# Accounting, Finance and Adverse Selection: Illustrations and Applications


**ABSTRACT**

Accounting is often viewed from a legalistic rather than economic perspective. Finance, on the other hand, is deeply rooted in economic theory, but at its heart is built on assumptions of frictionless markets. Neither perspective fully incorporates the rich economic environment in which we find the practice of accounting and finance; a market setting rife with information inefficiencies. We illustrate and review one such inefficiency, adverse selection. Adverse selection results when market participants have different levels of information about an attribute of payoff relevance. In such cases, less informed parties transact in a market where the profile of assets for sale or employees for hire is worse than the population as a whole. In general, adverse selection causes a loss of social welfare and, in extreme cases, may cause the breakdown of an entire market. Each illustration is based on one of the seminal papers written by the Nobel Laureates of 2001, recognized for their work on adverse selection. We then trace the insights into the accounting and finance literatures. We consider both disciplines jointly, because accounting information is often useful in mitigating the market inefficiencies studied in finance.

# 1 Introduction

Accounting is often viewed from a legalistic perspective – a collection of rules and procedures to be followed, interpreted, and perhaps bent if need be. Ball (2008, p. 428) expresses his dissatisfaction with this way of thinking: "I am continually dismayed by the number of accounting professors and students who appear to believe financial reporting practice arises merely from some combination of (1) [FASB or IASB] standards and (2) managers cheating." Finance, in contrast, is often deeply rooted in economic theory, but at its heart is built on assumptions of frictionless markets (Modigliani and Miller, 1958). In this paper we look at accounting and finance from an economic rather than legalistic perspective; one that explicitly incorporates market frictions, especially information asymmetry.

Accounting, at its core, is a source of information. In this capacity accounting can be useful for resolving many types of uncertainty, such as whether debt covenants were violated, annual sales increased, internal controls worked properly, or dividends were paid out of earnings.[1] A role at which accounting may be particularly adept is reducing market inefficiencies that arise due to asymmetrically informed market participants. We explore one such market inefficiency in this paper, *adverse selection*.

Adverse selection is the result of market participants having different levels of information about an attribute of payoff relevance. Examples include the health of an insurance applicant, the skill of a job applicant, and the quality of a used automobile. The result is the uninformed party faces a profile of insurance applicants, job applicants or assets for sale that are worse than the population as a whole - hence, the term "adverse" selection. In general, adverse selection results in loss of social welfare and, in extreme cases, it may cause the breakdown of an entire market. Its study was deemed worthy of the Nobel Prize in economics in 2001, awarded jointly to George A. Akerlof, A. Michael Spence, and Joseph E. Stiglitz.[2]

Although not as widely cited in the popular press as its close relative *moral hazard*, an understanding of adverse selection is crucial in interpreting behavior in financial markets.[3] For example, an unsophisticated view of financial markets might hold that, upon the release of new information traders update their beliefs in a Bayesian manner, considering only their prior beliefs on future cash flows. A more subtle view is that information is released into a market with deep information asymmetries. Price changes do not simply reflect updated beliefs on future cash flows, but also reflect changes in perceptions of others' informational advantage and others' willingness to trade conditional on price. In this way, market prices may change significantly more or less than that dictated by updated beliefs on cash flows alone. Therefore, an understanding of adverse selection provides a more explicit view of otherwise implicit forces underlying market outcomes.

In this paper we present three illustrations of adverse selection. Each is built around one of the seminal papers written by the Nobel Laureates of 2001. Following each illustration, the economic insights are traced to the finance literature and from there into the accounting literature. It is natural to consider accounting and finance together, because accounting information is often used to mitigate the effects of adverse selection present in financial markets.[4]

Our first illustration is a simple model of an asset market, where sellers know more than buyers about an asset's value, similar to Akerlof (1970). We then connect the Akerlof setting to the richer model of Myers and Majluf (1984) which addresses capital structure and seasoned equity offerings. We further review how accounting can be effective in mitigating some of the adverse selection problems associated with equity markets. Our second illustration is based on the signaling model of Spence (1973). After illustrating the basic model, we describe how dividends can be used as a signal of future cash flows as in Bhattacharya (1979) and, further, how accounting disclosures provide alternatives to costly dividend signaling. Our third illustration is an employment screening model, based on the Rothschild and Stiglitz (1976) model of insurance. We extend the discussion of screening to include bank lending, as described in Stiglitz and Weiss (1981). We also discuss the use of accounting information in screening in the contexts of both employment and lending.

We do not attempt to provide a typical comprehensive literature review of adverse selection in accounting and finance - the topic is far too vast. Rather, the literature we discuss should be viewed as representative. Our review is also atypical in that we use simple but formal mathematical models, not rhetoric, as the primary expositional tool. This is somewhat similar to the approach taken by Riley (2001), except our illustrations are by design simpler so as to be accessible to faculty, students, and practitioners.

The rest of this paper is organized as follows. Section 2 presents a simple asset market. Section 3 presents an illustration of costly signaling. Section 4 presents screening in the context of employment and borrowing. Section 5 concludes the paper.

## 2 Asset Market Model

This section presents an adapted version of the model of Akerlof (1970).[5] In his model, there exists an asset for sale where the seller knows more than the buyer regarding the asset's quality. It is further assumed that the buyer values the asset more than the seller. *Without* the first condition, the second condition guarantees there exists a price at which both parties would voluntarily trade. Akerlof shows, and we illustrate, that under specific circumstances, the first condition lowers the likelihood of a trade, and possibly leads to a total collapse of the market. We extend the model in two ways: by adding the possibility of an audit and by considering an asset whose value is non-linear in quality. Following the model we explore the role of accounting disclosure and auditing in reducing costs associated with adverse selection.

### 2.1 Basic Akerlof model

There exists an asset market consisting of multiple risk-neutral buyers and sellers. Asset $i$'s value to seller $i$ is equal to $v_i$, where $v_i$ has a common knowledge probability density function of $f(v_i) > 0$, if and only if $L \leq v_i \leq H$, and 0 otherwise. For simplicity we further assume $v_i$ has a uniform density: $v_i \sim U(L, H)$; the density function of $v_i$ is hence $\frac{1}{(H-L)}$ for $L \leq v \leq H$ (a more general formulation is shown in Appendix A). Asset values are independently drawn across assets, so that for two assets $i$ and $k$, $f(v_i) = f(v_i|v_k)$. To satisfy the condition that the buyer values the asset more than the seller, we assume the buyer value, $v_b$, is $\alpha v_i$, where $\alpha > 1$. Further, there are more buyers than assets for sale and the buyers' market is competitive.

As a benchmark, it is useful to calculate the expected welfare gain per tradable asset if all assets are traded. Given the symmetry of the uniform distribution, the expected value to the seller of any randomly drawn asset is $(H - L)/2$. The expected value to the buyer is $\alpha(H - L)/2$. Therefore, the expected gain from trade is $\alpha(H - L)/2 - (H - L)/2 = (\alpha - 1)((H - L)/2)$ per asset.

