1

Beauty Contests and Irrational Exuberance:

A Neoclassical Approach

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This version: February 2010

Abstract

The arrival of new, unfamiliar, investment opportunities—e.g., internet commerce, emerging markets, new financial intruments—is often associated with "exuberant" movements in asset prices and real investment. While irrational explanations of these phenomena abound, in this paper we show howt the dispersion of information that is likely to surround such unfamiliar investment opportunities may itself help explain these phenomena within an otherwise standard, rational, neoclassical framework. On the positive front, we identify a mechanism that amplifies the contribution of noise to equilibrium volatility, thereby leading to what may look like "irrational exuberance" to an outside observer. On the normative front, we show that this amplification is a symptom of constrained inefficiency: there exist policies that can mitigate the impact of noise and thereby improve welfare even if the government cannot centralize the information that is dispersed in the market. These findings rest on a simple insight. When information is dispersed, financial markets look at the real sector for signals of the underlying fundamentals, and vice versa. Such informational spillovers give rise to a form of strategic complementarity, which in turn induces a conventional neoclassical economy to behave as in Keynes' "beauty contest" metaphore.

Keywords: mispricing, heterogeneous information, information-driven complementarities, volatility, inefficiency, beauty contests.

*This is a thoroughly revised version of an earlier paper that circulated under the title "Wall Street and Silicon Valley: a Delicate Interaction." We thank Olivier Blanchard, Stephen Morris, Hyun Song Shin, Rob Townsend, Jaume Ventura, Iván Werning and seminar participants at MIT, the Federal Reserve Board, the 2007 IESE Conference on Complementarities and Information (Barcelona), the 2007 Minnesota Workshop in Macroeconomic Theory, and the 2007 NBER Summer Institute for useful comments. Angeletos and Pavan thank the NSF for financial support.

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1 Introduction

Episodes of large joint movements in asset prices and aggregate investment, such as the internet boom of the late 90s, pose a number of positive and normative questions. Do these movements simply reflect the arrival of news about the future profitability of physical (and intangible) capital? Or do they reflect an excessive response to temporary waves of "optimism" and "pessimism," appropriately defined? If so, is there a role for government intervention?

Addressing these questions requires moving away, to some extent, from the neoclassical paradigm: the observed movements appear too "exuberant" to be driven merely by the rational response of a representative-agent-like economy to noisy information. One approach is to assume that these movements are driven by the beliefs and behavior of irrational agents.[1] Although this may be part of the story, we do not go in that direction here. Instead, we show how the dispersion of information that is likely to surround such episodes may itself help explain these phenomena within an otherwise standard, rational, neoclassical framework.

This choice is motivated by three considerations. First, following the tradition of Hayek and Friedman, we are uncomfortable with policy prescriptions that rely on the presumption that the government has a superior ability to evaluate the economy's needs and opportunities than the market mechanism. Thus, as a matter of preferred methodology, we maintain the axiom of rationality and seek to stay reasonably close to the neoclassical paradigm of efficient markets.

Second, we are intrigued by the observation that the aforementioned episodes tend to coincide with the arrival of new, unfamiliar investment opportunities—whether it is a novel technology like the Internet during the late 90s, the opening of new markets in emerging economies, or the introduction of new financial instruments, as in the recent crisis. While one could simply assume that irrational forces are stronger during these episodes than in normal times, we find it quite plausible that the available information may be both more noisy and more dispersed than normally due to the unfamiliarity of these investment opportunities, the lack of historical data, and the absence of previous social learning.

Finally, we are intrigued by the informal argument, often heard in policy debates, that financial markets have a destabilizing role during these episodes, as the agents in charge of real investment decisions become "overly" concerned about the short-run valuation of their capital in financial markets instead of looking at underlying fundamentals. A variant of this argument can be traced back to Keynes' famous "beauty contest" metaphor:

> "...professional investment may be likened to those newspaper competitions in which the competitors have to pick out the six prettiest faces from a hundred photographs,

[1] Akerlof and Shiller (2009), Bernanke and Gertler (2001), Cecchetti et al. (2000), Dupor (2005), Shiller (2000).

> the prize being awarded to the competitor whose choice most nearly corresponds to the average preferences of the competitors as a whole; so that each competitor has to pick, not those faces which he himself finds prettiest, but those which he thinks likeliest to catch the fancy of the other competitors..." Keynes (1936, p.156).

Although intriguing, this argument makes no sense within a neoclassical asset-pricing framework as in Lucas (1978): agents share the same beliefs, asset prices only reflect their common expectation of the fundamentals, and it is thus irrelevant whether investors are concerned about fundamentals or asset prices when making their investment decisions. In contrast, dispersed information might help make sense of this argument by introducing a distinct role for higher-order beliefs.[2]

These considerations define the scope of the theoretical exercise in this paper. We start with a conventional neoclassical framework that features a perfectly efficient interaction between financial markets and the real economy. We deviate from this framework in a single dimension, by introducing dispersed information about the profitability of a new investment opportunity. Our contribution is then in showing how such a dispersion of information has two important implications. First, it can amplify the response of the economy to "noise shocks," thus helping explain why the episodes of interest may look to an outside observer as "exuberant" and hard to reconcile with fundamentals. Second, it can introduce a particular type of inefficiency, providing a formal interpretation of the argument that investors are excessively concerned with the short-run behavior of asset prices. At the heart of these results is the following mechanism: When information is dispersed, financial markets look at the real sector for signals of the underlying fundamentals, and vice versa. Such informational spillovers give rise to a form of strategic complementarity, which in turn induces an otherwise conventional neoclassical economy to behave as in Keynes' "beauty contest" metaphor.

Preview of model and results. Our baseline model features a large number of "entrepreneurs" who get the option to invest in a new technology. Entrepreneurs must make their decisions based on imperfect, and heterogeneous, information about the profitability of this technology. In a subsequent stage, after investment is sunk but before uncertainty is resolved, some entrepreneurs have to sell their capital in a competitive financial market. The "traders" in this market are also imperfectly informed, but get to observe prior aggregate investment decisions.

At the core of the model is thus a two-way interaction between financial markets and the real economy. On the one hand, entrepreneurs base their initial investment decisions partly on their expectations about the price at which they may sell their capital; this captures more broadly the idea that the incentives of those in charge of real investment decisions depend in part on their expectations of future asset prices. On the other hand, traders look at aggregate investment to learn about profitability; this captures more broadly the idea that financial markets follow closely the

[2] The role of higher-order beliefs was first highlighted by Morris and Shin (2002); we discuss the relation shortly.

release of macroeconomic and sectoral data, and constantly monitor corporate outcomes, looking for clues about underlying economic fundamentals.[3]

The first direction of the aforementioned two-way interaction identifies a *pecuniary externality*: part of the return to investment for one group of agents (the entrepreneurs) is the price at which they can sell their capital to another group of agents (the traders). The second direction identifies an informational spillover: the collective behavior of the former group impacts the information that is available to the latter group. As standard in competitive frameworks, a pecuniary externality is not itself a source of inefficiency: the possibility of trade among the two groups only improves welfare. Furthermore, the informational spillover itself is also beneficial: the transmission of information from one group of agents to another facilitates efficiency in investment and capital allocation. Our contribution is to show that, when information is dispersed, the interaction of these two forces leads to distinct positive and normative implications.

On the positive side, we show that the aforementioned informational spillover amplifies the response of real investment and asset prices to "noise shocks" relative to "fundamental shocks." The latter are defined as shocks to the underlying profitability of the new technology. The former are defined as correlated errors in the entrepreneurs' expectations of this profitability, and introduce in our model a source of "non-fundamental movements" in real investment and asset prices.[4]

To understand how this amplification emerges, suppose for a moment that the entrepreneurs' decisions were driven merely by their opinions about fundamentals. In equilibrium, the realized level of aggregate investment would then reveal the entrepreneurs' average opinion and would send a signal to the traders about underlying fundamentals. This signal is noisy: any given agent cannot tell whether higher aggregate investment is caused by a positive shock to fundamentals or by a positive correlated error in the entrepreneurs' opinions. However, relative to the typical trader, the typical entrepreneur is bound to have some private information about the noise in this signal. This is because the origin of this noise is in the information observed by the entrepreneurs. Notice that the entrepreneur does not need to perfectly observe the realizations of the noise shock. It is enough that he recognizes that some sources of information are more affected by this noise than others.

This asymmetry between entrepreneurs and traders is crucial, for it implies that the (rational) pricing errors that occur in the financial market are partly predictable by the typical entrepreneur. In particular, whenever a noise shock occurs, each entrepreneur will expect the average opinion of the other entrepreneurs—and hence aggregate investment—to increase more than his own opinion.

[3] Our baseline model focuses on the information that flows from the real sector to the financial market. Allowing the information to flaw also in the opposite direction, from the financial market to the real sector, may actually reinforce our results. See the discussion in Section 5.2.

[4] The existence of these shocks is taken for granted, as in any model with uncertain fundamentals; our contribution is to study how the interaction between real and financial activity impacts the propagation of these shocks when information about these shocks is dispersed.

But then the entrepreneur will also expect the financial market to overprice his capital. This in turn creates an incentive for the entrepreneur to invest more than what warranted from his expectation of the fundamentals—in other words, to engage in what may look ex post like "exuberant" investment. As all entrepreneurs do the same, their collective "exuberance" may trigger asset prices to inflate, as the traders will perceive this exuberance in part as a signal of good fundamentals. The anticipation of inflated prices can feed back to further exuberance in real economic activity, and so on.

Turning to the normative side, the question of interest is whether this amplification effect is also a symptom of inefficiency. To address this question, we consider a constrained-efficiency benchmark similar to the one in Angeletos and Pavan (2007, 2009). Namely, we consider the problem faced by a planner who has full power on the agents' incentives but has no informational advantage vis-a-vis the market—either in the form of additional information or in the form of the power to centralize the information that is dispersed in the economy. We then show that such a planner would dictate to the entrepreneurs to ignore the expected mispricing in the financial market and instead base their investment decisions merely on their expectations of the fundamentals. This is because any gain that the entrepreneurs can make by exploiting such a mispricing is only a private rent—a zero-sum transfer from one group of agents to another, which creates a wedge between the private and social return to investment. It follows that our amplification effect is also a symptom of inefficiency.

We conclude that our results open the door to policy intervention even if the government is restricted to base its policies only on information that is already in the public domain. We show how simple policies that stabilize asset prices, like those often advocated in practice, can lead to higher welfare, but we also identify their limitations. Finally, we discuss how certain more sophisticated, state-contingent, policies can do better, possibly restoring full efficiency.

Related literature. This paper adds to the recent and growing macroeconomic literature on dispersed information.[5] The contribution is to focus on the informational feedbacks between the real and the financial sector of the economy. In so doing, the paper builds on a long tradition in macro-finance that studies the interaction between the stock market and real investment. More closely related in this regard are recent papers by Albagli (2009), Hassan and Mertens (2009), Goldstein, Ozdenoren and Yuan (2009a), and Tinn (2009), which also focus on informational aspects of this interaction, although different than the ones in our paper.

Morris and Shin (2002) recently put forth the idea that models that combine strategic complementarity with dispersed information can be used to capture the role of higher-order beliefs in Keynes' beauty contest metaphor, spawning a rich literature. However, the framework used in Morris and Shin (2002) was abstract, lacking particular micro-foundations, and completely bypassed both the positive question of what is the origin of strategic complementarity and the normative

[5] See, e.g., Angeletos and La'O (2009), Mankiw and Reis (2009), Veldkamp (2009), and the references therein.

question of what is the cause of inefficiency, if any. Subsequent work by Allen, Morris and Shin (2006), Bacchetta and Wincoop (2005), and Cespa and Vives (2009) has provided a certain formalization of the *positive* aspect within dynamic asset pricing models, but has continued to bypass the *normative* question. The contribution of our paper relative to this work is (i) in providing a micro-founded model of the interaction between the real sector and financial markets; (ii) in identifying a novel information-driven complementarity; and (iii) in addressing the core of the normative question. In short, to the best of our knowledge, this paper is the first one to show how a conventional neoclassical production economy may display the positive and normative features of a Keynesian beauty contest.

The origin of both the complementarity and the inefficiency in our model is the signaling role of investment: entrepreneurs overreact to noise shocks because they expect the financial market to misinterpret their "exuberance" as a signal of high profitability. Interestingly, this occurs without any of the agents in our model being strategic, in the sense that they are all infinitesimal and take prices and aggregate outcomes as given when making their own choices. Thus, despite a certain similarity in flavor, our results are distinct from those in the finance literature which, in the tradition of Kyle (1985), focuses on how large informed players can manipulate asset prices.[6] Rather, the manipulation effects in our model are the by-product of the "invisible hand," that is, of the general-equilibrium interaction of multiple small players.

It is also worth noting that the normative result we document is distinct from the one usually associated with information externalities. A voluminous literature on herding and social learning has documented, in a variety of contexts, how individual agents may fail to internalize the impact of their own actions on the information available to other agents, which in turn may affect the efficiency of the decisions taken by the latter (e.g., Banerjee, 1992, Vives, 1997, 2008, Chari and Kehoe, 2003, Amador and Weill 2007, 2008). While important, this particular source of inefficiency is not central to our analysis. To make this clear, our baseline model makes assumptions that guarantee that the allocation of capital among the traders is irrelevant for welfare. Rather, the inefficiency in our baseline model rests on how the *anticipation* of the signaling role of investment affects the entrepreneurs' incentives. In this regard, the mechanics are more closely related to those in signaling games (e.g., Spence, 1973) than to those in the aforementioned herding literature, even though the "senders" in our model (the entrepreneurs) are non-strategic in the sense that the actions of each one alone do not affect the beliefs of the "receivers" (the traders).

Finally, by touching on the broader themes of heterogeneous beliefs and "mispricing" in financial markets, our paper shares a certain flavor with the recent literature that uses heterogeneous priors to explain the dot-com bubble or the recent crisis (e.g., Scheinkman and Xiong, 2003; Panageas, 2005;

[6] See, e.g., Goldstein and Guembel (2007), which emphasizes how this manipulation could distort real investment.

Geanakoplos, 2009). However, the positive and normative aspects of our contribution are quite distinct. First, this literature rules out the informational externality that drives our amplification results. Second, recall that the Welfare Theorems in the Arrow-Debreu model allow for subjective probabilities, thus guaranteeing that the type of speculative trades this recent literature focuses on are not by themselves a symptom of inefficiency. Justifying government intervention requires one to argue that the priors of some market participants are irrational—a position that we have sought to avoid as a matter of principle.

