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VALUATION, ADVERSE SELECTION, AND MARKET COLLAPSES

Michael J. Fishman  
Jonathan A. Parker

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**ABSTRACT**

Valuation has an externality: it creates information on which adverse selection can occur. We study a market in which investors (or lenders) buy uncertain future cash flows that are ex ante identical but ex post heterogeneous across assets from sellers (or borrowers) with reservation values. There exists a limited amount of a costly technology that can be purchased before the market opens that allows an investor to value an asset — to get a private signal of the future payoff of that asset. Because sellers of assets that are valued and are rejected can sell to other investors, there are strategic complementarities in the choice of the capacity to do valuation, the private benefits to valuation exceed its social benefits, the market can exhibit multiple equilibria, and the market can deliver a unique valuation equilibrium when it is more efficient to transact without valuation. In the region of multiplicity, the move from a pooling equilibrium to a valuation equilibrium is always socially inefficient and has many features of a financial crisis: interest rate spreads rise, trade declines, unsophisticated investors leave the market, and sophisticated investors make profits. The efficient equilibrium in the region of multiplicity can be ensured by a large investor with the ability to commit to a price. We characterize several policies that can improve on market outcomes.

Michael J. Fishman  
Kellogg School of Management  
Northwestern University  
Jacobs Center, Room 417  
2001 Sheridan Road  
Evanston, IL 60208-2006  
m-fishman@kellogg.northwestern.edu

Jonathan A. Parker  
Finance Department  
Kellogg School of Management  
Northwestern University  
2001 Sheridan Road  
Evanston, IL 60208-2001  
and NBER  
Jonathan-Parker@Kellogg.Northwestern.edu

# 1 Introduction

Most real investment – buying a house, starting or expanding a firm, or maintaining a business in bad times – relies on external financing, a transfers of resources today for a claim on uncertain resources in the future. Markets for external financing exhibit crises or panics in which both the volume of funding and prices collapse. Notable recent examples in the U.S. include collapses in markets for mortgages lending, for the commercial paper of financial institutions, for venture capital, and for trading and originating asset-backed securities.

In this paper, we present a theoretical model of a market for external financing and study booms and crashes based on different equilibrium levels of valuation by market participants. The model has four key ingredients. First, sellers seeking funds sell claims to future payments that are ex post heterogeneous but are ex ante identical. Second, a subset of financial investors (buyers) can commit to perform a limited number of costly evaluations of these ex ante identical assets and receive signals about future payoffs. Third, sellers have a fixed reservation value for selling due for example to the possibility of not undertaking the real activity being funded. Finally, assets that are evaluated by one investor and not bought can be sold to another investor.

In this setting, we show that valuation creates asymmetric information on which adverse selection can occur, and that this externality generates strategic complementarities in valuation that can lead to multiple equilibria. The move from an equilibrium without valuation to an equilibrium with valuation has many features of a credit crunch: when valuation increases, interest rate spreads rise, lending/trade in assets declines, unsophisticated investors leave the market, and sophisticated investors make profits. Because the private benefits to valuation exceed its social benefits, the equilibria without valuation are more efficient, so that in the region of multiplicity switching from an equilibrium without valuation to one with valuation is undesirable. In terms of policy, to ensure the efficient outcome requires not just a large, unsophisticated investor, but one with the ability to commit to a price ex ante, and, in some regions of the parameter space, also a subsidy for purchasing.

More specifically, we consider a rational expectations model of a competitive market in which risk neutral sellers (real investors) sell assets at prices above their reservation values, and risk neutral financial investors compete to purchase these assets given a fixed opportunity cost of capital. Assets are ex ante identical but ex post payoffs are heterogeneous across assets. Untraded assets disappear at the end of each period so that periods are physically unconnected.

There are two types of investors. *Unsophisticated* investors are competitive price-takers who buy assets at their expected present discounted values. *Sophisticated* investors invest ex ante in capacity to perform valuation and, through choice of funds, can commit to valuing before buying any assets. Valuation capacity is costly and limited in aggregate. The use of a unit of valuation capacity provides a signal of the quality of an asset. Conditional on a good signal, an asset is worth more than the reservation value in expectation; conditional on a bad signal, it is not. Valuation is unobservable and nonverifiable, and all sellers are anonymous in the sense that, the never-valued asset is indistinguishable from the previously-valued asset to every seller except the one that performed the valuation. Thus a sophisticated investor who values an asset, observes a bad signal of the future payoff, and does not buy it, decreases the average quality of the pool of assets for other investors, which lowers the equilibrium price paid by unsophisticated investors and raises the profitability of valuation. This externality makes valuation a strategic

complement.<sup>1</sup>

There is a range of parameters over which the market has multiple equilibria. In a *pooling equilibrium* no asset is valued, all assets are traded/funded, and because investors with unlimited capital compete to purchase assets, prices are high. In a *valuation equilibrium* sophisticated investors invest in valuation capacity, value as many assets as they can, and only good assets are sold/funded. In this valuation equilibrium, because sellers compete for limited valuation capacity, prices are low. The multiplicity is due to the strategic complementarity. The more assets are valued, the lower the average quality of unvalued assets. If the average quality falls below the seller's reservation value, unsophisticated investors leave the market, and only assets that are valued and found to be good are traded.

A switch from a pooling equilibrium to a pure valuation equilibrium matches many of the features observed in credit crunches or asset market panics.<sup>2</sup> In the pooling equilibrium (credit boom), market liquidity is high and all assets are traded/funded. In the valuation equilibrium, there is a decline in trade and observed prices fall (interest rates rise).<sup>3</sup> The price decline occurs because unsophisticated investors leave the market and market power changes from one in which assets are in short supply to one in which the ability to do valuation is in short supply. Sophisticated investors earn profits.<sup>4</sup> There is a credit crunch: in the collapse, sellers with assets (some good) that would have been sold in the pooling equilibrium are unable to get evaluated and so unable to sell in the valuation equilibrium. There is a flight to quality in two senses: only good assets are traded/funded, and unsophisticated investors leave the market and hold their funds elsewhere. Finally, because of the multiple equilibria, this shift need not be tied directly to changes in fundamentals, although changes in fundamentals can bring about the possibility of collapse and/or make collapse ultimately inevitable.

In this region of multiplicity, the benefit of valuation is not funding bad projects, yet the socially efficient outcome is the pooling equilibrium with no valuation. This follows from the fact that in the pooling equilibrium, the planner problem of whether to switch to the valuation equilibrium is (almost) the same as the sophisticated investor's problem in the decentralized market of whether to invest in the first unit of valuation capacity. Both decisions trade off funding conditional on valuation against funding without valuation given the population share of good assets. More strikingly, even in some regions where the market delivers only the valuation equilibrium, the pooling equilibrium is more efficient. This follows from the fact that in the pooling equilibrium, the presence of unsophisticated investors subsidizes investment in valuation capacity. If a seller had an asset that was valued and found to be bad and it could not go to an unsophisticated investor, it would be more averse to going to a sophisticated investor doing

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<sup>1</sup>In the language of Hellwig and Veldkamp (2009), the choice of the technology to uncover information is a strategic complement, but the actual information gathered is a strategic substitute, in that sophisticated investors want different information from each other (information about different assets).

<sup>2</sup>Over a different region of parameters, the market can either be in a pooling equilibrium or a constrained mixed equilibrium in which sophisticated investors value as many assets as they can and buy/fund the good ones and unsophisticated investors buy/fund both the rejected assets and the un-valued assets.

<sup>3</sup>In a bank run agents protect themselves by withdrawing funds because they expect others to do so and funds are not lent to a common entity; in our model, sophisticated agents protect themselves by investing in valuation capacity because they expect others to do so and funds are not lent to many distinct entities.

<sup>4</sup>While we do not model what happens to assets once sold, in mapping to the real world, all investors potentially have mark-to-market losses on asset holdings due to the price decline.

valuation. Thus, financial market crashes of the kind just described are inefficient, even in some cases where they are driven by fundamentals and are inevitable.

Can policy correct market outcomes when inefficient? First, subsidizing trade or lowering interest rates is counterproductive, in that it actually increases the region in which the valuation equilibria is the only equilibrium and the region in which it is a possible equilibrium. Second, subsidizing the payout of bad assets reduces the region in which valuation in equilibrium is possible by reducing the economic return to separating the good from the bad. Third, a tax on valuation capacity can ensure the pooling equilibrium wherever it is efficient.<sup>5</sup>

More interestingly, because the pooling equilibrium is more efficient, a large unsophisticated investor with the ability to commit to purchase assets at the pooling price can ensure that the market selects the pooling equilibrium wherever there are multiple equilibria. Further, if the government subsidizes this large investor, it can ensure that the economy is in a pooling equilibrium wherever a pooling equilibrium would be more efficient. That said, this policy can be quite detrimental if the model is misparameterized or misapplied so that the large investor does not deter valuation and purchases at a high price previously-valued assets.

