Valuation and the Volatility of Financing and Investment*

Michael J. Fishman† Northwestern University

Jonathan A. Parker‡ Northwestern University and NBER

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Abstract

The use of valuation has an externality: it creates information on which adverse selection can occur. We study a market in which investors provide external financing for real investment projects. A subset of investors, sophisticated investors, can buy a technology to value a given number of projects, and reject those with low payoffs, Because rejected projects can seek funding from other investors, there are strategic complementarities in the capacity for valuation, the private benefits to valuation exceed its social benefits, and the market can exhibit multiple equilibria. In one equilibrium, sophisticated investors do valuation, only sophisticated investors invest, and only good projects are funded; in another, sophisticated investors do not do valuation, and all projects are funded. In the region of multiplicity, the move from a pooling (socially efficient) equilibrium to a valuation (socially inefficient) equilibrium involves many features of a financial crisis: prices decline (interest spreads rise); real investment declines; unsophisticated investors leave the market (flight to quality) and sophisticated investors make profits; trust declines and due diligence increases.

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†Kellogg School of Management, Northwestern University, 2001 Sheridan Road, Evanston, IL 60208-2001, e-mail: M-Fishman@Kellogg.Northwestern.edu, www.kellogg.northwestern.edu/faculty/bio/Fishman.htm

‡Kellogg School of Management, Northwestern University, 2001 Sheridan Road, Evanston, IL 60208-2001, e-mail: Jonathan-Parker@Kellogg.Northwestern.edu, www.kellogg.northwestern.edu/faculty/parker/htm

1 Introduction

Most real investment – buying a house, starting a business, or expanding a firm – relies on external financing, an investor transferring resources today in exchange for an uncertain claim on future resources. External financing and the investment it funds are subject to booms and crashes, as exemplified by the volatility in the markets for internet startups, venture capital, housing, commercial paper seen in the last two decades in the U.S. as well as foreign direct investment and the 'sudden stops' observed in emerging markets. We present a theoretical model which shows how this volatility can arise from changes in the extent of valuation. In the model the use of valuation creates private information which leads to adverse selection, which in turn causes declines in real investment and prices. This externality generates strategic complementarities in valuation that are strong enough to lead to multiple equilibria. Finally, the equilibrium without valuation is Pareto superior to equilibria with valuation for all parameters where both exist and for some parameter values where the only market equilibrium has valuation.

Specifically, we consider a discrete-time, rational-expectations model of a competitive market. In each period, risk-neutral sellers try to get funding for (sell) investment projects at prices above their reservation value, and risk-neutral financial investors compete to fund (purchase) these projects given a fixed opportunity cost of capital. The future payoff of any investment project is uncertain. Unfunded projects disappear at the end of each period so that periods are physically unconnected.

There are two types on investors. *Unsophisticated_investors* are competitive price-takers who buy/fund projects at their expected present discounted value. *Sophisticated investors* must ex ante choose funds available to fund projects and can at a cost invest in capacity to perform valuation. Valuation provides a signal of the quality of a project. Conditional on good signal, a project is worth more than the reservation value in expectation, conditional on a bad signal, it is not. Aggregate capacity for valuation is limited. All investors are small in the sense that any one investor's actions do not influence the average quality of unfunded projects in the market.

A seller that goes to a sophisticated investor and is found to have a bad project and so does not get funding can either abandon its project and get its reservation value or seek funding from another investor in the same period. Thus valuation has an externality on unsophisticated investors.

Over a range of parameters, there exists an equilibrium in which no project is valued and all investment projects are funded. In this pooling equilibrium, because investors compete for projects, prices are high. Over another range of parameters, there exists an equilibrium in which sophisticated investors value as many projects as they can and only good projects are funded. In this valuation equilibrium, because projects compete for limited valuation capacity, prices are low. These ranges overlap, so that there is an area of multiple equilibrium. The key to this multiplicity is that the valuation externality makes valuation a strategic complement. Then, if enough projects are screened, the average quality of unvalued projects is less the seller's reservation value, unsophisticated investors leave the market, and only good projects are funded.

This switch from a pooling equilibrium to a valuation equilibrium matches many of the features observed in crashes in external financing and real investment in many markets, such as internet start-ups in the mid-1990's, sub-prime borrowers in 2007, or commercial paper in 2008. In the credit boom (the pooling equilibrium), all projects are funded. When the crisis comes (the valuation equilibrium), there is a decline in funding and associated real investment, and observed prices fall (interest rates rise). The price rise comes as unsophisticated investors leave the market and the market changes from one in which projects are in short supply to one in which the ability to do valuation is in short supply, and so sophisticated investors earn profits. There is flight to quality in two senses: only good projects are funded, and unsophisticated investors flee the market opting to park their funds elsewhere. Further, in the collapse, projects (even some good projects) that would have been funded under the pooling equilibrium find themselves unable to get funding or even get evaluated for funding. The move to valuation is a decline in trust, a rise in due diligence, and a tightening of underwriting standards. Finally, because of the multiple equilibria, this shift need not be tied directly to changes in fundamentals, although changes in fundamentals bring about the possibility of collapse and make collapse ultimately inevitable.

Obviously, some valuation occurs in all markets. But every project is valued up to some point, and then pooled with observationally equivalent projects. Our model captures the market for projects that are observationally equivalent, and the volatility we study comes from increases or decreases in valuation, and so increases or decreases in market segmentation and market depth. For our model to explain broad categories of real investment crashes, it must be that one market is particularly important – as for example the market for AAA commercial paper – or equilibrium selection must be correlated across sub-markets.

In addition to a pure valuation equilibrium, over a different range of parameters, there exists an equilibrium in which sophisticated investors value as many projects as they can and the remaining projects are funded by unsophisticated investors. This region also overlaps with the region in which the pure pooling equilibrium can occur. While investment is the same in this region in either equilibrium, prices are lower in the valuation equilibrium as valuation reduces the average quality of the projects that unsophisticated investors fund. Thus, in this region, a switch from the pooling equilibrium to the valuation equilibrium leaves investment unchanged but leads to a price decline (higher spreads), pure profits for sophisticated investors, and a partial tightening of underwriting standards and decline in trust.

In the regions of multiplicity, the socially efficient outcome is the pure pooling equilibrium. This follows because in the pooling equilibrium, the sophisticated investor considering investing in the capacity to do valuation and fund with valuation faces the population share of good projects like the central planner problem. More strikingly, even in some regions where the market delivers only the valuation equilibrium, the pooling equilibrium is Pareto superior. This follows from the fact that in the pooling equilibrium, the presence of unsophisticated investors subsidize investment in valuation capacity. If a seller has a project valued and found to be bad and it could not go to an unsophisticated investor, it would be more averse to seeking funding from a sophisticated investor doing valuation. Thus, from a social perspective, investment crashes of both kinds just described are suboptimal, even in some cases where they are driven by fundamentals and are inevitable.

Can policy correct the market outcomes? First, subsidizing funding or lowering interest rates actually increases the region in which the valuation equilibria is the only equilibrium and the region in which it is possible. Second, taxing valuation can ensure the pooling equilibrium wherever it is efficient, but this policy requires that be observable and the tax depends on the parameters of the model. Third, raising the payout of bad projects reduces the regions in which valuation in equilibrium is possible and the regions in which it is inevitable. This works because it reduces the economic return to separating the good from the bad. This policy has some of the flavor of the TARP programs that provided funding and took some of the downside risk of private investors asset purchases.