Layout. The rest of the paper is organized as follows. Section 2 introduces the baseline model. Section 3 characterizes the equilibrium and delivers the key positive results. Section 4 characterizes the constrained efficient allocation and contrasts it to the equilibrium. Section 4.2 discusses policy implications. Section 5 studies a more general model. Section 5.2 discusses the robustness and re-interpretation of our results in richer settings. Section 6 concludes. All proofs are in the Appendix.

2 The baseline model

Our baseline model features a single round of real investment followed by a single round of financial trading, uses a stylized payoff structure, and lets information flow only from the real sector to the financial market. These simplifying assumptions permit us to illustrate the mechanism and our core results in the simplest possible way. Various extensions are discussed in Sections 5 and 5.2.

2.1 Model set up

There are four periods, $t \in \{0, 1, 2, 3\}$, and two types of agents, "entrepreneurs" and "traders". Each type is of measure 1/2; we index entrepreneurs by $i \in [0, 1/2]$ and traders by $i \in (1/2, 1]$.

At $t = 0$, a new investment opportunity, or "technology," becomes available. The profitability of this technology is represented by a random variable $\tilde{\theta}$, which is assumed to be Normal with mean $\mu > 0$ and variance $1/\pi_\theta$ (i.e., π_θ is the precision). The realization θ of this random variable is unknown to all agents.[7]

At $t = 1$, the "real sector" of the economy operates: each entrepreneur gets the opportunity to invest in the new technology. Let k_i denote the investment of entrepreneur i. The cost of this investment in terms of the consumption good is $k_i^2/2$.[8] When choosing investment, entrepreneurs have access to various sources of information (signals) that are not directly available to the traders. Some of these signals may be exogenous, while others may come from various forms of private or social learning. The noise in some of these signals may be mostly idiosyncratic, while for other signals the noise may be correlated across entrepreneurs. In Section 5, we will consider a general

[7] Throughout, we use a "tildes" to denote random variables and drop them when denoting realizations.

[8] One can also think of this as the effort cost needed to produce k_i.

information structure along these lines. For now, to simplify matters, we assume that entrepreneurs observe two exogenous signals. The first one has purely idiosyncratic noise: it is given by $x_i = \theta + \xi_i$, where $\tilde{\xi}_i$ is Gaussian noise, independently and identically distributed across agents, independent of $\tilde{\theta}$, with variance $1/\pi_x$. The second one has perfectly correlated noise: it is given by $y = \theta + \varepsilon$, where $\tilde{\varepsilon}$ is Gaussian noise, common across entrepreneurs, independent of $\tilde{\theta}$ and of $\{\tilde{\xi}_i\}_{i\in[0,1/2]}$, with variance $1/\pi_y$.

At $t = 2$, the "financial market" operates: some entrepreneurs sell their installed capital to the traders.[9] In particular, we assume that each entrepreneur is hit by a shock with probability $\lambda \in [0, 1)$. This shock is i.i.d. across agents; by convention, λ is thus also the fraction of entrepreneurs hit by the shock. Entrepreneurs hit by the shock are forced to sell all their capital; they consume the proceeds of this sale and do not value consumption at any subsequent period. From now on, we refer to this shock as a "liquidity shock" (equivalently, as "death"). On the other hand, we assume that entrepreneurs not hit by the shock (also referred to as "surviving" entrepreneurs) are not allowed to participate in the financial market and they have to hold on to their capital through period 3. The last assumption is made only for simplicity and can be relaxed without affecting our results, provided that the asymmetry of information does not vanish at the time of trading in the financial market.[10]

The financial market is competitive and the market-clearing price is denoted by p. When the traders meet the entrepreneurs hit by the liquidity shocks in the financial market, they observe the quantity of capital that these entrepreneurs bring to the market. Since λ is known, this is equivalent to observing the aggregate level of investment, $K \equiv \int_0^1 k_i di$, determined at $t = 1$. They then use this observation to update their beliefs about θ.[11] Any other information the traders may have about the fundamentals is summarized in a public signal $\omega = \theta + \eta$, where $\tilde{\eta}$ is noise, independent of $\tilde{\theta}$, $\tilde{\varepsilon}$ and $\{\tilde{\xi}_i\}_{i\in[0,1/2]}$, with variance $1/\pi_\omega$.[12]

Finally, at $t = 3$, the profitability θ is publicly revealed and each unit of capital produces θ units of the consumption good, irrespective of whether the capital is held by an entrepreneur or by a trader.

All agents also receive an exogenous endowment e of the (nonstorable) consumption good in each period. Moreover, they are risk neutral and their discount rate is zero: preferences are given

[9] Throughout, we use the expressions "financial market" and "capital market" interchangeably. In other words, we do not explicitly model the distinction between trading claims over installed capital, and trading capital directly.

[10] See Section 6.2 in the earlier version of this paper (Angeletos, Lorenzoni and Pavan, 2007) for the complete analysis of an extension along these lines.

[11] Letting the traders observe the entire cross-sectional distribution of investments does not affect the results. This is because, in equilibrium, this distribution is Normal with known variance; the mean investment thus contains as much information as the entire cross-sectional distribution.

[12] While ω is modeled here as an exogenous signal, it would be straightforward to re-interpret it as the outcome of the aggregation of information that may take place in the financial market when the traders have dispersed private signals about θ. See the discussion in Section 5.2.

by $u_i = c_{i1} + c_{i2} + s_i c_{i3}$, where c_{it} denotes agent i's consumption in period t, while $\tilde{s}_i$ is a random variable that takes value 0 if the agent is an entrepreneur hit by a liquidity shock and value 1 otherwise. We allow agents to trade a riskless bond in each period and to trade insurance contracts on their idiosyncratic liquidity shocks at date 1. As we shall see, given risk neutrality, the presence of these additional securities is irrelevant for investment decisions and for the equilibrium asset price p.

Remarks. As mentioned already, the assumption of independence of the noises in the x_i signals and of perfect correlation of the noise in the y signal are only made for simplicity and are relaxed in Section 5. What matters for our results is that information is partly dispersed and that there is some correlation in the noises. Such a correlation can have various interpretations. As we discuss in Section 5.2, private signals about the actions of agents that moved in the past—e.g., traders in an earlier stage—may lead in equilibrium to signals about θ with correlated errors; the origin of correlation is then the errors in the information of these earlier traders. More broadly, network effects, social learning, and information cascades may explain this correlation. Moreover, as emphasized in Hellwig and Veldkamp (2009) and Myatt and Wallace (2009), strategic complementarity in actions—like the one that, as we will show, emerges endogenously in our economy—induces strategic complementarity in the acquisition of information. See also Dow, Goldstein, and Guembel (2007), Froot, Scharfstein, and Stein (1992), and Veldkamp (2006) for related justifications.

The liquidity shock should also not be taken too literally. Its presence captures the more general idea that when an entrepreneur makes an investment decision, be him a start-up entrepreneur or the manager of a public company, he cares about the market valuation of his investment at some point in the life of the project. A start-up entrepreneur may care about the price at which he will be able to do a future IPO; a corporate manager may be concerned about the price at which the company will be able to issue new shares. What matters for our results is that entrepreneurs do care about the future price of their installed capital when making their investment decisions and that they expect larger profits whenever they have the option of selling at an "inflated" price in the financial market. The assumption that each entrepreneur has no choice but to sell all his capital in the event of a liquidity shock and that each surviving entrepreneur has no choice but to hold on his capital till the end is not essential and is made only to make the analysis more tractable. In what follows, we thus interpret λ more broadly as a measure of the sensitivity of the entrepreneurs' investment decisions to forecasts of future equity prices.

3 Equilibrium

Given the agents' preferences, the equilibrium risk-free rate is zero in all periods and the agents' expected utility is equal to the expected present value of their net income flows.[13] For an entrepreneur hit by the liquidity shock net income flows sum up to $3e + pk_i - k_i^2/2$, while for a surviving entrepreneur they sum up to $3e + \theta k_i - k_i^2/2$. Therefore, up to a constant, each entrepreneur's expected utility at the time of investment is given by

$$\mathbb{E}[\tilde{u}_i|x_i, y] = \mathbb{E}[(1-\lambda)\tilde{\theta} + \lambda\tilde{p} - \tfrac{1}{2}k_i^2|x_i, y].$$

Entrepreneurs make individual investment decisions to maximize their expected utility. Because each entrepreneur faces the same problem, equilibrium investment decisions are described by a function $k : \mathbb{R}^2 \to \mathbb{R}$, where $k(x, y)$ denotes the investment made by an entrepreneur with signals (x, y). Aggregate investment is then a function of the aggregate shocks θ and ε.

Next, consider the traders. Let q_i denote the amount of capital purchased by trader i at $t = 2$. The trader's net income flow is then given by $3e + \theta q_i - pq_i$. Since a trader observes the exogenous signal ω and the aggregate capital K , his expected utility at the time of trading is, up to a constant, given by

$$\mathbb{E}[\tilde{u}_i|K, \omega] = \left(\mathbb{E}[\tilde{\theta}|K, \omega] - p\right) q_i.$$

Therefore, the unique market-clearing price in the financial market is given by the traders' expectation of the fundamental given K and ω: $p = \mathbb{E}[\tilde{\theta}|K, \omega]$.[14] Since K is a function of (θ, ε) and $\omega = \theta + \eta$, the equilibrium price can be expressed as a function of $(\theta, \varepsilon, \eta)$.

Definition 1 *A (symmetric rational expectation) equilibrium is an individual investment strategy $k(x, y)$, an aggregate investment function $K(\theta, \varepsilon)$, and a price function $p(\theta, \varepsilon, \eta)$ that satisfy the following conditions:*

(i) for all (x, y),

$$k(x, y) \in \arg\max_k \mathbb{E}\left[\ (1-\lambda)\tilde{\theta}k + \lambda p(\tilde{\theta}, \tilde{\varepsilon}, \tilde{\eta})k - \tfrac{1}{2}k^2 \ \middle|\ x, y\ \right];$$

[13] Given linear preferences, the consumption allocations and the equilibrium trades of bonds and insurance contracts are clearly indeterminate in equilibrium. Our analysis focuses on investment, the asset price p, and ex-ante welfare, which are all determinate.

[14] Since no trader has private information and since the entrepreneurs who sell their capital have perfectly inelastic supplies, the market-clearing price does not reveal any information. This explains why we omit conditioning on p when describing the traders' expectations. The case where p may convey additional information is discussed in Section 5.2. Also, for the equilibria that we will study, any value $K \in \mathbb{R}$ can be observed in equilibrium, which explains why we do not have to worry about describing out-of-equilibrium beliefs—beliefs are always pinned down by Bayes' rule.

(ii) for all (θ, ε),

$$K(\theta, \varepsilon) = \int k(x, y)\, d\Phi(x, y|\theta, \varepsilon), \tag{1}$$

where $\Phi(x, y|\theta, \varepsilon)$ *denotes the joint cumulative distribution function of* x *and* y*, given* θ *and* ε*;*

(iii) for all $(\theta, \varepsilon, \eta)$,

$$p(\theta, \varepsilon, \eta) = \mathbb{E}\left[\ \tilde{\theta}\ \middle|\ K,\ \omega\ \right],$$

where $K = K(\theta, \varepsilon)$ *and* $\omega = \theta + \eta$.

Condition (i) requires that the entrepreneurs' investment strategy be individually rational, taking as given the equilibrium price function. Condition (ii) is just the definition of aggregate investment. Finally, condition (iii) requires that the equilibrium price be consistent with market clearing and rational expectations, on the traders' side, of the entrepreneurs' investment decisions.

3.1 A benchmark with no informational spillovers

At this point, it is useful to examine a benchmark case in which there is no informational spillover between the real and financial sector. By this we mean a setting in which the aggregate level of investment K does not convey any additional information about fundamentals to the traders. In particular, suppose that the noise in the traders' signal ω vanishes ($\pi_\omega \to \infty$), so that θ is known at the time of trading. The financial market then clears if and only if $p = \theta$ and, by implication, the expected payoff of an entrepreneur who receives signals x and y is given by $\mathbb{E}[\tilde{\theta}|x, y]k - k^2/2$, where $\mathbb{E}[\tilde{\theta}|x, y]$ denotes the expectation of $\tilde{\theta}$ given x and y. The following is then an immediate implication.

Proposition 1 *In the absence of informational spillovers, the equilibrium level of investment is given by*

$$k(x, y) = \mathbb{E}[\tilde{\theta}|x, y] = \delta_0 + \delta_x x + \delta_y y,$$

where $\delta_0 \equiv \pi_\theta \mu / (\pi_\theta + \pi_x + \pi_y)$, $\delta_x \equiv \pi_x / (\pi_\theta + \pi_x + \pi_y)$, *and* $\delta_y = \pi_y / (\pi_\theta + \pi_x + \pi_y)$.

The response of individual investment to the available signals, captured here by the coefficients δ_x and δ_y, reflects merely the precisions of these signals. Aggregate investment is then given by

$$K(\theta, \varepsilon) = \delta_0 + \delta_\theta \theta + \delta_\varepsilon \varepsilon,$$

where $\delta_\theta \equiv \delta_x + \delta_y$ measures the response of aggregate investment to the fundamental and where $\delta_\varepsilon \equiv \delta_y$ measure its response to the noise. Aggregate investment is thus driven by two shocks: the *fundamental* shock θ and the *noise* shock ε.

As mentioned in the Introduction, this benchmark captures the idea that, absent informational spillovers from the real sector to the financial market, it is irrelevant whether investment is driven by the entrepreneurs' expectations of the fundamental or by their expectations of the financial market price. In either case, equilibrium investment is driven solely by first-order expectations regarding the fundamental and is independent of the intensity of the entrepreneurs' concern about financial prices, as measured here by λ. Importantly, this result does not require θ to be known by the traders; it applies more generally as long as the information that the traders possess about θ is a sufficient statistics for the information that the entrepreneurs, as a group, possess, in which case the signaling role of investment vanishes.[15] From now on, we refer to this benchmark as the case with no informational spillovers.