Finally, one might consider policy changes to the model environment to make valuation observable. This could eliminate the valuation externality. However, the incentive of the paired sophisticated investor and seller with a bad asset is to hide both the fact of and the outcome of valuation.

This model omits many factors that amplify and cause financial crises.<sup>6</sup> In what circumstances is its logic more likely to apply? Our model captures the market for assets that are ex ante equivalent and the financial fluctuations in the model are increases or decreases in valuation, and so increases or decreases in market segmentation and market depth. While some valuation occurs in all markets for external finance, every asset is valued up to some point, and then pooled with observationally equivalent assets. For our model to explain a part of a financial crises, it must be that one market is particularly important – as for example the market for AAA commercial paper or the mortgage market – or equilibrium selection must be correlated across markets. And the model is most relevant when bad signals are rare, as in markets for issuance either of highly-rated debt that is ex ante unlikely to default or of equity for new, firms that are almost sure to make productive use of new funds (e.g. the dot com or IPO markets).

We see two situations where the model may prove useful. First, in new markets there is little record on the performance of new types of assets and the investment associated with them. The cost of valuation for some information is initially high and the market is necessarily in a pooling equilibrium with respect to such information. As different assets/investments are observed to profit or fail, valuation costs may 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 investment opportunity. Second, in markets where initially all assets are good, the market

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<sup>5</sup>It is important to note that the model omits many benefits of valuation, most notably that valuation might reveal information about the aggregate payoff of all assets.

<sup>6</sup>A short list of important papers focussed on omitted factors: Diamond and Dybvig (1983) Bernanke and Gertler (1989), Kiyotaki and Moore (1997), Holmstrom and Tirole (1998), Caballero and Krishnamurthy (2003, 2008), and Geanakoplos and Foellmi (2009).

is automatically in a pooling equilibrium. But since there is no incentive to produce assets of higher quality among assets that are sold at identical prices, the share of good assets may naturally decline over time, which again makes a collapse to the valuation equilibrium possible and possibly inevitable.<sup>7</sup>

The paper is organized as follows. The next section describes the related literature not discussed elsewhere and Section 3 presents the model. Section 4, using two lemmas, derives the value functions as a function of equilibrium variables. Section 5 contains a characterization of the equilibria of the model. Section 6 gives our main result on multiplicity and efficiency of equilibria, interprets an equilibrium switch as a contributor to a financial crisis, and discusses the importance of several modelling assumptions. Section 7 contains analysis of five possible policy interventions to correct market inefficiencies and a final section concludes.

## 2 Related literature

Our main contributions – the multiple equilibria, booms/busts, and the welfare and policy implications – stem from endogenous acquisition of information possibly leading to market collapse due to adverse selection and so build directly on Akerlof (1970)’s seminal model and Hirshleifer (1971)’s insights about the timing of the arrival of information. The key to our results is the type of information acquired. Most work on information acquisition and the trading and pricing of financial assets assumes that the information acquired either reveals and makes into common knowledge information that which was previously private information and so solves problems of asymmetric information, or alternatively provides information about payoffs that are common across assets and so is revealed by trade and underproduced from a social perspective. In contrast, our key modelling choice is that valuation reveals information about a payoff that is common across agents but specific to the particular asset.<sup>8</sup> This sets our paper apart from the literature on the strategic revelation of private information (e.g. Berk and Uhlig (1991)), the literature on the incentive to value assets (and the Grossman-Stiglitz paradox), and the literature using costly state verification.<sup>9</sup> Relative to previous work on adverse selection in lending markets, we focus on parameters where the random, unvalued assets (loan) is worth buying (making) at a given market price and so the market can be operative without valuation.

Our results that the capacity to do valuation is a strategic complement and that valuation has a negative externality are closely related but distinct from previous insights in Dang (2008). Dang (2008) shows that increased information acquisition on one side of a trade increases the incentive to acquire information by the agent on the other side. In this sense, both papers contribute to research on the value of private information.<sup>10</sup> And while we address

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<sup>7</sup>Both situations, and the model, echo some of the features of the 2007-2008 financial crisis. See Gorton (2010) for example.

<sup>8</sup>An interesting paper with a similar approach to information but a different structure is Broecker (1990) in which valuation is costless but noisy, and correlated across lenders. In equilibrium, the winners curse from noisy valuation interacts with the adverse selection problem to generate an equilibrium with a continuum of interest rates across different banks.

<sup>9</sup>Models of costly state verification (Raviv (1975) and Townsend (1979)) typically use the verification technology to make what had been private information into common knowledge, so that valuation is used to eliminate problems associated with asymmetric information.

<sup>10</sup>See for example Angeletos and Pavan (2007), Mackowiak and Weiderholdt (2009), and Myatt and Wallace

different topics and use different screening technologies (costly state verification vs. screening with contracts), our paper is closely related to the contemporaneous paper Bolton, Santos, and Scheinkman (2011) which considers the long-term rise of the financial sector. In Bolton, Santos, and Scheinkman (2011), agents choose to become sophisticated as a career, and then compete with unsophisticated exchanges. Unlike in our model, sellers know their type and take unobserved actions leading to a moral hazard problem.

Our paper is far from the first to study fluctuations in the strength of adverse selection in financial markets; notable examples include Mankiw (1986), Eislefeldt (2004), Kurlat (2010), and Morris and Shin (2012).<sup>11</sup> In general, our contribution is to make the information on which adverse selection occurs endogenous, and as such it builds on the important papers Ruckes (2004) and Dell’Ariccia and Marquez (2006), which both consider how adverse selection and lending standards leads to contractions of credit in bad times.<sup>12</sup> The former shows how the probability that a borrower is of a bad type changes the private value of information which in turn is amplified through the winners curse. The latter focusses not on the creation of information but rather on contract terms (specifically collateral requirements) and how these change in response to exogenous 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, fewer new projects implies a lower share of good projects approaching banks and a tightening of lending standards and reduced credit.<sup>13</sup>

Finally, an important subset of this literature is that related to security design and securitization that focusses on how informed issuers destroy information to create a pooling equilibrium (Gorton and Pennacchi (1990), DeMarzo (2005), and DeMarzo and Duffie (1999)). 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 adverse selection on private information relative to the costs of reduced ex ante insurance. More closely related to our paper, Dang, Gorton, and Holmstrom (2009) considers security design when the aftermarket may have valuation that hinders trade (as in Dang (2008)). And Pagano and Volpin (2008) consider security design and then a later equilibrium in which trade occurs in a noisy rational expectations equilibrium so that information can get rents. While the model exhibits an externality from valuation, it does not generate multiplicity of equilibrium (beyond those always possible in noisy rational expectations equilibria (Breon-Drish (2011))), nor is there a role for commitment and so optimal policy is different.

### 3 The model

We consider a model in which periods are physically unconnected over time and focus on equilibria in the static game.<sup>14</sup> In this section we focus only on one period. In later sections we consider dynamics with exogenously changing parameters.

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(2009). Veldkamp (2011) provides an excellent and broad discussion of this literature.

<sup>11</sup>All of which in turn owe much to Stiglitz and Weiss (1981) and Rothschild and Stiglitz (1976).

<sup>12</sup>More recently, Gorton and Ordonez (2012) studies fluctuations in informed lending in secondary markets.

<sup>13</sup>There is also work on bank credit cycles, such as Gorton and He (2007) which studies changes in valuation driven by collapse of collusive equilibria among banks (ala Green and Porter (1984)).

<sup>14</sup>In Fishman and Parker (2012), we study a model in which assets do not disappear if unpurchased.

At the beginning of the period, a unit mass of risk-neutral sellers (real investors) each enter the market seeking to sell a risky claim to a real investment to a large number of competitive risk-neutral financial investors each with access to unlimited funds at constant gross interest rate  $R > 1$ . Each seller has one asset of fixed size, has no funds, and has a reservation price of 1. The asset if sold pays out a random amount  $D$  in the future and the seller must sell all the asset or none of it. The most natural interpretation of this setup is that the seller has a project that only it can undertake, that costs 1, and that therefore is only worth doing if it can sell the future stream of profits for more than the cost to undertake the project.<sup>15</sup> All sellers and investors initially have common expectations of the future payout of the asset,  $E[D]$ .

Sellers are anonymous: within the period, a seller can visit a finite number of 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.<sup>16</sup> Sellers that sell their assets leave the market at the end of the period and sellers with unsold assets disappear at the end of the period. Thus periods are not physically connected.