For further concreteness, assume $\alpha = 1.5, L = 0$, and $H = 3$. In order to see how all assets may trade, consider two polar assumptions regarding symmetric information. First, if for any asset $i$ buyer and seller both know $v_i$, any price between $v_i$ and $1.5v_i$, is mutually beneficial. Second, if the risk neutral buyer and seller have no information, any price between 1.5 and 2.25 makes them better off *ex ante*. The point is that a <u>sufficient</u> condition for efficient trade is no information asymmetry.

Let us now suppose that only the seller knows $v_i$. Therefore, $p$ now refers to the market price, not an asset specific price because all assets are identical. What is important now is that not only are sellers better informed than buyers, but that sellers can condition their entrance into the market on the price, $p$. If $p$ is less than $v_i$, the seller will not enter the market.[6] In this way, the sellers' decision whether to enter the market provides information to buyers. In particular, seller acceptance implies $p > v_i$ - bad news for the buyer. Hence, the assets offered for sale *conditional on* $p$ have a $v$ uniformly distributed between $p$ and 0, with $E[v|p] = \frac{p}{2}$.

We now assert that with our sample parameters, there is no price at which sales will occur in equilibrium. In order to see this, note that $E[v_b|p] = 1.5\frac{p}{2}$ and the buyer's conditional expected profit is $1.5\frac{p}{2} - p$, which is maximized at 0. Therefore, the equilibrium price is zero and no trade occurs, at a welfare loss of $(1.5 - 1)\frac{3}{2} = .75$/asset.[7] We demonstrate the non-existence of an equilibrium where $p \neq 0$, graphically in Figure 1. Note that the intercept of price and expected buyer value conditional on price occurs only at $p = 0$.

*[Place Figure 1 about here]*

## 2.2 Auditing and Adverse Selection

In this subsection we demonstrate how an audit technology can mitigate adverse selection. We continue to assume the parameters $\alpha = 1.5, L = 0$, and $H = 3$. Suppose an audit of the asset determines whether v is in the upper or lower half of its distribution. That is, the audit technology either sends a "low" report indicating v is in the range $[0, 1.5)$ or a "high" report indicating it is in the range $[1.5, 3]$. Continuing to exploit the uniform density assumption, the conditional expected value of v is halfway between the price offered and the lower bound of the audit range, but no larger than the midpoint of the audit range. That is, for a low audit report $E[v|p, low] = min(\frac{p}{2}, 0.75)$; and for a high audit report $E[v|p, high] = min(\frac{(p+1.5)}{2}, 2.25)$. As with the no audit case, there is no trade if the low report obtains. However, if the high report obtains, the conditional expected profit for buyers is $1.5(p + 1.5)/2 - p = 1.125 - 0.25p$, for $p \leq 3$. Notice at $p = 3$ this is positive, implying the equilibrium price is greater than 3 as competitive buyers will increase their price. Therefore, the conditional expected value of $v$ given the high audit report is $(1.5+3)/2 = 2.25$, and the equilibrium price is $1.5(2.25) = 3.375$. Figure 2a and figure 2b presents the effect of auditing graphically. The audit technology has allowed some assets to trade. Given our assumption of a competitive buyers market we may assume that higher quality sellers will pay for an audit.

*[Place Figure 2a about here]*

*[Place Figure 2b about here]*

One of the most striking effects of the audit is the large increase in offer price; from 0 when there was no auditing to 3.375 for the assets with a high audit report. Note that without auditing available, the population means are $v = 1.5$ and $v_b = 2.25$. With auditing and a report of high, the population means are $v = 1.5$ and $v_b = 3.375$. The increase in offer price not only reflects changes in the attributes of qualifying assets, but also the mitigation of adverse selection.[8] Therefore it is important when utilizing observational data to consider prior informational asymmetries when interpreting the effect of newly released information.

Another example of how adverse selection can alter our interpretation of observational data is the effect of newly released information on the willingness of the uninformed to trade. Imagine an oil company announces a major oil find. One might be tempted to conclude this announcement will reduce information asymmetry and increase willingness to trade. However, what may be observed instead is the disappearance of uninformed investors from trading in the firm's equity. This may be the case if some industry insiders have better information on the company's access to rig equipment needed to exploit the find. The announcement of the oil find may enhance their informational advantage, not decrease it.[9]

Returning to the illustration, equation 1 reports the welfare improvement per asset traded due to auditing. However, because the probability of trade is 0.5, the welfare gain per tradable asset is $0.5 * (1.125) = 0.5625$. The reason why the gain is more than half that of the no information asymmetry case, 0.5625 versus 0.75, is auditing allows the more profitable assets to be traded. We point out this is not an artifact of our model.

$$\text{Welfare gain per traded asset from auditing} = \frac{\int_{1.5}^{3} \frac{1}{3} 0.5 v dv}{\int_{1.5}^{3} dv} = \frac{0.5}{3} 6.75 = 1.125 \qquad (1)$$

One can show that the more precise an audit, the larger are the gains. For example, if the audit partitioned the value into three equal regions, [0,1), [1,2), or [2,3], trade would occur for all assets except those in the lowest range. The price for an asset in the range [1,2) and [2,3] is 2.25 and 3.75, respectively, and the average welfare gain per tradable asset is 0.667. We summarize our findings for auditing in Table 1.

*[Place Table 1 about here]*

### 2.3 The "Rookie Premium" Market

In our second look at the adverse selection problem in asset markets, we discuss a seemingly strange equilibrium outcome: only high prices justify trade. We have labeled this the "rookie premium market", or RPM, because of some resemblances to rookie salaries in sports or academia, where unproven talent appears to be paid more than those with experience. One explanation for high rookie salaries is that superstars are valued disproportionately, or more precisely, value is convex in ability (Rosen, 1981). A related explanation involves the Bandit Problem (Rothschild, 1974), taking its name from the nickname for slot machines; we illustrate the Bandit Problem in Appendix B.

We continue to assume v follows the uniform density in the previous section, but now assume the value to the buyer is $v_b = v^2$. The conditional expected profit for buyers is given by Equation 2 for $p \leq 3$. Unlike the previous case, where profits were a declining function of price, profit is now increasing in $p$ for $3/2 \leq p \leq 3$. The expression in (2) is maximized at $p = 3$ with expected profits of zero. Because all sellers have entered the market at $p = 3$, further price increases cannot raise expected buyer value. The expression for the expected buyer profit for $p \geq 3$ is given by expression (3), which is strictly decreasing in $p$ and maximized at $p = 3$. The equilibrium price is therefore $p = 3$.[10]

$$\frac{\int_0^p \frac{1}{3} v^2 dv}{\int_0^p \frac{1}{3} dv} - p = \frac{p^2}{3} - p \quad 0 \leq p \leq 3 \tag{2}$$

$$\frac{\int_0^3 \frac{1}{3} v^2 dv}{1} - p = 3 - p \qquad p \geq 3 \tag{3}$$

[Place Figures 3 and 4 about here]

Figures 3 and 4 provide graphic representations of the RPM. Examining Figure 3, we see that the convexity of buyer value in $v$ implies there are increasing returns to encouraging higher valued sellers to enter the market. In order to encourage them to enter, a high price must be offered. In fact, only with a high price can buyers justify entering the market. Figure 4 displays the relationship between offer price and buyer expected value, note the lines touch at $p = 3$.