3.2 Informational spillovers

We now characterize the equilibrium when informational spillovers are present. As usual, for tractability, we restrict attention to linear equilibria.[16]

Definition 2 *A linear equilibrium is an equilibrium where the investment strategy $k(x,y)$ is linear. That is, there exist scalars $\beta_0, \beta_x, \beta_y \in \mathbb{R}$ such that, for all (x,y),*

$$k(x,y) = \beta_0 + \beta_x x + \beta_y y. \tag{2}$$

It is natural to focus on situations where investment is increasing in both the idiosyncratic and the correlated signal, i.e., β_x and β_y are both positive. Below, we will first prove that an equilibrium with this property always exists and is unique for λ small enough. Next, we will examine the response of equilibrium prices and quantities to the fundamental and to the noise shock. We will also show how the properties of this equilibrium can be conveniently understood by representing the economy as a game with strategic complementarity. Finally, we will discuss some comparative statics and the possibility of multiple equilibria.

[15] To clarify this point, consider an arbitrary information structure. Let $\mathcal{I}_{i2} = \mathcal{I}_2$ denote the exogenous information of trader $i \in (1/2, 1]$ in period 2, where by exogenous we mean not indirectly inferred through K. Next, let $\mathcal{I}_{i1}$ denote the information possessed by entrepreneur $i \in [0, 1/2]$ at $t = 1$. Imposing that $\mathcal{I}_2$ is a sufficient statistics for $(\mathcal{I}_2, (\mathcal{I}_{i1})_{i=1}^{i=1/2})$ with respect to $\tilde{\theta}$ implies that $\mathbb{E}[\tilde{\theta}|\mathcal{I}_2, (\mathcal{I}_{i1})_{i=1}^{i=1/2}] = \mathbb{E}[\tilde{\theta}|\mathcal{I}_2]$. Because K is measurable in $(\mathcal{I}_{i1})_{i=1}^{i=1/2}$, the observation of K then does not reveal any information to the traders in addition to the one they already possess through $\mathcal{I}_2$. From market clearing, we then have that $p = \mathbb{E}[\tilde{\theta}|\mathcal{I}_2]$. From the law of iterated expectations, we then have that $\mathbb{E}[\tilde{p}|\mathcal{I}_{i1}] = \mathbb{E}[\mathbb{E}[\tilde{\theta}|\mathcal{I}_2, \tilde{K}]|\mathcal{I}_{i,1}] = \mathbb{E}[\mathbb{E}[\tilde{\theta}|\mathcal{I}_2, \tilde{K}, (\mathcal{I}_{i1})_{i=1}^{i=1/2}]|\mathcal{I}_{i,1}] = \mathbb{E}[\tilde{\theta}|\mathcal{I}_{i1}]$ for all $i \in [0, 1/2]$. It follows that every entrepreneur chooses $k_i = \mathbb{E}[\tilde{\theta}|\mathcal{I}_{i1}]$.

[16] A linear equilibrium can be defined as one where the price function is linear or as one where the investment strategy is linear. Since in our setting one definition implies the other, the two definitions are equivalent. Also note that, to be consistent with the pertinent literature, when we say linear we often mean affine.

3.2.1 Existence and uniqueness

When individual investment is given by condition (2), aggregate investment is given by

$$K(\theta,\varepsilon)=\beta_0+\beta_\theta\theta+\beta_\varepsilon\varepsilon, \tag{3}$$

where $\beta_\theta\equiv\beta_x+\beta_y$ and $\beta_\varepsilon\equiv\beta_y$. The response of individual investment to the signals x and y thus determines the response of aggregate investment to the two aggregate shocks θ and ε. Throughout the paper, we will be interested in characterizing the response of *aggregate* investment to the noise shock relative to its response to the fundamental shock; that is, we will focus on the ratio

$$\varphi\equiv\frac{\beta_\varepsilon}{\beta_\theta}=\frac{\beta_y}{\beta_x+\beta_y}.$$

This ratio is related one-to-one to the response of *individual* investment to the correlated signal, y, relative to the idiosyncratic signal, x, that is, to the ratio β_y/β_x.

Consider how the price in the financial market responds to the (rational) expectation that aggregate investment is given by (3). Note that, when $\beta_x+\beta_y\neq 0$, observing K is informationally equivalent to observing a Gaussian signal about θ. This signal can be expressed as

$$z\equiv\frac{K-\beta_0}{\beta_x+\beta_y}=\theta+\varphi\varepsilon \tag{4}$$

and its precision is given by $\pi_z\equiv\pi_y/\varphi^2$. Bayesian updating then implies that the traders' expectation of $\tilde\theta$ given the observation of K is a weighted average of the prior mean, μ, the exogenous signal ω, and the endogenous signal z:

$$\mathbb{E}[\tilde\theta|K,\omega]=\mathbb{E}[\tilde\theta|z,\omega]=\tfrac{\pi_\theta}{\pi_\theta+\pi_\omega+\pi_z}\mu+\tfrac{\pi_\omega}{\pi_\theta+\pi_\omega+\pi_z}\omega+\tfrac{\pi_z}{\pi_\theta+\pi_\omega+\pi_z}z. \tag{5}$$

By implication, the price of capital is given by

$$p(\theta,\varepsilon,\eta)=\tfrac{\pi_\theta}{\pi_\theta+\pi_\omega+\pi_z}\mu+\tfrac{\pi_\omega+\pi_z}{\pi_\theta+\pi_\omega+\pi_z}\theta+\tfrac{\pi_z}{\pi_\theta+\pi_\omega+\pi_z}\varphi\varepsilon+\tfrac{\pi_\omega}{\pi_\theta+\pi_\omega+\pi_z}\eta. \tag{6}$$

We infer that, when aggregate investment responds positively to both the fundamental θ and the noise ε, so does the price: because traders cannot distinguish between increases in investment driven by θ from those driven by ε, in equilibrium, the market-clearing price must necessarily respond (positively) to both θ and ε.

We are now ready to analyze the investment decisions of an individual entrepreneur who expects all other entrepreneurs to follow the strategy in (2) and, by implication, the price to satisfy (6).

Optimality requires that, for all (x, y),

$$k\,(x,y) = \mathbb{E}\left[(1-\lambda)\tilde{\theta} + \lambda p(\tilde{\theta}, \tilde{\varepsilon}, \tilde{\eta}) \middle| \, x, y\right]. \tag{7}$$

Substituting the price function (6) into (7) and solving for the expectation gives individual investment as a linear function of x and y. The coefficients in this function depend on π_z and φ and thereby on the coefficients $(\beta_0, \beta_x, \beta_y)$. Matching the coefficients in this best response function with the coefficients $(\beta_0, \beta_x, \beta_y)$ thus defines a fixed-point problem. A solution to this problem gives a linear equilibrium.

This fixed point problem captures the essence of the two-way feedback between the real and the financial sector of our model. On the one hand, the responses β_x and β_y of individual investment to the two signals x and y determine the relative response φ of aggregate investment to the two shocks θ and ε and thus the precision $\pi_z \equiv \pi_y/\varphi^2$ of the signal that K transmits to the traders. This precision in turn determines the response of the price $p(\theta, \varepsilon, \eta)$ to the two aggregate shocks θ and ε. On the other hand, the price response to the two aggregate shocks determines the entrepreneurs' behavior, for it determines the stochastic properties of p and the entrepreneurs' ability to forecast it. As we shall see in a moment, this forecasting problem plays a crucial role for our positive results. Before turning to these results, we establish existence and uniqueness of a linear equilibrium.

Proposition 2 *There always exists a linear equilibrium in which $\beta_x, \beta_y > 0$ and hence in which investment increases with both shocks, i.e., $\beta_\theta, \beta_\varepsilon > 0$. Furthermore, there exists a cutoff $\bar{\lambda} > 0$, such that, for any $\lambda < \bar{\lambda}$, this is the unique linear equilibrium.*

3.2.2 Mispricing, speculation, and amplification

We now turn to our main positive result. To this purpose, it is useful to rewrite the entrepreneurs' investment strategy as follows:

$$k\,(x,y) = \mathbb{E}\left[\tilde{\theta} + \lambda\left(p(\tilde{\theta}, \tilde{\varepsilon}, \tilde{\eta}) - \tilde{\theta}\right) \middle| \, x, y\right] = \mathbb{E}\left[\tilde{\theta} + \lambda\left(\mathbb{E}[\tilde{\theta}|\tilde{K}, \tilde{\omega}] - \tilde{\theta}\right) \middle| \, x, y\right] \tag{8}$$

This condition has a simple interpretation. The variable θ represents the fundamental valuation of a unit of capital. The gap $p - \theta = \mathbb{E}[\tilde{\theta}|K, \omega] - \theta$ thus identifies the traders' forecast error of that valuation, or equivalently the "pricing error" in the market. The component of investment that is driven by the forecast of this pricing error can then be interpreted as "speculative." For any given expectation of θ, an entrepreneur will invest more in response to a positive expectation of the traders' forecast error; this is because he expects to sell the extra capital in an "overpriced" market.

That entrepreneurs base their investment decisions both on their expectation of the fundamental *and* on their expectation of the financial price should not surprise. This property is likely to hold in any environment where entrepreneurs have the option to sell their capital in a financial market. In particular, this property also applies to the benchmark with no informational spillovers, i.e., to a setting where the asymmetry of information vanishes at the trading stage. What distinguishes the present case from that benchmark is that the entrepreneurs possess information that permits them to predict not only the fundamental, θ, but also the traders' forecast error and thereby the discrepancy between the financial price and the fundamental.

The possibility of speculative investment—equivalently, the entrepreneurs' ability to predict the traders' forecast errors—rests on two properties: (i) that the traders look at aggregate investment as a signal of the underlying fundamental; and (ii) that the entrepreneurs possess additional information about the sources of variation in their investment choices. In particular, note that, for given θ, a positive realization of the noise shock ε in the entrepreneurs' information causes a boom in aggregate investment. Since the traders cannot tell whether this boom was driven by a strong fundamental or by noise, they respond to this investment boom by raising their forecast of θ and bidding the asset price up. However, relative to the traders, the entrepreneurs have superior information about whether the investment boom was driven by the fundamental or by the noise shock (equivalently, by their collective "optimism"). This explains why they can, at least in part, forecast the traders' pricing errors and hence speculate on the market mispricing.

To see how this in turn impacts the entrepreneurs' incentives, note that each entrepreneur will adjust his response to the signals x and y so as to reflect his forecast, not only of θ, but also of ε. When it comes to forecasting θ, what distinguishes the two sources of information x and y is simply their precisions, π_x and π_y. When, instead, it comes to forecasting the noise ε, the signal y—which contains information on both θ and ε—becomes a relatively better predictor than the signal x—which only contains information on θ. This suggests that an entrepreneur who expects aggregate investment to increase with both the fundamental θ and the noise ε will find it optimal to give relatively more weight to the signal y than what he would have done in the benchmark with no informational spillovers (that is, in the case where his problem reduces to forecasting θ). As all entrepreneurs find it optimal to do so, the impact of the noise is amplified. This intuition is verified in the following proposition.

Proposition 3 *In any linear equilibrium in which $\beta_x, \beta_y > 0$, it is also the case that $\beta_x < \delta_x$, $\beta_y > \delta_y$, $\beta_\theta < \delta_\theta$, and $\beta_\varepsilon > \delta_\varepsilon$. That is, relative to the benchmark without informational spillovers, (i) individual investment responds less to the idiosyncratic signal and more to the correlated signal, and (ii) aggregate investment responds less to fundamental shocks and more to noise shocks.*

Proposition 3 illustrates the amplification mechanism generated by the interaction between real and financial decisions under dispersed information. In Section 5, we will show that this amplification mechanism is quite general, in the sense of being present in many richer environments. However, we will also see that the more robust positive prediction is about the *relative* response to the two shocks, $\varphi = \beta_\varepsilon/\beta_\theta$, rather than the absolute responses β_θ and β_ε. Therefore, in the corollary below we state the main positive prediction of the paper in the following form.

Corollary 1 (Main positive prediction) *In the presence of informational spillovers, the impact of noise shocks relative to fundamental shocks is amplified.*

Put it slightly differently, the signaling role of aggregate investment amplifies *non-fundamental* volatility relative to *fundamental* volatility; that is, it reduces the R-square of a regression of aggregate investment on expected profits. Unlike in the case with no information spillovers, the entrepreneurs' concern for financial prices (captured by λ) is crucial in determining the equilibrium behavior of investment and asset prices. Absent this concern (i.e., when $\lambda = 0$), investment is only driven by expected profitability, and there is no amplification. As we will show below, increasing λ, that is, strengthening the entrepreneurs' concern about asset prices, increases the amplification effect.

3.3 Information-driven complementarity and beauty contests

The literature on market microstructure emphasizes that certain market participants may bias their trading strategies in an attempt to influence the beliefs of other market participants, as, for example, in Kyle's (1985) seminal paper. This type of strategic behavior rests on market power (or price impact). It is absent in our setting, where each individual agent is atomistic and the financial market is Walrasian. Nevertheless, the entrepreneurs *as a group* can influence the beliefs of the traders. This induces a bias in their behavior: they rely more on sources of information with highly correlated noise, for such sources better permit them to coordinate their actions and they know that their coordinated actions have an effect on market beliefs. To better capture this intuition, it is useful to look at the problem from a different angle—one that permits us to re-interpret our Walrasian setting as a game of strategic complementarity.

Substituting (4) into (5), the traders' expectation of $\tilde{\theta}$ and therefore the equilibrium price can be rewritten as follows:

$$p(\theta, \varepsilon, \eta) = \gamma_0 + \gamma_K K(\theta, \varepsilon) + \gamma_\omega \omega, \tag{9}$$

where the values of the coefficients γ_0, γ_K and γ_ω are

$$\gamma_0 \equiv \frac{\pi_\theta \mu - \pi_z \beta_0 / \left(\beta_x + \beta_y\right)}{\pi_\theta + \pi_\omega + \pi_z}, \quad \gamma_K \equiv \frac{\pi_z / \left(\beta_x + \beta_y\right)}{\pi_\theta + \pi_\omega + \pi_z}, \quad \gamma_\omega \equiv \frac{\pi_\omega}{\pi_\theta + \pi_\omega + \pi_z}.$$

Replacing the price (9) into (7), we reach the following result.