Finally, because the pooling equilibrium is more efficient, a large unsophisticated investor with the ability to commit to fund projects at the pooling price can ensure that the market selects the pooling equilibrium wherever it is possible for the market to do so. Subsidizing this large investor can also ensure that the economy be in a pooling equilibrium wherever it is more efficient. And such a large investor has the incentive to monitor the market carefully since it would have a very low payoff if sophisticated investors invested in valuation capacity and it followed through on its commitment to fund projects at a high price that will on average be low quality. Finally, it is worth noting that in the pooling equilibrium, the large unsophisticated investor earns no rents, while in the valuation equilibrium, sophisticated investors make profits.[1]

What might drive these investment booms and crashes in practice? In the examples just cited, the projects initially there is little record on the post-funding performance of these new types of 'projects' like dot coms, sub-prime mortgages, more complex ABCP. In these cases the cost of valuation is naturally high and the market is necessarily in a pooling equilibrium where all potential projects meeting certain criteria are funded. As projects are observed to profit or fail however, valuation costs likely decline over time, and as valuation costs decline, the collapse to the valuation equilibrium becomes possible and ultimately inevitable. In this case, the precursors to collapse are the two main factors identified by Kindleberger (2000): credit – worsened by leverage which is not present in the model – and displacement – a new technology (or type of asset). Similarly, in a pooling equilibrium there is little incentive to produce projects of higher quality among projects treated as observationally similar (as in AAA MBS). Given this incentive, the share of good projects may naturally decline over time. Such a decline can also cause a

[1] This last policy example echos the history of Fannie Mae except for the careful monitoring.

collapse to a valuation equilibrium.

1.1 Related literature

First, we are closely related to the literature that considers the dynamics of adverse selection and our model builds directly on Akerlof (1970). Stiglitz and Weiss (1981), Rothschild and Stiglitz (1976), Mankiw (1986), considers how economic conditions change the degree of adverse selection and lead to limited transactions of market shutdown. Myers and Majluf (1984) apply this idea to show how raising funds to invest can be limited by adverse selection. Turning to dynamics, Eisfeldt (2004) shows how downturns can be amplified by adverse selection because rather than being a time when more assets are sold to raise funds, they are times when less selling is needed to raise capital for new investment projects. Dell'Ariccia and Marquez (2006), like our present model, focusses on the exacerbation of adverse selection due to changes in lending standards, but focusses not on the creation of information but rather on contract terms (specifically collateral requirements) and how these change in response to changes in the share of new projects about which no bank has information and existing projects, about which some bank has private information. In the model, declines in new projects lead to more adverse selection which is exacerbated by tightening of lending standards.[2] More recent contributions on the dynamics of adverse selection include Kurlat (2010) which shows how adverse selection that stops trade can propagate itself through time by limiting learning that could have reduced adverse selection sufficiently to allow trade.

Second, a large literature starting with Raviv (1975) and Townsend (1979), studies models with costly state verification. In this literature, verification of the state makes what had been private information into common knowledge, and so eliminates problems associated with asymmetric information. In contrast, in the present paper, costly state verification makes what had been unknown into private information and creates problems associated with asymmetric information.

Third, there is a literature on informational asymmetries in lending, and security design. Broecker (1990) considers a lending market in which, in contrast to our model, valuation is imperfect and errors imperfectly correlated across lenders.

The literature on securitization typically focusses on a monopolist who destroys information and creates a pooling equilibrium where before screening meant that unsophisticated traders suffered the externalities of the information that sophisticated investors had (Gorton and Pennacchi (1990), DeMarzo (2005)).

Fourth several papers consider bank credit cycles, and in particular, Gorton and He (2007) study changes in valuation, but driven by collapse of collusive equilibria among banks (ala Green and Porter (1984)).[3]

[2] See also Ruckes (2004)

[3] Marin and Rahi (2000) considers security design and shows how the optimality of complete vs. incomplete markets (complete vs. incomplete revelation of private information) depends on the costs of

Finally, we are related to theories of investment collapses and financial frictions in macroeconomics, such as those in Bernanke and Gertler (1989), Kiyotaki and Moore (1997), Holmstrom and Tirole (1998), Holmstrom and Tirole (1998), Caballero and Krishnamurthy (2003, 2008), and Geanakoplos and Fostel (2009) (Allen, Babus, and Carletti (2009) provides a review of such theories). This collapse can look like a bank run unrelated to fundamentals (sort of as in the model of a bank run by Diamond and Dybvig (1983)).

The paper is organized as follows. The next section sets out the model. Section 3 presents a lemma on the investment in valuation and funding capacity and the use of valuation and the market price as a function of equilibrium variables. Section 4 contains a characterization of the equilibria of the model. Section 5 gives our main result on multiplicity and efficiency of equilibria and discusses the dynamics of a collapse in external financing. Section 6 contains analysis of five possible policy interventions to correct market inefficiencies. A final section discusses the model.

2 The model

We consider a one-period model of a market with risk-neutral sellers and risk-neutral investors. In later sections we study dynamics as repeated equilibria in the static game with exogenously changing parameters over time.

At the beginning of the period, a unit mass of sellers (real investors) enter the market seeking external financing for new investment projects from a large number of competitive financial investors with access to unlimited funds at constant gross interest rate $R > 1$. Each seller has one investment project of fixed size, has no funds, and wishes to sell at or above a reservation price of 1. The payout of the each project is random and uncorrelated across projects and denoted D. All sellers and investors initially have common expectations of the future payout $E[D]$. Sellers who get funding take their money and leave the market at the end of the period and sellers with unfunded projects disappear at the end of the period.[4] Sellers are anonymous: within the period, a seller can visit many investors anonymously and simultaneously so that a seller turned away from one investor is able to go to another investor and appear indistinguishable from any other seller.[5]

adverse selection on private information relative to the costs of reduced ex ante insurance (the Hirshleifer effect).

[4]Thus, with multiple periods, periods are not physcically connected.

[5]We could instead explicitly model simultaneous application, which would require the additional complexity that, in the valuation equilibrium, a project could be valued by multiple sophisticated investors or by no other investors. This complication would increase the inefficiency of the valation equilibrium and create an endogenous capacity constraint on investment in valuation capacity. Ultimately however, this is a static analog to what is really a continuous process with valued projects indistinguishable from new entrants.

There are two types of investors. Unsophisticated investors cannot do valuation and have flexible access to funds. Sophisticated investors must choose at the beginning of the period both how much capital to raise to fund projects (f) and how much valuation capacity to acquire (h for human capital). We denote the aggregate amounts of funding and valuation capacity by F and H respectively. A unit of valuation technology allows the valuation of one project in the current period. Valuation reveals to the investor a binary signal of the quality of the project. The expected payoff of a project is $D^g = E[D|good])$ conditional on a good signal and $D^b = E[D|bad]$ conditional on a bad signal. A good project is worth investing in/buying and a bad project is not:

$$D^g > R > D^b$$

The population share of projects that are good, is $\lambda \in (0,1)$, so that

$$E[D] = \lambda D^g + (1-\lambda) D^b.$$

The outcome of valuation is observed by both the investor and seller, but is not observable by other investors or sellers. The cost of a unit of valuation capacity is c up to χ_i for sophisticated investor i, and infinite thereafter. The aggregate capacity constraint on valuation is $\chi < 1$.[6] Investors are not anonymous: market participants can observe available funds, investment in valuation technology, and the prices of transactions.