A vivid example of a product whose value is convex in quality is a parachute. It seems highly implausible that in purchasing a discounted parachute the savings in cost would ever outweigh the increased chance of failure. Another type of asset that has a value convex in quality is structural steel used in suspension bridges. At lower quality levels, small increases in quality mean little. If a bridge collapses in three years or five years, the consequences are pretty much the same. The steel will only be valuable if the bridge has a much longer life span.

It should also be clear from Figure 3 that the rookie premium market still has a welfare loss due to information asymmetry. The reason is that in equilibrium some assets that trade are worth less to the buyer than to the seller. For any asset with v strictly less than 1, $v_b$ is strictly less than v. In expression (4) we show the welfare gain per trade. In (5) we calculate the expected welfare gain conditional on the buyer making a profit, which occurs only when v is greater than one.

$$\text{Welfare gain per traded asset (RPM)} \quad = \int_0^3 \frac{1}{3}(v^2 - v)dv = 1.5 \tag{4}$$

$$\text{Welfare gain per traded asset (RPM}|v_b \geq v) \quad = \frac{\int_1^3 \frac{1}{3}(v^2 - v)dv}{\int_1^3 \frac{1}{3}dv} = 2.\overline{33} \tag{5}$$

What is notably different about this market than the basic asset market is that more assets trade in the information asymmetry case than in the no information asymmetry case. Without information asymmetry, no asset with $v < 1$ would trade; whereas all assets trade with information asymmetry. This is another example of why it is important to consider adverse selection when interpreting empirical data, as an increase in the variety of goods traded does not necessarily imply less information asymmetry. The welfare loss due to information asymmetry here is provided by equation (6).

$$\text{Welfare loss per traded asset (RPM}|v<1) = \frac{\frac{1}{3}\int_0^1 (v^2 - v)dv}{\frac{1}{3}\int_0^1 dv} = -\frac{1}{6} = -0.1\overline{66} \tag{6}$$

The rookie premium market appears to be a natural setting for auditing, because society is better off if some assets do not trade. An obvious audit partition is [0,1] and [1,3], which we analyze below. We only provide the pricing equation (7) for the upper partition, as clearly the assets in the lower partition will not trade.

$$\frac{\int_1^p v^2 dv}{\int_1^p dv} - p = 0, p \geq 0 \tag{7}$$

The equilibrium price is $4.\overline{33}$. For sellers whose assets provide positive social benefit in trade, auditing produces a 44% increase in price. There is a clear analog here to practice. Goods for which lower qualities have negative value in trade tend to have "minimum quality" audits.[11] Examples are meat and construction. Agricultural and building inspectors do not ensure the meat is of the choicest cut or the building will win an architectural prize, they simply check to make sure the meat or building is safe.[12]

### 2.4 Asset Markets - Discussion

In this subsection, we connect the basic insights of Akerlof (1970) to financial markets. In order to maintain a reasonable scope, we confine our attention to markets for equities. There are two classic conceptualizations of adverse selection in equities markets, one in the primary markets (direct sales from issuers to investors) and one in the secondary market (trades of equities between investors). Myers and Majluf (1984) model the decision of a firm to issue shares in the primary markets. In their model, managers know more about the value of their firm's equities than potential investors. These managers are assumed to act in the interest of current shareholders rather than future shareholders. Under these circumstances, the managers have the incentive to issue equity when the stock is overvalued. Given that potential investors are aware of this incentive, share prices fall on the announcement of a seasoned equity offering. The fall in price exacerbates the tendency to issue equity when share prices are overvalued. The drop in share price around a seasoned equity offering is a well-documented phenomenon (Masulis and Korwar, 1986). Houston and Ryngaert (1997) provide more direct evidence of the Myers and Majluf hypothesis by observing that bank mergers conducted with pure equity carry a higher discount than bank mergers conducted with a cash equivalency guarantee of the equity offered.

As one might expect, higher quality accounting and auditing reduce information asymmetry. For example, Slovin et al. (1990) find that declines in share price around SEO announcements are lower for firms that use Big 8 auditors, who presumably provide higher quality audits. Zhou and Elder (2004) document evidence specifically linking high quality auditing to lower information asymmetry. They find that the use of Big 5 auditors is associated with reduced earnings management around SEO announcements.[13] Finally, Lee and Masulis (2009) document that higher quality earnings, in the form of lower discretionary accruals, decrease both announcement date declines in share price and underwriter fees for SEOs.[14]

In the secondary equities market, information asymmetry is modeled between investors. Consider a market maker, someone standing ready to buy equities at a given price (the “bid”) and sell equities at a given price (the “ask”). The market maker is assumed to be uninformed, but rational. Market makers expect privately informed traders will buy when prices are too low and sell when prices are too high (Bagehot, 1971). Therefore, in response to increased perceptions of adverse selection, market makers protect themselves by lowering their bid and increasing their ask prices (Copeland and Galai, 1983; Glosten and Milgrom, 1985; Kyle, 1985).

As in the primary market, higher quality accounting and auditing are expected to reduce the magnitude of adverse selection (Lev, 1988). Using analysts’ ranking of disclosure quality, Welker (1995) finds support for Lev’s assertion. Firms with better disclosure rankings have lower bid-ask spreads. One caveat: there is a potential endogeniety problem with analyst ranking of disclosure quality, because analysts may look at bid-ask spreads when ranking firms. Leuz and Verrecchia (2000) study German firms that switch from German GAAP to IAS or U.S. GAAP, which increases disclosure quality. They find a reduction in several measures of adverse selection (the bid-ask spread, trading volume, and share price volatility).[15] However, the Leuz and Verrecchia (2000) study also has issues with endogeniety, as firms’ decisions to switch may be related to their disclosure quality.

It is useful to examine exogenous disclosure regime changes in order to control for endogeniety. A good example is the enactment of Regulation Fair Disclosure (Reg FD) in 2000, requiring firms to disclose to analysts and the general public simultaneously. On the one hand, Reg FD decreases information asymmetry between analysts and investors. On the other hand, it may increase information asymmetry between analysts and corporate insiders if insiders refrain from make disclosures to the public which their otherwise would have made privately to analysts. Fittingly perhaps, the evidence on Reg FD is mixed. While Eleswarapu et al. (2004), and Heflin et al. (2003) provide evidence consistent with lower adverse selection post-regulation, Sidhu et al. (2008) find the opposite. Another example of exogenous regime change is the Sarbanes-Oxley Act of 2002. The hope was that the act would increase disclosure quality. Jain et al. (2008) find evidence the act was effective in its goal. They show that bid-ask spreads decreased significantly, in the long run, after its enactment.

There are several studies that specifically pertain to the effectiveness of auditing in reducing adverse selection in the secondary equity markets. Danielsen et al. (2007) provide evidence that part of an auditor's fee is to reduce information asymmetry between informed and uniformed investors. Schauer (2002) finds that auditor industry specialty decreases the bid-ask spread attributable to adverse selection. Muller and Riedl (2002), using a special sample of UK property firms, find that independent real estate appraisals lower the bid-ask spread though not the choice of auditor. Finally, Hakim and Omri (2009) find that Tunisian firms using large auditors have a lower bid-ask spread than otherwise comparable firms. We summarize by noting that in both the primary and secondary equity markets higher quality accounting has been associated with lower adverse selection costs.