Lemma 1 *The equilibrium investment choices solve the following fixed-point problem:*

$$k(x,y) = \mathbb{E}\left[\ \kappa(\tilde{\theta}) + \alpha K(\tilde{\theta},\tilde{\varepsilon}) \ \middle|\ x,y\ \right], \tag{10}$$

where $\kappa(\theta) \equiv \lambda\gamma_0 + (1-\lambda+\lambda\gamma_\omega)\,\theta$ *and* $\alpha \equiv \lambda\gamma_K$*.*

Condition (10) describes the optimal investment of an individual entrepreneur as a function of his expectation about the fundamental θ and aggregate investment K. This permits us to reinterpret the equilibrium of our Walrasian economy as the Perfect Bayesian Equilibrium of a game in which the players are the entrepreneurs and their best responses are given by (10). Importantly, this game features strategic complementarity. The coefficient α measures the degree of strategic complementarity in this game: the higher α, the higher the slope of the best response of individual investment to aggregate investment, that is, the higher the incentive of entrepreneurs to align their investment choices. The origin of this complementarity is the signaling role of aggregate investment: as high aggregate investment is "good news" for profitability, financial prices increase with K, which in turn raises the individual incentive to invest. This explains why α is indeed positive if and only if investment increases with θ.

This representation, in turn, provides an alternative derivation of our amplification result.

Lemma 2 *In any linear equilibrium,*

$$\varphi = \frac{\pi_y}{\pi_x(1-\alpha)+\pi_y}. \tag{11}$$

Therefore, the relative response of individual investment to the correlated signal, and hence the relative impact of noise, is higher the higher the equilibrium degree of complementarity α*.*

The intuition for this result is essentially the same as in Morris and Shin (2002) and Angeletos and Pavan (2007, 2009): a stronger complementarity induces agents to rely more heavily on sources of information with highly correlated noise, for such sources better permit them to coordinate their actions. In fact, Lemma 1 establishes a certain isomorphism between our micro-founded economy and the more abstract games studied in this earlier work: condition (10) is formally equivalent to the best responses arising in those games. However, while the degree of strategic complementarity α is exogenous in those games, here it is an integral part of the equilibrium, as it rests on the informational spillover between the real sector and the financial market.

Moreover, while here we have modeled the noise shock as a correlated error in first-order beliefs, this game representation permits one to see that our mechanism also amplifies the impact of shocks to higher-order beliefs. Indeed, because agents are uncertain about one another's beliefs and actions, they face significant uncertainty about prices and economic activity *beyond and above* any uncertainty they face about the underlying economic fundamentals. It is this additional uncertainty that we mean to capture more generally when we talk about noise shocks. And it is this additional uncertainty that may look like "irrational exuberance" or "animal spirits" to an outsider.[17]

Finally, one can interpret the equilibrium behavior of our economy as reminiscent of a beauty contest as in Keynes' metaphor: due to complementarity generated by the informational spillover to the financial market, the entrepreneurs are concerned about predicting one another's opinions and actions, well and above predicting the underlying fundamentals. Below, we will complement this interpretation by establishing that this concern—equivalently, the strategic complementarity featured in equilibrium—is "excessive" from a social perspective.

3.4 Comparative statics and multiplicity

We conclude this section by studying how the amplification effect depends on λ, the strength of the entrepreneurs' concern for asset prices. To conduct the relevant comparative static exercise, we assume that $\lambda < \bar{\lambda}$, which, as indicated in Proposition 2, guarantees uniqueness of the linear equilibrium.

Proposition 4 *As long as the equilibrium remains unique, the relative sensitivity of equilibrium investment to noise increases with the strength of the entrepreneurs' concern for asset prices: φ increases with λ.*

To get some intuition for this result, it is useful to start by considering an economy where entrepreneurs do not care about financial prices, i.e., where $\lambda = 0$ and $\varphi = \delta_y / (\delta_x + \delta_y)$. As a simple partial equilibrium exercise, suppose that a single entrepreneur with $\lambda > 0$ joins this economy. Since the entrepreneur is atomistic, equilibrium aggregate investment and prices are unchanged, and so is φ. Now, substituting (6) into (7), it is easy to show that this entrepreneur's optimal strategy is given by a linear function $k(x, y) = \beta_0 + \beta_x x + \beta_y y$ with

$$\beta_x = \left(1 - \lambda\varphi \frac{\pi_y + \varphi\pi_\theta}{\pi_y + \varphi^2(\pi_\theta + \pi_\omega)}\right)\delta_x \qquad (12)$$

$$\beta_y = \left(1 + \lambda\varphi \frac{\pi_x + (1-\varphi)\,\pi_\theta}{\pi_y + \varphi^2(\pi_\theta + \pi_\omega)}\right)\delta_y \qquad (13)$$

Hence, the stronger this entrepreneur's concern for asset prices, the more his behavior will be biased in favor of the correlated signal y. Next, suppose that all entrepreneurs start caring about

[17] See also Angeletos and La'O (2009) for a discussion of this idea, along with an application to business cycles.

asset prices, that is, all entrepreneurs are now characterized by a positive λ. Relative to the partial equilibrium exercise above, now φ is endogenously determined, and the coefficient β_y in (13) changes with both λ and φ. Two additional forces are at work in general equilibrium. First, as all entrepreneurs respond more to y, aggregate investment becomes more sensitive to the noise shock ε. Second, the very fact that aggregate investment is more sensitive to ε makes K a noisier signal of the fundamental. The first effect tends to make the price more sensitive to ε, the second effect less sensitive, as it can be seen from (6). When the price becomes more responsive to ε, this further increases the entrepreneurs' reliance on the correlated signal y. Therefore, when the first effect dominates, increasing λ leads to a higher β_y, through the general equilibrium adjustment in the information structure.[18] Numerical examples show that indeed the first effect can dominate, so that a higher concern for financial prices can lead to a sizeable amplification of noise shocks.

The argument above highlights the potential destabilizing effect of the two-way feedback between real and financial activity mentioned in the Introduction. For certain parameter configurations, this feedback can be so strong that it generates multiple equilibria. In this case, different values of φ correspond to different equilibria. In the equilibria with a larger φ, the entrepreneurs' stronger relative response to noise is self-sustained: as they respond more to y relative to x, they make asset prices more sensitive to noise shocks relative to fundamental shocks, which in turn justifies their stronger response to the correlated signal y.

Proposition 5 *There is an open set $S \subset \mathbb{R}^5$ such that if $(\lambda, \pi_\theta, \pi_x, \pi_y, \pi_\omega) \in S$ there are multiple linear equilibria.*

Notice that multiplicity originates here from an informational externality rather than from the more familiar payoff interdependencies featured in coordination models of crises such as, for example, Diamond and Dybvig (1983) and Obstfeld (1996). In this respect, our multiplicity result is closer to the one in Gennotte and Leland (1990) and Barlevy and Veronesi (2003). These papers also document multiplicity results that originate in an information externality. However, there are important differences. Firstly, in these papers there is only a financial market, not a real sector. Secondly, the externality emerges only between informed and uninformed traders. As in these papers, multiplicity can lead to additional non-fundamental volatility: one can support sunspot equilibria, some featuring "crashes." But unlike these papers, in our setting this volatility shows up in both real investment and asset prices and it relies on the two-way feedback between the real sector and the financial market.

Clearly, the possibility of multiplicity reinforces the message of our paper. However, such a possibility is not central to our analysis. For the rest of the paper, we thus focus on the case where

[18] Formally, these two effects determine whether the expression $\varphi\left(\pi_x + (1-\varphi)\pi_\theta\right) / \left(\pi_y + \varphi^2(\pi_\theta + \pi_\omega)\right)$ in the right-hand side of condition (13) is increasing or decreasing in φ.

$\lambda < \bar{\lambda}$, in which case the linear equilibrium is unique.

4 Efficiency and Policy

The analysis so far focused on the positive properties of the equilibrium. We now turn to its normative properties and to policy implications.

4.1 Constrained efficiency

In this environment, the government could obviously improve upon the competitive equilibrium if it could collect all the information dispersed in the economy and make it public—this would remove any asymmetry of information and would achieve the first-best allocation. In practice, it seems implausible that the government be able to perform this task.[19] The question we tackle here is whether the government can improve upon the equilibrium merely by manipulating the agents' incentives through taxes, regulation, and other policy interventions. We thus consider a notion of constrained efficiency that is designed to address this question without getting into the details of specific policy instruments. Namely, we consider a planner who can dictate to the agents how to use their available information but cannot transfer information from one agent to another. This follows the general approach laid out in Angeletos and Pavan (2007, 2009).[20]

We start by defining a feasible allocation.

Definition 3 *A feasible allocation is a collection of investment choices k_i, one for each entrepreneur, together with a collection of consumption choices c_{it}, one for each entrepreneur and for each trader in each period, that jointly satisfy the following constraints:*

(i) resource feasibility:

$$\begin{aligned} \int_{i\in[0,1]} c_{i1} di &\leq e - \int_{i\in[0,1/2]} \tfrac{1}{2} k_i^2 di, \\ \int_{i\in[0,1]} c_{i2} di &\leq e, \\ \int_{i\in[0,1]} c_{i3} di &\leq e + \int_{i\in[0,1/2]} \theta k_i di \end{aligned}$$

with $c_{i3} = 0$ for all i such that $s_i = 0$ (i.e., for all entrepreneurs hit by the shock).

(ii) informational feasibility: for each entrepreneur $i \in [0, 1/2]$, c_{i1} and k_i are contingent on (x_i, y), c_{i2} is contingent on (x_i, y, s_i, K, ω), and c_{i3} is contingent on $(x_i, y, s_i, K, \omega, \theta)$; for each

[19] Why the government may not be able to centralizre the information that is dispersed in the economy is an important and difficult question that, as emphasized by Hayek, rests at the heart of the market mechanism and is certainly beyond the scope of this paper.

[20] See Angeletos and La'O (2009) and Lorenzoni (2010) for applications to business cycle models.

trader $i \in (1/2, 1]$, c_{i1} is non-contingent, c_{i2} is contingent on (K, ω), and c_{i3} is contingent on (K, ω, θ).

Definition 4 *An efficient allocation is a feasible allocation that is not Pareto dominated by any other feasible allocation.*

Because of the linearity of preferences in consumption, efficiency leaves the distribution of consumption across periods indeterminate. Moreover, the distribution of consumption across agents will depend in general on the point chosen on the Pareto frontier. However, the efficient investment strategy is uniquely determined and is the one that maximizes the welfare objective

$$W = \mathbb{E}\left[\tilde{\theta} \int_i \tilde{k}_i di - \tfrac{1}{2} \int_i \tilde{k}_i^2 di\right]$$

or, equivalently,

$$W = \mathbb{E}\left[\tilde{\theta} k(\tilde{x}, \tilde{y}) - \tfrac{1}{2} k(\tilde{x}, \tilde{y})^2\right]. \tag{14}$$

The following result characterizes the efficient investment strategy.

Proposition 6 *The efficient investment strategy is given by*

$$k(x, y) = \mathbb{E}\left[\tilde{\theta} | x, y\right] = \delta_0 + \delta_x x + \delta_x y, \tag{15}$$

all (x, y), where the coefficients δ_0, δ_x, and δ_y are the same as in Proposition 1.

The efficient strategy thus coincides with the equilibrium strategy in the benchmark with no informational spillovers. It follows that our key positive result has a normative counterpart.

Corollary 2 (Main normative prediction) *In the presence of informational spillovers, the impact of noise shocks relative to fundamental shocks is inefficiently high.*

As anticipated in the Introduction, the reason why the equilibrium is inefficient in the presence of informational spillovers is the following. Those agents in charge of real investment decisions possess information that permits them to forecast not only the long-run profitability of their investments but also the mispricing of this profitability by other agents at intermediate stages. The possibility of forecasting such a mispricing in turn gives rise to a "speculative return" which is however purely private and hence not warranted from a social viewpoint. Such a private benefit tilts the way entrepreneurs respond to their sources of information away from efficiency with negative implications for welfare.

Note that this result presumes that the equilibrium is unique, which is the case we have focused on. When there are multiple equilibria, the result holds for any equilibrium in which $\beta_x, \beta_y > 0$.

Since the efficient allocation satisfies $\beta_x, \beta_y > 0$, this also implies that, when there are multiple equilibria, no equilibrium is efficient.

4.2 Policy implications

While the preceding result indicates that there may exist policies that improve upon equilibrium welfare, it does not spell out the details of the specific policies that may achieve this goal. We now show how policies aimed at reducing asset price volatility may yield a welfare improvement. Our focus on this class of policies is motivated by two considerations. First, there is a vivid debate on whether the central bank, or the government more generally, should try to tame exuberant movements in financial markets. Second, such policies look a priori plausible in our setting, since the inefficiency in our model rests on how financial markets respond to the signals sent by the real sector.

Consider a proportional tax τ on financial trades at date 2.[21] The tax is assumed to be paid by the buyers: a trader who purchases q units of capital at $t = 2$ pays τq to the government. For simplicity, the tax takes the linear form:

$$\tau(p) = \tau_0 + \tau_p p, \tag{16}$$

where τ_0 and τ_p are scalars chosen by the government. The revenues collected by this tax are rebated as a lump-sum transfer. Because of linear preferences, the distribution of this lump-sum transfer is irrelevant.

The equilibrium price in the financial market now satisfies $p = \mathbb{E}[\tilde{\theta}|K, \omega] - \tau(p)$, which yields

$$p = \frac{1}{1+\tau_p}\left(\mathbb{E}[\tilde{\theta}|K, \omega] - \tau_0\right). \tag{17}$$

If the tax is procyclical, in the sense that $\tau_p > 0$, its effect is to dampen the response of asset prices to the traders' expectation of $\tilde{\theta}$, and thereby to the information contained in aggregate investment. In turn, this dampens the price response to the noise ε and reduces the relative bias towards the correlated signal y in the entrepreneurs' best responses (7). At the aggregate level, this tends to make investment less responsive to noise shocks relatively to fundamental shocks. As this happens, a second, countervailing effect emerges: because entrepreneurs assign relative less weight to y, aggregate investment K becomes a more precise signal of the fundamentals θ, making prices more responsive to K and thereby also to the noise ε. This effect, in turn, contributes towards making individual investment relatively more responsive to y, and aggregate investment relatively more

[21] This tax is meant to capture more broadly a variety of policies that may introduce a "wedge" between the asset price and the valuation of the asset by financial market participants, including not only taxes on capital gains but also regulatory interventions.

responsive to ε, thus counteracting to the first, more direct, effect of the tax. However, the first effect must always dominate—for if that were not the case, the second effect would not emerge in the first place.