There are two types of investors. Unsophisticated investors cannot do valuation and have a flexible amount of funds. Sophisticated investors must choose at the beginning of the period (before any buying or selling) both how much capital to raise to purchase assets ( $f$  for funds) and how much valuation technology to acquire ( $h$  for human capital).<sup>17</sup> The cost of a unit of valuation capacity is  $c$  up to  $\chi_i$  for sophisticated investor  $i$ , and infinite thereafter, so  $h_i \leq \chi_i$ .<sup>18</sup> We denote the aggregate amounts of funding and valuation capacity by  $F$  and  $H$  respectively, and the aggregate constraint on total valuation capacity by  $\bar{\chi} < 1$ , so

$$H \leq \bar{\chi}. \tag{1}$$

One unit of valuation technology allows the valuation of one asset which reveals a binary signal of the quality of that asset. The expected payoff of an asset is  $D^g = E[D|good]$  conditional on a good signal and  $D^b = E[D|bad]$  conditional on a bad signal. A good asset is worth investing in/buying and a bad asset is not:

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

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

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

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<sup>15</sup>An alternative interpretation is that the asset is an existing asset, but that the seller has limited exposure to the downside risk, for example due to bankruptcy, their particular compensation contract, or a bailout. In this alternative interpretation, if there is no social benefit to not selling bad assets, an equilibrium without valuation is more efficient for all parameter values.

<sup>16</sup>This assumption is a static analog to a continuous process with valued projects indistinguishable from new entrants. A similar mechanism is used in Zhu (forthcoming) in which sellers pursue sequential search but buyers do not know in what order the seller has gone to potential buyers. And to be clear, implicit in this assumption is the inability of sellers with unvalued projects to commit to delay sale ala Guerrieri and Shimer (2012) and Chang (2011).

<sup>17</sup>The choice of funding capacity is a device to allow buyers to commit to do valuation. This commitment is not infrequently simply assumed in the cited literature.

<sup>18</sup>The constraint on valuation could instead be assumed to be a limit on the amount of financial capital available to the sophisticated investors at the start of the period.



The outcome of valuation is observed by both the investor and seller, but is not observable by other investors or sellers. Investors are not anonymous: market participants can observe available funds, investment in valuation technology, and the prices of transactions.

Each period unfolds as follows. First, sophisticated investors choose valuation technology, then the market opens: *i*) each seller approaches a buyer/investor and either sells or repeats the process by continuing to another buyer; *ii*) unsophisticated act competitively to buy/fund assets; and *iii*) sophisticated investors use their funds and valuation technology to value and buy assets.

To complete the model we need to specify how prices are determined for a matched sophisticated investor and seller. For simplicity, we assume that when information creates a joint surplus for a matched investor-seller, the transaction price is set so that the entire surplus is captured by the investor.<sup>19</sup>

We rule out reputational equilibria and consider only the subgame perfect Nash equilibria of the period game. Sophisticated investors maximize profits by first choosing valuation capacity and funds taking as given their own future behavior, the strategies of other sophisticated investors, and the price that will be available from unsophisticated investors. Subsequently, sophisticated investors use funds and valuation technology and choose to buy and at what price taking as given the strategies of other agents and the price available from unsophisticated investors. Sellers do the same for their choices of what investors to approach and at what prices to sell. We assume that investors randomize across equivalent sellers and sellers randomize across equivalent investors and a law of large numbers allows us to ignore uncertainty from this randomization.

We discuss the importance of various assumptions not discussed elsewhere in Section 6.4. The next section derives value functions and the following section describes equilibria.

## 4 Equilibrium value functions

This section contains two subsections that characterize behavior and prices sufficient to derive the value functions for sellers and buyers: a first subsection for sophisticated investors and sellers approaching them, and a second subsection for unsophisticated investors and sellers approaching them. The description of the equilibria in the Introduction is useful for following the initial analysis of this section.

We denote the equilibrium price paid by a sophisticated investor for a good asset by  $P^g$  and for a bad asset by  $P^b$ , and the equilibrium price paid by an unsophisticated investor by  $P^U$ .

### 4.1 Sophisticated investors

Consider first a sophisticated buyer/investor matched with an asset that it has valued. The potential buyer values the asset at  $D^i/R$  for  $i = b$  or  $g$ , and the seller has three options besides selling: *i*) go to another sophisticated investor; *ii*) go to an unsophisticated investor; *iii*) keep

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<sup>19</sup>That is, the investor has all the bargaining power in a Nash bargaining situation. An alternative assumption with the same implications is that sophisticated investors post prices at which they are then committed to transact if they transact.

the asset and get 1. The buyer buys the asset as long as the value of the asset is greater than the largest of these three outside options at a price equal to this largest outside option.

First note that if the asset was found to be bad, there is no price at which this asset is purchased since the last outside option – keeping the asset – gives greater value than the value of the asset ( $D^b/R - 1 < 0$ ). Further, if the asset was found to be bad, leaving this seller destroys the value of the good information the seller and buyer share. Because valuation capacity is always insufficient to value all assets and because sellers are anonymous and valuation is nonverifiable, sophisticated investors do not compete for valued assets and do not bid prices above the better of the other two options.<sup>20</sup> Thus, provided the sophisticated investor has sufficient funds, an asset found to be good is purchased at

$$P_i^g = P^g = \max [P^U, 1] \quad (2)$$

and sellers with bad assets continue to search for buyers. The rejected seller has two remaining options: *i*) take its reservation value, 1; *ii*) go to an unsophisticated investor and sell for  $P^U$ . Summarizing this we have the following lemma.

**Lemma 1** *A sophisticated investor matched with an asset that it has valued*  
*(i) buys/funds the asset at  $P^g = \max [P^U, 1]$  if it is good and  $f > P^g$ .*  
*(ii) does not buy/fund the asset if it is bad.*

It is now useful to partially characterize  $P^U$ . Since unsophisticated investors compete to fund projects, they set prices equal to the present discounted value of dividends. When there is no valuation, this implies  $P^U = E[D]$ . When there is valuation, good projects are removed from this pool, and we claim (verified below) that  $P^U < E[D]$ .

Next, we turn to the question of the choice of funds by the sophisticated investor. If no valuation capacity is purchased, then we assume zero funds are chosen.<sup>21</sup> If valuation capacity is positive, a sophisticated investor chooses funds equal to the cost of purchasing all the good assets it would find using all its valuation capacity when only un-valued sellers approach it, which is  $P^g \lambda h_i$ .<sup>22</sup> It buys no bad assets and no assets without valuation. Why? If the sophisticated buyer chose less than this amount of funds, costly valuation capacity would go to waste. If it had funds to spare after funding good projects, it could buy some assets without valuation or buy some bad assets. Buying a random un-valued asset from the population of assets is strictly preferred whenever some valuation is happening because  $E[D] > P^U$ . But then, knowing this, sellers that have assets that they know are bad would approach this investor the same way they might approach an unsophisticated investor and the sophisticated investor would no longer be drawing a random asset from the population but instead from a pool of unvalued assets valued and those valued and found to be bad. Thus, a sophisticated investor that chooses funds sufficient to buy unvalued assets would reduce the quality of its pool of applicants and so reduce

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<sup>20</sup>It is straightforward to confirm that there is surplus:  $P^U < D^g/R$  or unsophisticated investors lose money, so that  $P^g < D^g/R$  for  $\lambda < 1$ .

<sup>21</sup>While it is possible that a sophisticated investor that does not invest in valuation capacity mimics 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.

<sup>22</sup>Sophisticated investors value a positive measure of assets and find a nonstochastic share of good projects.

the efficiency of its use of valuation, and would do so sufficiently as to be not worth doing. These results are summarized in the following lemma, proved in appendix A (following the above logic).

**Lemma 2** (*Funding with valuation, funding capacity, and share of good assets*)

*If  $h_i > 0$ , the sophisticated investor chooses  $f_i = P^g \lambda h_i$ , gets a share  $\lambda$  of good assets, only buys after valuation finds the asset to be good, and uses all its funding capacity.*

From here on, we refer only to valuation capacity since funding capacity is equal to valuation capacity.<sup>23</sup>

We can now write the value of a unit of sophisticated capital. The value of investing in a unit of valuation technology and an associated unit of funding capacity is

$$J^S = -c + \lambda \left( \frac{D^g}{R} - \max [P^U, 1] \right). \quad (3)$$

This equation is linear and decreasing in the one endogenous variable, the market price. Taking  $P^U$  as given, if  $P^U$  is such that  $J^S > 0$ , then sophisticated investors purchase valuation capacity up to the constraint,  $\bar{\chi}$ , that is:  $H = \bar{\chi}$ . Similarly if  $P^U$  is such that  $J^S < 0$ , then  $H = 0$ , and if  $J^S = 0$ , then  $H \in [0, \bar{\chi}]$ . Thus, the model will have regions of multiple equilibria as long as the price  $P^U$  decreases in the aggregate use of valuation.<sup>24</sup>

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

$$W^S = \lambda P^g + (1 - \lambda) \max [P^U, 1] - 1 \quad (4)$$

where the max term reflects the fact that the seller found to have a bad asset chooses between keeping the asset or selling the asset to an unsophisticated investor.