## 3 Signaling

In this section, we present a modified version of the model in Spence (1973). We then discuss the role of dividends as a costly signal, and provide evidence that the signaling value of dividends is diminished in the presence of reliable financial reporting.

As shown in the previous section, information mitigates adverse selection. In this section, we assume there is no way for sellers to credibly disclose information about the asset they have for sale. We illustrate that it is still possible for sellers to mitigate adverse selection through an activity known as *signaling*. The important difference between "signaling" and "auditing" is that signaling does not convey information *per se*. Despite this, signaling can be a valuable tool in mitigating information asymmetry problems, as demonstrated below.

Suppose some firms have assets worth 1, while other firms have assets worth $-0.6$ to prospective buyers (referred to as *good* and *bad* assets, respectively). For simplicity, we assume all firms wish to sell off their assets (they confer no benefits to sellers if unsold). Buyers cannot differentiate asset types but correctly believe the population contains 50% good types and 50% bad types. For additional concreteness, suppose there are exactly 100 assets and the buyers' market is competitive, which means sellers will reap all the benefit of trade.

The unconditional price paid in a market consisting of risk neutral buyers would be $0.2 = 0.5(1) + 0.5(-0.6)$. The total welfare gain from trade therefore is $0.2(100) = 20$. In contrast, if value were observable, the total welfare gain from trade would be $1(50) = 50$, because only the good assets would trade. The welfare loss due to information asymmetry is $50 - 30 = 20$, where 30 is equal to the number of bad assets (50) multiplied by their absolute value (0.6).

Let us assume the sellers can "list" their assets for sale on some well-known exchange. The exchange in no way attests to the value of the asset and the value of the asset does not change when listed because of changes in liquidity. However, suppose there is a difference between the costs of listing good and bad assets. The cost difference may arise because managers of the good assets may be more adept at completing the listing requirements, or the firm may be able to hold up to the scrutiny associated with being listed.

Continuing, assume the cost of listing a bad (good) asset is 1.1 (0.55). The listing decision of firms and the listing-contingent prices offered by buyers are made simultaneously.[16] We examine whether there exists an equilibrium where only the good types are listed. In this equilibrium, the conditional value of listed (unlisted) assets is 1 (-0.6).

Suppose buyers believe only firms with good assets will choose to list. Then they would assign values of 1 to those that list and -0.6 to those that do not. Given these beliefs, it is in the best interest of the firms with good assets to list, because if they are listed, they will improve their lot by $1 - 0.55 > 0$. Firms with bad assets will be worse off by choosing to list, as they would obtain an incremental gain of $1 - 1.1 < 0$. Thus, under this assumption about the beliefs of buyers, only firm with good assets would list, fully revealing their type, and buyers' conjectures are correct.

Three comments are in order. First, the type of equilibrium we are searching for is a Bayes-

Nash equilibrium. This is different than a Nash equilibrium, because we take into account buyers' and sellers' beliefs as well as actions. Second, the Bayes-Nash equilibrium identified above is not unique. There is another Bayes-Nash equilibrium where no assets are listed.[17] Third, the *sine qua non* of signaling is decreasing signal cost in quality. The important insight here is that in order for signaling to work, it must not only be more costly for lower quality assets, but the costs must be high enough that owners of lesser assets will not mimic the actions of owners of better assets.[18]

We should point out there does not always exist an equilibrium where the types are differentiated. Suppose the cost of listing for bad (good) assets is 0.8 (0.4). As before, suppose buyers believe only firms with good assets will choose to list. It is easy to verify that now both the good and bad firms choose to list; $1-0.4>0$ and $1-0.8>0$ for good assets and bad assets, respectively. Therefore, it is not a Bayes-Nash equilibrium for buyers to believe only good firms would list. The only Bayes-Nash Equilibrium is for no assets to be listed.

Returning the situation where the cost of listing is 0.55 and 1.1 for good and bad assets, respectively, the total welfare gain from trade is $50(1-0.55)=22.5$. Recall the gain from the non-informative equilibrium was 20, so signaling increases welfare by a relatively small 2.5. The improvement due to the bad assets not being traded is $0.5(100)(0.6)=30$ is mostly offset by the deadweight cost of listing, equal to $0.5(55)=27.5$. In this situation parties may be motivated to search for a less costly way to differentiate the two types of assets.

### 3.1 Signaling – Discussion

As illustrated above, signaling can be a useful tool when credible information transmission is not available. One of the most famous applied models of signaling in finance is that of *dividend signaling*. The seminal work of Miller and Modigliani (1961) shows dividends are irrelevant in a frictionless world. However, they suggest a potential role for dividends: Managers may use them to convey their superior information about the firms' future prospects, provided altering the dividend policy is sufficiently difficult (as in Lintner, 1956). The idea is that only higher quality firms would be willing to pay dividends, due to the difficulty in discontinuing paying them in the future.

There are several variants of the dividend signaling model; we provide a brief sketch of that by Bhattacharya (1979).[19] In his model, committing to dividend payments is costly because of the uncertain nature of future cash flows and the high costs of unplanned financing that would be needed to continue paying dividends in the face of a cash flow shortfall (this is related to Lintner's notion of the stickiness of dividends). It is less costly, in expectation, for high quality firms to issue dividends, because they have a lower likelihood of facing cash flow shortfalls. Current shareholders would like management to signal higher future cash flows because they have short time horizons and wish to sell their shares. Therefore, management sets dividends so that the marginal increase in share price of the firm due to signaling just equals the expected marginal decrease in share price caused by potential unplanned financing, as seen in Equation 3 in Bhattacharya (1979). Equilibrium exists because firms expecting lower cash flows find that the marginal benefit from signaling is less than the expected costs of future unplanned financing.[20] What is interesting from our perspective is that in order to focus on the role of dividends, Bhattacharya (1979, pg. 260) explicitly excludes accounting disclosures.[21]

In the absence of reliable accounting and auditing, dividends provide a credible means of signaling privately held information. In this vein, Sivakumar and Waymire (1993) find that equity prices in the early 20th century were influenced by dividend announcements significantly more than by earnings announcements. As Sivakumar and Waymire (1993) note, this was a period of little, if any, accounting or auditing standards.

The more pertinent question for current research is to what extent dividends and/or accounting reports are informative in the presence of the other? The evidence to date is mixed. Watts (1973) finds that unexpected dividends provide a signal of future earnings; however, the information content of the dividend is trivial. Benartzi et al. (1997) find further evidence against dividend signaling. They show that dividend changes provide information about contemporaneous earnings, but have no ability to predict future earnings. On the other hand, Subramanyam (1996) finds that dividends and earnings are *both* informative signals of future profitability. This makes sense as accounting, by design, does not transmit all information management has regarding the firm in a timely fashion. Nissim and Ziv (2001) also find support that unexpected dividends provide a signal for unexpected future earnings. Therefore, the question as to whether dividends are informative in the presence of audited accounting information is undecided. However, there is no question regarding whether earnings are informative in the presence of dividends.