Lemma 3 *As long as the equilibrium remains unique*[22]*, the sensitivity of investment to noise shocks relative to fundamental shocks, φ, is decreasing in τ_p.*

This result implies that the government can mitigate the relative impact of noise on real economic activity by stabilizing the volatility in financial markets, that is, by choosing a positive τ_p. Furthermore, a wide range of numerical results suggest that it is always desirable to do so.[23]

However, this kind of policy intervention reduces the impact of noise only by reducing the response of asset prices to all sources of variation in the traders' expectations of their valuation of capital. In so doing, it also reduces the response of asset prices to the fundamentals themselves. As the real sector anticipates this, the absolute response of real economic activity to fundamentals also goes down, which entails a welfare loss, since that response was already inefficiently low. It follows that this kind of policy intervention can improve welfare, but cannot fully restore efficiency.

Proposition 7 *A policy as in (16) can increase welfare by stabilizing asset prices. However, it cannot implement the constrained-efficient allocation.*

The analysis above thus provides a rationale for policies aimed at reducing asset price volatility, without invoking either the presence of any irrational forces among market participants or the presence any superior wisdom on the side of the government. At the same time, it highlights an important limitation of such policies: they may tame unwanted exuberance only by also dampening the response of the economy to fundamentals.

The government can, however, do better by considering more sophisticated policy interventions—by which we mean policies that are contingent on a wider set of publicly-available signals about both the exogenous fundamentals and the endogenous level of economic activity. In particular,

[22] The equilibrium is unique if λ and τ_p are small enough.

[23] While we have not been able to prove a formal result that the optimal τ_p is positive, we have found this to be the case for an extensive search of the parameter space: we have randomly drawn 10,000 values of the parameter vector $(\pi_\theta, \pi_x, \pi_y, \pi_\omega, \lambda)$ from $\mathbb{R}^4_+ \times (0,1)$. For each such vector, we have numerically computed the value of τ_p that maximizes welfare and we have found this to be strictly positive. At the same time, we could easily show that full price stabilization (i.e., $\tau_p \to \infty$) is never optimal. In this limit case, the equilibrium price converges to some fixed $\bar{p}$ (which is determined by the limit value of τ_0/τ_p) and therefore equilibrium investment converges to $k(x,y) = (1-\lambda)\,\mathbb{E}[\tilde{\theta}|x,y] + \lambda\bar{p}$. As the price ceases to respond to ε, the entrepreneurs are no longer concerned about forecasting the price movements driven by noise, and hence the the relative sensitivity of investment to noise, $\varphi = \beta_y/(\beta_x + \beta_y)$, is at its efficient level. However, since the price also ceases to respond to θ, the entrepreneurs also have a weaker incentive to respond to their information about the fundamentals θ, and therefore the absolute values of β_x and β_y are inefficiently low. At this point, a marginal increase in the relative sensitivity implies only a second-order welfare loss, while a marginal increase in the overall sensitivity implies a first-order welfare gain.

consider a tax on financial trades that is now contingent, not only on the asset price p, but also on the aggregate investment K:

$$\tau(p) = \tau_0 + \tau_p p + \tau_K K, \tag{18}$$

where τ_0, τ_p, τ_k are scalars. By choosing $\tau_K > 0$, the government can dampen the signaling effect of investment on asset prices and thereby ensure that asset prices no longer respond to the noise ε. At the same time, by choosing $\tau_p < 0$, the government can ensure that asset prices respond more strongly to all other sources of information that the traders have about the fundamentals. In fact, conditioning the tax on the asset price accomplishes the same as conditioning the tax on the signal ω, and thereby on the fundamentals θ. In terms of the game-theoretic representation of Section 3.3, this means that an appropriate combination of τ_K and τ_p permits the government to control separately α, the degree of strategic complementarity in investment decisions, and κ_θ, the sensitivity of best responses to (expectations of) the fundamentals. It then follows that these contingencies permit the government to reduce the relative impact of the noise while at the same time raising the absolute impact of the fundamentals, therefore restore full efficiency.

Proposition 8 *There exists a policy as in (18) that implements the constrained efficient allocation as a competitive equilibrium.*

This result highlights the distinct role that state-contingent policies can play in controlling the decentralized use of information, and thereby the response of the economy to the underlying fundamental and noise shocks, when information is dispersed. While we illustrated this insight focusing on taxes on financial trades, its applicability is broader. For example, consider a tax on eventual capital returns (or firm profits). If this tax is non-contingent, then it can affect the incentives faced by the entrepreneurs and/or the traders only in a uniform way across all states of nature. In so doing, it can affect the average level of investment and the average level of the price, but cannot affect their response to the underlying shocks. In contrast, if this tax is contingent on certain public signals (e.g., the price p and aggregate investment K as of $t = 2$, or the realized aggregate output θK as of $t = 3$), then this tax can impact incentives in a different way across different states of nature; this is because different states of nature, and different information sets, are associated with different expectations at $t = 1$ regarding these contingencies. It follows that these contingencies can help control the response of the economy to the underlying fundamental and noise shocks, much alike the taxes on financial trades studied above.[24]

[24] Whether such state-contingent policies are time-consistent or politically feasible is an important question, but well beyond the scope of this paper. Also, the ability of such state-contingent policies to restore *full* efficiency may well rest on special features of our model, such as the absence of risk aversion and the ability of the government to perfectly observe the signals that the real sector sends to financial markets. However, the (weaker) result that these contingencies can control how agents respond to their different sources of information, and in so doing control the

4.3 Optimal release of information

The preceding analysis has focused on the ability of the government to improve welfare without providing the economy with more information. We now turn to policies that directly affect the information available to the agents. This seems relevant given the role of the government in collecting various data on economic activity at either the sectorial or the macroeconomic level.

To capture this role, suppose that the financial market can observe the activity of the real sector only with noise. In particular, the traders observe a signal $K^o = K + \varsigma$, where $\tilde{\varsigma}$ is a random variable, independent of all other random variables, with mean zero and variance $1/\pi_\varsigma$. This random variable is meant to capture the measurement error in sectorial or macroeconomic data; π_ς is then a measure of the quality of these data (or of the speed with which they get collected and released). For the purposes of the present exercise, the government is assumed to control π_ς directly.

By varying π_ς, the government can control the weight that the traders assign to K^o when estimating the fundamental $\tilde{\theta}$: the lower the quality of the investment signal, the lower the response of the traders' expectations to this signal. The government can thus use π_ς to manipulate the response of asset prices to aggregate investment, much alike as she could do with the price-stabilization taxes considered in (16). In fact, it is easy to show that there is a formal equivalence between the two policies: for each precision π_ς of the investment signal, there is a price elasticity τ_p of the tax in (16) that induces the same response of the price to aggregate investment, and vice versa. We infer that the choice of π_ς is subject to essentially the same trade-offs as those emphasized for the aforementioned price-stabilization policies: decreasing π_ς reduces the relative response of investment to noise, but it also reduces its response to fundamentals. An intermediate quality of macroeconomic data is thus likely to be optimal, even when the cost of improving this quality is negligible.

This result is reminiscent of Morris and Shin (2002), who showed how more precise public information may reduce equilibrium welfare in certain environments that resemble beauty contests. However, as emphasized by Angeletos and Pavan (2007), this possibility crucially rests on the inefficiency of the equilibrium: whenever the equilibrium is efficient, an analogue of Blackwell's theorem guarantees that more information is necessarily welfare improving, irrespective of the environment under consideration. Within the context of our model, this means that restricting the information that is available to the market can be welfare enhancing, but only if the more sophisticated policies of Proposition 8 are not set in place.

impact of noise and fundamental shocks, is not sensitive to the details of our model. See Angeletos and Pavan (2009) for the broader applicability of this insight in an abstract, but flexible, class of environments with dispersed info. See also Angeletos and La'O (2008) and Lorenzoni (2009) for applications in canonical business-cycle models.

5 Extensions

The main contribution of the paper is to identify a mechanism through which the dispersion of information associated to the arrival of new investment opportunities can lead to amplification and inefficiency. In this section we discuss various extensions, showing that our results are robust to more general information and payoff structures and exploring further the informational role of financial markets in the model.

5.1 Generalizing the information and payoff structure

To generalize the information structure, we let the entrepreneurs observe multiple private signals about θ. We index these signals by $s \in \{1, ..., S\}$ and write them as $x_{is} = \theta + \xi_{is}$, where ξ_{is} is the error in the s-th signal observed by entrepreneur i. These errors can be imperfectly correlated across entrepreneurs, with different signals featuring different correlations. This information structure helps to clarify that our results do not require the presence of a signal commonly observed by all entrepreneurs, like y in the baseline model.

To generalize the payoff structure, assume that the value of holding k units of capital in period 3 is $V^e(\theta, K, k)$ for an entrepreneur and the value of holding q units of capital is $V^t(\theta, K, q)$ for a trader. An entrepreneur's payoff is then $V^e(\theta, K, k) - k^2/2$ if he is not hit by a liquidity shock and $pk - k^2/2$ otherwise. A trader's payoff is $V^t(\theta, K, q) - pq$. We impose that $V^e_{kk} \leq 0$ and $V^t_{qq} \leq 0$, so that the individual decision problems are concave, and that $V^e_{k\theta} > 0$ and $V^t_{q\theta} > 0$, so that we can interpret higher θ as better fundamentals.[25] This payoff structure helps to capture a variety of technology, preference, or market effects that are absent in the baseline model. In particular, we allow the value of capital to differ between traders and entrepreneurs and we allow for diminishing returns in V^e and V^t (in k and q) which can come from the technology or from transaction costs. The dependence of V^e and V^t on K allows us to capture the pecuniary externalities that can arise when other inputs, such as labor, are used in production.[26]

The traders' optimality condition implies that the asset price satisfies $p = \mathbb{E}_t[\tilde{v}^t]$ where $v^t \equiv V^t_q(\theta, K, \lambda K)$ is the traders' marginal valuation of the asset and $\mathbb{E}_t[\cdot]$ denotes the traders' expecta-

[25] Throughout, subscripts denote partial derivatives.

[26] For example, take a neoclassical setting with a Leontief technology which employs one unit of capital and one unit of labor to produce θ units of consumption in period 3. The net return to capital is $r = \theta - w$, where w is the wage rate. Labor is supplied by traders and their preferences are given by $u = c - H(\ell)$, where c is consumption, ℓ is labor supply, and H is a strictly convex function. Equilibrium in the labor market requires $\ell = K$ and $w = H'(K)$. Then, the payoff of a surviving entrepreneur is $rk - \frac{1}{2}k^2 = [\theta - H'(K)]k - \frac{1}{2}k^2$ and the payoff of a trader is $(r - p)q + w\ell - H(\ell) = [\theta - H'(K) - p]q + H'(K)K - H(K)$. This example is nested in our general payoff structure by letting $V^e(\theta, K, k) = [\theta - H'(K)]k$ and $V^t(\theta, K, q) = [\theta - H'(K)]q + H'(K)K - H(K)$.

tion. Then, after some algebra, the entrepreneur's optimality condition yields:

$$k_i = \mathbb{E}_i\left[\tilde{w}_i\right] + \lambda \mathbb{E}_i\left[\mathbb{E}_t[\tilde{v}^t] - \tilde{v}^t\right], \tag{19}$$

where $w_i \equiv (1-\lambda)V_k^e(\theta, K, k_i) + \lambda V_q^t(\theta, K, \lambda K)$ and $\mathbb{E}_i[\cdot]$ denotes the entrepreneur's expectation. The expression $\mathbb{E}_t[\tilde{v}^t] - v^t$ captures the pricing error in the financial market, that is, the error the traders make in estimating their own valuation of the asset. Therefore, the second term in (19) is the entrepreneur's forecast of the pricing error.

Our constrained efficient benchmark is defined as in the baseline model. The planner can dictate how entrepreneurs respond to available information in period 1, but cannot give them more information than they have in the competitive economy. We also assume that in period 2 the planner can reallocate to the traders the capital of entrepreneurs hit by the liquidity shock, but cannot transfer capital to or from entrepreneurs not hit by the shock.[27]

To keep our focus on the inefficiencies that originate from dispersed information, we assume that the functions V^e and V^t satisfy

$$(1-\lambda)V_K^e(\theta, K, K) + V_K^t(\theta, K, \lambda K) = 0 \tag{20}$$

for all K. This assumption guarantees that the complete-information equilibrium is first-best efficient.[28] Under this assumption, the variable w_i defined above captures the marginal social value of capital and efficient investment is characterized by the condition $k_i = \mathbb{E}_i\left[\tilde{w}_i\right]$. Therefore, the entrepreneurs' forecast of the traders' pricing error in (19) introduces a wedge between the equilibrium and the efficient valuation of capital.

These derivations suggest that the mechanism at work in the baseline model is still at work here. As in the baseline model, entrepreneurs have private information about the sources of variation behind the signal (aggregate investment) that they collectively send to the traders. This makes the traders' pricing error at least in part forecastable by the entrepreneurs. In particular, they expect the pricing error to be higher the higher the common noise in their information about fundamentals. This gives them an incentive to react more to common noise, leading to amplification and inefficiency. The analysis that confirms this intuition is in Appendix B. For tractability, we restrict V^e and V^t to be linear-quadratic functions and all noise variables to be Gaussian.[29] We

[27] We do not explicitly impose such a restriction in the baseline model, as it would be completely inconsequential.

[28] See Lemma 4 in the appendix. It is easy to check that (20) is satisfied in the example of footnote 26, given that pecuniary externalities are not, per se, a source of inefficiency in Walrasian settings.

[29] These restrictions guarantee the existence of equilibria in which the investment strategy of each entrepreneur is a linear function of his signals and the asset price is a linear function of aggregate investment and of the traders' information about the fundamentals. However, notice that the key intuition in equation (19) does not require these restrictions.

then prove that the positive and the normative results established in Corollaries 1 and 2 also hold in the general model.

5.2 More on the informational role of financial markets

We now discuss extensions of the model that capture the role of the financial market as provider of information, rather than as simple receiver of information as in the baseline model. We will see that our basic mechanism is still present in these extensions and that further feedbacks between financial and real variables can be at work.