Following sophisticated investors' choices of valuation and funding capacity, sellers choose among funding from different investors and taking their reservation value to maximize their expected payoff, potentially going to more than one investor. Unsophisticated investors set prices to maximize their expected payoffs. Sophisticated investors choose how to use their capital and ability to do valuation and set prices conditional or unconditional on valuation in order to maximize their expected payoffs.

We consider competitive Nash equilibria of the period game in which all agents take as given the share of good and bad projects in the market in equilibrium.[7] Sophisticated investors choose valuation capacity and funding capacity optimally taking as given their own future behavior and the market equilibrium. Subsequently, all agents choose strategies to maximize payoffs taking as given the valuation capacity and funds of sophisticated investors, the shares of good and bad projects in the market, and market prices. Investors randomize across equivalent sellers and sellers randomize across equivalent investors.

[6] The constraint on valuation can also (or instead) be viewed as a limit on the total amount of capital available to the sophisticated investors at the start of the period. While here we assume a capacity constraint and constant cost, what matters is that marginal costs be increasing (most simply across the unit mass of investors).

[7] An in Dubey and Geanakoplos (2002). This assumption would be a result if we assumed that each investor could fund only up to a finite number of projects.

3 Equilibrium prices, funding capacity, and the use of valuation

In the first subsection, we show that, if a sophisticated investors chooses to invest in the valuation technology, it chooses its funding capacity equal to its valuation capacity and uses all its valuation capacity. Further, only projects that have not been previously valued approach sophisticated investors for valuation. Given these features of equilibrium, we derive the price used by sophisticated investors to fund good projects after valuation, again in terms of endogenous variables. In the second subsection, we use a zero-profit condition to derive the price used by unsophisticated investors to fund projects without valuation as a function of the share of good projects in the market.

Denote the equilibrium price paid by a sophisticated investor for a good project by P^g and the equilibrium price paid by an unsophisticated investor by P. It is useful to sketch the equilibria to better understand the preliminary analysis of this section. In an equilibrium in which no valuation capacity is chosen, unsophisticated investors fund all projects at a price equal to their expected discounted value. In an equilibrium with valuation, valuation capacity is insufficient to value the projects of all sellers, so that the market price is set either by the reservation value of the sellers or by the competitive fringe of unsophisticated investors funding both projects that have not been valued and projects that have been valued and found to be bad. These descriptions are of course to be shown.

3.1 Sophisticated investors

Consider first a sophisticated investor matched with a project that it has valued. If the project is good, then the investor funds the project if $P^g \leq D^g/R$. Sellers seek out this investor and accept funding if good if $P^g \geq P$ and $P^g \geq 1$ and if the this price is weakly better than alternative *available* prices at other investors with valuation capacity. Since unsophisticated investors fund without valuation, their price must below the value of a project known to be good. Thus, $P < D^g/R$ and $P^g \in [D^g/R, \max[P, 1]]$ and sophisticated investors fund all projects valued and found to be good.

Alternatively, if the project is valued and found to be bad, then if the investor funds the project the investor gets expected value $D^b/R - P^b$ and the seller gets $P^b - 1$ for some P^b. Since $D^b/R - 1 < 0$, there is no price at which this project is funded. Thus, all projects found to be bad are not funded by that investor. The rejected seller has three options: i) do not do the project and get its reservation value, 1; ii) go to an unsophisticated investor to fund the project and get P; iii) go to another sophisticated investor.

Next we turn to whether sophisticated investors might fund projects without valuation.

Since the costs of valuation are sunk, each sophisticated investor does not want limited funding to constrain its funding of good projects. Since funding capacity is free, each sophisticated investor chooses funding capacity at least as great as its funding needs following from valuation. Further, the following lemma shows that each sophisticated investor does not choose funds in excess of the amount to fund the good projects it finds using all its valuation capacity. Finally, each sophisticated investor only funds after valuation and no known-bad projects approached it for funding.

Lemma 1 *(Funding with valuation, funding capacity, and share of good projects)*
(i) If $h_i > 0$, the sophisticated investors sets $f_i = \lambda h_i$, uses all its funding capacity, and only funds after valuation;
(ii) The share of good projects going to sophisticated investors with $h_i > 0$ is λ.

Proof. Given a unit of valuation and a project, it is always more profitable to value the project and fund it if good, than to fund without valuation. Thus valuation is only slack if there are insufficient projects approaching a sophisticated investor. But such a sophisticated investor increases profits by offering a slightly higher price, making slightly less on each project and funding more projects by using all its valuation capacity. Thus it chooses at least funds sufficient to value all projects found to be good when using all its valuation capacity.

The only reason to choose funds greater than valuation capacity would be to fund some projects without valuation. Suppose that a sophisticated investor funded more projects that its capacity to do valuation. In this case, any seller going to this investor would have a positive probability of getting funded without valuation at P^g. Thus this sophisticated investor, if it were approached by sellers, would draw sellers with previously-valued projects that know that they are bad as well as projects that do not know the quality of their project. The share of good projects would be the same as for unsophisticated investors, the market share of good projects. If P^g were weakly greater than the expected value of these projects, then the sophisticated investor would not be making money on funding without valuation and making less per unit of valuation than if only sellers with unvalued projects approached it. Funding only after valuation would keep known-bad projects away and thus be more profitable. If the market price were less than the expected value of funding without valuation, then funding some projects without valuation could be optimal, but the competitive fringe of unsophisticated investors means this cannot happen. Thus, it is optimal for sophisticated investors to only fund after valuation.

A sophisticated investor with funds greater than its valuation capacity could not commit to value all projects before funding and not use these additional funds. If there is valuation in equilibrium, then the share of good projects in the market for funding without valuation is less than that in the population. Thus, if only unvalued projects approached the sophisticated investor, the investor would find it profitable to fund without valuation at a price equal to the expected value of the unvalued project sold to the unsophisticated investors (or 1 if the unsophisticated investors are not in the market $P < 1$). Thus, $f > \lambda h$ cannot be an equilibrium if we are to have sophisticated investors funding only after valuation. Therefore, sophisticated investors must choose funding capacity (f) equal to population share of good projects (λ) times their valuation capacity (h) and only sellers with unvalued projects with probability λ of being good approach the sophisticated seller. ■

From here on, we refer only to valuation capacity since funding capacity is equal to valuation capacity.[8]

We can now write the value of investing in a unit of valuation technology and an associated unit of funding capacity as

$$J^V = -c + \lambda \left(\frac{D^g}{R} - P^g \right)$$

for $P^g \in [D^g/R, \max[P, 1]]$.

Sophisticated investors choose capacity to maximize profits. Thus, aggregate valuation capacity is maximized at χ if $c < \lambda \left(\frac{D^g}{R} - P^g \right)$, zero if $c > \lambda \left(\frac{D^g}{R} - P^g \right)$ and an intermediate amount if $c = \lambda \left(\frac{D^g}{R} - P^g \right)$.