It might be natural to assume that in those present-day markets that have less stringent accounting and auditing standards, dividends play a relatively larger and earnings a relatively smaller role in conveying privately held information. As far as we are aware, there is no cross sectional design specifically addressing this issue, and we suggest it as a possible fruitful avenue for further study.

## 4 Labor Market Model

In the preceding sections we focused on situations where the informed party may employ costly mechanisms to credibly reveal their information. This information may be provided directly, through an audit or other verification by third party, or indirectly, through signaling. We now turn our attention to settings where the uninformed party may engage in information gathering activities known as *screening*. Our representative example is a labor market where potential employees have heterogeneous skill levels that they alone observe. After the model presentation, we discuss screening in the context of bank lending and review some evidence on the use of accounting information as a device to screen borrowers.

Some have theorized that once an employer knows an employee is highly productive, she will attempt to retain his services and keep the employee out of the labor pool (Greenwald, 1986). In consequence, those that offer their labor at the going rate are those without a better alternative and likely not the best candidates (Gausch and Weiss, 1981). Therefore, adverse selection is ubiquitous in labor markets, which helps explain the prevalence of costly screening mechanisms such as extensive and intensive interviewing and probationary periods.[22]

We consider a different type of screening mechanism, via a simple model that is in the spirit of Rothschild and Stiglitz (1976).[23] A risk neutral firm owner hires one risk averse employee with utility for money, $u(w) = \sqrt{w}$. The employee is endowed with a skill that is unobservable to the owner but known by the employee. The employee's skill affects the distribution of gross cash flow to the owner. Specifically, a cash flow of 1000 (500) has a 0.7 (0.3) probability of occurring if the employee's skill is high and a 0.3 (0.7) probability of occurring if the employee's skill is low. The high skilled (low skilled) employee has a next best alternative that yields expected utility of 10 (8). Cash flows are observable, so we do not have a conflating moral hazard problem. We begin by assuming that high skilled and low skilled employees are equally distributed in the population.

### 4.1 Benchmark Solution (Skill Observable by Owner)

The owner publicly offers a single employment contract. Any potential employee is free to accept the contract. If more than one accepts, the owner randomly chooses.[24] The contract will consist of conditional payments to the employee, one for each possible outcome. Let $w_{500}$ and $w_{1000}$ be the payment for an outcome of 500 and 1,000, respectively. Let $E_{high}$ and $E_{low}$ be the expected payments to high-skilled and low-skilled employees, respectively. Finally, let $U_{high}$ and $U_{low}$ be the expected utility of high-skilled and low-skilled employees respectively.

As a benchmark, we first analyze the case where the owner knows the applicant's skill, in order to expose the effects of the employee's skill being unobservable by the employer. We consider the possibility that the owner may wish to employ the high-skilled or low-skilled employee, so there are two different contracting programs below.[25] In each case, the Participation Constraint (PC) ensures that the contract offered to the employee offers him an expected utility at least as great as that obtained at his next-best alternative. A contract that satisfies this constraint ensures the employee of the specified type is willing to participate in the firm.

High-skilled employee program:

$$\min_{w_{500},w_{1000}} \quad 0.3w_{500} + 0.7w_{1000}$$

subject to

$$0.3\sqrt{w_{500}} + 0.7\sqrt{w_{1000}} \geq 10 \tag{PC-H}$$

The solution for the high-skilled employee is $w_{500} = w_{1000} = 100$ with $E_{high} = 100$ and $U_{high} = 10$, meaning the employee receives no rents.[26] The expected net cash flow is $0.3(500)+0.7(1000)-100 = 750$.

Low-skilled employee program:

$$\min_{w_{500},w_{1000}} \quad 0.7w_{500} + 0.3w_{1000}$$

subject to

$$0.7\sqrt{w_{500}} + 0.3\sqrt{w_{1000}} \geq 8 \tag{PC-L}$$

The solution for the low-skilled employee is $w_{500} = w_{1000} = 64$ with $E_{low} = 64$ and $U_{low} = 8$, meaning the employee receives no rents. The owner's expected net cash flow is $0.3(1000)+0.7(500)-64 = 586$.

The above analysis indicates that if the owner can observe the applicant's type, she would prefer to hire a high-skilled employee ($700 > 586$). However, this need not be the case. For example, if the two gross cash flows were 970 and 1000, the owner would prefer to hire the low-skilled employee. To create a more interesting setting, we proceed with parameter values such that the high-skilled is preferred.

### 4.2 Skill Unobservable by Owner

In this subsection we assume the owner cannot distinguish types. She offers a single contract to all potential employees. We assume the owner designs the contract such that some individual will find it acceptable.[27] The owner's contracting options now include the following: (1) design a contract that is attractive to *only* a high-skilled employee, (2) design a contract that is attractive to *only* a low-skilled employee, or (3) design a contract that is attractive to both types of workers (and randomly select an employee). The constrained optimization programs below solve for each of these contracts, with the exception that there is no need to write the program to attract only the low-skilled type (case 2), because the solution found above when hiring an employee *known* to be of low skill would not be attractive to a high-skilled employee.

The programs we must now add the appropriate self-selection constraints to ensure only the intended employee types apply. For example, in the program immediately below designed to be attractive to only a high-skilled employee, ($SS_H$-H) ensures the high-skilled employee wishes to apply, and ($SS_H$-L) ensures the low-skilled worker does not wish to apply. We have assumed here (and below) that when the employee is indifferent he will behave as desired by the owner.[28]

Only high-skilled employees apply:

$$\min_{w_{500},w_{1000}} 0.3w_{500} + 0.7w_{1000}$$

subject to

$$0.3\sqrt{w_{500}} + 0.7\sqrt{w_{1000}} \geq 10 \quad \text{(SS}_\text{H}\text{-H)}$$

$$0.7\sqrt{w_{500}} + 0.3\sqrt{w_{1000}} \leq 8 \quad \text{(SS}_\text{H}\text{-L)}$$

The solution is $w_{500} = 42.25$ and $w_{1000} = 132.5$, with $E_{high} = 105.25$ and $U_{high} = 10$. The hired employee receives no rents, with his expected utility equal to his next best alternative. The owner's expected net cash flow is $850 - 105.25 = 744.75$. This is the optimal contract.

Both high-skilled and low-skilled employees apply:

$$\min_{w_{500},w_{1000}} 0.5[0.3w_{500} + 0.7w_{1000}] + 0.5[0.7w_{500} + 0.3w_{1000}]$$

subject to

$$0.3\sqrt{w_{500}} + 0.7\sqrt{w_{1000}} \geq 10 \quad \text{(SS}_\text{B}\text{-H)}$$

$$0.7\sqrt{w_{500}} + 0.3\sqrt{w_{1000}} \geq 8 \quad \text{(SS}_\text{B}\text{-L)}$$

The solution is $w_{500} = 42.25$ and $w_{1000} = 132.5$, the same as above. Remember the low-skilled employee was indifferent above, we now assume he takes the offer. Neither type receives economic rents. The owner's expected gross cash flow is $0.5(850)+0.5(650) = 750$, and the expected payments to the employees is equal to 87.25. The lower expected cash flow and wage reflects the inclusion of the low-skilled employee. The owner's expected net cash flow is $750 - 87.25 = 662.75$, which is less that the high-skilled only solution. Table 2 summarizes our results.