It is worth pausing to note that, given our assumptions, investors would like to use contract terms to screen assets and save on valuation capacity. This could be done by sophisticated investors with an ex ante fee, which in the model is ruled out twice. First, we assume that sellers have no funds: since no sellers have any funds, an application fee would make no profits and buy no assets. Second, we assume that after valuation, investors have all the power in the bargaining relationship. Given this, after valuation, the best price a seller can hope for is the market price (or reservation value), meaning that no seller would pay a fee in equilibrium.<sup>25</sup> An alternative screening mechanism would be to allow investors to impose a penalty on the seller whose asset pays off poorly – have the seller bear some risk. Two common foundations for the assumption that the seller must sell all the asset are either moral hazard on the part of the new owner (investor) or there being no resources for the investor to collect if the asset turns out to be bad.

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<sup>23</sup>While it is possible that a sophisticated investor that does not invest in valuation capacity mimics 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.

<sup>24</sup>And will for more general cost functions as long as cost is not increasing faster than price is decreasing.

<sup>25</sup>Relaxing both these assumptions and allowing a fee, investors will generally find it profitable to choose more funds and do stochastic valuation, funding some projects without valuation. We conjecture than equilibria of similar flavor exist in a model in which valuation is noisy and the fee is capped due to the inability to commit to a share of the surplus (or due to the possibility of other agents mimicking sophisticated investors and charging a fee but not funding any applicants). But we have also found models in which no equilibria exist (for similar reasons as in insurance markets).

## 4.2 Unsophisticated investors

Since all valuation capacity is used, the aggregate share of assets that are valued in equilibrium is  $H$ . Of these,  $\lambda H$  are found to be good and so are purchased by sophisticated investors. The total number of assets remaining is the sum of the  $1 - H$  assets that are not valued and the  $H(1 - \lambda)$  that are valued and found to be bad, so that the share of assets that are good and seek to sell without valuation is

$$\frac{\lambda(1 - H)}{1 - \lambda H}. \quad (5)$$

When no assets are valued,  $H = 0$ , and this equals the population share of good assets,  $\lambda$ .

We denote by  $J^U$  an unsophisticated investor's value of a buying an asset without valuation. This value is the expected discounted payout of the asset less the price paid for the asset

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

For a seller (with or without information about its asset's value), the (net) value of going to an unsophisticated investor is

$$W^U = \max [P^U - 1, 0] \quad (6)$$

which is also the social surplus of this transaction.

Price competition among unsophisticated investors leads to zero-profits in equilibrium,  $J^U = 0$ , which implies that the price paid by the unsophisticated investors is:

$$P^U(H) = \frac{\lambda(1 - H) D^g + (1 - \lambda) D^b}{(1 - \lambda H) R} \quad (7)$$

Thus, unsophisticated investors set the market price as a function of the average quality of assets they face in equilibrium. If that price is below the reservation value of sellers, then they do not purchase any assets.

To complete our specification, denote the market price at which transactions occur by

$$P = \text{Max} [P^U, 1] \quad (8)$$

Equation (7) and the value function of the sophisticated investors, equation (3), illustrate the main externality in the model. The profits of the sophisticated investors are decreasing in  $P^U$  which in turn is decreasing in the aggregate amount of valuation capacity purchased. More valuation worsens the pool of asset purchased by unsophisticated investors, which lowers the price they are willing to pay, which lowers the price that sophisticated investors have to pay for good assets, which makes valuation more profitable.

## 5 Equilibria

Equilibria can now be characterized using equations (2), (3), (4), (6), (7), (8), and our characterization of optimal choice of  $H$ .

There are four types of equilibria: pooling, valuation, constrained mixed, and unconstrained mixed.

## 5.1 The pooling equilibrium

In a pooling equilibrium all assets trade without valuation at the same price and no valuation technology is used. For this equilibrium to exist, a sophisticated investor must find it unprofitable to invest in valuation capacity and uninformed sellers must prefer selling to unsophisticated investors to keeping the asset, both when  $H = 0$ :

$$\begin{aligned} J^S &\leq 0 \\ W^U &\geq 0 \end{aligned}$$

The second inequality implies  $P^U - 1 \geq 0$  (when  $H = 0$ ), so that with equation (7) these conditions can be written as

$$\begin{aligned} c &\geq \lambda(1 - \lambda) \frac{D^g - D^b}{R} \\ \lambda &\geq \frac{R - D^b}{D^g - D^b} \end{aligned} \tag{9}$$

and all assets trade, so volume is 1, at price equal to the unconditional expected value,

$$P = \frac{\lambda D^g + (1 - \lambda) D^b}{R} = E[D] / R.$$

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 asset being good ( $\lambda$ ) times the joint gain in value when it is good ( $(1 - \lambda) \frac{D^g - D^b}{R} = \frac{D^g}{R} - \frac{\lambda D^g + (1 - \lambda) D^b}{R} = \frac{D^g}{R} - P$ ), which is the private value of information at the margin in the pooling equilibrium.

## 5.2 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 buy as many good assets as they can and make profits, and the residual pool of assets is so poor on average that unsophisticated investors do not buy assets. Second, there is a *constrained mixed equilibrium* which is like the valuation equilibrium except that the residual pool of assets is good enough on average that the remaining assets are purchased by unsophisticated investors. Finally, there is an *unconstrained mixed equilibrium* in which sophisticated investors invest in some valuation capacity  $< \bar{\chi}$ , perform valuation and invest in some assets, unsophisticated investors buy the remaining assets, no investors make profits, and all uninformed sellers are indifferent between investors.

### 5.2.1 The valuation equilibrium

For the valuation equilibrium to exist, each sophisticated investors must prefer to invest in valuation up to its capacity constraint, and each uninformed sellers must prefer to go to a

sophisticated investor or keep its asset instead of going to an unsophisticated investor, both when  $H = \bar{\chi}$ :

$$\begin{aligned} J^S &\geq 0 \\ 0 &> W^U \end{aligned}$$

Since  $0 > W^U$  implies  $P^U < 1$ , we have that  $P^S = 1$ , and these conditions become

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

and only good assets that have been valued trade, so volume is  $\bar{\chi}\lambda < 1$ , at price equal to the reservation value,  $P = 1$ .

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 asset and ii) the share of good assets is low enough (or  $\bar{\chi}$  high enough) that buying with, out valuation is not profitable after  $\bar{\chi}\lambda$  good assets are bought by sophisticated investors.

It is worth noting that in the pooling equilibrium (equation (9)), the benefit of a marginal unit of valuation is the ability to avoid the unvalued assets that are bad with probability  $1 - \lambda$ . In the valuation equilibrium, there is an additional benefit, the ability to avoid all assets that have previously been found to be bad by others. Thus, as the share of good assets in the population ( $\lambda$ ) increases to 1 (and  $\bar{\chi}$  near one), the valuation equilibrium can occur for higher valuation costs (the first equation (10)) even though in aggregate the information gained by valuation in equilibrium is vanishing. This previews one of the results of section 6.2, that valuation can be socially inefficient but privately optimal.<sup>26</sup>

### 5.2.2 The constrained mixed equilibrium

In the second possible equilibrium with valuation, sophisticated and unsophisticated investors both purchase assets. While as in the valuation equilibrium, sophisticated investors are at capacity and make profits, here valuation capacity is so limited or the share of good assets so high that the remaining, unvalued assets still have positive expected net present value and are bought 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 maximization implies that uninformed sellers are indifferent between types of investors. Thus, for  $H = \bar{\chi}$

$$\begin{aligned} J^S &> 0 \\ W^S &= W^U \geq 0 \end{aligned} \tag{11}$$

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<sup>26</sup>There is a discontinuity (outside our assumed range) at  $\lambda = 1$ , where the valuation equilibrium cannot occur for  $c > 0$  even when  $\chi = 1$ .

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

$$H \leq \tilde{H} := 1 - \frac{(1 - \lambda)(R - D^b)}{\lambda(D^g - R)} \quad (12)$$

which implies that this equilibrium requires  $\bar{\chi} \leq \tilde{H}$ . With  $P^U \geq 1$ , the equality  $W^S = W^U$  implies

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

Given this price,  $J^S > 0$  and  $\bar{\chi} \leq \tilde{H}$  simplify to the two conditions for the equilibrium to exist:

$$\begin{aligned} c &< \frac{1}{1 - \lambda\bar{\chi}} \lambda(1 - \lambda) \frac{D^g - D^b}{R} \\ \lambda &\geq \frac{R - D^b}{(D^g - D^b) - \bar{\chi}(D^g - R)} \end{aligned} \quad (13)$$

The first inequality is the reverse of a ‘scaled up’ (by  $\frac{1}{1 - \lambda\bar{\chi}}$ ) version of the first inequality for the pooling equilibrium. That is, costs have to be low enough so that valuation is profitable, and the ‘scaling’ factor represents the difference between the temptation to purchase valuation when no other agent does (and prices are high) and the purchase of the last unit when all other agents purchase valuation (and so prices are lower). The second inequality states that the share of good assets is high enough (or  $\bar{\chi}$  low enough) that transacting without valuation is profitable after  $\bar{\chi}\lambda$  good assets are bought by sophisticated investors. As  $\bar{\chi} \rightarrow 1$ , this lower bound on  $\lambda$  goes to 1. It is the exact complement to the second equation for the pure valuation equilibrium.

