogeneity of the information upon which $\hat{\Theta}$ is computed (and upon which k is chosen) introduces the same kind of informational externality as in the baseline model. Disregard momentarily this externality, that is, treat the distribution of $\hat{\Theta}$ as exogenous to entrepreneurial entry. Then, the planner's optimal plan has entrepreneur i choose $n_i = 1$ if and only if $\Omega_i \geq 0$, where

$$\Omega_i = \mathbb{E}_i\left[\Theta f(k) - (kN)^{\epsilon}k - 1\right]$$

measures the social return to entry, or the derivative of (A.23) with respect to n_i. Using (A.24) and the fact that $f'(k)k = \alpha f(k)$, we can rewrite the above as

$$\Omega_i = \mathbb{E}_i\left[\left(\Theta - \alpha\hat{\Theta}\right)f(k) - 1\right].$$

By contrast, in equilibrium $n_i = 1$ if and only if $B_i \geq 0$, where

$$B_i = \mathbb{E}_i[\Pi - 1]] = \mathbb{E}_i\left[(1-\alpha)\Theta f(k) - 1\right]$$

is the private return to entry. It follows that, as long as we abstract from the endogeneity of $\hat{\Theta}$, the wedge between the social and the private return to entry is given the following term:

$$\mathbb{E}_i\left[\alpha\left(\Theta - \hat{\Theta}\right)f(k)\right].$$

Clearly, this expression has exactly the same meaning (and indeed the same mathematical expression), as in the baseline model: it corrects for the "speculative" motive in the entrepreneurs' start-up decisions.

Finally, consider the informational externality. Because the investments made at $t = 2$ are efficient conditional on the information available at this point, the more information the entry decisions carry about Θ the higher the welfare. It follows that the information externality is (qualitatively) the same as in the baseline model: the planner still likes to induce a more informative N at $t = 1$ than that obtained in equilibrium in order to better guide the investments made at $t = 2$.

Both sources of inefficiency are thus qualitatively he same as in the baseline model.

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