*[Place Table 2 about here]*

The cost of adverse selection in the labor market model is that the risk neutral owner must place risk on the risk-averse employee in order for him to properly self-select. This is clearly suboptimal risk sharing. Therefore, the expected wages must be higher than in the setting where the owner observes the applicant's skill. Table 2 indicates that wages increased from 100 to 105.25 and therefore the cost of adverse selection in this example is 5.25.

Even though it is not optimal for the owner, it is useful to consider the second contract, wherein either type is willing to apply for employment. Notice the expected wage of 87.75 is lower than the *second-best* wage of 105.25. Recall the population has 50% high-skilled types and 50% low-skilled types. Expected payments decrease due to the pooling of high- and low-skilled types, with low-skilled types more frequently encountering the lower-paying 500 gross revenue. One question that arises is why not simply offer a fixed wage of 100 and avoid the risk premium altogether, while still attracting both types of workers? Recall that in the optimal contract the risk premium paid to the high type is 5.25. This compares to the savings by having the low type sometimes take the job with an expected wage of 69.25 versus a no risk premium wage of 100. Therefore the expected savings on the low type from risky payments $30.75(100-69.25)$ exceeds the additional cost on the high type from risky payments $5.25(105.25-100)$, which is why the owner prefers the approach of levying risk on the high-skilled employee.

### 4.3 Separating vs. Pooling Equilibrium

In the previous example, the unique equilibrium of only attracting high-skilled employees is known as a *separating* equilibrium because can infer an applicant's skill level from his decision to apply: high-skilled types apply and low-skilled types do not apply. However, with different parameter values there might exist a *pooling* equilibrium. A pooling equilibrium is one in which the owner finds it optimal to offer a contract where both skill levels are willing to accept the contract. Intuitively, a pooling equilibrium might arise if the types are not that different. In that case it would not be worth paying the risk premium to separate them. What is less intuitive is that a pooling equilibrium might arise if one type is very rare. We now illustrate the latter situation.

We generalize by assuming the population proportion of high- and low-skilled types is $p_H$ and $(1-p_H)$, respectively. Changing the population parameter in this way has no effect on the high-skilled only solution, which can be verified by looking back at the program. The contracting program for the case where both types apply appears below.

Both high-skilled and low-skilled employees apply (generalization):

$$\min_{w_{500},w_{1000}} p_H[0.3w_{500} + 0.7w_{1000}] + (1 - p_H)[0.7w_{500} + 0.3w_{1000}]$$

subject to

$$0.3\sqrt{w_{500}} + 0.7\sqrt{w_{1000}} \geq 10 \quad \text{(SS}_\text{B}\text{-H)}$$

$$0.7\sqrt{w_{500}} + 0.3\sqrt{w_{1000}} \geq 8 \quad \text{(SS}_\text{B}\text{-L)}$$

Suppose the probability of a high-skilled type is $p_H = 0.9$. The solution is $w_{500} = 76.82$, $w_{1000} = 110.87$, $E_{high} = 100.65$, $E_{low} = 87.03$, $U_{high} = 10$, and $U_{low} = 9.29$. The owner's expected net cash flow is $830 - 99.29 = 730.71$.

When $p_H = 0.9$, there is less spread in the payments than when $p_H = 0.5$. Thus, the owner pays the high-skilled type a lower risk premium. However, the low-skilled type now receives rents, as $U_{low} > 8$. Relative to the $p_H = 0.5$ case, the expected wage of the high-skilled employee decreases while the expected wage of the low-skilled employee increases.

While the owner's welfare when offering a pooling contract improves in the $p_H = 0.9$ case, the owner still does better offering a separating contract that attracts only the high-skilled types. We must further contract the supply of low-skilled types to produce a pooling equilibrium. For example, at $p_H = 0.98$, pooling is optimal. The solution is $w_{500} = 94.78$, $w_{1000} = 102.28$, $U_{high} = 10$, $U_{low} = 9.85$, $E_{high} = 100.03$, and $E_{low} = 97.03$. The owner's expected net cash flow is $846 - 99.97 = 746.03$. The expected net profit to the owner, 746.03, is greater than the payoff from the separating equilibrium, 744.75. The incidence of low-skilled employees is so rare that the owner effectively ignores them, paying the applicant almost a flat wage. Therefore, the high-skilled worker demands little risk premium – his expected wage is just above 100. In contrast, the low-skilled acquires considerable rents, but is very low probability of attracting a low-skilled type.[29]

*[Place Figure 5 about here]*

*[Place Figure 6 about here]*

Figures 5 and 6 provide a graphical representation of the convergence towards a pooling equilibrium. In Figure 5 we see the convergence of the expected wages of the high-skilled and low-skilled types. Also the owner's expected profit is increasing in the percent of high-skilled types in the population. Although profit appears to be a linear function of the population parameter, it is in fact slightly convex beyond the point where the wages of the high-skilled and low-skilled types converge. In Figure 6, we find the expected utility of the high-skilled type unchanged in the population parameter. In contrast, the low-skilled type has his expected utility rising above his next best alternative; in other words, he is collecting economic rents. One of the interesting economics interpretations of our illustration is that in a world with few inferior quality goods, inferior quality goods can pass for normal, as little effort would be made to screen types.

### 4.4 Screening – Discussion

Let us consider screening in another context; bank lending. Stiglitz and Weiss (1981) theorize that banks will use interest rates to screen borrowers. Higher interest rates are assumed to attract worse credit risks because they know they are less likely to pay the loan back. Therefore banks have incentives to keep interest rates relatively low and loan demand may exceed capital available for lending. As a result, some applicants will receive loans while others will not, even if they are observationally identical and the applicants who are refused are willing to pay more interest. The underlying economic rationale is that by increasing the price of money, (which is the expected behavior of "sellers" in the face of excess demand) banks will encounter an adverse selection problem where the mix of "good" and "bad" borrowers change in such a way that the bank is not compensated by the higher interest rates. This is similar to the result in the RPM where lowering the price below 3 would reduce the quality of the assets for sale more than the savings in cost. The analog in the labor market is that employers will not drop wages in the face of excess labor supply due to the fear of attracting poorer quality workers that will more than offset the lower wages (Foster and Wan Jr., 1984).

Similar to Bhattacharya (1979), accounting is not considered in Stiglitz and Weiss (1981). In contrast Zazzaro (2005) explicitly includes accounting standards in his model of bank lending screening and finds that increased accounting disclosure improves credit allocation. There is also a great deal of empirical evidence to demonstrate how accounting is used to screen of borrowers. For example, Beaver (1968), Altman (1968) and Ohlson (1980) all show that accounting data is an important factor in predicting corporate failure and hence valuable as a screening device in lending. Horrigan (1966) finds that for those whose business it is to predict business failure, debt rating agencies, accounting is, or should be, a key ingredient in their ratings. Finally, Edmister (1972) finds evidence on the value of accounting in screening small firms that are not publicly traded. We should point out the importance of screening and monitoring provided by financial intermediaries to the economy as a whole is very significant (Bernanke, 1983; Diamond, 1984).