### 5.2.3 The unconstrained mixed equilibrium

In the final type of equilibrium, for some  $H \in (0, \bar{\chi}]$ , all uninformed sellers are indifferent between sophisticated and unsophisticated investors and sophisticated investors are indifferent between investing in more capacity and not. In appendix B, we show that this unconstrained mixed equilibrium exists for parameters such that the pooling equilibrium exists and either the valuation equilibrium or the constrained mixed equilibrium exists.

We do not focus on this equilibrium because it is ‘unstable’ in the sense that if a sophisticated investor invested in more valuation capacity, it would reduce the quality of the assets bought by the unsophisticated investors, 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 assets choosing to use unsophisticated investors would raise the unsophisticated market price, raising  $P^S$ , and all sophisticated investors would prefer not to have invested in capacity to do valuation.

## 6 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.

## 6.1 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 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 (9) and equation (10) and allowable parameters that satisfy equation (9) and equation (13). Part (iii) is proved in appendix B. ■

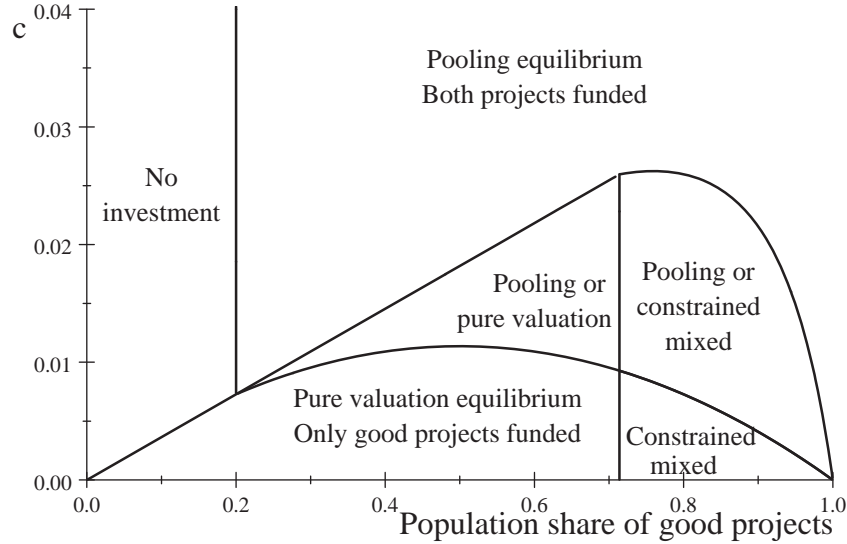


Figure 1: The regions for the pooling, valuation, and constrained valuation equilibria

Figure 1 plots the areas in which each equilibrium exists in  $\lambda - c$  space (and for  $R = 1.1$ ,  $D^g = 1.14$ ,  $D^b = 1.09$ , 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 assets is low enough, no equilibria or only the pure valuation equilibrium exist. When the share of good assets is large enough, only the pooling equilibrium exists. For intermediate costs of valuation and an intermediate share of good assets, multiple equilibria exist.



## 6.2 Efficiency of equilibria

We define efficiency as maximizing social surplus: the sum of the value functions of the unit mass of sellers and all investors who buy assets. In this subsection, we first show that in the regions of multiplicity, the socially efficient outcome is always the pooling equilibrium. More strikingly, even in some regions where the market delivers only an equilibrium with valuation, it would be more efficient to buy/fund all assets without valuation (Pareto superior with transfers). This second region occurs because the market has a tendency to produce too much information due to the externality that valuation decreases the average quality of assets purchased by unsophisticated investors.

Consider first the parameter set for which the unconstrained mixed equilibrium exists. The pooling equilibrium exists wherever this equilibrium exists. And the mixed equilibrium is clearly inefficient since all assets are traded, as in the pooling equilibrium, but in addition some valuations are done at cost  $c$  per unit of valuation capacity.

Second, consider the parameters set for which the constrained mixed equilibrium exists. Since again the pooling equilibrium leads to all assets trading but without the costs of valuation, the pooling equilibrium is more efficient than the constrained mixed equilibrium.

Third, consider the parameter set for which the pure valuation equilibrium exists and suppose that agents were playing their pooling equilibrium strategies, so no investors purchase the capacity to do valuation. We show that the parameter set over which a sophisticated investor would choose to invest in valuation capacity is strictly greater than the parameter set over which a social planner would invest in valuation technology if she could ensure that assets known to be bad were not funded/sold.<sup>27</sup> Thus, where the market can deliver either equilibrium, the pooling equilibrium is more efficient. And in a subset of the parameter space where the market delivers only the valuation equilibrium, the planner would like to prohibit valuation.

To develop intuition, first assume that  $\bar{\chi}$  is arbitrarily close to one, so there is no inefficiency in the valuation equilibrium from not being able to value all assets. The planner would like to invest in a unit of 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 asset is bad ( $1 - \lambda$ ), times the gain from not trading it, which in turn is the reservation value of the seller less the present value of the asset ( $1 - D^b/R$ ).<sup>28</sup> Given linearity (and  $\bar{\chi}$  almost one), if the planner would choose to value one asset, it would choose to value all assets and so the valuation equilibrium would be more efficient.

Now consider a sophisticated investor choosing whether to invest in a unit of valuation or instead to mimic an unsophisticated investor and buy/fund one asset without valuation. In either cases, if the asset is good, the investors buys it 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 an asset is bad – again, as in the social planner's problem – times the gain to this sophisticated investor of not buying it, which is the market price less the payout of the bad asset ( $P - D^b/R$ ), which is greater than the benefit in the planner's problem since the pooling price is greater than or equal to the reservation value ( $P \geq 1$ ) for

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<sup>27</sup>Such as if anonymity could be destroyed by announcing that a valuation was done. As discussed in Section 7, such an announcement technology would not be used by private agents since it destroys match value.

<sup>28</sup>There is no gain associated with good projects since they are funded in both equilibria.

any parameters in which the pooling equilibrium exists. Thus, the planner prefers the pooling equilibrium for all parameter values for which a sophisticated investor acting alone does not undermine it – that is for all parameter values where it exists, including the region of multiplicity.

Further, for some parameter values for which only the pure valuation equilibrium exists, trading all assets without valuation is more efficient. Why? Because valuation allows investors to avoid buying/trading bad assets. The cost of buying/trading a bad asset is the effective price paid less the payout, where the effective price is the market price for the sophisticated investor but only the reservation price for the planner. Thus, the existence of transactions without valuation at  $P > 1$  makes valuation worth more to sophisticated investors than to the planner, which, for some parameters, undermines the existence of the pooling equilibrium where it would otherwise be more efficient.

When  $\bar{\chi} < 1$ , the argument must account for the additional inefficiency of the pure valuation equilibrium that some unvalued assets that have positive expected surplus are not traded/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:

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

If instead all assets are traded without valuation, investors all make zero profits and 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 no-valuation and having all assets sold/funded is socially preferred to the valuation equilibrium whenever the total cost of valuation capacity and the cost of not trading the unvalued assets exceeds the benefits of not buying the valued assets found to be bad:

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

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  $\lambda$  where the pure valuation equilibrium exists and  $c = 0$  (where  $P = 1$  also).

To sum up, we state these results formally.