Turning to sellers, the (net) expected value to the (uninformed) seller of going to a sophisticated investor is

$$W^V = \lambda P^g + (1 - \lambda) \max[1, P] - 1 \tag{1}$$

where the max term reflects the fact that the seller found to have a bad project chooses between keeping the project or selling the project at the pooling price.

After the lemma, it is worth pausing to note that, given our assumptions, investors would like to use contract terms to screen projects and save on valuation capacity. This could be done with an ex ante fee, which we have ruled out by assuming that projects have no funds: since no sellers have any funds, an application fee would make no profits and fund no projects.[9] Alternatively, investors would like to impose a penalty on the seller whose project pays off poorly. This latter is ruled out by assumption, but could be due to moral hazard on the part of the new owner (investor) or there being no resources for the investor to collect if the project turns out to be bad.

3.2 Unsophisticated investors

Unless unsophisticated investors are driven from the market, they set the market price as a function of the average equilibrium quality of projects seeking funding from them.

Denote by ψ the aggregate share of projects that are valued in equilibrium. Then the total number of projects available for funding without valuation is the sum of the $1 - \psi$

[8] While it is possible that a sophisticated investor that does not invest in valuation capacity mimcs an unsophisticated investor and chooses a large amount of funding capacity, this does not affect the equilibrium price or quantity and we ignore this for ease of exposition.

[9] Once a fee is possible, investors will generally find it profitable to do stochatic valuation. We conjecture than equilibria of similar flavor exist in a model in which the fee is capped, say due to the possibility of mimicing a sophisticated investor and charging a fee and rejecting all applicants.

projects that are not valued and the $\psi(1-\lambda)$ that are valued and found to be bad, so that the share of projects that are good and seek funding without valuation is

$$\frac{\lambda(1-\psi)}{(1-\psi)+(1-\lambda)\psi}=\frac{\lambda(1-\psi)}{1-\lambda\psi}. \tag{2}$$

When no projects are valued, this equals the population share of good projects, λ. Knowing that all valuation capacity is used, we can write the aggregate constraint on valuation capacity as

$$\psi \leq \chi. \tag{3}$$

We denote by J^P an investor's value of a funding a project without valuation. This value is the expected discounted payout of the project less the price paid for the project

$$J^P=\frac{\left(\frac{\lambda(1-\psi)}{1-\lambda\psi}\right)D^g+\left(1-\frac{\lambda(1-\psi)}{1-\lambda\psi}\right)D^b}{R}-P$$

Price competition among unsophisticated investors leads to zero-profits in equilibrium, which implies that the pooling price is:

$$P(\psi)=\frac{\lambda(1-\psi)D^g+(1-\lambda)D^b}{(1-\lambda\psi)R} \tag{4}$$

Since the reservation value is one, the (net) value to the seller is

$$W^P=P-1 \tag{5}$$

which is also the social surplus. These is not accepted either if W^P is negative or if a sophisticated investor with funds is available and the expected value of going to this sophisticated investor is greater given the sellers information.

4 Equilibria

Given that valuation capacity is in short supply, investors must compete to fund projects with unsophisticated investors and with the sellers' reservation value. Thus P^g is determined by the indifference of sellers between going to a sophisticated investor and the better of the price offered by an unsophisticated investor and the reservation value ($W^V = Max\left[W^P, 0\right]$ and $\psi=\chi$) which implies

$$P^g=\max[P,1]. \tag{6}$$

Equilibria can now be characterized using equations (5), (4), (**??**), (1), (6), and (3). In any period, there are four possible equilibria to consider.

4.1 The pooling equilibrium

The first equilibrium is a strictly pooling equilibrium in which only no sophisticated investors invest in the valuation technology. In this equilibrium no projects are valued and every project has the population probability of turning out to be good. For this equilibrium to occur, a sophisticated investor must find it unprofitable to invest in valuation capacity and uninformed sellers must prefer going to unsophisticated investors to keeping the project, both when $\psi = 0$:

$$\begin{aligned} J^V &\leq 0 \\ W^P &\geq 0 \end{aligned}$$

The second inequality implies $P - 1 \geq 0$ (when $\psi = 0$), so that these conditions can be written as

$$\begin{aligned} c &\geq \lambda (1-\lambda) \frac{D^g - D^b}{R} \\ \lambda &\geq \frac{R - D^b}{D^g - D^b} \end{aligned} \tag{7}$$

The pooling equilibrium exists as long as i) the marginal cost of the valuation technology is large enough relative to the gain from valuation and ii) the population expected return without valuation is high enough. Note that the right hand side of the first inequality is equal to the probability of the project being good (λ) times the joint gain in value when it is good ($\frac{D^g}{R} - P = \frac{D^g}{R} - \frac{\lambda D^g + (1-\lambda) D^b}{R}$), which is the private value of information at the margin in the pooling equilibrium.

4.2 Equilibria with valuation

There are three possible types of equilibria in which investors invest in the valuation technology. First, there is a valuation equilibrium in which sophisticated investors value and fund as many good projects as they can and make profits, and the residual pool of projects is so poor on average that unsophisticated investors fund no projects. Second, there is a constrained mixed equilibrium in which sophisticated investors invest is an much valuation technology as they can, fund as many good projects as they can, and make profits, and the residual pool of projects is good enough on average so that the remaining investment is funded by unsophisticated investors. Finally, there is an unconstrained mixed equilibrium in which sophisticated investors invest in some valuation capacity $< \chi$, perform valuation and invest in some projects, unsophisticated investors fund the remaining projects, no investors make profits, and all uninformed sellers are indifferent between investors.

4.2.1 Pure valuation equilibrium

Consider first the valuation equilibrium. For this equilibrium to occur, each sophisticated investors must prefer to invest in valuation capacity and each uninformed sellers must prefer to go to a sophisticated investor or keep its project instead of going to an unsophisticated investor, both when $\psi = \chi$:

$$\begin{aligned} J^V &\geq 0 \\ 0 &\geq W^P \end{aligned}$$

Since $0 \geq W^P$ implies $P \leq 1$, we have that $P^g = 1$ and these conditions become

$$\begin{aligned} c &\leq \lambda \left(\frac{D^g}{R} - 1 \right) \\ \lambda &\leq \frac{R - D^b}{(D^g - D^b) - \chi (D^g - R)} \end{aligned} \tag{8}$$

The valuation equilibrium exists as long as i) the marginal cost of valuation is low enough relative to the gain from valuation, which is the probability that transaction occurs times the gain from transacting rather than the seller keeping the project and ii) the share of good projects is low enough that funding without valuation is not profitable after $\chi\lambda$ good projects are funded by sophisticated investors.