One could assume that traders are risk averse and observe private signals about θ of the form $\omega_i = \theta + \eta_i$, where η_i is noise. This would make the model of the financial market closer to the literature on rational expectations in the tradition of Grossman and Stiglitz (1976) and Hellwig (1980). Specifically, assume traders' preferences display constant absolute risk aversion and assume all random variables are Gaussian. Each trader's demand for the asset is then $q_i = \left(\mathbb{E}_i[\tilde{\theta}] - p\right) / \left(\Gamma Var_i[\tilde{\theta}]\right)$, where $\mathbb{E}_i[\tilde{\theta}] \equiv \mathbb{E}[\tilde{\theta}|\omega_i, p, K]$, $Var_i[\tilde{\theta}] \equiv Var[\tilde{\theta}|\omega_i, p, K]$ and where Γ is the coefficient of absolute risk aversion. Note that the market clearing price now serves as a signal about θ, for it aggregates the information dispersed among the traders. However, as long as there are additional unobserved sources of variation in the demand or supply of the asset, the equilibrium price will not be perfectly revealing. For example, suppose the noises η_i are correlated: the price will then reveal the average ω_i which is a noisy signal of θ. Finally, suppose that the entrepreneurs not hit by the liquidity shock are allowed to trade in the financial market, but their valuations are subject to an additional common shock that is not observable by the traders. Once again, this shock guarantees that the price does not perfectly reveals the fundamental to the traders.[30] As long as the price is not perfectly revealing, the traders will continue to use K as a signal of θ. Therefore, the crucial source of our information-driven complementarity would still be present in this extension.

Furthermore, because our mechanism reduces the informativeness of aggregate investment, it also implies that the traders end up in equilibrium with less information: the conditional uncertainty faced by each trader, $Var_i[\tilde{\theta}]$, is higher. When this is the case, each trader will, not only require a higher risk premium for holding the asset, but also be less reluctant to react to any private information she may have about θ. The equilibrium price will then also do a worse job in aggregating this information, for it will be relatively more sensitive to other sources of aggregate noise. It follows that our mechanism may reduce the informational efficiency of the financial market. On the positive side, this means that our mechanism may raise risk premia in financial markets and amplify their non-fundamental volatility. On the normative side, the increased uncertainty may also exacerbate

[30] Whether or not the price reveals θ to the entrepreneurs is not crucial. For a full analysis of an extension along these lines, see the earlier version of this paper, Angeletos, Lorenzoni and Pavan (2007).

the misallocation of the asset, which in turn would reinforce our welfare implications: the planner would like entrepreneurs to react more to the fundamentals and less to their correlated noise, not only for the reasons emphasized in our baseline model, but also because is would transmit more precise information to the financial market and thereby improve informational and allocative efficiency.

Next, suppose we introduce a second round of real investment decisions, which takes place after the financial market closes. Now information would travel not only from the first round of investment to the financial market, but also from the latter to the second round of investment. This would capture the role of asset prices in guiding investment decisions by revealing valuable information that is dispersed in the marketplace and not directly available to corporate managers (e.g., Dow and Gorton, 1997, Subrahmanyam and Titman, 1999, Chen, Goldstein and Jiang, 2007). Importantly, our mechanism would then imply a deterioration in this functioning of financial markets. This is a direct implication of the argument made in the previous paragraph regarding the informational efficiency of asset prices.

Alternatively, suppose that we introduce a financial market before the first round of real investment. This market includes some informed traders, who may or may not be present at subsequent rounds of trading, as well as some uninformed liquidity traders, whose role is to preclude perfect information aggregation. Suppose further that the entrepreneurs observe some private signals about the trading positions of the informed traders; think of this assumption as a parable for the fact that investors and firm managers are often anxious to collect information about the positions taken by some key informed big players in financial markets.[31] Then, we could re-interpret some of the exogenous signals that the entrepreneurs receive in our model as imperfect private learning about the actions of these big players. In this case, the origin of the correlation in the entrepreneurs' signals—and thereby the initial source of "noise" or "exuberance" in our model—could well be the errors of these early traders.[32]

Furthermore, because these earlier traders may themselves have some private information about the sources of variation behind the signals they send to entrepreneurs and later traders, they may also be able to forecast the errors made by these subsequent agents. An information-driven

[31] For the sake of this discussion, ignore the additional effects that may obtain when these big players attempt to manipulate asset prices and/or real economic activity.

[32] Indeed, suppose that the entrepreneurs, in addition to the market-clearing price in the first round of trading (which itself conveys information about θ but which is likely to be observed also by late traders) observe two purely idiosyncratic signals, one about the fundamentals θ and one about the position Q of the early informed traders. Let these signals be $x_i = \theta + \xi_i$ and $y_i = Q + \varsigma_i$ and impose that the noises ξ_i and ς_i are independent across i and of any other random variable. Next, suppose that the equilibrium value of Q is a linear function of the early traders' forecast of θ, which in turn is a linear function of θ itself and some noise ε: $Q = \psi_0 + \psi_1\theta + \psi_2\varepsilon$. The observation of the signal y_i is then informational equivalent to the observation of the signal $x_{i2} \equiv (y_i - \psi_0)/\psi_1 = \theta + \frac{\psi_2}{\psi_1}\varepsilon + \frac{1}{\psi_1}\varsigma_i$. Clearly, this is a signal about θ whose error is correlated across the entrepreneurs and which is not directly observed by the late traders. We thus expect a mechanism similar to the one in the baseline model to be at play in this setting as well.

complementarity similar to the one that emerges among the entrepreneurs may then emerge also among the traders. This complementarity, in turn, is likely to be stronger the higher the degree of short-termism of the traders: the more the early traders' portfolio choices are driven by forecasts of future pricing errors, as opposed to forecasts of the fundamentals, the stronger the complementarity in their choices, much alike what happens in the case of the entrepreneurs in our model. An extension along these lines could thus not only reinforce our results, but also bring our analysis closer to Froot, Scharfstein, and Stein, (1992), Allen, Morris and Shin (2006), and other papers that study the implications of short-termism in financial markets.

6 Conclusion

This paper examined the interaction between the real and financial sectors of an economy in which information about underlying fundamentals (e.g., the profitability of a new investment opportunity) is dispersed. By conveying a positive signal about profitability, higher aggregate investment—or, more broadly, higher real activity—increases asset prices, which in turn raise the incentives to invest. This creates an endogenous complementarity, making investment decisions sensitive to higher-order expectations. As a result, agents behave *as if* they were engaged in a "beauty contest." Such a behavior in turn amplifies the impact of noise on equilibrium outcomes, possibly leading to phenomena that may look like "irrational exuberance" in the eyes of an external observer. Importantly, these effects are symptoms of constrained inefficiency, are driven purely by dispersed information, and obtain in an otherwise canonical, neoclassical setting.

Our baseline model illustrated this mechanism in a simple framework with a single round of real investment, a single round of financial trading, and information flowing only from the real sector to the financial market. We discussed how our analysis can be extended to richer settings and why our results may actually be reinforced when there are multiple rounds of investment and trading, with information flowing in both directions. The origin of "exuberance" may then be the rational errors that some economic actors make in early rounds of either trading or investment decisions. Our mechanism helps propagate and amplify the impact of these early errors to subsequent rounds of trading and investment.

The effects analyzed in this paper are likely to be stronger during periods of intense technological change, when the dispersion of information about the potential profitability of new investment opportunities is particularly high. Our analysis therefore predicts that these innovations are likely to come hand-in-hand with episodes of high non-fundamental volatility and comovement in investment and asset prices. At some level, this seems consistent with the recent experiences surrounding the internet revolution or the explosion of investment opportunities in emerging economies. What looks like "irrational exuberance" may actually be the amplified but rational reaction to noise in information.

While both irrationality and the dispersion of information can justify policy intervention, correcting the inefficiency that originates in the dispersion of information does not require any presumption of superior rationality, or intelligence, on the government's side. We showed how stabilization policies that are contingent both on (signals about) exogenous fundamentals (e.g., financial prices) and on (signals of) endogenous measures of economic activity (e.g., aggregate investment) can indirectly tax/subsidize the response of economic agents to different sources of information. Through a proper design of such contingencies, the government can in turn dampen the magnitude of non-fundamental volatility, increase the impact of fundamental shocks, and in certain cases even restore full efficiency.[33]

Finally, while we focused on episodes surrounding the arrival of new investment opportunities, our mechanism represents a likely source of non-fundamental volatility and inefficiency also for ordinary cyclical fluctuations. Indeed, information regarding aggregate supply and demand conditions seems to be widely dispersed, as indicated by surveys of forecasts and by the financial markets' anxiety preceding the release of key macroeconomic statistics. This opens the door to the possibility that effects similar to the ones documented in this paper may also operate over the business cycle. Embedding the mechanism of this paper into full-fledged business-cycle settings appears to be a fruitful direction for future research.

[33] See also Angeletos and Pavan (2009).

Appendix A: Proofs

Proof of Proposition 2. The proof proceeds in three steps. Step 1 fills in the details of the equilibrium characterization in the main text. Step 2 analyzes the fixed point problem and proves existence of a linear equilibrium with $\beta_x, \beta_y > 0$. Step 3 proves uniqueness of the linear equilibrium for λ small enough.

Step 1. First note that there exist no equilibria in which $\beta_\theta \equiv \beta_x + \beta_y = 0$. Indeed, in any such equilibrium, K would convey no information to the financial market. The equilibrium price would then simply be equal to $\mathbb{E}[\tilde{\theta}|\omega]$. Because this is an increasing function of θ, the entrepreneurs' best responses would then impose that they react positively to both signals, thus contradicting the assumption that $\beta_\theta = 0$.

Next, note that there exists no equilibrium in which $\beta_\varepsilon \equiv \beta_y = 0$. Indeed, in any such equilibrium, K would perfectly reveal θ to the traders in which case the equilibrium price would be equal to θ. But then again each entrepreneur would find it optimal to follow a linear strategy that responds positively to both x and y, contradicting the assumption that $\beta_y = 0$.

Hence any linear equilibrium must satisfy $\beta_x + \beta_y \neq 0$ and $\beta_y \neq 0$. From the analysis in the main text, we then have that in any linear equilibrium the price is given by (6) and the entrepreneurs' investment strategy is given by (7).

Substituting (6) into (7), and using $\pi_z = \pi_y/\varphi^2$, $\mathbb{E}[\tilde{\theta}|x,y] = \mu + \delta_x (x-\mu) + \delta_y (y-\mu)$, $\mathbb{E}[\tilde{\varepsilon}|x,y] = y - \mathbb{E}[\tilde{\theta}|x,y]$, and $\mathbb{E}[\tilde{\eta}|x,y] = 0$, we have that, in any linear equilibrium, the entrepreneurs' investment strategy must satisfy

$$k(x,y) = \mu + \left(1 - \lambda\varphi \tfrac{\pi_y + \varphi\pi_\theta}{\pi_y + \varphi^2(\pi_\theta + \pi_\omega)}\right) \delta_x (x-\mu) + \left(1 + \lambda\varphi \tfrac{\pi_x + (1-\varphi)\pi_\theta}{\pi_y + \varphi^2(\pi_\theta + \pi_\omega)}\right) \delta_y (y-\mu) \tag{21}$$

for all (x,y). Condition (21) represents the best response for an individual entrepreneur who expects all other entrepreneurs to follow the linear strategy $\beta_0 + \beta_x x + \beta_y y$ and the financial market to correctly expect these entrepreneurs to follow such a strategy. Since in equilibrium the expression on the right-hand side must be equal to $\beta_0 + \beta_x x + \beta_y y$ for all x and y, the following conditions must hold:

$$\beta_0 = \left(1 - \beta_x - \beta_y\right)\mu \tag{22}$$

$$\beta_x = \left(1 - \lambda\varphi \frac{\pi_y + \varphi\pi_\theta}{\pi_y + \varphi^2(\pi_\theta + \pi_\omega)}\right) \delta_x \tag{23}$$

$$\beta_y = \left(1 + \lambda\varphi \frac{\pi_x + (1-\varphi)\pi_\theta}{\pi_y + \varphi^2(\pi_\theta + \pi_\omega)}\right) \delta_y \tag{24}$$

Any linear equilibrium must thus satisfy (**??**)-(24), with

$$\varphi = \frac{\beta_y}{\beta_x + \beta_y}.$$

Step 2. To establish existence of a linear equilibrium in which $\beta_x, \beta_y > 0$, let $b \equiv \beta_y/\beta_x$. Dividing (24) by (23) and noting that $\varphi = b/(1+b)$ yields

$$b = \frac{\pi_y + \left(\frac{b}{1+b}\right)^2 (\pi_\theta + \pi_\omega) + \lambda \frac{b}{1+b} \left(\pi_x + \frac{1}{1+b}\pi_\theta\right)}{\pi_y + \left(\frac{b}{1+b}\right)^2 (\pi_\theta + \pi_\omega) - \lambda \frac{b}{1+b} \left(\pi_y + \frac{b}{1+b}\pi_\theta\right)} \frac{\delta_y}{\delta_x}. \tag{25}$$

Using the definitions of δ_x, and δ_y, as in Proposition 1 one can then show that the right-hand side of (25) is equivalent to the following function of b

$$F(b) \equiv \frac{\delta_y}{\delta_x} \left\{ 1 + \frac{\lambda (1+b) b}{[(1-\lambda)(1-\delta_x) + \Omega] b^2 + (2-\lambda)\delta_y b + \delta_y} \right\} \tag{26}$$

where $\Omega \equiv \frac{\pi_\omega}{\pi_x + \pi_y + \pi_\theta} > 0$.

Note that F is well defined and continuous on $\mathbb{R}_+$, with $F(\delta_y/\delta_x) > \delta_y/\delta_x$ 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 a linear equilibrium can be established by construction. First, the equilibrium value of β_y is obtained substituting $\varphi = b/(1+b)$ into (24) and is clearly positive. Next, the equilibrium value of β_x is given by β_y/b and is also positive. Finally, given β_x and β_y, the equilibrium value of β_0 is given by (22).

Step 3. To prove uniqueness, first notice that there exist no equilibria in which $\beta_x = 0$. This can be seen directly from (23). This in turn implies that all linear equilibria, irrespective of the sign of β_x and β_y, must correspond to a fixed point of the function F defined in (26).