**Proposition 2** *Ranking of equilibria*

- i) For parameters such that the pooling equilibrium exists, it is more efficient than 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 less efficient than no valuation and trading all assets without valuation;*
- iii) for parameter values such that the only market equilibrium is the pure valuation equilibrium, if*

$$c \geq c^{Eff} := \frac{(1 - \lambda \bar{\chi}) R - (1 - \lambda) D^b - (1 - \bar{\chi}) \lambda D^g}{\bar{\chi} R} \tag{14}$$

*then the market equilibrium is less efficient than no valuation and trading all assets without valuation.*

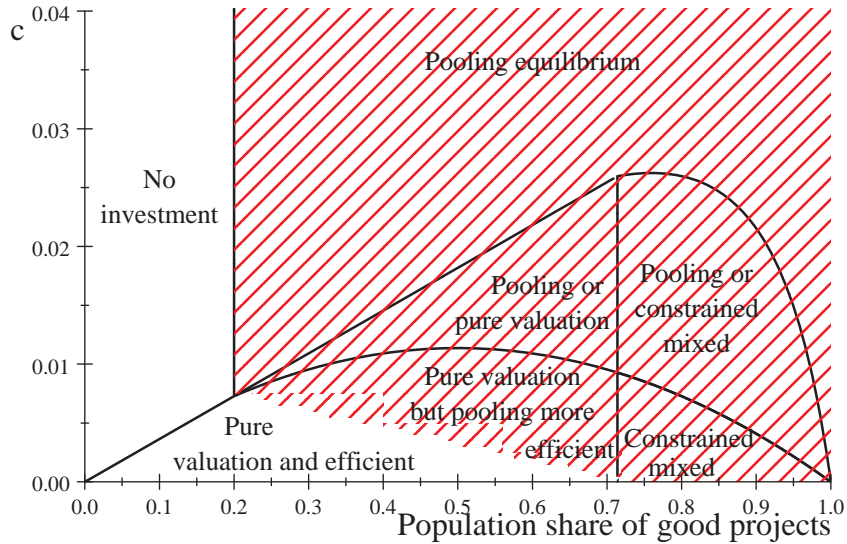


Figure 2: The region where funding without valuation is more efficient than equilibria with valuation

### 6.3 Application to a financial crisis

In this section, we interpret a switch from an equilibrium without valuation to an equilibrium with valuation as a financial market collapse. While the circumstances in which a collapse is possible are exogenous in the model, we discuss two scenarios in which parameters might naturally change over time so as to lead the market into the region of multiplicity or collapse. With the temporal interpretation, the results of the previous section imply that collapse is inefficient when it occurs. The next section discusses what policies would address this inefficiency.

Financial market booms and crashes often follow new real investment opportunities or the development of new financial assets (Kindleberger (2000)). Because such investment opportunities are new, there is limited evidence about which assets will pay off well and which poorly, so that valuation beyond a certain point is costly to impossible and, conditional on certain characteristics, all investment is funded or assets traded. However, two factors can change. First, over time specialists observe returns and may become better able to distinguish which assets will succeed and which fail, so that 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 assets may decline over time. In our model, either of these (exogenous) changes can bring about the possibility of a sudden financial collapse that has many of the features of the collapse of a bubble or a ‘run’ in the market. Presumably, following the collapse, over time the scarce resource that earns profits expands so that there is sufficient valuation capacity and trade volume recovers.

Consider first a decline across periods in the marginal costs of valuation, so that  $\{c_t\}$  declines over time to zero, and let the share of good assets,  $\lambda$ , be in an ‘intermediate’ range where the pure

valuation equilibrium can exist. For high enough  $c_0$ , the market starts in a pooling equilibrium and all assets are traded. 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.<sup>29</sup> 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, the increase in valuation is associated with:

- *Investment collapse*: The volume of transactions declines from 1 to  $\bar{\chi}\lambda$  as only sellers that can get their assets valued and who have good assets sell/are funded.
- *Price collapse*: Transaction prices fall from  $\frac{\lambda D^a + (1-\lambda)D^b}{R}$  to 1 (spreads or interest rates increase). This occurs because in the pooling equilibrium assets are scarce and valuation is not required to invest without losses, so sellers get high prices and marginal investment earns the opportunity cost of funds. In the valuation equilibrium, only skilled investors purchase assets, sellers compete for this limited valuation technology, and prices for assets are low as skilled investors earn profits and sellers receive their outside option.
- *Nonfundamental volatility*: The timing of the crash is not driven by fundamentals, but rather could be triggered by any small coordinating event, although fundamentals make collapse ultimately inevitable.
- *Credit crunch*: Some assets that would have been sold/funded in the pooling equilibrium, even some unvalued assets (and so some good assets), cannot get sold/funded in the valuation equilibrium.
- *Flight to quality*: Unsophisticated investors leave the market as the chance of buying a bad asset increases and only good assets trade.
- *Profits for sophisticated investors*: Sophisticated investors make profits/valuation capacity earns rents.

What if the share of good assets is higher so that the market ultimately switches from the pooling equilibrium to the constrained mixed equilibrium? In this case, the switch in equilibrium exhibits a (smaller) collapse in price, possibly not driven by fundamentals, a decline in trust, and profits for sophisticated investors. But trade volume does not decline, there is no credit/funding crunch, and there is no flight to quality.

The second scenario for a financial collapse is the deterioration in the average quality of assets. When a market is not doing valuation, there is no reward to a seller for higher asset quality. While the quality is exogenous in the model, in applications, the share of good assets may decline over time in the pooling equilibrium because there is no return to sellers of improving their assets in the dimension not valued.<sup>30</sup>

<sup>29</sup>The date of collapse could be determined by assumptions about lack of common knowledge about fundamentals, following the literature on multiple equilibria building on Morris and Shin (1998).

<sup>30</sup>As an aside, there is also no higher payment to the sellers of good assets relative to bad assets in the pure valuation equilibrium as both receive their reservation values. This result would change if sophisticated investors sometimes valued the same asset and competed to buy it.

Consider a sequence of equilibria in which  $\{\lambda_t\}$  starts very close to one and declines and in which  $c$  is in an intermediate range where the pure valuation equilibrium is possible. In this case, if the market begins in the pooling equilibrium, as  $\lambda$  declines, first a price collapse becomes possible as the constrained mixed equilibrium becomes possible, then a collapse becomes possible as the pure valuation equilibrium becomes possible. If  $\lambda$  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  $c$ ).

## 6.4 Discussion of assumptions

Before moving on, we discuss the importance of four assumptions (others are discussed elsewhere).

First, it is not essential that valuation capacity be strictly limited, but it must have increasing costs. If the cost of valuation capacity to sophisticated investors were increasing in the aggregate amount of valuation purchased, our results would be qualitatively similar (if increasing ‘enough’) except that the sophisticated investors would not earn rents (which instead would presumably accrue to the providers of the valuation capacity). A capacity constraint significantly simplifies the analysis.

Second, instead of assuming that valuation capacity is sunk, we could have assumed that the unsophisticated investors were small and competitive price takers as in the equilibrium concept in Dubey and Geanakoplos (2002). This would lead to the same regions, would not require that sophisticated investors be competitive, but obviously would change the importance of commitment for policy, discussed next. Without sunk valuation, competition in prices by deep-pocketed unsophisticated investors could eliminate the possibility of multiple equilibria (but not change outcomes in the region in which the valuation equilibrium is unique but funding without valuation more efficient).

Fourth, the assumption that the investor gets all the surplus when matched with a seller known to be good is important only for the equations that determine where different regions occur (as long as the investor gets some of the surplus) and for what parties earn rents in the valuation equilibria. This follows because, in equilibria with valuation, sophisticated buyers are making sellers weakly prefer to sell to them, so changing this to a strict condition does not change the qualitative results.

Finally, the fact that valuation is not observed – that a seller with a previously-valued asset is indistinguishable from a seller with a valued and rejected asset – is critical. But as noted, it is also incentive compatible for the buyer-seller pair with a known-bad asset. More generally, sophisticated investors prefer equilibria with valuation and unsophisticated investors are indifferent as they make no pure profits. Sellers prefer the equilibrium without valuation. This ordering makes it suspect that investor groups that self regulate and share information, such as through industry-wide credit bureaus, actually share this type of information.<sup>31</sup>

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<sup>31</sup>It seems more likely that credit bureaus, like ratings agencies, simply segment assets into markets, each of which is either in a pooling equilibrium or valuation equilibrium where buyers do or do not investigate beyond the credit check. It is notable that credit bureaus typically do not reveal the identity of those who conduct credit checks and so do not reveal the purpose of the check (something that an unsophisticated investor would find useful).

## 7 Policy

There is the potential for efficiency-improving coordination or government policy in the regions of the parameter space for which there are multiple equilibria and for which the market delivers only the valuation equilibrium and  $c > c^{Eff}$ . Given that the model omits any social benefits of private information and is solved as a rational expectation equilibrium, 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 more efficient equilibrium? The first answer is that valuation has social costs greater than its private benefits – it creates information on which adverse selection can occur. Thus a first approach to optimal policy is to tax valuation or eliminate adverse selection.

One optimal policy is to tax units of valuation capacity with tax,  $\tau$ , so that the use of valuation is deterred where it is inefficient, which is any  $\tau$  such that

$$\tau + c \geq \left\{ \begin{array}{ll} \lambda \left( \frac{D^g}{R} - 1 \right) & \text{if } c \geq c^{Eff} \text{ and } \lambda \leq \frac{R - D^b}{(D^g - D^b) - \bar{\chi}(D^g - R)} \\ \frac{1}{1 - \lambda \bar{\chi}} \lambda (1 - \lambda) \frac{D^g - D^b}{R} & \text{if } c \geq c^{Eff} \text{ and } \lambda \geq \frac{R - D^b}{(D^g - D^b) - \bar{\chi}(D^g - R)} \end{array} \right\}$$

This tax ensures the pooling equilibrium wherever it is ex ante socially efficient. This of course has the real-world problems of both distinguishing this type of valuation from other types of valuation (such as about value that is common across assets) and monitoring and observing valuation.