It is worth noting that in the valuation equilibrium, the gain to a marginal valuation is the screening of all the bad projects that have been found to be bad, whereas in the pooling equilibrium (equation (7)), the gain to valuation is based on valuation when all projects have probability λ of being good. Thus, as the share of good projects in the population (λ) increases to 1, the valuation equilibrium can occur for larger valuation costs (the first equation (8)) even though the information gained by valuation in equilibrium is vanishing. This previews one of the results of section 5.2, that valuation can be socially inefficient but privately optimal.[10]

4.2.2 The constrained mixed equilibrium

In the second possible equilibrium, sophisticated and unsophisticated investors both fund projects. While as in the pure valuation equilibrium, sophisticated investors are at capacity and make profits, here valuation capacity is so limited or the share of good projects so high that the remaining, unvalued projects still have positive expected net present value and are funded without valuation by unsophisticated investors. As above, sophisticated investors have market power and earn the rents of valuation, but now compete with unsophisticated investors rather than the seller's outside option. In this equilibrium, profit

[10] There is a discontinuity (outside our assumed range) at $\lambda = 1$, where the valuation equilibrium cannot occur for $c > 0$ even when $\chi = 1$.

maximization implies that uninformed sellers are indifferent between types of investors. Thus, for $\psi = \chi$

$$\begin{aligned} J^V &> 0 \qquad\qquad \text{(Constrained mixed equilibrium)} \\ W^V &= W^P \geq 0 \end{aligned}$$

The inequality $W^P \geq 0$ implies $P \geq 1$ which places an upper bound on ψ:

$$\psi \leq \bar{\psi} := 1 - \frac{(1-\lambda)\left(R - D^b\right)}{\lambda\left(D^g - R\right)} \tag{9}$$

With $P \geq 1$, the equality $W^V = W^P$ implies $P^g = P$. If $P^g > P$, every seller would prefer to first try to be funded by a sophisticated investor, so sophisticated investors would increase profits by decreasing P^g. Thus,

$$P^g = P = \frac{\lambda(1-\chi)D^g + (1-\lambda)D^b}{(1-\lambda\chi)R}$$

and the two conditions for the equilibrium to exist simplify to

$$\begin{aligned} \lambda &\geq \frac{R - D^b}{\left(D^g - D^b\right) - \chi\left(D^g - R\right)} \\ c &< \frac{1}{1-\lambda\chi}\lambda(1-\lambda)\frac{D^g - D^b}{R} \end{aligned} \tag{10}$$

The first inequality is the opposite of the first inequality for the valuation equilibrium and simply states that χ must be small enough or λ large enough that the sophisticated investors do not fund so many good projects that the funding without valuation has negative expected surplus because remaining projects are of such poor average quality. It is the complement to the first equation for the pure valuation equilibrium. As $\chi \to 1$, this lower bound on λ goes to 1. The second inequality is the reverse of a 'scaled up' (by $\frac{1}{1-\lambda\chi}$) version of the first inequality for the pooling equilibrium. More generally, these conditions require 'intermediate' values of parameters. If valuation is too expensive, funding with valuation cannot co-exist with funding without valuation. If the good project is too much better than the bad, funding without valuation is not profitable once sophisticated investors have funded some good projects after valuation.

4.2.3 The unconstrained mixed equilibrium

In the final type of equilibrium, for some $\psi \in (0, \chi]$, all uninformed sellers are indifferent between sophisticated and unsophisticated investors and sophisticated investors are indifferent between investing in more capacity and not. In appendix A, we show that this unconstrained mixed equilibrium exists for parameter values such that multiple equilibria are possible, that is for parameters such that the pooling equilibrium can exist and either the pure valuation or constrained valuation equilibrium can exist.

We do not focus on this equilibrium because it is 'unstable' in the sense that if enough sophisticated investors invested in more valuation capacity, they would reduce the quality of the sellers funded by the unsophisticated investors and valuation would make more profits and all sophisticated investors would like to have invested in more capacity to do valuation. Similarly, a slightly higher share of projects choosing to use unsophisticated investors would raise the price of funding without valuation, raising P and P^g and all sophisticated investors would have liked to have not invested in any capacity to do valuation.

5 Analysis

We first formally state our main results that there are regions of multiple equilibria, then rank them by efficiency, and finally, turn to the dynamics of a crash from the pooling equilibrium to a pure valuation or to a constrained mixed equilibrium.

5.1 Regions of multiple equilibria

The analysis of the previous section implies the following theorem.

Proposition 1 *(Multiple equilibria) In any period,*
(i) the region of parameters in which the pure valuation equilibrium can exist overlaps the region of parameters in which the pooling equilibrium can exist
(ii) The region of parameters in which the constrained mixed equilibrium can exist overlaps the region in which the pooling equilibrium can exist
(iii) The union of these two regions of multiplicity define the set of parameters in which the unconstrained mixed equilibrium exists.

Proof. There are allowable parameters that satisfy equation (7) and equation (8) and allowable parameters that satisfy equation (7) and equation (10). Part (iii) is proved in appendix A. ■

Figure 1 plots the areas in which each equilibrium exists in $\lambda - c$ space (and for $R = 1.1$, $G = 1.14$, $B = 1.09$, and $\chi = 0.90$). When the cost of valuation is low enough, only equilibria with valuation exist. When it is high enough, only the pooling equilibrium is possible. When the share of good projects is low enough, no equilibria or only the pure valuation equilibrium exist. When the share of good projects is large enough, only the pooling equilibrium exists. For intermediate costs of valuation and an intermediate share of good projects, multiple equilibria exist.

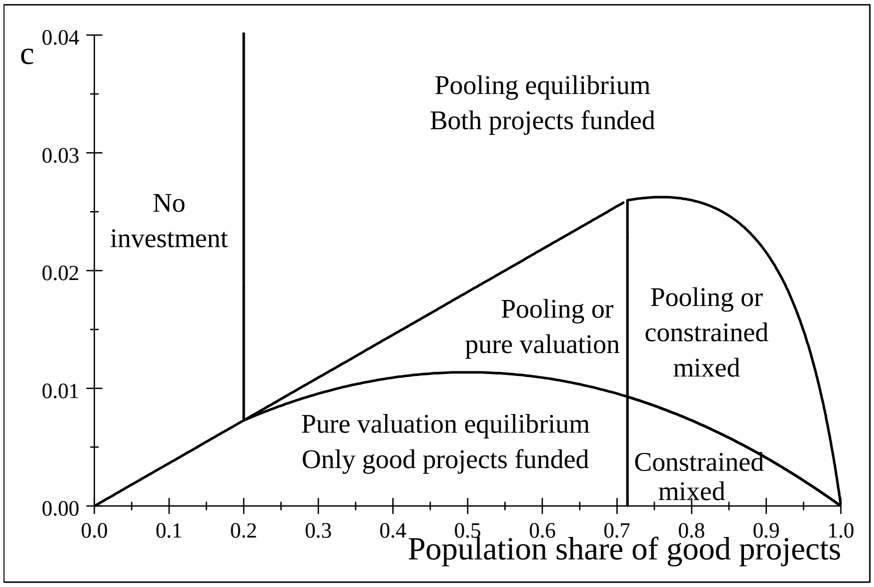


Figure 1: The regions where the pooling, pure valuation, and constrained valuation equilibria exist

5.2 Efficiency of equilibria

In this subsection, we first show that in the regions of multiplicity, the socially efficient outcome is the pooling equilibrium. More strikingly, even in some regions where the market delivers only an equilibrium with valuation, funding all projects without valuation would be Pareto superior. This latter occurs because the market has a tendency to produce too much information due to the externality that, when unsophisticated investors fund projects, bad projects lower the average quality of the projects that they fund.

Consider first the unconstrained mixed equilibrium The pooling equilibrium exists wherever this equilibrium exist. And the mixed equilibrium is clearly Pareto inefficient since all investment projects are undertaken, as in the pooling equilibrium, but in addition some valuations are done at cost c per unit of valuation capacity.

