Product market efficiency:

The bright side of myopic, uninformed, and passive external finance

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Abstract

We show that introducing an external capital market with information asymmetry into a product market model reduces opportunistic substitution of sub-standard goods and encourages producers to concentrate on long-run reputation building. We test this result with a laboratory experiment. We find that, when the problem of product market opportunism is moderate, i.e., reputation formation equilibria exist when firms raise external funds but not when they rely on internal funds, external financing results in much higher (roughly double) economic surplus. This external finance premium results primarily from higher levels of output caused by the reduced likelihood or market failure.

JEL Classification Codes: C91, D82, G31, G32, L15; *Keywords*: adverse selection, financing, reputation

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Preliminary. Please do not quote. For comments and suggestions, we thank seminar participants at the University of Colorado and the Economic Science Association. We also thank Andrew Lemmenes, Mike Maier and Mike O'Doherty for assistance running experimental sessions. All errors are our own.

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1. Introduction

We demonstrate that, when firms have information that investors do not, consumers can benefit. We derive this result simply by introducing a Myers and Majluf (1984) financial market with adverse selection into a classic Kreps and Wilson (1982), Milgrom and Roberts (1982) model of product market reputation formation.

Our model consists of three agents: investors, entrepreneurs and consumers; acting in two markets: capital and product. On the product market side of our model, acting as producers, entrepreneurs cannot commit to product quality and consumers cannot observe quality before product purchase. As a result entrepreneurs can capture short term gains by producing low quality goods. Alternatively, entrepreneurs can opt for high quality goods and attempt to capture long-run benefits from reputation formation. On the capital market side, investors are simple capital providers. They lack monopoly power and monitoring ability. They cannot affect the firm's productivity and have no private information nor ability to generate such information. Moreover they hold short term claims and, thus, have no incentive to encourage producers to behave in a farsighted fashion. In short, investors are uninformed, passive, and myopic. These very characteristics account for their benevolent effect on economic welfare.

The adverse selection costs generated by investors' lack of information acts as a tax on entrepreneur opportunism. When production is financed internally, entrepreneurs capture the entire gain from opportunistic reductions in product quality. In contrast, when production is financed by an uninformed, competitive, external capital market, rational expectations dictates that investors' claims are priced correctly on average. As a result, investors' claims must be underpriced when the entrepreneur is capturing short-term gains from producing inferior goods and overpriced when the entrepreneur eschews such gains. This tax reduces the incentive of entrepreneurs to act opportunistically, thereby increasing the quality and quantity of output and, thus, economic surplus.

The benefit of passive external finance contrasts with the standard capital markets result that such financing decreases welfare, either by reducing effort incentives and encouraging perk consumption (Jensen and Meckling, 1976) or by leading entrepreneurs to forego good projects (Myers and Majluf, 1984). While our results are novel, they do not rest upon novel specifications of financial or product market behavior. Our model of external financing under asymmetric information is classic

Myers and Majluf (1984). Similarly, the product side of our model is based on the classic Kreps and Wilson (1982) and Milgrom and Roberts (1982) models of reputation formation in markets with finitely lived agents that Maksimovic and Titman (1994) have already adopted to consider product market reputation in a finance context. Rather, our result's novelty rests on the interaction between the contracting problems in financial and product markets. Adding a contracting problem in the financial market decreases the agency costs in the product market. Although other authors have shown that the combined effects of agency problems (Mookherjee and Png, 1995) or agency problems combined with adverse selection problems (Noe and Rebello, 1995) can lead to unexpected results, our paper is the first to consider the specific combination of opportunism in the product market and adverse selection in the capital market.

After deriving our predictions, we test them experimentally. Subjects are assigned the roles of investor, entrepreneur and consumer and endowed with the appropriate incentives. We consider three model parameterizations. In parameterization one, the gains from opportunism are small enough that entrepreneurs should form reputations for high quality production in equilibrium whether projects are internally or externally financed. Under parameterization two, a pure reputation formation equilibrium only arises for externally financed entrepreneurs. With internal financing, opportunism should reduce financing, output, product quality, and economic surplus. Under parameterization three, the problem of opportunism is so severe that, with internal finance, product markets fail in equilibrium. With external finance, equilibria exist which support partial reputation formation. Here, external finance allows some production, some of it high quality, that would not otherwise occur.

Like our theoretical work, the novelty of our experimental design rests not on its individual components–laboratory implementation of a capital market and a product market–but on their combination. Our experiments are unique in three important ways. First, in "external financing" treatments, we study both the investor/entrepreneur interaction in the capital market and the entrepreneur/consumer interaction in the product market simultaneously. On the financial market side, our work is most similar to Cadsby, Frank, and Maksimovic (1990, 1998), who investigated the pricing of external financing in a Myers and Majluf (1984) setting. On the product market side our work is similar in spirit to Camerer and Weigelt (1988) and Brandts and Figueras (2003), who allow reputations to develop in repeated games, but more closely resembles work of Lynch, Miller,

Plott and Porter (1986) and Cason and Gangadharan (2002). To our knowledge, ours is the first experimental research to combine the two markets in a single, two-sided reputation game.[1]

Second, we compare directly games with external financing to those without to explicitly document the effects of external financing. The potential benefits and possible adverse effects of active capital markets are often discussed, but can seldom be tested in naturally occurring environments without numerous confounding factors. Here, in a controlled environment holding all other factors constant, we isolate the effects of the external capital market alone.

Third, we implement both the cost of financing and the product price through an adapted Becker, DeGroot and Marschak (1964) procedure. We think this adapted procedure will be useful in a variety of experimental contexts. It allows an experimenter to elicit a competitive price from a single subject. It is fast to implement. It avoids complications from auction procedures (e.g., overbidding as in Kagel and Levin, 1993). It does not require pre-specifying a limited set of allowable prices (e.g., Forsythe, Lundholm and Rietz, 1999). It allows subjects to profit in situations where competitive predictions would otherwise predict zero profits. Finally, recent research shows that, on average, it elicits risk neutral valuations (Berg, Dickhaut and McCabe, 2005) which, in our case, correspond to competitive prices.

Some of our experimental results mirror previous work on one-sided reputation games. We find that the degree of reputation formation does not follow game theoretic predictions exactly, but is affected by parameters, experience and learning. In particular, our data supports the idea that subjects do not automatically backward induct or arrive at the equilibrium via fictitious play. Instead, as suggested by Camerer and Ho (1989), direct experience is an important determinant of their actions.

We observe unique outcomes from introducing the external capital market and comparing one- and two-sided reputation games. As predicted, external finance reduces the incidence of product market failure and increases production in all treatments. The increase is much larger under some parameterizations than others, also as predicted. External finance never significantly decreases surplus and increases it significantly when full reputation formation is predicted only with external financing. Consistent with theory, external finance has little effect on surplus under pa-

[1]We note that there is some limited empirical research including Hellmann and Puri (2000) who study the relationship between venture capital and the production process in technology firms and Campello (2003), who studies the effects of capital structure on markups and sales growth.

rameterization one. The most significant deviation from predictions is for external finance under parameterization three. Here, incentives for opportunism are very high and neither internal nor external finance supports complete reputation formation in equilibrium. External finance stimulates production much more than theory suggests. However, product quality is much lower than predicted. These two effects offset each other, resulting in a similar level of economic surplus with and without external financing.

Overall, our experimental results support our prediction that external finance by uninformed and myopic outsiders can increase production and consumer surplus. Along with our derivation of the benign effect of external finance in a rational choice context, our experimental results support the idea that raising funds from an uninformed capital market may be beneficial.

The remainder of the paper proceeds as follows: In the next section, we describe the framework for our analysis and derive the predictions for our experimental study. Section **??** is devoted to a description of our experimental procedures. We describe and analyze the experimental outcomes in Sections **??** and **??** We conclude the paper with an overview of our results in Section **??** Proofs of all claims are presented in Appendix I. In Appendix II, we establish that single-period debt financing also supports equilibrium outcome similar to those described below. Finally, Appendix III contains the experimental instructions.

2. Model

Consider an n-period world with three types of risk-neutral agents: investors, entrepreneurs, and consumers, who discount cash flows at a risk-free rate of zero. Each period, an entrepreneur can produce one unit of a good. The good can be either low (l) or high (h) quality, each with an associated cost. The good is sold to consumers at a competitive, market determined price, p. In each period, production of the good requires one unit of capital. Capital is either obtained internally or externally from investors operating in a competitive capital market at the start of the period. In exchange for capital, external investors obtain a claim entitling them to α percent of end-of-period cash flows, where α is competitively determined. The investor claims resemble equity. However, unlike equity, they only dictate the distribution of cash flow during the period and expire thereafter. As we demonstrate in the appendix, our results are not an artifact of this

security design. However, we base our analysis on this security design because it is simple and its cash flow implications are easily understood. These features make it ideal for use in experiments.

Consumers observe quality only after purchasing a good. High quality goods increase utility by u_h, while low quality goods increase utility by $u_l < u_h$. The cost of producing a low quality product is normalized to zero, while the cost of producing a high quality product is $c < u_h - u_l$. This ensures that the increase in a consumer's utility from improved product quality exceeds the incremental cost of producing high quality.

The incremental cost of increased quality is paid at the end of the period, when the good is sold to the consumer. If internally financed, the entrepreneur keeps the net end-of-period cash flows. If externally financed, end-of-period cash flows are shared between the entrepreneur and investor based on the claim issued at the beginning of the period.

There are two types of entrepreneurs: flexible (F) and high quality (H). High quality entrepreneurs always produce high quality goods, while flexible entrepreneurs choose between high and low quality based on expected wealth maximization. The entrepreneur's type is private information. However, both consumers and investors have a prior distribution on the entrepreneur's type. At time zero, they assess a probability of π to the producer being type-H.

We employ the Bayesian Nash equilibrium concept. This requires that flexible entrepreneurs maximize payoffs in each sub-game given consumer and investor responses. Investors and consumers base their financing and product pricing decisions on a system of beliefs which are conditioned on the past actions of the entrepreneur. These beliefs, whenever possible, must be consistent with Bayes' rule. An important condition of the Bayesian Nash equilibria is that both consumers and investors correctly conjecture entrepreneur behavior. This implies that, in equilibrium, both consumers and investors have to maintain the same beliefs regarding the entrepreneur's type.

Table 1 shows the three parameter sets used in our experiments. For each set of parameters n=3.[2] Under the first parameterization, both internal and external financing result in entrepreneurs producing in every period in equilibrium. Further, regardless of the financing source, entrepreneurs eschew low quality production until the final period. Under the second parameter set, entrepreneur opportunism is higher than under parameter set one. In equilibrium, some internally financed entrepreneurs produce low quality goods prior to period 3. Under the final parameterization,

[2]To test the robustness of our results, we also ran experimental sessions with n ranging from 1 to 4.

entrepreneur opportunism is so acute that production is never undertaken without outside financing. Below, we describe the equilibria supported by each parameterization under both internal and external financing.

Table 1: *Pameterizations*

Parameterization	π	I	u_h	u_l	c
1	0.5	400	1000	400	200
2	0.75	500	1000	400	400
3	0.25	500	1000	400	400

2.1. Parameterization one

Parameterization one supports pure strategy equilibria where type-F entrepreneurs produce high quality until the final period, when they switch to low. Prices in both the capital market and the product market reflect agents' beliefs that type-F entrepreneurs will follows this strategy. We now characterize the equilibria and demonstrate that these are the only equilibria in pure strategies under parameterization one.