Eliminating the adverse selection that follows from valuation is more effective in that it allows the use of valuation when privately efficient while eliminating its social loss. Such a policy is at odds with the assumptions of the model and not straightforward to implement given agent's incentives. But consider making it public knowledge that an asset had been valued. Then valued and rejected assets would remain unsold. Unvalued assets would be sold to unsophisticated investors at the pooling equilibrium price (iff  $\geq 1$ ). And unvalued sellers would only approach sophisticated investors if the expected value of their outside options after valuation were at least equal to the price available without valuation, which cannot happen unless either sophisticated investors pay fees to unvalued sellers prior to valuation or sophisticated sellers can commit to posted prices.<sup>32</sup> Considering the case of commitment to posted prices, the sophisticated investor would post the minimum price to attract unvalued assets, which is  $P^g$  such that

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

Valuation would be undertaken when  $J^S \geq 0$  (with  $P^U = 1$ ), which is when

$$c \leq \lambda \left( \frac{D^g}{R} - 1 \right). \quad (15)$$

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<sup>32</sup>The ability of sophisticated investors to commit to prices would not change the results of sections 5 and 6. A fee would have the same implications as the price described in the main text and would satisfy:

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

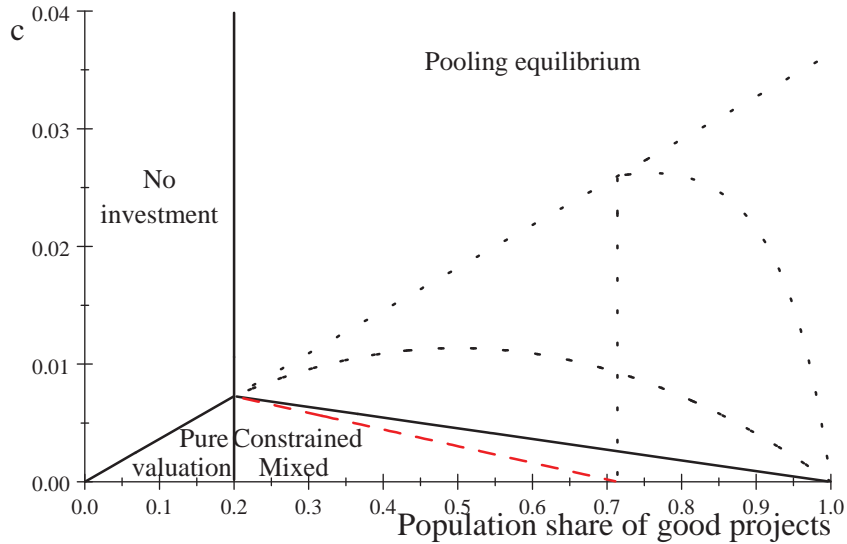


Figure 3: The region where eliminating adverse selection delivers the efficient outcome

This boundary lies above the boundary for efficiency of the pooling equilibrium with anonymity (equation (14)); equations (14) and (15) converge as  $\bar{\chi} \rightarrow 1$ ).

In Figure 3, the solid lines delineate the three equilibria when there is price commitment (dotted lines delineate the baseline model regions; and the dash lines delineates the boundary of the region in which funding without valuation is efficient). There is a larger region in which the pooling equilibrium exists, determined by equation (9) with the first inequality replaced by the complement of equation (15). There is a new type of constrained mixed equilibrium in which the price is the same as the pooling equilibrium, trade is  $\lambda\bar{\chi} + (1 - \bar{\chi})$ , and  $(1 - \lambda)\bar{\chi}$  bad assets are not traded, determined by equations (9) and (15). Third, there is a region of pure valuation in which the price is 1 and trade is  $\lambda\bar{\chi}$ , determined by equation (10) with the second inequality replaced by  $\lambda \leq \frac{R-D^b}{D^g-D^b}$ . Finally, there a region of no trade which covers the same region as before.

Three results follow. First, with observed valuation and without anonymity, the market equilibrium is always efficient; there are no externalities and no regions of multiplicity.<sup>33</sup> Second, some valuation is efficient for a larger set of parameters than in the original model with anonymity because valued assets that are found to be bad are not traded, and do not reduce the average quality of assets remaining after valuation. Finally, there are strict efficiency benefits to making valuation observable and eliminating anonymity if and only if original market equilibrium has valuation and unvalued assets are worth selling/funding (in Figure 3, any region with valuation in the baseline model (dotted lines) and to the right of the vertical line  $\lambda = \frac{R-D^b}{D^g-D^b}$ ).

Whether such a policy is optimal of course depends on its cost to implement. Further, such a policy is not incentive compatible given only lack of anonymity. Sophisticated investors and

<sup>33</sup>This follows from similar arguments to section 6.2.



assets found to be bad have a joint incentive to hide the fact that a valuation was done.<sup>34</sup>

The second answer to why the market does not deliver the more efficient equilibrium is that unsophisticated agents do not have the ability to commit to purchase at high prices (they do not compete in contracts with commitment). If unsophisticated investors had commitment, a large unsophisticated investor could post a price equal to the price in the pooling equilibrium,  $P = \frac{\lambda D^g + (1-\lambda)D^b}{R}$ , which would ensure that the market is in the pooling equilibrium wherever it exists as a market equilibrium. This result follows from the efficiency of the pooling equilibrium.<sup>35</sup> Thus, if private agents were unable and the government were able, the government could commit to purchase at the pooling equilibrium price. Or alternately, the government could commit to insure all mortgages at the ex ante fair price for the pooling equilibrium.<sup>36</sup>

However, the ability of a large unsophisticated investor to commit does not ensure that valuation is not used outside the region of multiplicity where the efficient outcomes still involves no valuation. To ensure this, the government further has to subsidize purchases by the large investor, as for example by a proportional subsidy  $\sigma$  that implies  $P^U = (1 + \sigma) \frac{\lambda D^g + (1-\lambda)D^b}{R}$  and  $J^S \leq 0$ . That is, if  $c \geq c^{Eff}$  and  $c \leq \lambda(1 - \lambda) \frac{D^g - D^b}{R}$ , then

$$\sigma = \frac{(1 - \lambda) (D^g - D^b) - cR/\lambda}{\lambda D^g + (1 - \lambda) D^b}$$

(along with ex ante commitment by a large unsophisticated agent) ensures that  $J^S < 0$  and the economy is in a pooling equilibrium wherever it is more efficient (ignoring the cost of the subsidy).

The model provides an interpretation of the government-sponsored enterprises Fannie Mae and Freddie Mac. In the market for conforming mortgages a small fraction of assets (mortgages) are ‘bad’ so that  $\lambda$  is close to one. For  $\lambda$  close to one, equilibria with valuation when they exist are inefficient for a wider range of parameters than when  $\lambda$  is lower. And a large investor with commitment and a subsidy that funds a large fraction at high prices can keep other from investing in valuation capacity and so optimally ensure the efficient equilibrium. One might then interpret the demise of these institutions as due to their committing to purchase at the expected present discounted value of a random (unvalued) mortgage with  $\lambda$  too low to support this as a pooling equilibrium price. In this case, the commitment to purchase (or insure) mortgages assuming no adverse selection when the market actually has valuation and adverse selection is extremely costly to the government (or GSE). It is also worth noting that, as with some other mechanisms to eliminate adverse selection, there are incentives to undermine this policy: in the pooling equilibrium, unsophisticated investors earns no rents, while in the valuation equilibrium, sophisticated investors make profits.

We conclude by considering two policies in which the government changes parameters of the market.

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<sup>34</sup>Sorkin (2009) describes several episodes during the US financial crisis of commercial banks valuing an investment bank for purchase in which both parties, but especially the investment bank, tried to keep secret the fact that a valuation was occurring.

<sup>35</sup>Since  $P^S \geq P$  to compete, it is straightforward to verify that  $J^S < 0$  wherever the pooling equilibrium is possible, so that no sophisticated investors would invest in valuation and the multiplicity is eliminated.

<sup>36</sup>It is not sufficient to insure the mortgages at an ex post fair price, since then sophisticated investors can do valuation, insure only the bad assets, and destroy the insurance scheme.