Second, consider parameters such that the constrained mixed equilibrium exists. Since again the pooling equilibrium funds all investment at less cost, the pooling equilibrium Pareto dominates the constrained mixed equilibrium. Further, even where the market does not deliver the pooling equilibrium, funding all investment without valuation is a more efficient outcome.

Third, consider parameter values such that the pure valuation equilibrium exists. In this region the constrained mixed equilibrium does not exist and, for high enough marginal cost of valuation technology, the pooling equilibrium does. Positing that the economy is in a pooling equilibrium, we show that the range of parameters over which a sophisticated investor would choose to invest in valuation capacity is a subset of the range over which a social planner – who can choose whether a project is funded following valuation – would invest in valuation technology.

To develop intuition first, assume that χ is arbitrarily close to one, so there is no inefficiency in the valuation equilibrium from not being able to value all projects. The central planner would like to invest in valuation capacity only if the cost, c, is less than the expected social benefit. This benefit is the probability in the population that any given project is bad $(1-\lambda)$, times the gain from not funding it, which in turn is the reservation value of the seller less the present value of the project $(1 - D^b/R)$.[11] Given linearity (and $\chi = 1$), if the central planner chooses to do one valuation, they would choose to value all projects and prefer the valuation equilibrium.

Now consider a sophisticated investor choosing whether to invest in a unit of valuation or instead to mimic an unsophisticated investor and fund one project without valuation. In either cases, if the project is good, it is funded at the market price P. The private cost of valuation capacity is the same as in the social planner's problem, c. The expected private benefit is the population probability that a project is bad – again, as in the social planner's problem – times the gain to not funding it, which is the market price less the payout of the bad project $(P - D^b/R)$, which is greater than the benefit in the central planner's problem since the pooling price is greater than or equal to the reservation value $(P \geq 1)$ for any parameters in which the pooling equilibrium exists. Thus we conclude both that the pooling equilibrium is Pareto superior to an equilibrium with valuation wherever both exist and that outside of this region, where the only the pure valuation equilibrium exists, there are parameters such that funding all investment without valuation is Pareto superior.

The interesting insight is that the existence of funding without valuation subsidizes the valuation by sophisticated investors and so limits the region where the pooling equilibrium can exist. Considering a small investment in valuation capacity from the pooling equilibrium, if sellers whose projects were found to be bad could not get funding from an unsophisticated investor, they would require a higher price to go to a sophisticated investor.

When $\chi < 1$, the argument must account for the additional inefficiency of the pure valuation equilibrium that some unvalued projects that have positive expected surplus are not funded. In the pure valuation equilibrium, since sellers are all at their reservation values total social surplus is given by the sum of the profits of the valuation done by sophisticated investors:

$$\chi\left(-c + \lambda\left(\frac{D^g}{R} - 1\right)\right)$$

If instead all projects are funded without valuation, investors all make zero profits and

[11] There is no gain associated with good projects since they are funded in both equilibria.

total social surplus is given by the total payouts to the unit mass of sellers:

$$\frac{\lambda D^g + (1-\lambda) D^b}{R} - 1.$$

Subtracting gives that pooling is thus socially preferred to valuation when

$$c \geq \frac{(1-\lambda\chi) R - (1-\lambda) D^b - (1-\chi) \lambda D^g}{\chi R}.$$

As shown in Figure 2, the lower bound of this region is the line (in $\lambda - c$ space) that runs from the point on the boundary between the pure valuation and pooling equilibria where $P = 1$ to the maximum λ where the pure valuation equilibrium exists and $c = 0$ (where $P = 1$ also).

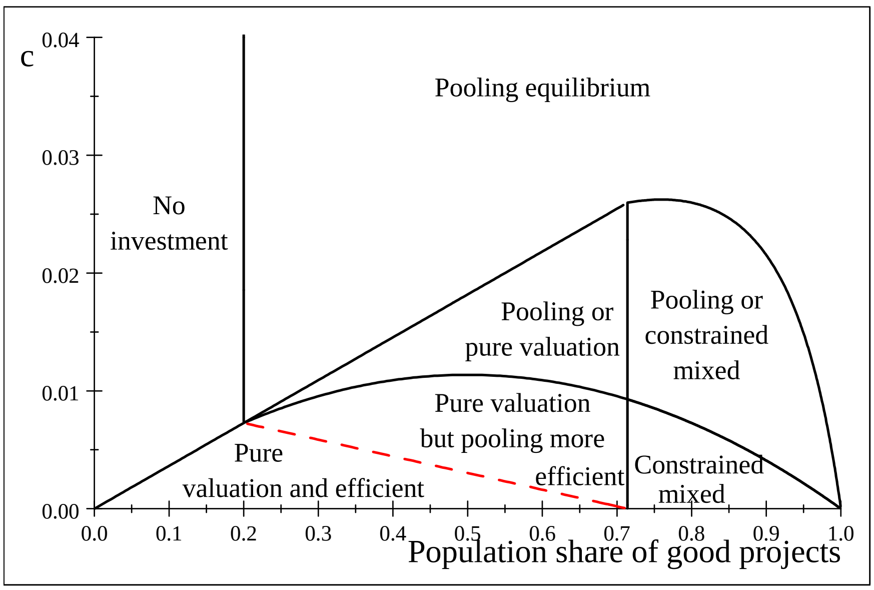


Figure 2: Figure 2: The regions where the pooling, pure valuation, and constrained valuation equilibria exist

To sum up, we state these results formally.

Proposition 2 *Pareto ranking of equilibria*
i) For parameters such that the pooling equilibrium exists, it Pareto dominates the pure valuation equilibrium, the constrained mixed equilibrium, and the unconstrained mixed equilibrium;
ii) for parameter values such that the only market equilibrium is the constrained mixed equilibrium, this equilibrium is Pareto dominated by no valuation and funding all investment;

iii) for parameter values such that the only market equilibrium is the pure valuation equilibrium, if

$$c \geq \frac{(1-\lambda\chi) R - (1-\lambda) D^b - (1-\chi) \lambda D^g}{\chi R}$$

then the market equilibrium is Pareto dominated by no valuation and funding all investment.

5.3 Investment crashes as sequences of equilibria

Investment booms and crashes often accompany new real investment opportunities or new assets. For many new investment opportunities – such as sub-prime mortgages, internet start-ups, FDI in China, asset-backed commercial paper, firms in a newly reformed developing economy – we observe the common market belief that, conditional on some observable conditions being met, the investment has positive net present value. Rates of investment are high and credit is easy. Because this is a new type of investment opportunity, there is a limited track record of which investment projects will pay off well and which poorly. In these circumstances, valuation beyond a certain point is difficult. However, over time, specialists observe returns and are better able to distinguish which projects will succeed and which fail, and the cost of valuation declines. Alternatively (or additionally), since capital is flowing into the market without careful valuation, the quality of the pool of sellers of these projects may decline over time (as, for example occurred in the case of sub-prime mortgages). In our model, either of these (exogenous) changes can bring about an investment collapse that has many of the features of the collapse of bubbles or a 'run' on an asset class.