First consider the entrepreneur's choice in the final period. Fixing consumer beliefs (because the consumer cannot observe quality until after the purchase), a type-F entrepreneur can switch quality without affecting prices. Further, in the final period, the entrepreneur's decision has no effect on cash flows in future periods. Because low quality goods cost less to produce, the entrepreneur maximizes his payoff by opting for low quality in the final period. This is the case whether or not the entrepreneur raises outside financing.

Lemma 1 *In all equilibria supported by parameterization one, a type-F entrepreneur produces low quality goods in period n.*

While the entrepreneur will always choose low quality in the final period in pure strategy equilibria supported by parameterization one, he will produce high quality goods in all prior periods. Switching to low quality before the final period reveals the entrepreneur's type (F) to consumers and investors. This will ensure that he earns a zero payoff for the remaining periods. On the other hand, if the entrepreneur continues producing high quality goods until the penultimate period, he

can earn a positive payoff because consumers are willing to pay more than the incremental cost of producing high quality.

Lemma 2 *In all equilibria supported by parameterization one, a type-F entrepreneur produces high quality until period n.*

The two results above imply that, under parameterization one, type-F entrepreneurs will produce high quality until period $n-1$ in any pure strategy equilibrium. This is driven by the threat of being revealed as a type-F entrepreneur. Moral hazard limits the profitability of a type-F entrepreneur once he is revealed. Consumers and investors cannot observe the quality of his good until the end of the period so a revealed type-F entrepreneur has an incentive to maximize his current period payoff by producing low quality. In turn, because consumers and investors cannot credibly commit to future penalties for producing low quality, they assume the entrepreneur will produce low quality, and thus limit his profitability.

Lemma 3 *In all pure strategy equilibria supported by parameterization one, only high quality is produced until period n. In period n, flexible entrepreneurs produce low quality. The product is priced at $u_h = 1000$ until period n and at $\pi\, u_h + (1-\pi)\, u_l = 700$ in period n. Investors demand $\frac{I}{u_h - c} = \frac{1}{2}$ of the entrepreneur's profits until period n and $\frac{I}{\pi\, u_h + (1-\pi)\, u_l - \pi\, c} = \frac{2}{3}$ of profits in period n. If the entrepreneur produces low quality prior to period n, in all subsequent periods consumers pay $u_l = 400$ for his product and investors demand $\frac{I}{u_l} = 100\%$ of the profits.*

2.2. Parameterization two

Parameterization two differs from parameterization one in three dimensions: (1) the investment expense is higher at 500, (2) the incremental cost of producing high quality is twice as high at 400, and (3) the likelihood of the entrepreneur being type-H is 50% higher at 0.75. With these changes, high quality production until period $n-1$ can only be consistently sustained if entrepreneurs can access capital markets. Overall, these changes encourage entrepreneur opportunism, but highlight the role of the capital market in limiting this opportunism.

First note that, with the increased capital investment, production is no longer economically

viable if consumers price the product as if it were low quality because

$$u_l = 400 < 500 = I. \tag{1}$$

Consequently a type-F entrepreneur will only operate if consumers cannot detect the entrepreneur's type. The increased capital investment may also make production uneconomic for a type-H entrepreneur who cannot access the capital market. Such a situation occurs if consumers assume that the proportion of type-F entrepreneurs in the producing population equals the prior probability and that all will produce low quality. Given these consumer beliefs, the product price will fall short of the cost of producing high quality, i.e.,

$$\pi\, u_h + (1-\pi)\, u_l = 0.75 \times 1000 + 0.25 \times 400 = 850 < 500 + 400 = I + c. \tag{2}$$

Because type-H entrepreneurs cannot profit from high quality production under these conditions, there exists no pure strategy equilibrium in which production occurs with internal financing. However, there exist equilibria in which type-F entrepreneurs employ mixed strategies. In these equilibria, entrepreneurs uniformly produce high quality goods in the first period. In the subsequent period they randomize between high and low quality. In the final period, they produce only low quality goods. Early defection to low quality is induced by product prices that decline over time in response to the decline in the average quality of goods. Early defectors are forced to shut down production in future periods, thereby increasing the conditional probability that remaining viable entrepreneurs are type-H. These pooling equilibria exist because, by the final period, the conditional probability that an entrepreneur is type-H is sufficiently high to ensure that consumers pay at least 900 for goods. This allows economically viable production by type-H entrepreneurs.

Lemma 4 *When entrepreneurs finance internally, there do not exist pure strategy equilibria that support production. However, there exists a mixed strategy equilibrium in which a type-F entrepreneur follows the following strategy:*

a. In period 1, always produce high quality.

b. In period 2, if high quality was produced in period 1 produce high quality with probability $\frac{3}{5}$ *and low quality with probability* $\frac{2}{5}$*; if high quality was not produced in period 1, shut down.*

c. *In period 3, if high quality was produced in period 2, produce low quality with probability 1 if high quality was not produced in period 1, shut down.*

Consumers price as follows: If the entrepreneur failed to produce high quality in any preceding period, offer $u_l = 400$*. Otherwise, in period 1, offer,* $u_h = 1000$*; in period 2, offer* 940 *and in period 3, offer* 900*.*

This result arises because, under parameterization two, type-F entrepreneurs have more to gain from opportunistic behavior than they do under parameterization one. When a producer accesses capital markets, however, he must share the gains from opportunism with the investor. This dilutes the entrepreneur's incentive to act opportunistically. In fact, as we demonstrate below, external financing dilutes the incentives for opportunistic behavior so much that all type-F entrepreneurs will eschew low quality production until the final period.

Lemma 5 *When entrepreneurs use external finance, in all pure strategy equilibria supported by parameterization two, only high quality is produced until period 3. In period 3, the entrepreneur switches to low quality. The product is priced at* $u_h = 1000$ *until period 3 and at* $\pi\, u_h + (1-\pi)\, u_l = 850$ *in period 3. Investors demand* $\frac{I}{u_h - c} = \frac{5}{6}$ *of the entrepreneur's profits until period 3 and* $\frac{I}{\pi\, u_h + (1-\pi)\, u_l - \pi\, c} = \frac{10}{11}$ *of profits in period 3. If the entrepreneur produces low quality prior to period 3, in all subsequent periods consumers pay* $u_l = 400$ *and investors demand* $\frac{I}{u_l} = \frac{5}{4}$ *of the profits, i.e., they refuse to finance the entrepreneur.*

One interesting aspect of Lemma **??** is that, in the final period, the equilibrium price of 850 is *lower* than the break even price of 900 for producing high quality goods. Nevertheless, externally financed high quality entrepreneurs continue producing in the face of prices below the overall break-even level because they earn a fraction of the net cash flow of $850 - 400 = 450$. Investors incur a loss of $\frac{10}{11}(850 - 400) - 500 = -90.91$ conditional on financing a type-H entrepreneur. However, they are willing to finance entrepreneurs overall because, on average, their profits from financing type-F entrepreneurs exactly offset the losses from funding type-H entrepreneurs.

2.3. Parameterization three

The only difference between parameterizations two and three is a much lower prior probability of the producer being type-H in the latter. This raises the amount of opportunism sufficiently to ensure that production is no longer sustainable if entrepreneurs use internal financing.

Lemma 6 *In parameterization three, there exists no equilibrium in which production occurs for internally financed entrepreneurs.*

Even when entrepreneurs raise external financing, they resort to low quality production prior to the final period. As we demonstrate above, capital market access dampens the incentive for type-F entrepreneurs to act opportunistically. However, here, this effect is not strong enough to ensure that type-F entrepreneurs produce high quality goods until the final period. Instead, there exist mixed strategy equilibria, where type-F entrepreneurs begin producing low quality goods from period 1 itself. Once again, early defection to low quality production is facilitated by price declines that reflect the declining average quality of output over time, and type-H entrepreneurs continue to operate despite receiving prices lower than the break-even price of 900.

Lemma 7 *In parameterization 3, when entrepreneurs can access the capital market, there exists a mixed strategy equilibrium in which type-F entrepreneurs use the following strategy:*

a. *In period 1, produce high quality with probability* 0.636 *and low with probability* 0.364*.*

b. *In period 2, if high quality was produced in period 1 produce high quality with probability* 0.411 *and low with probability* 0.589*; if high quality was not produced in period 1, shut down.*

c. *In period 3, if high quality was produced in periods 1 and 2, produce low quality with probability 1; if not, shut down.*

Consumers price according to the following strategy: If the entrepreneur failed to produce high quality in any preceding period, offer $u_l = 400$. Otherwise, in period 1, offer, 836.4*; in period 2, offer* 768.1 *and in period 3, offer* 736.2*.*
Investors use the following strategy: If the entrepreneur failed to produce high quality in any preceding period, refuse to finance, i.e., demand more than 100% *of profits. Otherwise, in period 1, demand* 91.7%*; in period 2 demand* 95.7% *and in period 3 demand* 97.6% *of profits.*

Thus, overall our results suggest that financing by uninformed investors can alter entrepreneur incentives. More specifically, because entrepreneurs have to share gains from opportunistic actions with investors, they have less incentive to act opportunistically when they receive external financing. Thus, they tend to produce higher quality goods even though consumers are uninformed about the quality of goods at the time of purchase. Because capital market financing raises the average quality of goods, it also raises the profitability of entrepreneurs that are wedded to producing high quality goods, enabling them to sustain production. This in turn, ensures the vitality of the product market, which demonstrates that capital market access also boosts production.

3. Experimental design

In experimental sessions, paid subjects play the roles of investors, entrepreneurs and consumers in a 2x3 design. We run the three parameterizations from Table 1. Under each, we run a session with internal and one with external financing. Sessions are labeled as follows:

Table 2: *Experimental Design*

Parameterization	Internal Financing	External Financing
1	I1	E1
2	I2	E2
3	I3	E3

3.1. External finance treatments

In each game under external financing, three subjects are assigned to a group. One acts as the investor, one as the entrepreneur and one as the consumer. Groups remain constant for three periods to allow a common history and reputation formation. Though they keep their roles (investor, entrepreneur and consumer) throughout a session, subjects are randomly reassigned to new groups after each 3-period game. This is similar to DeJong, Forsythe and Lundholm (1984), Camerer and Weigelt (1988) and King (1996).

Each period within the game, the investor sets a rate for funding production. This portion of the

design is similar to Cadsby, Frank and Maksimovic (1990 and 1998), but differs in implementation.[3] The rate for funding production determines the percentage of the entrepreneur's profits that must be exchanged for funding. By setting a percentage greater than or equal to 100%, the investor can halt production for the period.[4] Knowing the terms of financing, the entrepreneur makes a quality choice that affects the value of the product to the consumer. The consumer sets a price to purchase the product before the quality choice is known. Bidding on an item before its quality is known is common (e.g., Miller and Plott, 1985) and the quality choice is sometimes endogenous (e.g., DeJong, Forsythe and Lundholm, 1984, and King, 1996). Again, our implementation differs from prior researchers. Further, having both a capital and product market is unique.

3.2. Internal finance treatments

In each game under internal financing, two subjects are assigned to a group. One acts as the entrepreneur and one as the consumer. Again, groups remain constant for three periods and are randomly re-assigned after every three-period game. Subjects keep their roles throughout a session.

Each period, the entrepreneur determines the quality type produced. The consumer sets a price to purchase the product before the quality choice is known. If the profits from the sale are sufficient to cover capital costs, production occurs. If not, production is halted.