Next, note there exists $\lambda' > 0$ such that, for any $\lambda \in [0, \lambda']$ the denominator in the fraction in the right-hand side of (26) is strictly positive, for any $b \in \mathbb{R}$. This implies that, when $\lambda \in [0, \lambda']$, the function F is defined and continuously differentiable over the entire real line, with

$$F'(b) = \lambda \frac{\delta_y}{\delta_x} \frac{[\delta_y - (1-\lambda)(1-\delta_x-\delta_y) - \Omega] b^2 + 2\delta_y b + \delta_y}{\{[(1-\lambda)(1-\delta_x) + \Omega] b^2 + (2-\lambda)\delta_y b + \delta_y\}^2}$$

Moreover,

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

Thus, from now one, restrict attention to $\lambda < \lambda'$. We now need to consider two cases. First, suppose $\delta_y = (1-\lambda)(1-\delta_x) + \Omega$. 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 $\delta_y \neq (1-\lambda)(1-\delta_x) + \Omega$. Then $F'(b)$ has two zeros, respectively at $b = b_1$ and at $b = b_2$, where

$$b_1 \equiv \frac{-\delta_y - \sqrt{[(1-\lambda)(1-\delta_x-\delta_y)+\Omega]\delta_y}}{\delta_y - (1-\lambda)(1-\delta_x-\delta_y) - \Omega} \text{ and } b_2 \equiv \frac{-\delta_y + \sqrt{[(1-\lambda)(1-\delta_x-\delta_y)+\Omega]\delta_y}}{\delta_y - (1-\lambda)(1-\delta_x-\delta_y) - \Omega}.$$

When $\delta_y \neq (1-\lambda)\delta_0 + \Omega$, 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 $\lambda \to 0$. But then F converges uniformly to δ_y/δ_x as $\lambda \to 0$. It follows that for any $\varepsilon > 0$, there exists a $\hat{\lambda} \leq \lambda'$ so that, whenever $\lambda < \hat{\lambda}$, 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 $F(b;\lambda)$, to highlight the dependence of F on λ. Notice that $\partial F(b;\lambda)/\partial b$ is continuous in b at $(b;\lambda) = (\delta_y/\delta_x, 0)$ and $\partial F(\delta_y/\delta_x; 0)/\partial b = 0$. It follows that there exist $\tilde{\varepsilon} > 0$ and $\tilde{\lambda} \in (0, \hat{\lambda}]$ such that $\partial F(b;\lambda)/\partial b < 1$ for all $b \in [\delta_y/\delta_x - \tilde{\varepsilon}, \delta_y/\delta_x + \tilde{\varepsilon}]$ and $\lambda \in [0, \tilde{\lambda}]$. Combining these results with the continuity of $F(\cdot;\lambda)$, we have that there exist $\bar{\varepsilon} > 0$ and $\bar{\lambda} > 0$ such that, for all $\lambda \in [0, \bar{\lambda}]$, the following are true: for any $b \notin [\delta_y/\delta_x - \bar{\varepsilon}, \delta_y/\delta_x + \bar{\varepsilon}]$, $F(b;\lambda) \neq b$; for $b \in [\delta_y/\delta_x - \bar{\varepsilon}, \delta_y/\delta_x + \bar{\varepsilon}]$, F is continuous and differentiable in b, with $\partial F(b;\lambda)/\partial b < 1$. It follows that, if $\lambda \leq \bar{\lambda}$, F has at most one fixed point, which establishes the result. ■

Proof of Proposition 3. In any equilibrium with $\beta_x, \beta_y > 0$, we have that $\varphi \in (0,1)$. From conditions (23) and (24) in the proof of Proposition 2, it then follows that $\beta_x < \delta_x$ and $\beta_y > \delta_y$. Moreover, the two inequalities imply

$$\frac{\varphi}{1-\varphi} = \frac{\beta_y}{\beta_x} > \frac{\delta_y}{\delta_x} = \frac{\pi_y}{\pi_x}. \tag{27}$$

Finally,

$$\begin{aligned}
\beta_\theta &\equiv \beta_x + \beta_y \\
&= \delta_x + \delta_y + \lambda \frac{\varphi \pi_y}{\pi_\theta + \pi_x + \pi_y} \frac{\pi_x + (1-\varphi)\pi_\theta}{\pi_y + \varphi^2(\pi_\theta + \pi_\omega)} - \lambda \frac{\varphi \pi_x}{\pi_\theta + \pi_x + \pi_y} \frac{\pi_y + \varphi \pi_\theta}{\pi_y + \varphi^2(\pi_\theta + \pi_\omega)} \\
&= \delta_x + \delta_y + \lambda \frac{\varphi \pi_\theta}{\pi_\theta + \pi_x + \pi_y} \frac{(1-\varphi)\pi_y - \varphi \pi_x}{\pi_y + \varphi^2(\pi_\theta + \pi_\omega)} < \delta_x + \delta_y
\end{aligned}$$

where the last inequality follows from (27). ■

Proof of Lemma 2. Substituting $K = \beta_0 + \beta_x \theta + \beta_y y$ into (10) and rearranging, yields

$$k(x, y) = \kappa_0 + \alpha \beta_0 + (\kappa_\theta + \alpha \beta_x) \mathbb{E}[\tilde{\theta}|x, y] + \alpha \beta_y y. \tag{28}$$

Substituting $\mathbb{E}[\tilde{\theta}|x, y] = \delta_0 + \delta_x x + \delta_y y$ in the right-hand side and $k = \beta_0 + \beta_x x + \beta_y y$ in the left-hand side of (28) gives

$$\beta_0 + \beta_x x + \beta_y y = \kappa_0 + \alpha \beta_0 + (\kappa_\theta + \alpha \beta_x) [\delta_0 + \delta_x x + \delta_y y] + \alpha \beta_y y \tag{29}$$

Since (29) must hold for all x and y, it must be that

$$\begin{aligned} \beta_x &= (\kappa_\theta + \alpha \beta_x) \delta_x \\ \beta_y &= (\kappa_\theta + \alpha \beta_x) \delta_y + \alpha \beta_y \end{aligned}$$

Rearranging, and using $\delta_y / \delta_x = \pi_y / \pi_x$ and the fact that $\beta_y \neq 0$, gives the result. ■

Proof of Proposition 4. Consider the function $F(b; \lambda)$ introduced in the proof of Proposition 2. For any $\lambda \in [0, \bar{\lambda})$, the function $F(\cdot; \lambda)$ is continuously differentiable over $\mathbb{R}$. Take any pair $\lambda', \lambda'' \in [0, \bar{\lambda})$ with $\lambda'' > \lambda'$, and let b' and b'' be the unique solutions to $F(b; \lambda) = b$, respectively for $\lambda = \lambda'$ and $\lambda = \lambda''$ (existence and uniqueness of such solutions follows directly from Proposition 2). Furthermore, as shown in the proof of Proposition 2, $F(b, \lambda') - b > 0$ for all $b \in [0, b')$. Simple algebra then shows that $\partial F(b; \lambda) / \partial \lambda \geq 0$ 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 $\varphi \equiv b/(1 + b)$. ■

Proof of Proposition 5. Consider the function $F(b; \lambda, \delta_x, \delta_y, \Omega)$ introduced in the proof of Proposition 2; 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 $(\lambda, \delta_x, \delta_y, \Omega) = (.75, .2, .1, .1)$. 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 Proposition 2. Moreover, at the point b_2, we have that $F(b_2; \lambda, \delta_x, \delta_y, \Omega) < b_2 < 0$. These properties, together with the properties that $F(0; \lambda, \delta_x, \delta_y, \Omega) > 0$ and $\lim_{b \to -\infty} F(b; \lambda, \delta_x, \delta_y, \Omega) > 0 > -\infty$, ensure that, in addition to a fixed point in $(\delta_y/\delta_x, +\infty)$, 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 $(b; \lambda, \delta_x, \delta_y, \Omega)$ in an open neighborhood of $(\lambda, \delta_x, \delta_y, \Omega) = (.75, .2, .1, .1)$, there necessarily exists an open set $B \subset (0, 1)^3 \times \mathbb{R}$ such that F admits at least three fixed points whenever $(\lambda, \delta_x, \delta_y, \Omega) \in B$. The result in the proposition then follows by noting that for any $(\lambda, \delta_x, \delta_y, \Omega) \in B$, there corresponds a unique set of parameters $(\lambda, \pi_\theta, \pi_x, \pi_y, \pi_\omega) \in \mathbb{R}^5$. ■

Proof of Lemma 3. Substituting the price (17) into the entrepreneurs' best response (7) and using (5), one obtains a system of equations for β_0, β_x and β_y, as in the proof of Proposition 2. Following similar steps as in the proof of that proposition, it is possible to show that a linear equilibrium is characterized by a ratio $b = \beta_y/\beta_x$ that satisfies $b = F(b;\Psi)$ where

$$F(b;\Psi) \equiv \frac{\delta_y}{\delta_x}\left[1 + \frac{b(1+b)\lambda\Psi}{((1-\lambda)(\delta_0+\delta_y+\Omega)+\lambda\Omega\Psi)b^2 + (2(1-\lambda)+\lambda\Psi)\delta_y b + (1-\lambda+\lambda\Psi)\delta_y}\right]$$

with $\Psi \equiv 1/(1+\tau_p)$. Following steps similar to those in the proof of Proposition 2, one can then easily see that (i) there always exists a solution to $F(b;\Psi) = b$ with $b > \delta_y/\delta_x$ and (ii) that, starting from such a solution, one can construct a linear equilibrium in which $\beta_x, \beta_y > 0$. Furthermore, for any $b > 0$, $F(b;\cdot)$ is increasing in Ψ. We thus conclude that, as long as the equilibrium is unique, the equilibrium value of b is increasing in Ψ and hence φ is decreasing in τ_p. Lastly, following steps similar to those in the proof of Proposition 2, one can also verify that the equilibrium is indeed unique when λ and τ_p are small enough. ■

Proof of Proposition 7. The first claim can be established easily by numerical example. To prove the second claim, suppose, by contradiction, that there exists a policy as in (16) that implements the constrained efficient allocation as a competitive equilibrium. Comparing the entrepreneurs' equilibrium best responses (8) with the efficiency condition (15), one can immediately see that efficiency requires that the following condition holds:

$$\mathbb{E}\left[\tilde{p} - \tilde{\theta}\,\middle|\, x, y\right] = 0 \text{ for all } x, y.$$

Substituting the equilibrium price (17), this condition can be rewritten as

$$\mathbb{E}\left[\frac{1}{1+\tau_p}\left(\mathbb{E}[\tilde{\theta}|\tilde{K},\tilde{\omega}] - \tau_0\right) - \tilde{\theta}\,\middle|\, x, y\right] = 0 \text{ for all } x, y. \tag{30}$$

By Proposition 6, the fact that the policy implements the efficient allocation in turn implies that $K = \delta_0 + \delta_\theta\theta + \delta_\varepsilon\varepsilon$. This implies that $\mathbb{E}[\tilde{\theta}|K,\omega] = \gamma_0 + \gamma_K K + \gamma_\omega\omega$ where the coefficients $(\gamma_0, \gamma_K, \gamma_\omega)$ are as in Subsection (3.3) with $\beta_0 = \delta_0$, $\beta_x = \delta_x$, and $\beta_y = \delta_y$. Therefore, (30) can be rewritten as

$$\mathbb{E}\left[\frac{1}{1+\tau_p}\left[\gamma_0 + \gamma_K\left(\delta_0 + \delta_\theta\tilde{\theta} + \delta_\varepsilon\tilde{\varepsilon}\right) + \gamma_\omega\tilde{\omega} - \tau_0\right] - \tilde{\theta}|x, y\right] = 0.$$

Taking unconditional expectations, one can then see that τ_0 and τ_p must satisfy

$$\frac{1}{1+\tau_p}\left[\gamma_0 + \gamma_K(\delta_0 + \delta_\theta\mu) + \gamma_\omega\mu - \tau_0\right] - \mu = 0.$$

Subtracting side by side the last two equations, after some manipulation, one obtains that

$$\left[\frac{1}{1+\tau_p}\left(\gamma_K\delta_\theta+\gamma_\omega\right)-1\right]\mathbb{E}\left[\tilde{\theta}-\mu|x,y\right]+\frac{1}{1+\tau_p}\gamma_K\delta_\varepsilon\mathbb{E}\left[\tilde{\varepsilon}|x,y\right]=0.$$

Substituting for the terms in expectation yields

$$\begin{aligned}&\left[\frac{1}{1+\tau_p}\left(\gamma_K\delta_\theta+\gamma_\omega\right)-1\right]\left[\delta_x(x-\mu)+\delta_y(y-\mu)\right]\\&+\frac{1}{1+\tau_p}\gamma_K\delta_\varepsilon\left[y-\mu-\delta_x(x-\mu)-\delta_y(y-\mu)\right]=0 \text{ for all } x,y.\end{aligned}$$

Given that this condition must hold for all x and y, it must be that

$$\begin{aligned}\frac{1}{1+\tau_p}\left(\gamma_K\delta_\theta+\gamma_\omega\right)-1-\frac{1}{1+\tau_p}\gamma_K\delta_\varepsilon &= 0,\\ \left[\frac{1}{1+\tau_p}\left(\gamma_K\delta_\theta+\gamma_\omega\right)-1\right]\delta_y+\frac{1}{1+\tau_p}\gamma_K\delta_\varepsilon\left(1-\delta_y\right) &= 0.\end{aligned} \tag{31}$$

Substituting the first condition into the second gives

$$\frac{1}{1+\tau_p}\gamma_K\delta_\varepsilon=0.$$

This last condition cannot be true given that, when investment is efficient, γ_K is necessarily positive, and given that $\delta_\varepsilon>0$ and τ_p must be finite to ensure that (31) is satisfied. Therefore, there is a contradiction. We conclude that a simple stabilization policy as then one given in (16) cannot implement the constrained efficient allocation as a competitive equilibrium. ■

Proof of Proposition 8. To establish the result, it suffices to show that there exists a policy of the type given in (18) such that, under this policy, there exists a competitive equilibrium in which

$$\mathbb{E}\left[\tilde{p}-\tilde{\theta}\middle|\,x,y\right]=0 \text{ for all } x,y. \tag{32}$$

To see that this is indeed the case, note that, under any such policy, the equilibrium price must satisfy

$$p=\mathbb{E}[\tilde{\theta}|K,\omega]-\tau_0-\tau_p p-\tau_K K,$$

or, equivalently,

$$p=\frac{1}{1+\tau_p}\left[\mathbb{E}[\tilde{\theta}|K,\omega]-\tau_0-\tau_K K\right]. \tag{33}$$

Next note that if the policy (τ_0, τ_p, τ_K) implements the constrained efficient allocation, then

$$\mathbb{E}[\tilde{\theta}|K, \omega] = \gamma_0 + \gamma_K K + \gamma_\omega \omega \tag{34}$$

with coefficients $(\gamma_0, \gamma_K, \gamma_\omega)$ as in Subsection (3.3) with $\beta_0 = \delta_0$, $\beta_x = \delta_x$, and $\beta_y = \delta_y$. Replacing (34) into (33), one can then easily see that the policy with coefficients

$$\tau_0 = \gamma_0, \quad \tau_K = \gamma_K, \quad \tau_p = \gamma_\omega - 1.$$

is such that $p - \theta = \omega - \theta = \eta$. Since the entrepreneurs possess no information on the shock η at time 1, we then have that $\mathbb{E}\left[\tilde{\eta}|x, y\right] = 0$ which verifies that, under the identified policy, condition (32) is satisfied. Finally, note that, as claimed in the main text, $\tau_K > 0$ and $\tau_p < 0$ (this last result follows from the definition of γ_ω which implies that $\gamma_\omega \in (0, 1)$). ■

Appendix B: Analysis of the model in Section 5.1

The following proposition provides a characterization of the equilibrium for the general model of Section 5.1.