First, motivated by the improvements in the ability to value new investments over time, consider our model in which the marginal costs of valuation (exogenously) declines over time to zero, so that $\{c_t\}$ is a declining sequence. Also, initially assume that the share of good projects is in an 'intermediate' range where the pure valuation equilibrium can exist. As long as valuation costs are high enough, the market is in a pooling equilibrium and all projects are funded by all investors. However, as valuation costs decline the market enters the region of multiple equilibria where the pure valuation equilibrium and the pooling equilibrium are possible. In this region, investment can collapse or boom as either equilibrium can be selected in any period.[12] However, once valuation costs fall low enough, the market necessarily falls into the valuation equilibrium.

The movement from the pooling to the valuation equilibrium exhibits many of the stylized features of investment crashes. In particular

1. Investment collapse: The volume of investment declines from 1 to $\chi\lambda$ as only sellers that can get their projects valued and whose projects are found to be good receive

[12] The date of collapse could be determined by assumptions about lack of common knowledge about fundamentals, following the literature on multiple equilibria builind on Morris and Shin (1998).

funding.

2. Price collapse: Transaction prices fall from $\frac{\lambda D^g+(1-\lambda)D^b}{R}$ to 1 (spreads or interest rates increase). This occurs because in the pooling equilibrium projects are scarce and valuation is not required to invest profitably so projects get high prices and marginal investment earns the opportunity cost of funds. In the valuation equilibrium, only skilled investors fund projects, compete for this limited valuation technology, and prices for projects are low as skilled investors earn profits and sellers receive their outside option.

3. Nonfundamental volatility: The crash may not be driven by fundamentals, but rather could be triggered by any small coordinating event, although fundamentals make collapse ultimately inevitable.

4. Funding crunch: Some projects that would have been funded in the pooling equilibrium, even some unvalued projects (and so some good projects), cannot get funding in the valuation equilibrium.

5. Flight to quality: Unsophisticated investors no longer channel funds to these investment but instead invest in their alternatives. Also, only good projects get funded, where before all projects were funded.

6. Trust declines/lending standards tighten/due diligence increases: No investor invests without valuation.

7. Profits for sophisticated investors: Sophisticated investors make profits and unsophisticated investors fund no investment.

What if the share of good projects is 'high' so that the market ultimately switches from the pooling equilibrium to the constrained mixed equilibrium? In this case, the switch in equilibrium exhibits features 2, 3 and 7 and partly 6. Prices fall from $\frac{\lambda D^g+(1-\lambda)D^b}{R}$ to $\frac{\lambda(1-\chi)D^g+(1-\lambda)D^b}{(1-\lambda\chi)R}$ (interest rates rise), the collapse may be triggered by a non-fundamental event, sophisticated investors make profits, and trust declines but some investment occurs without valuation. But real investment does not decline, there is no funding crunch, and no flight to quality.

The second scenario for an investment collapse is the deterioration in the average quality of projects. When a market is not doing valuation, there is no reward to a seller for higher project quality. While the quality is exogenous in the model, in the world, the share of good projects may decline because there is no return to the sellers of projects to improving their projects in the dimension not valued in the pooling equilibrium.[13]

In our model, consider a sequence of equilibria in which $\{\lambda_t\}$ starts very close to one and declines and c is in an intermediate range where, for some λ, the pure valuation

[13] Alternatively, sellers with known bad projects may try to bring them to this market.

equilibrium is possible. In this case, if the market begins in the pooling equilibrium, as λ declines, first a price collapse becomes possible as the constrained mixed equilibrium becomes possible, then an investment collapse becomes possible as the pure valuation equilibrium becomes possible.[14] If λ continues to decline, either the market can return to (or remain in) the pooling equilibrium and eventually shut down (for high c), or it enters the pure valuation equilibrium and eventually shuts down (low c).

6 Policy

In our rational expectations modelling approach, all agents know which equilibrium is preferable, so there is the potential for Pareto improving coordination or government policy in the model. Given the many extant arguments for the value associated with the creation of information, and since in reality government policy interventions operate in a world of highly imperfect information, it is worth emphasizing that this section studies optimal policy in the model not the real world.

To begin, why does the market not deliver the Pareto superior equilibrium? The first answer is that valuation has an externality – it creates information on which adverse selection can occur which then undermines the no-valuation equilibrium. An alternative way of viewing this externality is that funding by unsophisticated investors subsidizes the valuation by sophisticated investors since any project found to be bad can still get funded at the market price. The most direct optimal policy is then to tax investment in valuation capacity. That is, if the market may have valuation and the pooling equilibrium is optimal, set the cost of valuation capacity to τc and set τ high enough that valuation is not a market.

We consider four other policies.

First, subsidizing investment or lowering interest rates actually increases the region in which the valuation equilibria is the only equilibrium and the region in which it is possible. Raising the interest rate can held reduce valuation by lowering the present value of the information gathered by valuation, which is proportional to $\frac{D^g - D^b}{R}$. In the figure below raising the interest rate (from $R = 1.10$, solid lines, to $R = 1.11$, dashed lines) reduces the size of region of multiplicity and the size of the region in which valuation can occur in conjunction with pooling.

[14] Once the pure valuation equilibrium occurs, there is no incentive for further deterioration in λ.

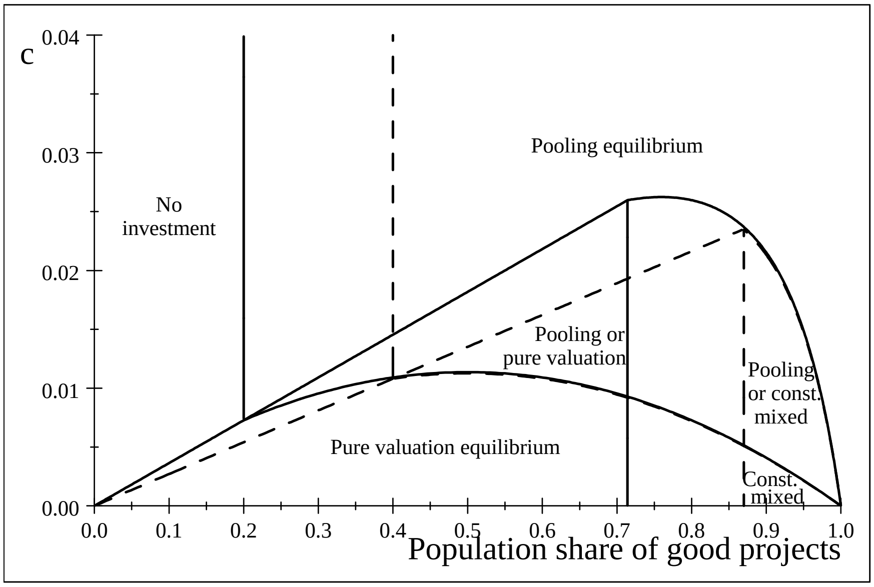
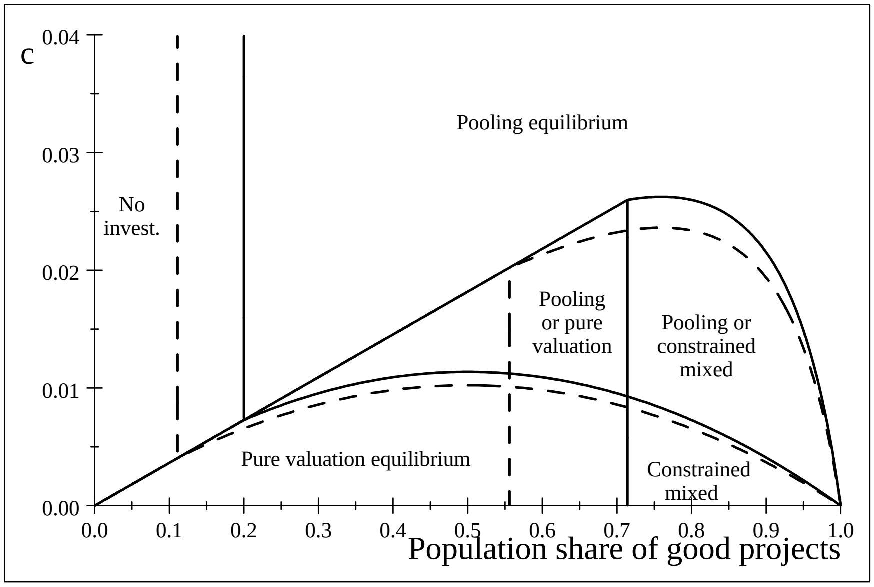