3.3. Common experimental design elements

The subjects were recruited from a volunteer subject pool of undergraduate and MBA students taking business classes at the University of Iowa. Subjects were asked to come to a session that would last up to three hours and were paid $5 for showing up on time. During the session, payments were denominated in "francs," the experimental medium of exchange. At the end of the session, francs were converted into dollars at the known exchange rate of $0.002 per franc. Sessions typically lasted less than three hours. Payments to subjects (including the $5 show up fee) averaged $28.52.

[3]Other researchers study the financing decision in contexts that differ considerably from ours. These include Asparouhova (2006) and Camerer and Weigelt (1988).

[4]This is explicitly stated and given as an option in treatments E2 and E3. Because it is not an optimal equilibrium response in treatment E1, halting production was not discussed explicitly. However, if the investor did not feel that profits would be sufficient to cover costs, he or she could ask for 100% of the profits. This effectively allowed the investor to opt out of the process according to the modified Becker, DeGroot and Marschak (1964) procedure we used (discussed later). This would halt production in real environments, so we count it as a production halt here.

The high was $37.02 and the low was $21.90.

Upon arrival, subjects were seated at separate computer terminals and given instruction sets, experimental forms and receipts that would be filled in during the session. The instructions are reproduced in the appendix. The sessions themselves were not computerized, but each subject had a "trial" spreadsheet available on the computer that would calculate payoffs to all players after the subject entered hypothetical decisions for all players. The instructions were read aloud and all questions were answered in public before each session began.

In the external financing treatments, subjects were split into three types called "Red Players" (investors), "Blue Players" (entrepreneurs) and "Green Players" (consumers). In the internal financing treatments, subjects were split into two types called "Blue Players" (entrepreneurs) and "Green Players" (consumers). While we will refer to the players as investors, entrepreneurs and consumers here, these terms were not used during the experiment to avoid value-laden connotations. Players kept their types for the entire session. Each player was given a fixed endowment of francs each period that depended on his or her type. Except for the investor (as discussed below), this endowment was independent of the actions he or she took during the period. The endowments helped equalize expected net profits across player types and provided payments for players who "sat out" in any given period because of the Becker, DeGroot and Marschak (1964) procedures (as discussed below).

In the external financing treatments, one investor, one entrepreneur and one consumer were matched into each group. In the internal financing treatments, one entrepreneur and one consumer were matched into each group. In both cases, groups lasted three periods and were then randomly re-assigned. In addition, the entrepreneurs were assigned to a sub-type labeled "R" for restricted or "F" for flexible. Depending on the parameterization, exactly half, on average one-quarter or on average three-quarters of the entrepreneurs were assigned sub-type "F." Sub-types remained constant for an entire set of group interactions, but were randomly reassigned when groups were reassigned. Groupings and type assignments were randomly determined before the experimental session. The assignment rules were commonly known.

In the external financing treatments, each period was conducted in three stages. The goal of the first stage was to elicit a competitive share of the profits that the investor would demand in exchange for the capital needed to engage in production. This was implemented by adapting a

Becker, DeGroot and Marschak (1964) procedure (hereafter "BDM procedure"). Each investor was asked to give the minimum percentage of the entrepreneur's profits for which he or she would exchange an initial endowment of 400 or 500 francs (depending on the parameterization). This number determined the "established percentage" of profits that the entrepreneur was required to give up at the end of the period. If the number was greater than 100%, production was not allowed and the investor simply kept his or her endowment.

After all investors had given their established percentages, the experimenter drew a ticket from a box containing 100 tickets numbered 1-100 representing percentages from 1% to 100%. If the ticket drawn was greater than or equal to the established percentage set by the investor, the investor funded the project and gave up his or her initial endowment. In exchange, he or she received from the experimenter a percentage of profits equal to the random draw. (This was called a "marked-up percentage.") If not, the investor simply kept his or her endowment.

To this point, this was an ordinary BDM procedure and should have, on average, elicited risk neutral (i.e., competitive) valuations from the investors (Berg, Dickhaut and McCabe, 2005). Our adaptation allowed the game to continue whether the investor funded the project or not, so long as the investor asked for less than 100% of the profits. In Stage II, the entrepreneur was told the percentage established by the investor. Then, the experimenter actually funded the project in exchange for the established percentage (so long as it was less than 100%) regardless of whether the investor was participating or "sat out" according to the BDM procedure. In either case, the experimenter took from the entrepreneur the established percentage of profits and, if necessary, made up the difference between this and the marked-up percentage to the investor. This created an incentive compatible mechanism to elicit the minimum percentage of demanded profits from the investor and always required that the entrepreneur pay this percentage.

After learning the established percentage, entrepreneurs chose whether to produce a "round" item (high quality) or a "square" item (low quality) in Stage II. For restricted entrepreneurs, the choice was restricted to the high quality item. Flexible entrepreneurs could choose either quality type. While we will refer to these as high and low quality items here, these terms were not used during the experiment to avoid value-laden connotations. Item values and production costs were dictated by the parameterizations.

The goal of Stage III was to elicit a competitive price for the item that the consumer would be

willing to pay. Again, this was implemented by adapting a BDM procedure. Each consumer was asked to give the highest price he or she would be willing to pay for the item (with the restriction that the price be between 400 and 1000 inclusive). This number determined the established price of the item that the entrepreneur would receive at the end of the period. After all consumers had given their established prices, the experimenter drew a ticket from a box containing 601 tickets numbered 400-1000 representing prices from 400 to 1000 francs. If the ticket drawn was less than or equal to the established price indicated by the consumer, the consumer bought the item from the experimenter at a price equal to the random draw. This was called a "discounted price." If not, the consumer did not purchase the item.

Again, to this point, this was an ordinary BDM procedure and should have, on average, elicited risk neutral (i.e., competitive) valuations from the consumers. Our adaptation allowed the game to continue whether the consumer bought the item or not. If production was allowed, the experimenter gave the entrepreneur the consumer established price of the item regardless of whether the consumer purchased it. In turn, the consumer bought the item from the experimenter if the discounted price was lower than the established price and the experimenter made up the difference. This created an incentive compatible mechanism to elicit the maximum price the consumer was willing to pay and the entrepreneur always received this price.

Internal financing treatments effectively combined stages I and II of the external financing treatments with the least possible change in instructions and actions taken by the subjects. With internal financing, the experimenter simply set the "established percentage" equivalent to the percentage that would exactly cover the capital costs of production. If profits were insufficient to cover capital costs, production was not allowed. This makes the experimenter and "Blue" player act together like an entrepreneur with the following characteristics: The entrepreneur knows the capital costs of production, contributes it and will demand it be covered as the minimum necessary profit on the sale of the item. The entrepreneur determines the quality type of the production each period. Given the price and the quality commitment, the entrepreneur can choose to halt production if profits are insufficient to cover capital costs. This eliminates what would otherwise be a conflict of interest between the entrepreneur and investor that would lead the entrepreneur to produce even when profits would not cover capital costs. Other aspects of the experiment remain unchanged. While this enforces some rationality and foresight on the entrepreneur's actions, it was

the minimum design change necessary to create an integrated financing/production decision. This integrated decision reflects the important aspects of the entrepreneur's decision while allowing us to isolate it completely from confounding effects of other design changes.

In each stage under either treatment, regardless of whether production occurred, the experimenter picked up forms from the subjects that indicated the subjects' choices in that stage and period ("percentage forms" from the investors in Stage I if appropriate, "item forms" from the entrepreneurs in Stage II and "price forms" from the consumers in Stage III). Sample forms can be found in the instructions in the appendix. During each stage, the experimenter entered subject choices in a computer and, at the end of the period, printed out summary sheets and distributed them to each player. Each player's summary sheet gave the actions of all players in his or her group that period and his or her own payoffs. After the experimenter had players check for errors in these summary sheets (making corrections as needed) and answered any questions, the experiment moved on to the next period.

Payoffs each period were determined as follows. Consumers started each period with an endowment of x francs. If a consumer purchased the item (i.e., if the discounted price was less than his or her established price), he or she received the redemption value (1,000 francs if the item was high quality and 400 francs if the item was low quality) minus the discounted price. Thus, the consumer's payoff was:

$$x + (\text{redemption value} - \text{discounted price} | \text{discounted price} < \text{established price}) \tag{3}$$

Entrepreneurs started each period with an endowment of y francs. The profit on the sale of the item was the established price minus 200 or 400 (depending on the parameterization) if the item quality was high and simply the established price if the item quality was low. Each entrepreneur kept one minus the established percentage of this profit. Thus, under external financing, the entrepreneur's payoff was:

$$y + (1 - \text{established percentage}) \times (\text{established price} - \text{cost}), \tag{4}$$

where cost $= c$ if the entrepreneur produced high quality and 0 otherwise. On the other hand,

internal financing, the payoff was

$$y + (\text{established price} - \text{cost} - \text{required investment}), \tag{5}$$

where cost = c if the entrepreneur produced high quality and 0 otherwise.

Investors started each period with an endowment of z = I francs. If an investor funded a project (i.e., if the marked-up percentage was larger than his or her established percentage), he or she gave up the endowment of francs and received the marked-up percentage of the profits. Thus, the investor payoff was:

$$I + (-I + \text{mper} \times (\text{eprice} - \text{cost}) | \text{mper} > \text{eper}), \tag{6}$$

where *mper* is the marked-up percentage, *eprice* is the established price, *eper* is the established percentage and *cost* = c if the entrepreneur produced high quality and 0 otherwise.

All subjects kept their endowments if production was halted by the investor or entrepreneur. In each session, six groups ran simultaneously and each subject participated in eight three-period groups sequentially. At the end of the session, subjects totaled their payoffs from each period and added their $5 show up fee. They were paid this amount in cash before leaving the session.

4. Experimental outcomes

In this section, we describe the experimental outcomes. We begin by examining the influence of external capital markets on economic surplus. Then we examine, in turn, how external capital markets affects the determinants of economic surplus and its division between agents—the level of output, product quality, and prices (which drive the division of surplus).

4.1. Surplus

One way of capturing the influence of external capital markets is to estimate their effect on economic surplus. Here, economic surplus is a good's value minus its (total) production cost. Under parameterization one, the economic surplus is 1000 - (400 + 200) = 400 when an entrepreneur produces a high quality good, and 400 - (400 + 0) = 0, when a low quality good is produced. When

no good is produced, the economic surplus is also 0. In equilibrium, all entrepreneurs produce high quality goods until the final period then flexible entrepreneurs defect and produce low quality. Thus, the predicted economic surplus per entrepreneur is 400 in all but the final period, when it will drop to $\frac{1}{2} \times 400 + \frac{1}{2} \times 0 = 200$.

In parameterizations two and three high quality production increases economic surplus while low quality production reduces surplus. However, in equilibrium, low quality production should seldom occur. In treatment E2 (external finance, parameter set 2), our model predicts an economic surplus of 100 per entrepreneur except in the final period when predicted surplus drops to $\frac{3}{4} \times (1000 - (500 + 400)) + \frac{1}{4} \times (400 - (500 + 0)) = 50$. In treatment I2, because $\frac{3}{5}$ of the flexible entrepreneurs will produce low quality in period 2, average predicted economic surplus declines from 100 in period 1 to 80 in period 2. Finally, in period 3, flexible entrepreneurs who produced low quality in period 2 will be shut down. The rest produce low quality. This drops the predicted average surplus to 60. For similar reasons, in treatment E3, predicted surplus falls from 45.5 in period 1 to 16.5 in period 2, and 5.4 in period 3. In contrast, because production should not occur, predicted economic surplus is zero in treatment I3.

In Table **??**, we report the average economic surplus per period across all six treatments. To facilitate comparisons across the three parameterizations, the surplus figures presented in the table are normalized by the surplus produced under the Pareto optimal outcome.