Returning to the labor market, Cadenillas et al. (2005) develop a model which shows how executive stock options can be used as a screening device. In their model, there exists a high quality CEO and low quality CEO. The high quality CEO is willing to accept option compensation with a higher strike price because if the value of the stock drops quickly, the high quality CEO can counteract the drop in stock price more easily than the low quality CEO. In this way, stock options can screen out the bad CEOs. Accounting information plays a crucial though implicit role in such a model, because it is accounting information that partially transmits the CEOs quality to the market. We end our discussion of screening by re-iterating the observation we made in the introduction. Accounting is often a partial solution for many of the adverse selection problems identified in finance. Thus the joint study of accounting and finance is important to understanding many aspects of the firm and the economy in general.

## 5 Conclusion

In this paper we present three illustrations of adverse selection; a basic asset market, an asset market with costly signaling and a labor market. In the asset market model, we demonstrate that adverse selection can cause the collapse of an entire market; one that would have provided significant welfare gains if trades had occurred. In conjunction with the basic asset market we explore the role of auditing. In the signaling model, we show how signals with no inherent information content can nonetheless provide information in a Bayes-Nash Equilibirum. In the labor market model, we find employers use costly screening mechanisms to distinguish between "high" skilled and "low" skilled employees. Unlike the asset market and signaling applications, where the informed and takes action to reveal his type, screening mechanisms are employed by the uninformed party to sort out types from the pool. Each of the basic illustrations is then connected to the accounting and finance literatures. Our goal is to provide a different perspective to view accounting and finance for students, scholars and practitioners.

## Notes

[1]The point is that accounting is not exclusively related to valuation [(Christensen and Demski, 2003)]. Also closely related is Gjesdal (1981).

[2]Another important early contributor to the field of information economics is George Stigler, who won the Nobel Prize in economics in 1982 (Stigler, 1961).

[3]See Prescott (1999) for a simplified overview of moral hazard modeling.

[4]Pope (2010) also advocates the joint consideration of accounting and finance.

[5]The example in Section 2.1 is also closely related to the "heirloom" example in Demski (2008).

[6]This is a subtle but very important point. The adverse selection problem can be mitigated by having sellers commit to sell prior to viewing prices. For example Jullien and Mariotti (2006) show that informed sellers in an auction commit to observable reservation prices that are increasing in seller value. The idea is that reservation prices trade off profit conditional on sale against likelihood of auction failure. Sellers of low value assets have less to lose from auction failure so announce lower reservation prices. An equilibrium where reservation prices are informative is possible.

[7]For a closely related example where adverse selection again leads to a welfare loss, but some assets are traded (Demski, 2008, pgs. 248-249).

[8]The rise in asset prices due to the resolution of adverse selection is consistent with the idea that firms in countries with better regulatory and disclosure regimes have a lower cost of capital (higher asset prices) (Hail and Leuz, 2006).

[9]This phenomenon is related to the idea that there are multiple sources of information in the market (Antle et al., 1994). Specific evidence consistent with adverse selection increasing around announcements is found in Krinsky and Lee (1996) and Chae (2005).

[10] There is another, less interesting equilibrium, at $p = 0$.

[11]This is similar in spirit to Demski et al. (2009) where "certification" is used to prevent socially un-beneficial assets from trading.

[12]Agrawal (2009) examines minimum quality standards in equity markets as embodied in by states' "blue sky laws". He argues that securities issued by firms in industries with intangible/unobservable assets, such as the mining during early 20th century, were often fraudulent. He documents that the passage of the blue sky laws increased firm values, improved in operating performance, increased dividends, and increased security issuances by the firms in the industry.

[13]Of course not all Big 5 auditors are the same. Rauterkus and Song (2005) investigate the effect of diminished reputation in their finding that SEOs audited by Arthur Andersen around the time of their Enron-related collapse had more severe under-pricing than otherwise similar SEOs.

[14]Auditing also helps mitigate adverse selection problems for initial public offerings (Beatty, 1989).

[15]For a short discussion of different measures of adverse selection, see Lee and Masulis (2009, pg. 444).

[16]That is, listing decisions cannot be made conditional on price offers. This maintains the spirit of the Spence (1973) model.

[17]If buyers do not believe any assets will be listed, they can rationally offer a price of 0.2 invariant to listing status. Good assets will not get listed because certification results in a gain of $0.2 - 0.55 = -0.35$ while no listing results in a gain of 0.2. In this alternative equilibrium buyers and sellers beliefs and actions are completely consistent.

[18]For those who are interested in economic history, we note that the central premise of Thorstein Veblen's classic, *The Theory of the Leisure Class* is that most consumption is largely a matter of signaling (Veblen, 1899). People consume not because they inherently enjoy the consumption but rather to signal that they can afford the consumption. Less wealthy individuals cannot mimic this signal.

[19]Miller and Rock (1985) and John and Williams (1985) also provide models of dividend signaling. They differ in how dividends are costly. In Miller and Rock (1985), dividends are costly because of the foregone investment. In John and Williams (1985), it occurs because of the double taxation of dividends. The common theme in these papers is that dividends have information content and dividend changes are signals of future earnings prospects. Dividend cuts are penalized severely in the market. So, poor firms are unlikely to mimic the signal. For a more complete discussion about dividend signaling theory and empirical evidence, see Allen and Michaely (2003).

[20]Other signaling models include capital structure (Ross, 1977), insider ownership (Leland and Pyle, 1977), IPO under pricing (Allen and Faulhaber, 1989) and choice of underwriter (Carter and Manaster, 1990).

[21]Bhattacharya (1979), foreshadowing much future work, goes on to say in footnote 2 that a fuller model would incorporate the role of accounting.

[22]Adverse selection based on the unobservable traits of individuals is not confined to the labor market. Other examples include marriage (Lillard and Panis, 1996) and immigration (Katz and Stark, 1987).

[23]The model is an extension and elaboration of a short unpublished case by Joel S. Demski.

[24]Alternatively the owner can offer multiple contracts. However, with only a single opening, low skilled employees will never reveal their type through their choice of employment contract. Therefore constraining the owner to a single contract does not decrease generality.

[25]These and all subsequent constrained optimization programs can be solved using Lagrange multiplier techniques or numerical optimizers, available in various spreadsheet software programs.

[26]In general, rents refer to above-normal returns to capital or labor. In the context of this model, rents to labor exist when the expected utility from the employment contract exceeds the expected utility from the next-best alternative.

[27]For simplicity, no sequential sampling or bargaining is permitted.

[28]In the case where the owner wishes to attract only the high-skilled employee, indifference is easily broken by increasing $w_{1000}$ and decreasing $w_{500}$ by small amounts.

[29]Those familiar with Rothschild and Stiglitz (1976) may be surprised that we have found a pooling equilibrium. There are two important differences between our illustration and their model. The first is we have a monopoly firm, as in Stiglitz (1977). The second is that there is only a single opening, not a willingness to take all profitable applicants as in the insurance models. In short, the low skilled employee will not consent to reveal his type unless the owner has already committed to accepting him, which we rule out by assumption.