Figure Comparative statics: higher real interest rate

Second, raising the payout of bad projects reduces the regions in which valuation in equilibrium is possible and the regions in which it is inevitable. This works because it reduces the economic return to separating the good from the bad. This policy has some of the flavor of the TARP programs that provided funding and took some of the downside risk of private investors asset purchases. The figure shows that raising the payout of the bad projects (from $D^b = 1.090$ (solid line) to $D^b = 1.095$(dashed line)) increases the size of the pure pooling equilibrium and decreases the size of the pure valuation region, and raises the size of the region where the pooling equilibrium coexists with the constrained mixed equilibrium.



Higher value of bad project

Third, because the pooling equilibrium is more efficient, a large unsophisticated investor with the ability to commit to fund projects at the pooling price can ensure that the market selects the pooling equilibrium wherever it is possible for the market to do so. Specifically, consider the strategy of a large unsophisticated investor that can commit before investments in valuation capacity are made to funding all projects at a given price. If it chooses the price that would occur in the pooling equilibrium, $P = \frac{\lambda D^g + (1-\lambda) D^b}{R}$, then since $P^g \leq P$ to compete with this source of funds, it is straightforward to verify that $J^v < 0$. Thus, no sophisticated investors would invest in valuation and only the pooling equilibrium would exist. This policy is closely related to models of securitization (Gorton and Pennacchi (1990) and DeMarzo (2005)).

Further, subsidizing this large investor can also ensure that the economy be in a pooling equilibrium wherever it is more efficient. In terms of applicability, such a large investor has the incentive to monitor the market carefully since it would have a very low payoff if sophisticated investors invested in valuation capacity and it followed through on its commitment to fund projects at a high price that will on average be low quality. It is also worth noting that there are incentives to undermine this policy: in the pooling equilibrium, the large unsophisticated investor earns no rents, while in the valuation equilibrium, sophisticated investors make profits.

Fannie Mae and Freddie Mac seem like examples of this policy in practice (including the large losses scenario). In the market for conforming mortgages for example, a small fraction of projects (mortgages) are 'bad' so that λ is close to one. For λ close to one, equilibria with valuation when they exist are likely to be inefficient. And a large investor that funds a large fraction at high prices can keep other from investing in valuation capacity.

Finally, and violating the assumptions of the model, if the government could make either valuation, or better, its outcome publicly observable, then valuation would not have an externality and the market outcome would be optimal. The real world difficulties are both that the sophisticated investors and projects found to be bad have an incentive to hide the outcome of valuation and that sellers can repackage projects (a reformed business plan, attempting to purchase a different house, etc.) and decrease the informativeness of this public signal.

7 Concluding discussion

What assumptions of the model are robust and which not?

First, consider the assumption that the outcome of valuation is not observed. There is no incentive for the parties involved to reveal this information. In fact, when the unsophisticated investors are funding investment, there is exactly the opposite incentive. The sophisticated investor can fund a seller with project at a lower price if the seller can subsequently fund the project at a pooling price if valuation shows that the project is bad. Similarly, sophisticated investors make profits in the valuation equilibrium, and for parameters such that the pooling equilibrium is also possible, unsophisticated investors would eliminate those profits if the unsophisticated investors could observe who was and was not valued.[15]

Credit bureaus seem to provide some of this information. But one might infer that they work for sophisticated investors since they do not reveal who has conducted credit checks to other users (something that an unsophisticated (Countrywide) mortgage broker would find useful).

Second, the fact that sellers have no funds and so cannot be charged an arbitrarily large fee does matter for the equilibria we describe. As noted, we conjecture, based on preliminary work, that with a fee bounded by the ability of the investor to collect a fee and always reject, a qualitatively similar region of Pareto-ranked multiple equilibria exist. More generally, screening with contracts is simple in theory and complex in practice. Even in a model, with enough heterogeneity in project size, available funds, and risk aversion, and a realistic lack of single-crossing properties, our main results may still hold.

[15] Where pooling and valuation equilibria both exist, the pooling equilibrium is more efficient. Thus the unsophisticated investor would fund a pool of unvalued projects at a high enough price that the sophisticated investor does not find it worth investing in valuation capacity.

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Appendices

A The unconstrained mixed equilibrium

This equilibrium can occur if for some $\psi \in (0, \chi)$,

$$\begin{aligned} J^S &= 0 \qquad \text{(Indifferent mixed equilibrium)} \\ W^S &= W^P \geq 0 \end{aligned}$$

As for the constrained mixed equilibrium, this thus requires, $\psi \leq \bar{\psi}$ and $P^g = P$. If this were not the case, every sellers would prefer to first try a sophisticated investor, so sophisticated investors would invest in more valuation technology. Equations (Indifferent mixed equilibrium) and (6) imply $P^g = \frac{D^g}{R} - \frac{c}{\lambda}$, so that $P^g = P$ implies

$$\psi^* = \frac{1}{\lambda} - (1 - \lambda) \frac{D^g - D^b}{R} \frac{1}{c} \tag{A.1}$$

Thus, this equilibrium exists when

$$\psi^* \in \left(0, \min\left[\chi, \bar{\psi}\right]\right]. \tag{A.2}$$

or

$$\begin{aligned} c &> \lambda (1 - \lambda) \frac{D^g - D^b}{R} \\ c &\leq \frac{1}{1 - \lambda\chi} \lambda (1 - \lambda) \frac{D^g - D^b}{R} \\ c &\leq \lambda \left(\frac{D^g}{R} - 1 \right) \end{aligned}$$

The first inequality is a strict inequality version of the first condition for the pooling equilibrium (equation (7)) and implies that valuation must be costly enough that not all sophisticated investors choose to do valuation. The second inequality is the same as the second inequality for the constrained mixed equilibrium, and so is the reverse of a 'scaled up' (by $\frac{1}{1-\lambda\chi}$) version of the first inequality for the pooling equilibrium. is a strict inequality version of the first condition for the valuation equilibrium (equation (8)).The third inequality is the same as the first inequality for the valuation equilibrium.

This equilibrium is unique, in that there is only being one ψ that supports this equilibrium.