Normalized surplus averages 57.6 in treatment I1. In treatment E1 the average surplus was 60.4. Generally, external financing leads to higher average surpluses than internal. Sometimes this effect is large and significant. For example, the average surplus of 53.3 in treatment E2 is statistically significantly higher than the surplus of 22.9 generated in treatment I2. Thus, our results suggest that access to capital markets increases economic surplus.

Overall, average surpluses decline monotonically from parameterization one to parameterization two and from two to three. A similar pattern holds on a period-by-period basis. The pattern is consistent with our predictions under internal financing, but the difference between the surplus in treatments E1 and E2 is not consistent with our predictions. Further, in contrast to predictions, the surplus produced does not decline monotonically over time.

While some broad patterns of surplus generation conform with our predictions, comparing actual to predicted surplus for each treatment paints a different picture. With the exception of the surplus

generated in period 3 of the six treatments (when flexible entrepreneurs have a dominant strategy), both overall and periodic average realized surpluses fall significantly lower than predicted. These results suggest that, in periods 1 and 2, a significant fraction of flexible entrepreneurs either did not produce or produced low quality goods.

Not only are realized surplus levels consistently lower than predicted, but the positive influence of external financing sometimes differs from predictions. For parameterization one, we find that there is no statistical difference between the experimental outcomes and our predictions. Under parameterization two, external financing should have little effect. In fact, it increased surplus significantly by reducing the (negative) deviation in surplus from the prediction. Under parameterization three, external financing also increased surplus dramatically. However, it falls short of the predictions as shown by the large negative deviations from predictions. As a result, external financing increases surplus, as predicted by theory, but not exactly in the manner or extent predicted.

4.2. Production

Now we examine the components of economic surplus. First we examine production. Then we turn to the quality of goods produced.

Under parameterization one, we predict entrepreneurs will produce in every period regardless of the financing means. Under parameterizations two and three, predicted production levels vary with financing. In both cases, external financing limits the opportunistic behavior of entrepreneurs, sustaining higher levels of production. Under parameterization two, we predict full production with external financing. With internal financing, production is only sustained by limiting the number of flexible entrepreneurs who operate in the final period. Thus, while we expect 100 percent production in periods 1 and 2, only $\frac{3}{5}$ of flexible entrepreneurs should produce in period 3. This reduces production to 90% of instances in period 3. Under parameterization 3, even this is not feasible, and we predict no production under internal financing. External financing should boost production by allowing 100%, 63.6% and 26.1%, of flexible entrepreneurs to operate in periods 1, 2, and 3, respectively. Thus, we expect to see entrepreneurs producing 100% of the time in period 1, 72.4% of the time in period 2, and 44.6% of the time in period 3.

Table **??** documents production frequencies across all six treatments. The average production

frequency is approximately 88.9% in treatment I1. In treatment E1, the production frequency is 97.9%. This pattern of higher average production under external financing is repeated for parameterizations two and three. These production differences are statistically significant for all three parameterizations, and in the case of parameterizations two and three the outcomes are consistent with our predictions.

As predicted, production occurs most frequently under parameterization one. However, contrary to our predictions, more production occurs under parameterization three than under parameterization two. In fact, with external financing, production in every period is higher under parameterization three than under parameterization two. Consistent with our predictions, we also find that, with the exception of treatments I1 and I2, production declines monotonically over time.

While some broad patterns of production conform with our predictions, observed production tends to diverge significantly from our prediction. The only exception is treatment E1. In treatments I1, I2, and E2, production tends to be significantly lower than predicted. In contrast, in treatments E3 and I3, production is generally higher than predicted. This pattern is reversed when we examine the effect of external capital market access on the difference between the incidence of production and predictions. For parameterization one and two capital market access boosts production by significantly more than the amount predicted by our model. This effect is strongest for parameterization two. However, under parameterization three, the production boost from capital market access is significantly lower than expected. As a result, external financing increases production, as predicted by theory, but not exactly in the manner or extent predicted.

4.3. Quality of output

Now we turn to the frequency of high quality production. Under parameterization one, we predict all entrepreneurs produce high quality goods in periods 1 and 2. In period 3, high quality production occurs only half of the time because all flexible entrepreneurs switch to low quality. With external financing under parameterization two, we should observe identical behavior from flexible entrepreneurs. However, because they now constitute only 25% of the population, high quality goods should be produced 75% of the time in period 3. With internal financing, period 1 quality should remain unchanged. However, in periods 2 and 3, high quality production rates fall

to 90% and 75%, respectively. Under parameterization 3, external financing is predicted to result in high quality production 72.7% of the time in period 1, 44.6% in period 2, and 25% in period 3. Internal financing should drive out all high quality production.

Table **??** shows the frequency of high quality production in each of our six treatments. Consistent with our predictions, we find that external capital market access promotes the production of high quality goods. This effect is significant when it is predicted (under parameterizations two and three). Average rates of high quality production decline monotonically from treatments I1, to I2, and from I2 to I3. With external financing, quality production rates are highest under parameterization two followed by one then three. Both of these patterns are consistent with our predictions. Further, access to external capital markets drives quality production rates down monotonically over time as predicted. This is not the case under internal financing.

Once again, while some broad patterns emerge as predicted, high quality production rates consistently fall below predicted levels. In one instance, the first period in treatment I2, this shortfall is as high as 91.7%. Further, while external capital market access promotes quality more than we anticipate in parameterization two, external capital market access has a significantly weaker influence on quality than predicted in parameterization three.

4.4. The division of surplus

Now we turn from examining the influence of external capital markets on aggregate economic activity to their influence on the division of surplus between agents. Given that the established percentage demanded by the investor is determined competitively, we expect that the investor should be unable to capture a share of the economic surplus with this percentage. Similarly, competitive pricing should prevent consumers from capturing any surplus at these prices.[5] Thus, the entire economic surplus should be appropriated by the entrepreneurs. As a result, while external capital markets may affect overall surplus, they should have no effect on its division.

Table **??** shows the division of surplus in all six treatments. To allow for comparisons across treatments, we have normalized the surplus shares by the surplus under the Pareto optimal decision, production of high quality goods. As expected, producers capture the largest share of the surplus,

[5]We compute the surpluses based on the established percentages and prices from th experiment determined by investors and consumers, not the random-draw-determined "marked-up percentages" and "discounted prices."

with the exception of treatment E2. While consumer shares are not statistically different from zero in treatments E1, I1, and E3, they capture a large share of the surplus in treatment E2 and end up with negative surplus in treatments I2 and I3. These results suggest that, on average, product prices were too high in treatments I2 and I3, and too low in treatment E2. Investors also earned negative surpluses in treatments E2 and E3. This suggests that they overpriced the securities they received in exchange for capital. In fact, in both treatments, investor losses exceeded the predicted surplus in these treatments, indicating that they subsidized production quite heavily.

The source of financing affects consumer surplus. It is higher in the presence of capital markets. For parameterizations two and three, where investors incur significantly large losses, consumer gains are significantly higher with capital markets. Capital markets have a more muted effect on the surplus earned by entrepreneurs, generally resulting in no significant change in entrepreneur surplus. However, for parameterization one, capital market access actually significantly reduced entrepreneur surplus.

4.5. Entrepreneur actions

In Table **??**, we summarize the actions of flexible entrepreneurs in our experiment. We observe all entrepreneur decisions, including decisions regarding product quality when they do not produce output. Because we observe these "off-equilibrium-path-actions" and because entrepreneur's equilibrium strategies also call for specific actions off-equilibrium, the table presents entrepreneur actions whether they actually produced or not.

First note that producing high quality goods in period 3 is a dominated strategy for flexible entrepreneurs as the prices they receive cannot be conditioned on the quality off their output. Thus, in all equilibria, where entrepreneurs play undominated strategies, flexible entrepreneurs should always produce low quality goods in period 3. As demonstrated earlier, in treatments E1, E2, and I1, flexible entrepreneurs should produce high quality goods until period 3. In treatment, I2, the mixed strategy equilibrium results in flexible entrepreneurs producing high quality output until period 3 60% of the time. The remaining flexible entrepreneurs should produce high quality in period 1 and low quality in period 2. While these entrepreneurs should not produce in period 3, their (off) equilibrium strategies call for low quality goods in period 3. Similarly, in treatment

E3, we should observe high quality production until period 3 by flexible entrepreneurs 26.2% of the time. Flexible entrepreneurs should produce high quality goods in period 1 and low quality goods in period 2 37.5% of the time. Finally, 36.4% of flexible entrepreneurs should produce low quality goods in period 1. After entrepreneurs produce low quality, their off equilibrium actions should also result in low quality output thereafter. In treatment I3, flexible entrepreneurs should always play the off-equilibrium strategy of producing low quality goods.

There are three striking results in this table. First, entrepreneur actions tended not to resemble those predicted by the equilibria. In fact, the predicted frequency of action sequences was seldom approached by actual play. Generally, when we predict a pure strategy will be followed, the actual percentage of entrepreneurs following that strategy is closer to Selten's (1991) measure of area for that strategy than 1. This means, the observation is closer to the frequency predicted by random behavior than our model. The one exception to this rule is in treatment I3, where we predict that all flexible entrepreneurs will produce low quality and they actually do 63.9% of the time. The model fares no better when it makes mixed strategy predictions. Again, with one exception, the actual frequencies of strategies are closer to random behavior than the predicted frequencies. The exception is in treatment E3, strategy LLL, where random behavior would predict 12.5% of the observations, our model predicts 36.4% and the actual frequency was 72.2%.

Second, the most frequently observed strategies are the ones where flexible entrepreneurs produce low quality goods in all three periods. In fact, in treatments E2, E3, I2, and I3, the majority of flexible entrepreneurs adopt this strategy. Further, in treatments E2, E3, and I2 the realized frequencies of this particular action sequence significantly exceeded the frequency of these actions predicted by random play, which is higher than the frequency with which this action sequence should be observed in equilibrium, 0.

Third, flexible entrepreneurs produced high quality goods in period 3 under parameterization one, when this should be strongly dominated. These frequencies sometimes rise to surprisingly high levels under parameterizations two and three. However, the incentives against high quality production are attenuated to the degree that these entrepreneurs are not financed.

Overall, entrepreneur behavior is not well predicted by the sequential equilibrium. This accords with experimental work on one-sided reputation games (e.g., Brandts and Figueras, 2003) that reputation formation in short games is difficult to achieve even when it is the sequential equilibrium.

On possible explanation for the divergence between observed and equilibrium entrepreneur behavior is that entrepreneurs may be responding to the out-of-equilibrium behavior of the consumers and investors. We turn to explaining actual behavior after discussing the robustness of these outcomes.

4.6. Assessment and Robustness Checks

We ran several sessions to serve as checks on our procedures and to asses the robustness of our results. We describe these briefly here.

To assess the results of the stage game with the modified BDM procedures, we ran single period games with 50% flexible entrepreneurs. Not allowing reputation formation simplifies the game considerably. Flexible entrepreneurs have a dominant strategy: produce low quality each period. With no reputations to consider, the consumer's problem is simply to determine the frequency with which firms will produce low quality and price accordingly. The investor's problem is to demand an appropriate share given the quality distribution and expected prices. Again, there are no reputation issues. In reality, flexible entrepreneurs produced high quality 15% of the time.[6] Risk neutral consumers should price at 0.5x1000+0.5x400 =700 in theory and at 0.575x1000+0.425x400 = 745 empirically. The actual prices averaged 757, significantly higher than the 700 theoretical prediction, but not significantly different from the observed values. Investors should demand 400/[0.5x(700-200)+0.5x700] = 67% of the proceeds in theory. Since the average entrepreneur profit was 642, investors needed to demand 62% empirically to break even. In reality, they demanded an average of 71% and made an average profit of 52 francs, significantly higher than 0. We conclude that, in a simpler environment, entrepreneurs generally avoid dominated strategies and the modified BDM procedure yields empirically risk neutral prices. However, there is a slight upward bias in demanded returns to investors. We conclude that the losses incurred by investors in other treatments are not an artifact of the stage game or the BDM procedure.