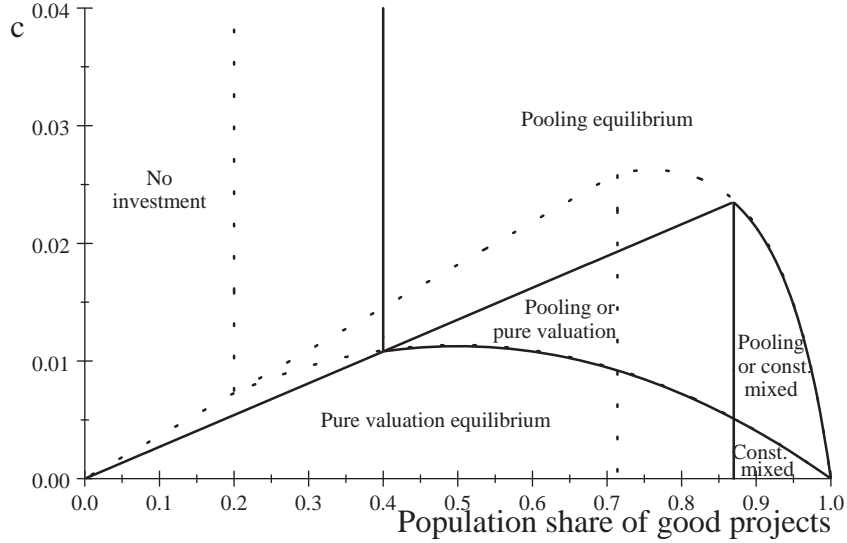


Figure 4: The effect of a higher real interest rate

First, cutting the interest rate is counterproductive. The set of (other) parameters for which equilibria with valuation are possible with a lower interest rate covers that with a higher interest rate. In contrast, raising the interest rate can held reduce valuation. These effects work by changing the present value of the information gathered by valuation, which is proportional to  $\frac{D^g - D^b}{R}$  without changing its cost. Figure 4 shows how raising the interest rate (from  $R = 1.10$ , dotted lines to  $R = 1.11$ , solid lines) reduces the size of region of multiplicity and the size of the region in which valuation can occur in conjunction with pooling. Note that the policy also increases the region in which no investment occurs.

Second, policies which reduce the difference in payoffs across assets of different quality reduce the size of the regions in which equilibria with valuation are possible. Such policies reduce the incentive to do valuation by reducing the benefits to separating the good from the bad. Figure 5 depicts how subsidizing the payout of the bad asset bad assets (from  $D^b = 1.090$  (solid line) to  $D^b = 1.095$  (dotted 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. 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.

More generally, for any given parameterization, efficiency can be ensured through a balanced-budget subsidy ( $\sigma$ ) to ultimately bad assets that is paid for by a tax ( $\tau$ ) on ultimately good assets that satisfies

$$\begin{aligned}
 c &\geq \lambda \left( \frac{(1-\tau)D^g}{R} - 1 \right) && \text{if } \lambda \leq \frac{R-D^b}{(D^g-D^b)-\bar{\lambda}(D^g-R)} \\
 c &\geq \frac{1}{1-\lambda\bar{\lambda}} \lambda(1-\lambda) \frac{(1-\tau)D^g-(1+\sigma)D^b}{R} && \text{if } \lambda \geq \frac{R-D^b}{(D^g-D^b)-\bar{\lambda}(D^g-R)}
 \end{aligned}$$

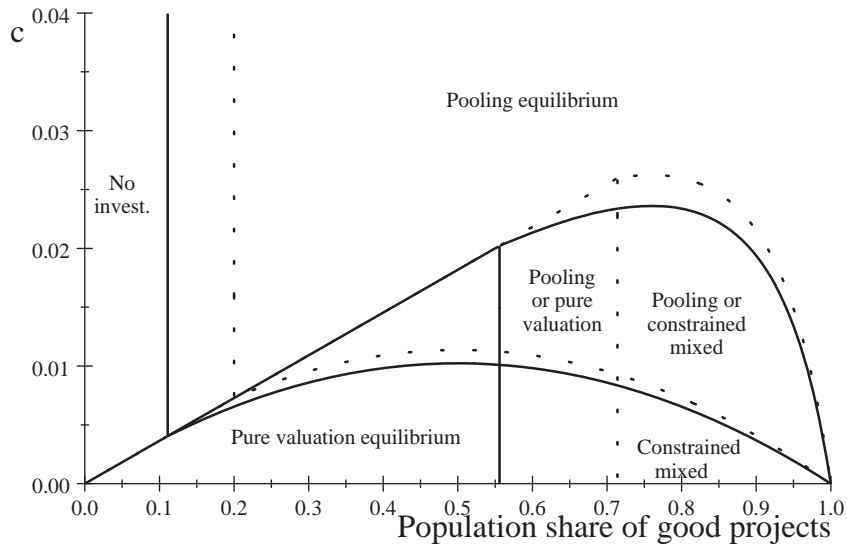


Figure 5: The effect of a higher value of bad project

where  $\tau\lambda D^g = \sigma(1-\lambda)D^b$  ensures revenue neutrality. Of course this policy is effective because private agents are assumed to be unable to commit to a similar insurance contract. And, similar to a tax on valuation, in practice this solution blunts any incentives to buy good assets in other (unmodelled) dimensions in which valuation may be optimal.<sup>37</sup>

## 8 Conclusion

In this paper we have considered a model in which valuation creates private information about a single asset and in which the benefits of the rents of this information are captured by the informed buyer. This result stands in contrast to most research on financial markets which studies the discovery of information that is common to a class of assets and is transmitted by actions through prices. In our model, too much information is created because it creates asymmetric information and causes problems of adverse selection, while in the canonical model information tends to be under-produced and markets learn too late.

<sup>37</sup>Although, if the tax and subsidy plan were explicitly balanced budget and orthogonal to the mean payoff, then such a policy could avoid diminishing the incentive to collect information about asset-class wide payoffs.

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# Appendices

## A Proof of lemma 2

**Lemma 3** (*Funding with valuation, funding capacity, and share of good assets*)

*If  $h_i > 0$ , the sophisticated investor chooses  $f_i = P^g \lambda h_i$ , gets a share  $\lambda$  of good assets, only buys after valuation finds the asset to be good, and uses all its funding capacity.*

Proof: Valuation cannot be slack since it is costly ex ante. Thus sophisticated investors choose funds at least sufficient to buy all assets found to be good when using all their valuation capacity.

Suppose that a sophisticated investor bought more assets than its capacity to do valuation. In this case, any seller going to this investor would have a positive probability of selling without valuation at a price equal to its outside option. Thus this sophisticated investor, would be approached by sellers with previously-valued assets that they know to be bad as well as by sellers that do not know the quality of their assets. Thus the share of good assets would be the same as for unsophisticated investors, the market share of good assets. Since this sector is competitive, any purchases without valuation would not make profits. At the same time the existence of such purchases reduces the share of sellers with good assets that approach the sophisticated investor, so that a unit of valuation is less likely to uncover a good asset. Thus, buying only conditional on a good valuation, which would keep known-bad assets away, is more profitable.

A sophisticated investor with funds greater than its valuation capacity can not commit to value all assets before funding and not use these additional funds. If there is valuation in equilibrium, then the share of good assets in the market for funding without valuation is less than that in the population. Thus, if only unvalued assets 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 asset sold to the unsophisticated investors (or 1 if the unsophisticated investors are not in the market  $P < 1$ ). Thus,  $f_i > \lambda h_i$  cannot be an equilibrium if we are to have sophisticated investors funding only after valuation. Therefore, sophisticated investors must choose funding capacity ( $f_i$ ) equal to population share of good assets ( $\lambda$ ) times their valuation capacity ( $h_i$ ) and only sellers with unvalued assets with probability  $\lambda$  of being good approach the sophisticated seller.

## B The unconstrained mixed equilibrium

This equilibrium can occur if for some  $H \in (0, \bar{\chi})$ ,

$$\begin{aligned} J^S &= 0 \\ W^S &= W^U \geq 0 \end{aligned} \tag{B.1}$$

As for the constrained mixed equilibrium, this thus requires,  $H \leq \tilde{H}$  and  $P^g = P^U = P$ . Equation (B.1) implies  $P^g = \frac{D^g}{R} - \frac{c}{\lambda} = P^U(H)$  which, together with equation (7), implies that

the level of valuation capacity that gives indifference is

$$H^* = \frac{1}{\lambda} - (1 - \lambda) \frac{D^g - D^b}{R} \frac{1}{c} \quad (\text{B.2})$$

Thus, this equilibrium exists when

$$H^* \in \left(0, \min \left[\bar{\chi}, \tilde{H}\right]\right). \quad (\text{B.3})$$

or

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

The first inequality is a strict inequality version of the first condition for the pooling equilibrium (equation (9)) 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  $\frac{1}{1 - \lambda\bar{\chi}}$ ) version of the first inequality for the pooling equilibrium. The final inequality is a strict inequality version of the first condition for the valuation equilibrium (equation (10)). The third inequality is the same as the first inequality for the valuation equilibrium.

It is straightforward to verify there is only one  $H^*$  is unique and thus that there is at most one unconstrained mixed equilibrium for any parameter configuration.