Proposition 9 *(i) There exist a linear function $\kappa(\theta)$ and a scalar α such that, in any linear equilibrium of the general model, the investment strategy satisfies:*

$$k_i = \mathbb{E}_i[\kappa(\tilde{\theta}) + \alpha \tilde{K}]. \tag{35}$$

(ii) There exist a linear function $\kappa^*(\theta)$ and a scalar α^* such that in the unique constrained efficient allocation investment satisfies:

$$k_i = \mathbb{E}_i[\kappa^*(\tilde{\theta}) + \alpha^* \tilde{K}]. \tag{36}$$

(iii) If there are no informational spillovers, the equilibrium is unique and constrained efficient.

(iv) If there are informational spillovers, there exists a constant $\psi > 0$ such that

$$\alpha = \alpha^* + \psi \lambda \frac{\partial \mathbb{E}_t[\tilde{\theta}]}{\partial K}. \tag{37}$$

By implication, $\alpha > \alpha^*$ if and only if investment increases with θ.

Proof. (i) As argued in the main text, the equilibrium level of investment must satisfy

$$k_i = \mathbb{E}_i[w(\tilde{\theta}, \tilde{K}, k_i)] + \lambda \mathbb{E}_i \left[\mathbb{E}_t[V_q^t(\tilde{\theta}, \tilde{K}, \lambda \tilde{K})] - V_q^t(\tilde{\theta}, \tilde{K}, \lambda \tilde{K}) \right], \tag{38}$$

where $w(\theta, K, k) \equiv (1-\lambda)V_k^e(\theta, K, k) + \lambda V_q^t(\theta, K, \lambda K)$. Note that this condition must hold irrespective of whether there are informational spillovers from the real sector to the financial market; in fact, this condition holds for any information structure.

Because the functions V^e and V^t are both linear-quadratic, the function w is itself linear:

$$w(\theta, K, k) = w_0 + w_\theta \theta + w_K K + w_k k, \tag{39}$$

where w_0, w_θ, w_K, w_k are scalars pinned down by the payoff structure, with $w_\theta \equiv (1-\lambda)V_{k\theta}^e + \lambda V_{q\theta}^t > 0$ and $w_k \equiv V_{kk}^e \leq 0$.

Because K is known to the traders, and because the function V_q^t is linear, we have that the traders' error in forecasting their valuations is proportional to their error in forecasting θ:

$$\mathbb{E}_t[V_q^t(\tilde{\theta}, \tilde{K}, \lambda\tilde{K})] - V_q^t(\theta, K, \lambda K) = V_{q\theta}^t \cdot \left(\mathbb{E}_t[\tilde{\theta}] - \theta\right) \tag{40}$$

Substituting (39) and (40) into (38), we have that, in equilibrium, the investment strategy must satisfy

$$k_i = \mathbb{E}_i\left[\frac{w_0}{1-w_k} + \frac{w_\theta}{1-w_k}\tilde{\theta} + \frac{w_K}{1-w_k}\tilde{K} + \lambda\psi\left(\mathbb{E}_t[\tilde{\theta}] - \tilde{\theta}\right)\right] \tag{41}$$

where

$$\psi \equiv \frac{V_{q\theta}^t}{1-w_k} > 0.$$

Next, note that, in any linear equilibrium, the entrepreneurs' investment strategy is given by

$$k_i = \beta_0 + \sum_{s=1}^{S} \beta_s x_{i,s}$$

for some scalars $\beta_0, \beta_1, ..., \beta_S$. By implication, aggregate investment is given by

$$K = \beta_0 + \beta_\theta(\theta + \varepsilon)$$

where $\beta_\theta \equiv \sum_{s=1}^{S} \beta_s$ and where $\varepsilon \equiv \sum_{s=1}^{S} \frac{\beta_s}{\beta_\theta}\varepsilon_s$ is a weighted average of the correlated errors in the entrepreneurs' signals. It follows that, in the eyes of the traders, K is a Gaussian signal of θ, which in turn implies that their forecast of θ can be written as follows:

$$\mathbb{E}_t[\tilde{\theta}] \equiv \mathbb{E}[\tilde{\theta}|\omega, K] = \gamma_0 + \gamma_\omega\omega + \gamma_K K \tag{42}$$

where ω is the exogenous information of the traders and where $\gamma_0, \gamma_\omega, \gamma_K$ are scalars, with $\gamma_K > 0$ if and only if $\beta_\theta > 0$. Next, note that, since the entrepreneurs have no information about the error in the traders' exogenous signal ω, their forecast of $\tilde{\omega}$ coincides with their forecast of $\tilde{\theta}$: $\mathbb{E}_i[\tilde{\omega}] = \mathbb{E}_i[\tilde{\theta}]$.

Substituting (42) into (41) and using $\mathbb{E}_i[\tilde{\omega}] = \mathbb{E}_i[\tilde{\theta}]$, we then conclude that, in any linear equilibrium, the investment strategy must satisfy the following fixed-point relation:

$$k_i = \mathbb{E}_i \left[\kappa_0 + \kappa_\theta \tilde{\theta} + \alpha \tilde{K} \right]$$

where

$$\kappa_0 \equiv \frac{w_0}{1 - w_k} + \lambda \psi \gamma_0, \quad \kappa_\theta \equiv \frac{w_\theta}{1 - w_k} + \lambda \psi (\gamma_\omega - 1), \quad \text{and} \quad \alpha \equiv \frac{w_K}{1 - w_k} + \lambda \psi \gamma_K \tag{43}$$

The result in part (i) then follows by letting $\kappa(\theta) \equiv \kappa_0 + \kappa_\theta \theta$.

(ii) Next, consider the constrained efficient allocation. First, note that, irrespective of the information structure and irrespective of the investment strategy at $t = 1$, the planner always finds it optimal to allocate the supply of capital λK at $t = 2$ uniformly across the traders: $q_i = \lambda K$ for all $i \in (1/2, 1]$. This is a direct implication of the concavity of payoffs with respect to q. It follows that the welfare objective is given by

$$W = \mathbb{E} \left[-\tfrac{1}{2} \tilde{k}^2 + (1 - \lambda) V^e(\tilde{\theta}, \tilde{K}, \tilde{k}) + V^t(\tilde{\theta}, \tilde{K}, \lambda \tilde{K}) \right]$$

Clearly, this is the same as welfare in a variant economy where there is only one class of agents, say the entrepreneurs, whose payoffs are given by

$$U = -\tfrac{1}{2} k^2 + (1 - \lambda) V^e(\theta, K, k) + V^t(\theta, K, \lambda K)$$

This variant economy is directly nested in the class of economies studied in Angeletos and Pavan (2007). That paper assumes a particular information structure with only two signals. However, as one can see from the proof of Proposition 2 in that paper, the characterization of the fix-point condition for the efficient allocation is independent of the details of the information structure (see also Angeletos and Pavan, 2009, for similar arguments). From the results in that paper (see in particular the proof of Proposition 2), we then have that the constrained efficient allocation is pinned down by the following condition:

$$\mathbb{E}_i \left[U_k(\tilde{\theta}, \tilde{K}, k_i) + U_K(\tilde{\theta}, \tilde{K}, \tilde{K}) \right] = 0$$

Using the definition of U, the above can be rewritten as follows:

$$\mathbb{E}_i \left[-k_i + (1 - \lambda) V^e_k(\tilde{\theta}, \tilde{K}, k_i) + (1 - \lambda) V^e_K(\tilde{\theta}, \tilde{K}, \tilde{K}) + V^t_K(\tilde{\theta}, \tilde{K}, \lambda \tilde{K}) + \lambda V^e_q(\tilde{\theta}, \tilde{K}, \lambda \tilde{K}) \right] = 0$$

or, equivalently,

$$k_i = \mathbb{E}_i \left[w(\tilde{\theta}, \tilde{K}, k_i) + (1-\lambda) V_K^e(\tilde{\theta}, \tilde{K}, \tilde{K}) + V_K^t(\tilde{\theta}, \tilde{K}, \lambda \tilde{K}) \right] = 0 \tag{44}$$

Under the assumption that $(1-\lambda)V_K^e(\theta, K, K) + V_K^t(\theta, K, \lambda K) = 0$ (recall that this condition guarantees that the complete-information equilibrium is first-best efficient), condition (44) reduces to

$$k_i = \mathbb{E}_i[w(\tilde{\theta}, \tilde{K}, k_i)]. \tag{45}$$

Using (39), we conclude that, at any efficient allocation, the investment strategy must satisfy the following fixed-point relation:

$$k_i = \mathbb{E}_i[\kappa_0^* + \kappa_\theta^* \tilde{\theta} + \alpha^* \tilde{K}], \tag{46}$$

where

$$\kappa_0^* \equiv \frac{w_0}{1-w_k}, \quad \kappa_\theta^* \equiv \frac{w_\theta}{1-w_k}, \quad \text{and} \quad \alpha^* \equiv \frac{w_K}{1-w_k}. \tag{47}$$

Existence and uniqueness of fixed point to condition (46) follows from essentially the same steps as in the proof of Proposition 1 of Angeletos and Pavan (2009). The result in part (ii) then follows by letting $\kappa^*(\theta) \equiv \kappa_0^* + \kappa_\theta^* \theta$.

(iii) Next, consider the case with no informational spillovers. Because the information ω that the traders possess is a sufficient statistics for the entire information that the entrepreneurs collectively possess, $\mathbb{E}_t[\tilde{\theta}|\omega, K] = \mathbb{E}_t[\tilde{\theta}|\omega]$ irrespective of the investment strategy, $\mathbb{E}_i[\left(\mathbb{E}_t[\tilde{\theta}] - \tilde{\theta}\right)] = 0$, in which case from (41), one can immediately see that the equilibrium allocation coincides with the constrained efficient allocation and, by implication, is also unique. This completes the proof of part (iii).

(iv) The proof for part (iv) follows directly from the definition of α in (43) and α^* in (47) by noting that, in any linear equilibrium, γ_K is the slope of $\mathbb{E}_t[\tilde{\theta}]$ with respect to K and that $\gamma_K > 0$ if and only if $\beta_\theta > 0$. ■

This result establishes a useful parallel between our competitive economy and the games with dispersed information analyzed in Angeletos and Pavan (2007, 2009). In particular, (i) and (ii) show that the equilibrium allocation and the efficient allocation can be represented as Perfect Bayesian Equilibria of games among the entrepreneurs, with best responses given, respectively, by (35) and (36). The coefficients α and α^* identify the degree of strategic complementarity in these games.

In the baseline model, the game representing the competitive economy features strategic complementarity—α is positive—and this complementarity is inefficient—α^* is zero—as established in Sections 3.3 and 4. In the general case treated here, both the game representing the competitive economy and the game representing the planner's allocation can feature either strategic complementarity or strategic substitutability. That is, α and α^* can be positive or negative.[34] However, the presence of informational spillovers still biases the entrepreneurs' behavior in the direction of more strategic complementarity (or less strategic substitutability), exactly as in the baseline model. This is shown in part (iv) of Proposition 9 which shows that α is always higher than α^*, as long as investment is good news for profitability.

To interpret this result it is useful to distinguish *payoff-driven* sources of strategic substitutability/complementarity, which come from the shape of V^e and V^t, from the *information-driven* strategic complementarity which comes from the fact that the actions of the entrepreneurs send informative signals to the traders. Payoff-driven sources of complementarities/substitutability are not, per se, a source of inefficiency. Actually, we made assumption (20) precisely to ensure that these sources of complementarity/substitutability are fully efficient (see Lemma 4 below). It's the information-driven complementarity that makes α greater than α^*, and that generates amplification and inefficiency.

Having established a comparison between the degrees of complementarity α and α^*, we can turn to the equilibrium response to noise (the collection of all correlated errors in the signals x_{is}). From Proposition 3 in Angeletos and Pavan (2009), we know that the relative impact of noise on investment is higher in equilibrium than in the constrained efficient allocation if and only if $\alpha > \alpha^*$. The following is an immediate implication.

Corollary 3 *The positive and normative results stated in Corollaries 1 and 2 for the baseline model, hold also in the general model of Section 5.1.*

To conclude, we prove that assumption (20) implies that under complete information the equilibrium is first-best efficient.

Lemma 4 *Under assumption (20) the equilibrium with complete information is efficient.*

Proof. Consider the complete information case in which all agents observe θ. Optimality for the traders gives $p = V^t_q(\theta, K, q)$ and asset market clearing requires that $q = \lambda K$. It follows that $p = V^t_q(\theta, K, \lambda K)$. Optimality for the entrepreneurs gives $k = (1-\lambda)V^e_k(\theta, K, k) + \lambda p$. Combining, we infer that equilibrium investment satisfies

$$k = K = (1-\lambda)V^e_k(\theta, K, K) + \lambda V^t_q(\theta, K, \lambda K).$$

Next, consider the first best allocation. Because of the concavity of V^e and V^t, social welfare is maximal when $k_i = K$ all $i \in [0, 1/2]$ and $q_i = \lambda K$ all $i \in (1/2, 1]$ in which case social welfare is,

[34] For example, when capital competes for labor, as in the example in footnote 26, higher aggregate investment raises the demand for labor, increasing equilibrium wages and thereby reducing the expected return on capital. Absent informational spillovers this yields $\alpha = \alpha^* < 0$.

up to a constant, equal to $W = (1-\lambda)V^e(\theta, K, K) + V^t(\theta, K, \lambda K) - K^2/2$. The efficient level of K then satisfies

$$K = (1-\lambda)[V^e_K(\theta, K, K) + V^e_k(\theta, K, K)] + [V^t_K(\theta, K, \lambda K) + \lambda V^t_q(\theta, K, \lambda K)].$$

Therefore, the equilibrium is first-best efficient if and only if (20) holds. ■

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