While three periods per group are sufficient to study reputation formation and early versus late defection, we also run two periods-per-group and four-periods-per group games. Results mirror the three-periods-per group treatments reported here. With two periods per group, 20% of flexible entrepreneurs followed a reputation strategy, 13% followed a dominated strategy and the rest (67%)

[6]This level remained fairly steady. It was 17% in the first half of the session and 13% in the second half.

followed the defection strategy. Average values (750) were not significantly different from average prices (707). Average investor returns (418) did not differ significantly from the contribution of 400. These two results mirror the results in the one-period-per group treatment. With four periods per group, 20% of flexible entrepreneurs followed the reputation strategy, none followed dominated strategies, 33% followed the defection strategy throughout the four periods and the rest follow various other strategies (all ending with a low quality). Average prices (709) fell significantly below average values (790). Average investor returns (336) fell significantly below their contribution of 400. These two results mirror the typical three-periods-per-group results.

Finally, we ran sessions where participants had prior experience in two ways. One session included subjects with experience in two-period games immediately before participating in three-period games. Another session included subjects who had participated in previous sessions. Both sessions produced similar results to each other and to the other three-period game sessions. With experience, 19% of the flexible entrepreneurs followed the reputation strategy, 10% followed dominated strategies, 52% followed the defection strategy and 19% followed various other strategies. Average prices (764) did not differ significantly from average values (774). Average investors returns (463) significantly exceeded their contribution of 400. The only real difference is that investors may be learning to ask for higher percentages in the very long run.

5. Explaining subject behavior

While our model predicts the general impact of external capital markets on aggregate measures of production and efficiency, individual subject behavior diverges considerably from predictions. To gain a better understanding of subject behavior, we now focus on identifying the forces that influenced subjects. First, we examine consumer behavior, then entrepreneur and investor behavior. We will show that the subjects are responding to the factors we predict, but often not to the degree predicted.

For each subject type, a regression given in Table **??** analyzes how they are reacting to various factors. All variables are defined in the table. Many of them are obviously defined. A set of dummy variables indicates the period in the group interaction and whether the entrepreneur was previously revealed as flexible. A set of variables corresponds to the parameterizations and financing

treatments. A single variable proxies for experience by using the round in the experimental session (as opposed to the specific group interaction).

Two variables for each subject type are not obvious, but are particularly interesting in explaining behavior. For consumers, we summarize their experience with observed quality types by defining a (within group) historical average quality, where prior qualities are coded with +1 for high and -1 for low. We also define an experience weighted version of this variable where we weight by 1 if the consumer actually purchased the item according to the BDM procedure and 0 if not. Both historical quality variables are set at 0 in period 1 of a group interaction. For investors, we summarize their experience with observed profitability by defining a (within group) historical average profitability defined as the ratio of the profits on the sale to the capital expense. We also define an experience weighted version of this variable where we weight by 1 if the investor actually participated in the profits according to the BDM procedure and 0 if not. Again, both variables are set to 0 in the first period. Finally, for entrepreneurs, we measure the costs and benefits of high quality production. The short run cost of high quality is the realized profit on the sale times the percentage of profits kept by the entrepreneur. We define the long run benefit as the (within session) average maximum payoff to a continuing strategy after high quality production minus the maximum payoff to a continuing strategy after low quality production.

5.1. Consumer behavior

To understand consumer behavior, we focus on their pricing decisions. More specifically, we examine whether these pricing decisions are influenced by the history of play, information set and experience of the consumer and the parameterization. We employ these variables to estimate the censored regression presented in Panel A of Table **??**.

The regression estimates suggest that a consumer's experience with an entrepreneur matters. Prices rise over time as long as the entrepreneur is not revealed to be flexible, with period 3 prices for the output from an unrevealed entrepreneur being significantly higher than the period 1 price. However, if an entrepreneur is revealed as flexible, consumers reduce the price they are willing to pay. This reduction is significant in period 3. The coefficients estimated for the historical quality variables provide additional evidence that a history of high (low) quality products leads to higher

(lower) prices, with the changes being more marked when the consumer actually acquires the goods rather than find out about product quality from the experimenter. The negative and significant sign for the cost of high quality suggests the consumers are sensitive to the strength of entrepreneur's incentive to produce low quality goods. However, it appears that consumers behavior is not affected by the presence of capital markets or the prior probability that an entrepreneur is flexible.

Overall, consumer behavior is consistent with an anchor and adjust model where initial expectations are that most (or all) flexible entrepreneurs will produce low quality. Conditional expectations adjust upward as high qualities are observed and downward as low qualities are observed. However, these adjustments, especially the downward adjustments, are not as rapid as predicted by theory. Consistent with Camerer and Ho (1996), consumers respond more when they actually experience the quality types through purchasing the good rather than merely observing them.

5.2. Entrepreneur behavior

To understand entrepreneur behavior, we focus on their quality decisions. More specifically, we examine whether these quality decisions are influenced by the history of play and tradeoffs faced by the entrepreneur. We employ these variables to estimate the logistic regression presented in Panel B of Table **??**. The dependent variable in this regression is a dummy variable that indicates whether the entrepreneur chooses high quality.

The regression estimates suggest that, in line with our model predictions, entrepreneurs are significantly more likely to produce high quality goods in the initial rounds of a group. In addition, once entrepreneurs reveal themselves as flexible, they are more likely to produce low quality goods. A higher production cost for high quality goods encourages entrepreneurs to opt for low quality as does a higher short run cost of producing high quality. Entrepreneur's quality choices do not appear to be significantly influenced by long-run considerations.

Overall, entrepreneurs respond to market incentives, but more to short run incentives than long. This explains both the high degree of opportunism relative to predictions and the large impact of the attenuation in incentives for opportunism driven by external financing.

5.3. Investor behavior

To understand investor behavior, we focus on their security pricing decisions. More specifically, we examine whether the demanded percentage of profits are influenced by the history of play, information set and experience of the investor and the parameterization. We employ these variables to estimate the censored regression presented in Panel C of Table **??**.

The estimated coefficients indicate that investors demand higher profit shares over time whether the entrepreneur is revealed as flexible or not. Further, the negative coefficients on the historical break-even variables indicate that a history of higher profits induces investors to reduce their profit shares, with the reduction being more marked if they have actually capitalized the entrepreneur in the past. Investors also appear to be sensitive to both the prior distribution of entrepreneurs and the amount of capital needed by entrepreneurs, demanding more of the profits at the percentage of flexible entrepreneurs in the population and their capital needs rise. Finally, investors appear to demand larger profit shares as they become more experienced. This seems reasonable given that, on average, their profit shares were too low to compensate them for their investment expense.

Overall, investor behavior appears myopic initially, but adjusts with specific and general experience. Again, consistent with Camerer and Ho (1996), investors respond more when they actually experience the results of financing a firm rather than merely observing them.

6. Concluding comments

We highlight an unrecognized benefit of capital markets access by examining the effect of introducing capital markets into a production-market-reputation model. We demonstrate that external finance dilutes entrepreneurs' incentives to enjoy short-term gains by selling low quality goods to uninformed consumers. By inducing entrepreneurs to produce higher quality goods, capital markets support higher product prices. These higher prices, in turn, raises economic welfare by increasing both entrepreneur (i.e., firm) profitability and production. We also describe the outcomes of experiments designed to investigate the benevolent effects of external finance. These outcomes support our prediction that capital markets boost economic welfare, raise output, and improve product quality. Further, capital markets skew the division of economic surplus towards consumers.

Our novel results arise by combining the problem faced by uninformed investors who finance a

firm, and uninformed consumers who purchase the output of the firm that has the ability to develop a reputation for producing high-quality goods. Each of these problems has been extensively studied in isolation and the implications of these studies for capital and product markets are well known. However, our analysis demonstrates that combining these two well understood problems generates unanticipated outcomes.

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Table 3: *Economic surplus.* This table presents the average per-round economic surplus in each of our treatments. The economic surplus generated equals the value of the good produced less the production cost. All surplus figures are normalized by the Pareto optimal surplus. The table presents the period-by-period predicted value of surplus as well as the realized surplus by period in our experiments. The table presents statistical tests for the difference between the predicted surplus and the realized surplus. An "*" in the deviation row indicates the predicted surplus differs from the mean actual surplus according to a t-test with a 95% confidence level. For each parameterization, it also presents the effect of introducing external capital markets on economic surplus as well as the difference between the deviations from the predicted surplus across the two treatments employing that parameterization. An "*" in either treatment effect row indicates a significant effect according to a t-statistic at the 95% confidence level.

		Panel A: Parameter set 1				Panel B: Parameter set 2				Panel C: Parameter set 3			
Financing			Period				Period				Period		
Treatment	Item	Overall	1	2	3	Overall	1	2	3	Overall	1	2	3
	Prediction	83.3	100.0	100.0	50.0	80.0	100.0	80.0	60.0	0.0	0.0	0.0	0.0
Internal	Actual	57.6	54.2	66.7	52.1	22.9	0.0	31.3	37.5	-29.9	-52.1	-27.1	-10.4
	Deviation	-25.7*	-45.8*	-33.3*	2.1	-57.1*	-100.0*	-48.8*	-22.5*	-29.9*	-52.1*	-27.1*	-10.4
	Prediction	83.3	100.0	100.0	50.0	85.0	100.0	100.0	55.0	22.4	45.5	16.5	5.4
External	Actual	60.4	66.7	62.5	52.1	53.3	60.0	47.5	52.5	-34.0	-27.1	-37.5	-37.5
	Deviation	-22.9*	-33.3*	-37.5*	2.1	-31.7*	-40.0*	-52.5*	-2.5	-56.5*	-72.5*	-54.0*	-42.9*
Treatment Effect	Difference	2.8	12.5	-4.2	0.0	30.4*	60.0*	16.3	15.0	-4.2	25.0	-10.4	-27.1
on Levels	p-value	0.63	0.22	0.67	1.0	0.00	0.00	0.28	0.23	0.65	0.11	0.51	0.08
Treatment Effect	Difference	2.8	12.5	-4.2	0.0	25.4*	60.0*	-3.8	20.0	-26.6*	-20.5	-26.9*	-32.5*
on Deviations	p-value	0.61	0.22	0.67	1.0	0.00	0.00	0.78	0.08	0.00	0.12	0.04	0.01

Table 4: *Production levels.* This table presents the frequency with which entrepreneurs produce in each of our treatments. The table presents the period-by-period predicted frequency of production as well as realized production by period in our experiments. The table presents statistical tests for the difference between predicted production and the realized production. An "*" in the deviation row indicates a deviations from production that differ significantly from zero according to a t-test at the 95% level of confidence. For each parameterization, it also presents the effect of introducing external capital markets on production as well as the difference between the deviations from the predicted production across the two treatments employing that parameterization. An "*" in either treatment effect row indicates a significant effect at the 95% level of confidence. The tests are difference in proportions tests for treatment effects on levels and t-tests for treatment effects on deviations.

		Panel A: Parameter set 1				Panel B: Parameter set 2				Panel C: Parameter set 3			
Financing			Period				Period				Period		
Treatment	Item	Overall	1	2	3	Overall	1	2	3	Overall	1	2	3
	Prediction	100	100	100	100	96.7	100	100	90	0	0	0	0
Internal	Actual	88.9	79.2	93.8	93.8	35.4	16.7	52.1	37.5	47.9	52.1	47.9	43.8
	Deviation	-11.1*	-20.8*	-6.3	-6.3	-61.2*	-83.3*	-47.9*	-52.5*	47.9*	52.1*	47.9*	43.8*
	Prediction	100	100	100	100	100	100	100	100	72.4	100	72.4	44.6
External	Actual	97.9	100.0	97.9	95.8	80.0	90.0	77.5	72.5	91.0	97.9	91.7	83.3
	Deviation	-2.1	0.0	-2.1	-4.2	-20.0*	-10.0*	-22.5*	-27.5*	18.5*	-2.1	18.9*	38.7*
Treatment Effect	Difference	9.0*	20.8*	4.2	2.1	44.6*	73.3*	25.4*	35.0*	43.1*	45.8*	43.8*	39.6*
on Levels	p-value	0.00	0.00	0.31	0.65	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Treatment Effect	Difference	9.0*	20.8*	4.2	2.1	41.2*	73.3*	25.4*	25.0*	-29.4*	-54.2*	-29.0*	-5.0
on Deviations	p-value	0.00	0.00	0.31	0.65	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.63

Table 5: *Quality produced.* This table presents the frequency with which entrepreneurs produce high quality goods in each of our treatments. The table presents the period-by-period predicted frequencies of high quality production as well as the realized frequencies in our experiments. The table presents statistical tests for the difference between the predicted frequencies of high quality production and the realized frequencies. An "*" in the deviation row indicates the predicted level differs from the mean actual level according to a t-test with a 95% confidence level. For each parameterization, the table also presents the effect of introducing external capital markets on the frequency of high quality production as well as the difference between the deviations from the predictions across the two treatments employing that parameterization. An "*" in either treatment effect row indicates a significant treatment effect according to a t-statistic at the 95% confidence level.

		Panel A: Parameter set 1				Panel B: Parameter set 2				Panel C: Parameter set 3			
Financing			Period				Period				Period		
Treatment	Item	Overall	1	2	3	Overall	1	2	3	Overall	1	2	3
	Prediction	83.3	100.0	100.0	50.0	88.3	100.0	90.0	75.0	0.0	0.0	0.0	0.0
Internal	Actual	57.6	54.2	66.7	52.1	29.2	8.3	41.7	37.5	9.0	0.0	10.4	16.7
	Deviation	-25.7*	-45.8*	-33.3*	2.1	-59.2*	-91.7*	-48.3*	-37.5*	9.0*	0.0	10.4*	16.7*
	Prediction	83.3	100.0	100.0	50.0	92.5	100.0	100.0	77.5	47.4	72.7	44.6	25.0
External	Actual	60.4	66.7	62.5	52.1	66.7	75.0	62.5	62.5	28.5	35.4	27.1	22.9
	Deviation	-22.9*	-33.3*	-37.5*	2.1	-25.8*	-25.0*	-37.5*	-15.0	-19.0*	-37.3*	-17.5*	-2.1
Treatment Effect	Difference	2.8	12.5	-4.2	0.0	37.5*	66.7*	20.8	25.0*	19.4*	35.4*	16.7*	6.3
on levels	p-value	0.63	0.21	0.67	1.00	0.00	0.00	0.05	0.02	0.00	0.00	0.04	0.45
Treatment Effect	Difference	2.8	12.5	-4.2	0.0	33.3*	66.7*	10.8	22.5*	-28.0*	-37.3*	-27.9*	-18.8*
on Deviations	p-value	0.63	0.21	0.67	1.00	0.00	0.00	0.31	0.03	0.00	0.00	0.00	0.02

Table 6: *Division of surplus.* This table presents the division of the average per-round surplus between the agents in the experiments. The surplus figures presented are normalized by the Pareto optimal surplus. The table presents the average levels of surplus received by each agent type and the predicted surplus for the entrepreneur. Predictions for Consumers and Investors are always zero. An "*" indicates when an agent's surplus is statistically different from the predicted surplus for that agent according to a t-test. For each parameterization, the table also presents the effect of introducing external capital markets on the consumer and entrepreneur surplus. An "*" in either treatment effect row indicates a significant effect according to a t-statistic at the 95% confidence level.

		Panel A: Parameter set 1				Panel B: Parameter set 2				Panel C: Parameter set 3			
Financing	Surplus		Period				Period				Period		
Treatment	Item	Overall	1	2	3	Overall	1	2	3	Overall	1	2	3
	Consumer	-2.8	2.5	4.9	-15.7	-22.4*	-26.8	-40.5*	0.1*	-124.4*	-178.7*	-125.0*	-69.5*
Internal	Entrepreneurs	60.4*	51.6*	61.8*	67.8*	45.3*	26.8*	71.7	37.4*	94.5*	126.6*	97.9*	59.1*
	Pred. Entrepreneurs	83.3	100.0	100.0	50.0	80.0	100.0	80.0	60.0	0.00	0.00	0.00	0.00
	Investor	0.7	-4.8	0.7	6.1	-137.3*	-188.9*	-107.1*	-116.0*	-121.2*	-155.4*	-104.7*	-103.5*
External	Consumer	10.5	26.6*	9.9	-5.0	132.8*	186.4*	101.4*	110.7*	-14.3	16.7	-39.8	-19.8
	Entrepreneurs	49.2*	44.8*	51.9*	51.0	57.8*	62.5*	53.2*	57.8	101.4*	111.6*	107.0*	85.8*
	Pred Entrepreneurs	83.3	100.0	100.0	50.0	85.0	100.0	100.0	55.0	22.4	45.5	16.5	5.4
Treatment	Consumers	13.3	24.1	5.0	10.7	38.8*	53.3*	35.5*	27.6*	27.5*	48.8*	21.3*	12.4
effect on	Entrepreneurs	-11.2*	-6.87	-10.0	-16.9*	3.1	8.9*	-4.6	5.1	1.7	-3.7	2.3	6.7

Table 7: *Firm actions.* This table presents the production strategies followed by flexible Entrepreneurs. It gives the area of a strategy according to Selten's measure, the predicted frequency of each strategy under each treatment and the actually frequency. An "*" denotes a frequency that differs significantly from Selten's area according to a one-sided binomial test statistic at the 95% level of confidence.

Panel A: Parameter set 1							
	Normal	Selten's	Internal Financing		External Financing		Treatment
Strategy	form	area	Predicted	Actual	Predicted	Actual	effect
Full Reputation	HHL	0.125	1.000	0.250	1.000	0.042	-0.208*
Partial Reputation	HLL	0.125	0.000	0.250	0.000	0.208	-0.042
Myopic Response	LLL	0.125	0.000	0.333*	0.000	0.417*	0.083
Other	LHL	0.125	0.000	0.083	0.000	0.208	0.125
Dominated Strategy	XXH	0.500	0.000	0.083*	0.000	0.125*	0.042
Panel B: Parameter set 2							
Full Reputation	HHL	0.125	0.600	0.000	1.000	0.222	0.222
Partial Reputation	HLL	0.125	0.400	0.167	0.000	0.000	-0.167
Myopic Response	LLL	0.125	0.000	0.583*	0.000	0.556*	-0.028
Other	LHL	0.125	0.000	0.000	0.000	0.000	0.000
Dominated Strategy	XXH	0.500	0.000	0.250	0.000	0.222	-0.028
Panel A: Parameter set 3							
Full Reputation	HHL	0.125	0.000	0.000*	0.262	0.028	0.028
Partial Reputation	HLL	0.125	0.000	0.056	0.375	0.111	0.056
Myopic Response	LLL	0.125	1.000	0.639*	0.364	0.722*	0.083
Other	LHL	0.125	0.000	0.111	0.000	0.056	-0.056
Dominated Strategy	XXH	0.500	0.000	0.194*	0.000	0.056*	-0.056

Table 8: *Subject behavior regressions.* Independent variables are product price, a quality dummy (1=high, 0=low) and the percentage of profits demanded by the investor. Period Dummies equal 1 in the corresponding group interaction period. Period, Revealed Flexible Dummies equal 1 in the corresponding period low quality had been observed earlier in the group. The SR Net Cost of High Quality is the high quality cost times one minus the percentage demanded by the investor or to cover capital expenses. The LR Benefit of High Quality is the difference between the highest average (by session) payoff continuing strategies after high quality and low quality choices. Historical quality is coded as -1 for low and +1 for high. Avg. Hist. Quality averages (by group) the prior coded qualities. Avg. Hist. Profitability averages (by group) the ratio of the profits on the sale to the capital investment. Exp. Wtd. Avg. Hist. Quality weights the coded qualities by 1 if the buyer actually purchased the item and 0 if not, then averages. Weighting is similarly defined for the Exp. Wtd. Avg. Profitability. Parameterizations give the Additional Cost of High Quality, Percentage of Flexible Entrepreneurs and Required Capital Investment. The External Financing Dummy equals 1 if financing was external. Rounds of Experience variables equal total number of periods to date in the experimental session.

Panel A: Consumer behavior		Panel B: Entrepreneur behavior		Panel C: Investor behavior	
Dependent variable	Price	Dependent variable	Quality Dummy	Dependent variable	Equity percentage
Regression type	dual censored	Regression type	logistic	Regression type	dual censored
Censored at	400, 1000	Cluster by	session	Censored at	0, 1
Observations	840	Observations	423	Observations	408
constant	756.682***	constant	0.471	constant	0.215**
	(19.26)		(1.22)		(2.29)
Period 2 Dummy	58.421	Period 2 Dummy	1.509***	Period 2 Dummy	0.121***
	(1.22)		(2.66)		(4.05)
Period 2, Revealed	-40.491	Period 2, Revealed	-1.095**	Period 2, Revealed	0.053
Flexible Dummy	(-0.45)	Flexible Dummy	(-2.05)	Flexible Dummy	(1.61)
Period 3 Dummy	90.172*	Period 1 Dummy	0.927***	Period 3 Dummy	0.152***
	(1.84)		(2.92)		(4.49)
Period 3, Revealed	-146.920*	Short Net Run Cost	-0.019***	Period 3, Revealed	0.032
Flexible Dummy	(-1.89)	of High Quality	(-4.68)	Flexible Dummy	(1.10)
Avg Hist. Quality	113.586***	Long Run Benefit	0.002*	Avg. Hist. Break-	-0.079***
(+1="H", -1="L")	(2.63)	of High Quality	(1.65)	Profitability	(-2.96)
Exp. Wtd. Avg.	48.330**			Exp. Wtd. Avg.-	-0.088***
Hist. Quality	(2.06)			Profitability	(-4.44)
External Financing	-16.151	External Financing	-0.048		
Dummy	(-1.05)	Dummy	(-0.31)		
Additional Cost	-0.235***	Additional Cost	-0.005***	Required Capital	0.001***
of High Quality	(-2.86)	of High Quality	(-4.08)	Investment	(6.46)
Percentage of Flexible	21.159	Percentage of Flexible	-0.125	Percentage of Flexible	-0.138***
Entrepreneurs	(0.52)	Entrepreneurs	(-0.19)	Entrepreneurs	(-3.32)
Rounds of	-1.926			Rounds of	0.003***
Buyer Experience	(-1.72)			Investor Experience	(2.82)

Appendix I: Proofs

Proof of Lemma ??: We prove this result using a contradiction. Suppose that there exists an equilibrium where, at the beginning of period n, consumers and investors believe that the entrepreneur is type-H with probability r. Further they believe that a type-F entrepreneur will produce low quality with probability θ. Then the price, p^*, that an entrepreneur will be able to obtain for his product in period n is given by

$$p^* = [r + (1-r)(1-\theta)]\, u_h + (1-r)\,\theta\, u_l. \tag{A-1}$$

Further if the entrepreneur accesses the capital market for financing, he will have to give an investor α^* equity, where

$$I = \alpha^* \left(p^* - [r + (1-r)(1-\theta)]\, c\right). \tag{A-2}$$

Now consider the entrepreneur's decision: If he accesses the capital market and produces low quality in period n, his payoff is

$$(1-\alpha^*)p^*. \tag{A-3}$$

On the other hand, if he produces high quality his payoff is

$$(1-\alpha^*)(p^* - c). \tag{A-4}$$

It follows that the entrepreneur will prefer to produce low quality. If the $(1-\alpha^*)$ terms are eliminated from the above expressions and a minus I term is added to each expression, we obtain the payoffs to an entrepreneur who does not access the capital market. It follows that even a producer who does not access the capital market will produce low quality in period n. □

Proof of Lemma ??: We employ a contradiction to prove this result. Suppose there exists an equilibrium where prior to $t^* < n$ the entrepreneur always produces high quality and at t^* the entrepreneur switches to low quality if he is type-F. Because consumers and investors cannot

identify type-F entrepreneurs until period t^*+1, in period t^*, the price for the product satisfies

$$p_{t*} = \pi\, u_h + (1-\pi)\, u_l. \tag{A-5}$$

and investors will demand, α_{t*}, where

$$I = \alpha_{t*}(p_{t*} - \pi\, c). \tag{A-6}$$

Now note that if he does produce low quality at time t^*, in all subsequent periods the entrepreneur will be identified at a type-F entrepreneur. Further, once the entrepreneur is identified as type-F, consumers will always pay only u_l for this goods and investors will always demand $\alpha = \frac{I}{u_l}$ for financing his project. This follows because there cannot exist sub-game equilibria where the type-F entrepreneur, once identified as such, will produce high quality. For a sub-game equilibrium where a type-F entrepreneur produces high quality after being identified to exist, it must be the case that he is being induced to produce high quality by the threat of retaliation in subsequent periods. Note however, that consumers and investors cannot commit to rewarding an entrepreneur in the final period for production decisions made earlier and thus such a threat cannot induce a type-F entrepreneur to produce high quality in period $n-1$. By induction, it follows that this sort of trigger strategy cannot be effective in inducing a type-F entrepreneur to produce high quality in earlier periods either. It follows that once the entrepreneur produces low quality he will produce low quality in all subsequent periods.

Now suppose that the entrepreneur, if he is type-F, opts to produce high quality at time t^* and low quality in every subsequent period, i.e., he delays switching to low quality production by one period. First note that the entrepreneur's payoff in all periods subsequent to period t^*+1 will be the same as his payoffs would have been had he switched to low quality at time t^*. Thus, delayed switching can only affect his payoffs in periods t^* and t^*+1. Further note that in period t^*+1 his product and equity claims will be priced as if he is a type-H producer. Thus, the sum of the two period's payoff with delayed switching is

$$(1-\alpha_{t*})(p_{t*} - c) + \left(1 - \frac{I}{u_h - c}\right) u_h, \tag{A-7}$$

while the sum of the payoffs from switching in period t^* is

$$(1-\alpha_{t*})p_{t*} + \left(1 - \frac{I}{u_l}\right) u_l. \tag{A-8}$$

It is easy to verify that delayed switching generates higher payoffs under parameterization one whether or not the entrepreneur is restricted from accessing the capital market. □

Proof of Lemma ??: First note that, consumer and investor responses along the equilibrium path in all periods subsequent to the production of low quality are based on beliefs consistent with Bayes rule. Further note that, given the pricing in product and capital markets subsequent to the production of low quality, in any sub-game beginning with a period in which the entrepreneur produces low quality, the entrepreneur's best response is consistent with the pricing, that is he maximizes his payoff by producing low quality in all subsequent periods.

To complete the proof we have to establish that a type-F entrepreneur will not produce low quality prior to the final period. To see this note that in period $n-k$ by producing high quality until the final period the entrepreneur earns

$$k\left(1 - \frac{I}{u_h - c}\right)(u_h - c) + \left(1 - \frac{I}{\pi\, u_h + (1-\pi)\, u_l - \pi\, c}\right)(\pi\, u_h + (1-\pi)\, u_l). \tag{A-9}$$

If he switches to producing low quality in period $n-k$, the present value of his payoffs until the end of the game equals

$$\left(1 - \frac{I}{u_h - c}\right) u_h + k\left(1 - \frac{I}{u_l}\right) u_l. \tag{A-10}$$

The proof is concluded by noting that the payoffs from producing high quality until period n are higher under parameterization one whether or not the entrepreneur can access the capital market.□

Proof of Lemma ??: First we will establish that no equilibria in pure strategies exist. Then we will establish our claim regarding pooling equilibria.

First note that, given (**??**), there cannot exist equilibria where a type-F entrepreneur only produces low quality or switches from producing low quality to producing high quality. Now we demonstrate that, given (**??**), there cannot exist equilibria in which the entrepreneur switches from

high quality to low quality if he is type-F. Combined with Lemma **??** this ensures that there cannot exist any equilibria where a type-F entrepreneur produces high quality.

First suppose there exists an equilibrium where, if he is type-F, the entrepreneur produces high quality until period $t \leq n$, and then switches to producing low quality. Also suppose that the entrepreneur continues to produce if he is type H. Given that consumers will price the product based on their priors in period t, it follows from (**??**) that the type-H entrepreneur will find production uneconomic. This contradiction proves that there cannot exist an equilibrium in which a type-H entrepreneur produces in the period in which a type-F entrepreneur is expected to switch to low quality.

Now suppose that there exists an equilibrium where, if he is type-F, the entrepreneur produces high quality until period $t \leq n$, and then switches to producing low quality. Also suppose that the entrepreneur does not produce in period t if he is type-H. Then in period t the product will be priced at u_l. However, from (**??**) it follows that production is uneconomic for the type-F entrepreneur. Thus, there cannot exist such equilibria.

It follows that the only potential equilibria are ones where a type-F entrepreneur produces high quality until some period t and then ceases production. However, these equilibria cannot exist because the period before ceasing production a type-F entrepreneur can maximize profits by producing low quality.

Now we will establish our claim regarding pooling equilibria. First we show that consumer prices are consistent with rational expectations: Given that only a type-F entrepreneur is capable of producing low quality and given that a type-F entrepreneur never produces high quality after producing low quality, the consumer belief that all goods produced subsequent to the production of low quality are low quality is consistent with rational expectations. Moreover, such a belief supports the prices specified in the equilibrium. Now, consider prices when low quality has not been produced a previous period. First consider period 1. Because the entrepreneur is producing high quality with probability 1, the consumer's belief that the market is producing high quality with probability 1 is consistent with rational expectations and justifies the price specified in the equilibrium. In period 2, if type-F entrepreneur produce high quality with probability $3/5$ and type-H with probability 1, given the prior that the entrepreneur is type-H is $3/4$, the probability of high quality production in period 2 must equal 0.90. This implies a price of $u_h(0.90) + u_l(0.10) = 940$, the price specified in

the equilibrium. Now consider the last date. Bayes rule implies that consumers asses the likelihood that an entrepreneur producing high quality in periods 1 and 2 is a type-F entrepreneur at

$$\frac{\frac{1}{4} \times \frac{3}{5}}{\frac{1}{4} \times \frac{3}{5} + \frac{3}{4}} = \frac{1}{6} \tag{A-11}$$

Thus, rational expectations requires that consumers offer

$$\frac{5}{6}u_h + \frac{1}{6}u_l = 900, \tag{A-12}$$

exactly the price specified in the equilibrium.

Next we show that, given consumer offers, the strategies of a type-F entrepreneur are sequentially rational. First consider the last period, period 3. In this period low quality is clearly optimal when the entrepreneur is type-F. Moreover, if the entrepreneur has ever failed to produce high quality in a previous period, then the market price that will be offered for its goods, which equals 400 (u_l) is far less than its total production costs of 900, hence the entrepreneur's payoff is maximized by shut down as specified in the equilibrium. It only remains to consider quality decisions of a type-F entrepreneur given that the entrepreneur has never failed to produce high quality in a previous period. First consider period 2. In period 2, high quality production will yield a production cost of $c+I = 900$. Low quality production will yield a production cost of $I = 500$. Thus, switching to low quality will yield a gain of $c = 400$ at date 2. The cost of low quality is that profits from period 3 production will be lost. These profits equal the period 3 price less the cost of low quality production, i.e., they equal $900 - I = 400$. Thus, type-F entrepreneur are indifferent between high and low quality, this payoff structure rationalizes the equilibrium strategy of randomizing in period 2. Now consider period 1. Producing low quality in period 1 saves the entrepreneur $c = 400$ in operating costs. The loss is the foregone profit from producing in periods 2 and 3, which also equals $940 - 500 = 440$ Thus, producing high quality in period 1, as specified in the equilibrium is rational for the entrepreneur if he is type-F. □

Proof of Lemma ??: Part of the proof follows from Lemmas **??** and **??**. The remainder is virtually identical to the proof of Lemma **??**. □

Proof of Lemma ??: First note that if production occurs in period 3, the market price must at least equal 900 for entrepreneurs that produce high quality in the previous periods. We establish this using the following contradiction. Suppose that the market price is less than 900 in period 3. Then a type-F entrepreneur's gain from producing high quality in period 2, which is the period 3 price less the investment of 500 would be less than the cost of producing high quality goods in period 2, which is 400. Thus, a type-F entrepreneur would produce low quality with probability 1 in period 2. But then Bayes rule would imply that all firms that produce high quality in period 2 would be type-H firms and thus the price in period 3 after high quality production in periods 1 and 2 would have to be $u_h = 1000$. But at this price, a type-F entrepreneur would prefer to produce high quality in period 2. This contradiction shows that, in any equilibrium in which production occurs in period 3, the price must at least equal 900. The same argument can be applied at earlier dates to show that the market price conditioned on always producing high quality, must at least equal 900.

For a price of 900 or above to satisfy rational expectations, there must be no more than a $\frac{1}{6}$ probability that the low quality is produced. Consider a candidate equilibrium and let, σ_t be the likelihood in periods $t = 1, 2$ that a type-F entrepreneur produces low quality at date t given that the entrepreneur has never failed in the past to produce high quality. Bayes rule implies that, for the likelihood of low quality (conditioned on no failure to produce high quality in the past) to at least equal $\frac{1}{6}$ in periods 1, 2, and 3, given that the prior probability of an entrepreneur being type-F is $\frac{3}{4}$ as is assumed by parameter region 3, the following inequalities must be satisfied:

$$\frac{3\sigma_1}{4} \leq \frac{1}{6} \tag{A-13}$$

$$\frac{3(1-\sigma_1)\sigma_2}{4\left(\frac{3(1-\sigma_1)}{4} + \frac{1}{4}\right)} \leq \frac{1}{6} \tag{A-14}$$

$$\frac{3(1-\sigma_1)(1-\sigma_2)}{4\left(\frac{3}{4}(1-\sigma_1)(1-\sigma_2) + \frac{1}{4}\right)} \leq \frac{1}{6} \tag{A-15}$$

$$\sigma_1 \in [0, 1] \tag{A-16}$$

$$\sigma_2 \in [0, 1]. \tag{A-17}$$

However, no solution to this system of inequalities exists. Thus, there exists no equilibrium in which production occurs.

At the same time note that an equilibrium does exist in which production fails in all periods. To see this note that if, at date 3, consumers offer a price less than 900, production will be canceled because type-H entrepreneurs will lose from producing. So to show that an equilibrium exists in which no production occurs we need only rationalize a price less than 900 at all nodes of the game. After low quality production, a price of less than 900 can always be rationalized by the belief that the good is being offer by a type-F entrepreneur that will produce low quality. The problem is how to rationalize low prices after high quality production.

Now, let, σ_t be the likelihood in periods $t = 1, 2$ that a type-F entrepreneur produces low quality at date t given that the entrepreneur has never failed in the past to produce high quality. Bayes rule implies that, for the likelihood of low quality (conditioned on no failure to produce high quality in the past) to be greater than $\frac{1}{6}$ at dates 1, 2, and 3, given that the prior probability that an entrepreneur is type-F is $\frac{3}{4}$ as given in parameterization three, the following inequalities must be satisfied:

$$\frac{3\sigma_1}{4} > \frac{1}{6} \tag{A-18}$$

$$\frac{3(1-\sigma_1)\sigma_2}{4\left(\frac{3(1-\sigma_1)}{4} + \frac{1}{4}\right)} > \frac{1}{6} \tag{A-19}$$

$$\frac{3(1-\sigma_1)(1-\sigma_2)}{4\left(\frac{3}{4}(1-\sigma_1)(1-\sigma_2) + \frac{1}{4}\right)} > \frac{1}{6} \tag{A-20}$$

$$\sigma_1 \in [0, 1] \tag{A-21}$$

$$\sigma_2 \in [0, 1]. \tag{A-22}$$

This system of equations has many solutions, e.g., $\sigma_1 = \frac{3}{8}$ and $\sigma_2 = \frac{5}{16}$. Given this pattern of randomization by the entrepreneur when it is type-F, rational prices are less than 900. This implies that a type-H entrepreneur cannot profit from production at any node, thus production fails and there is no output at any date or history of the game. □

Proof of Lemma ??: Let p_t represent the equilbirum price at date t for output from "unrevealed

entrepreneurs," entrepreneurs who have never failed to produce high quality. Let q_t represent the probability at date t that an unrevealed entrepreneur produces low quality. Let σ_t be the probability that an unrevealed type-F entrepreneur produces low quality at date t = 1, 2, 3. Let α_t represent the fraction of the entrepreneur's cash flow demanded by the investor in exchange for providing financing. Next note that, at unrevealed nodes, rational expectations on the part of consumers is satisfied if and only if

$$p_t = u_l\, q_1 + u_h\,(1 - q_1), \quad t = 1, 2, 3. \tag{A-23}$$

The competitive capital market and rational expectations for investors is satisfied if and only if

$$\alpha_t\,(q_t\, p_t + (1 - q_t)\,(p_t - c)) = I, \quad t = 1, 2, 3. \tag{A-24}$$

Bayes rule is satisfied if and only if (recall that the prior probability that the firm is flexible under parameter set 3 is 3/4)

$$q_1 = \frac{3}{4}\,\sigma_1, \tag{A-25}$$

$$q_2 = \frac{3\,(1 - \sigma_1)\,\sigma_2}{4\left(\frac{3}{4}\,(1 - \sigma_1) + \frac{1}{4}\right)}, \tag{A-26}$$

$$q_3 = \frac{3\,(1 - \sigma_1)\,(1 - \sigma_2)}{4\left(\frac{3}{4}\,(1 - \sigma_1)\,(1 - \sigma_2) + \frac{1}{4}\right)}. \tag{A-27}$$

Randomization is a best response for unrevealed type-F entrepreneur in both period 1 and period 2 if and only if

$$((1 - \alpha_t)\,(p_t - c) + (1 - \alpha_{t+1})\,p_2) - (1 - \alpha_t)\,p_t = 0, \quad t = 1, 2 \tag{A-28}$$

In period 3, the strategy of always producing low quality ($\sigma_3 = 1$) is clearly the unique best response for type-F entrepreneurs.

We aim to verify the existence of an equilibrium with the following properties: at all revealed histories of the game, histories subsequent to a failure of the entrepreneur to produce high quality, consumers price the good at $u_l = 400$. At all such histories, the investor refuses to provide funding. At unrevealed histories, the actions of consumers, entrepreneurs and capitalists are defined as follows: First, let x^* represent the unique real number in the interval (0, 1) which solves the

equation

$$-42450 + 376491\,x - 1298865\,x^2 + 2377271\,x^3 - 2535761\,x^4 + 1591842\,x^5 - 547880\,x^6 + 80000\,x^7 = 0; \quad \text{(A-29)}$$

and let y^* represent the unique real number in the interval (0, 1) which solves the equation

$$-3804480 + 21742776\,y - 57235260\,y^2 + 91050246\,y^3 - 91564373\,y^4 + 56230563\,y^5 - 18789162\,y^6 + 2753440\,y^7 = 0. \quad \text{(A-30)}$$

Define candidate actions at unrevealed histories as follows:

$$\begin{aligned}
&\sigma_1^* = \frac{4}{3}\,x^*, \quad \sigma_2^* = y^*, \quad \sigma_3^* = 1 \\
&q_1^* = \frac{3}{4}\,\sigma_1^*, \quad q_2^* = \frac{3\,(1-\sigma_1^*)\,\sigma_2^*}{4\left(\frac{3}{4}\,(1-\sigma_1^*)+\frac{1}{4}\right)}, \quad q_3^* = \frac{3\,(1-\sigma_1^*)\,(1-\sigma_2^*)}{4\left(\frac{3}{4}\,(1-\sigma_1^*)\,(1-\sigma_2^*)+\frac{1}{4}\right)} \\
&p_t^* = 400\,q_t^* + 1000\,(1-q_t^*) \quad t = 1,2,3 \\
&\alpha_t^* = \frac{5}{2(3-q_t^*)} \quad t = 1,2,3
\end{aligned} \qquad \text{(A-31)}$$

A numerical approximation to this exact solution is given by

$$\begin{aligned}
&\sigma_1^* = 0.364, \sigma_2^* = 0.589, \sigma_3^* = 1.000, \\
&q_1^* = 0.273, q_2^* = 0.387, q_3^* = 0.440, \\
&p_1^* = 836.367, p_2^* = 768.055, p_3^* = 736.244, \\
&\alpha_1^* = 0.917, \alpha_2^* = 0.957, \alpha_3^* = 0.976.
\end{aligned} \qquad \text{(A-32)}$$

The reader can verify that (**??**) satisfies the equilibrium conditions, (**??**), (**??**), (**??**), (**??**), (**??**). Verification can be affected either by substituting the exact solution (**??**) into a symbolic algebra programming language, e.g., *Mathematica*, or by substituting the approximate solution, (**??**) into the same equations in which case the equalities will only be approximately satisfied. □

Appendix II: Debt financing

In this appendix we demonstrate that even access to single-period debt financing supports equilibrium outcomes that result in higher production and higher quality than outcomes where the firm is restricted to financing itself internally. In order to keep the analysis tractable, we assume, as in the case of parameterizations 2 and 3, $u_l = c < I$. We also modify the model slightly. After a type-F firm has made its quality choice, a random act of nature can affect product quality. This act of nature occurs with probability $1-\theta$ and is observed by investors, entrepreneurs, and consumers. Once it occurs, the firm's quality decision is irrelevant and current period output and all future output is low quality. If the act of nature does not occur, as is the case in our earlier analysis, the entrepreneur's quality decision alone determines product quality.

This additional assumption considerably simplifies the analysis. It ensures that firm's can finance itself with single-period debt whose payoffs are determined only by the firm's current period cash flows, because the firm is either able to pay off its entire debt in the current period or the firm itself ceases to exist. Note also that it is still the case that once the firm has been revealed as type-F it will be unable to operate.

To ensure that the firm can always obtain financing so long as nature has not acted and the firm has not been revealed to be type-F, we assume that θ is sufficiently high so that

$$\theta(\pi u_h + (1-\pi)u_l - c) > I. \tag{B-1}$$

Now note that when a type-F firm chooses high quality, the cash flow available to investors is $p-c$ while if the firm chooses low quality, the cash flow available to pay investors is p. Thus, when a type-F firm finances itself with single-period debt, rational pricing dictates that the promised repayment D satisfy

$$D\theta + (1-\theta)qu_l = I, \tag{B-2}$$

where q represents the probability than an unrevealed type-F firm chooses low quality. Thus, rational pricing dictates that the promised payment on single-period debt be given by

$$D = \frac{I - qu_l(1-\theta)}{\theta}. \tag{B-3}$$

We now demonstrate that any set of parameters that supports reputation building by a firm that is entirely financed by the entrepreneur will also support reputation building when the entrepreneur can raise single-period debt. We now establish that in period 2, if an unrevealed firm that is self financed chooses high quality so will a similar firm that is debt financed. First note that, in period 2, a self-financed entrepreneur who chooses high quality can expect a payoff of

$$\theta[p_2 + (\theta p_3 + (1-\theta)u_l - I)] + (1-\theta)u_l - I - c, \tag{B-4}$$

where p_2 and p_3 represent period 2 and period 3 if the firm is not revealed to be type-F. If the entrepreneur chooses low quality in period 2 she can expect,

$$\theta p_2 + (1-\theta)u_l - I. \tag{B-5}$$

It follows that the entrepreneur will only choose high quality so long as

$$\theta(\theta p_3 + (1-\theta)u_l - I) - c \geq 0. \tag{B-6}$$

Now consider the entrepreneur's period 2 quality choice when the firm is financed with single-period debt. If the entrepreneur chooses high quality, his expected payoff is

$$\theta[p_2 - c - D_2 + \theta(p_3 - D_3)], \tag{B-7}$$

where D_2 and D_3 represent period 2 and period 3, debt payments respectively. If the entrepreneur chooses low quality, however, his expected payoff is

$$\theta(p_2 - D_2). \tag{B-8}$$

The preceding two expressions, together, imply that the entrepreneur will choose to produce high quality in period 2 so long as

$$\theta\theta(p_3 - D_3) - c \geq 0. \tag{B-9}$$

Noting that $u_l = c$ and taking the difference between the left hand sides of (**??**) and (**??**), we obtain

$$\theta(I - \theta D_3) + c(\theta - 1)^2. \tag{B-10}$$

Because rational pricing implies that $I \geq \theta D_3$, this expression must be positive in any equilibrium. This establishes that, in period 2, any set of parameters that supports high quality production with self financing must also support high quality when the entrepreneur finances with debt. Note that the incentive to deviate from the reputation formation equilibrium is higher in period 2 than it is in period 1. Thus, if high quality production is optimal in period 2, it must also be optimal in period 1. Thus, any set of parameters that supports reputation formation with self financing also supports reputation formation with debt finance.

It is easy to verify that condition (**??**) is satisfied while (**??**) is violated when D_2 and D_3 are set under the assumption that type-F firms will choose high quality in period 2 and low quality in period 3, $\pi = 0.082$, $\theta = 0.945$, and the remaining parameters equal their values under parameterizations 2 and 3. Because incentives to deviation from reputation formation are lower in period 1, this establishes that there exist parameter values that support reputation formation with debt finance but not with self financing.