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**Appendix A: General adverse selection formulation**

This appendix provides the general formulation of the adverse selection problem. The asset's value to the seller is v, where v has a common knowledge probability density function of $f(v) > 0$ if and only if $L \leq v \leq H$, where $\int_L^H f(v)dv = 1$. The buyer's value is equal to $v_b(v)$ and is solely a function of $v$.

The buyer's expected profit from trade conditional on an offer price of $p$ is found in A1.

$$\text{Buyers' expected profit} = \frac{\int_L^p v_b(v) f(v) dv}{\int_L^p f(v) dv} - p \tag{A1}$$

A competitive buyers' equilibrium satisfies two conditions: a) buyers' expected profit equals zero and b) buyers' expected profit is non-increasing in price. The second condition ensures that competitive buyers will not continue to bid up the price.

As an example assume $L = 0$, $H = 3$, $f(v) = \frac{1}{9}v^2$ and $v_b(v) = 1.5v$. Expected profit for buyers is shown in A2.

$$\frac{\int_0^p 1.5v * v^2 dv}{\int_0^p \frac{1}{9}v^2 dv} - p \tag{A2}$$

Equation A2 has a kink at the upper bound of the integral ($p = 3$) as shown below in A3 and A4:

$$\frac{4.5p}{4} - p, \text{ for } 0 \leq p \leq 3 \tag{A3}$$

and

$$\frac{4.5 * 3}{4} - p, \text{ for } p \geq 3 \tag{A4}$$

Therefore, the unique equilibrium price is 3.375. This example is somewhat similar to the RPM. In the RPM, higher quality assets were worth relatively more than lower quality assets. In this market, there is a greater density of higher quality assets. In both cases, these properties lead to the location of an equilibrium with $p \neq 0$, whereas in the base case there was no equilibrium other than $p = 0$.

**Appendix B - The Bandit Problem**

Suppose there existed a machine with two levers, A and B. Lever A always returns £10, while Lever B returns £0 with probability 0.91 and £100 with probability 0.09. Therefore, the E[A] = £10 and E[B] = £9. If a gambler were given the option of which lever to chose, it seems obvious the choice is A, assuming risk neutrality. If there was only one pull available, this would be the preferred choice. However, suppose there are two pulls available. Further, suppose that whichever outcome Lever B returns on the first pull it will return on the second pull. Note, Lever B still has an unconditional expectation of £9. If on the first pull the gambler chooses A, he will also choose A on the second pull, because as we have established, A is the better choice with only one pull left. However, suppose the gambler chooses B on the first pull. Then he will choose A on the second pull if and only if he received £0 on their first pull. Below we calculate the expected returns on pulling A or B first.

A: 2(10) = 20

B: 0.91(0+10) + 0.09 (100+100) = 27.10

Hiring a rookie represents a sort of option on a potentially higher return, which can only be gained by "sampling" from the market.

Figure 1: **Expected Buyer Value Conditional on Offered Price**


Equilibrium is where the lines intercept at p = 0.

Figure 2a: **Expected Buyer Value Conditional on Offered Price, Lower Partition of Audit**

Figure 2b: **Buyer Value Conditional on Offered Price, Upper Partition of Audit**

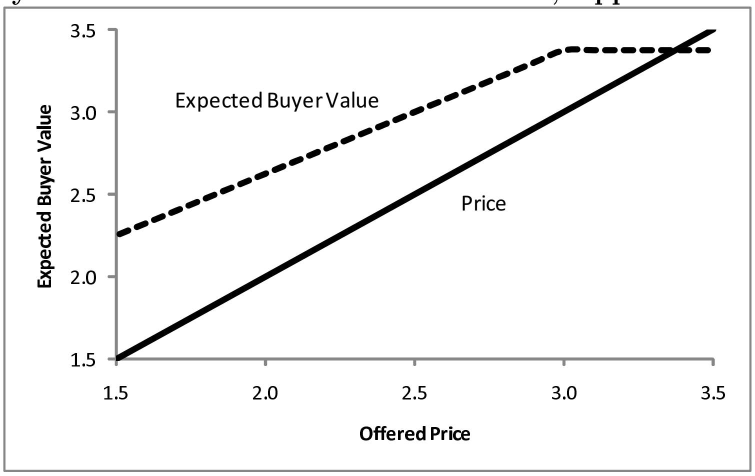



Figure 3: **Buyer and Seller Values in the Rookie Premium Market**

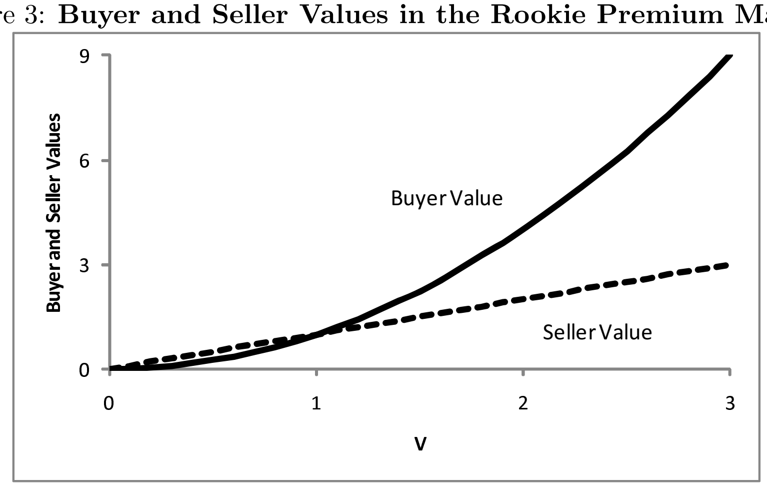
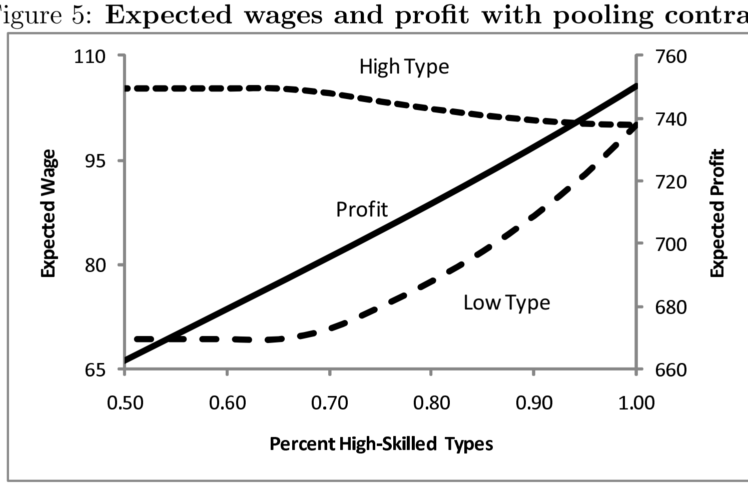


Figure 4: **Expected Buyer Value Conditional on Offered Price - Rookie Premium Market**


There are two equilibria, one at $p = 0$ and one at $p = 3$.

Figure 5: **Expected wages and profit with pooling contract**

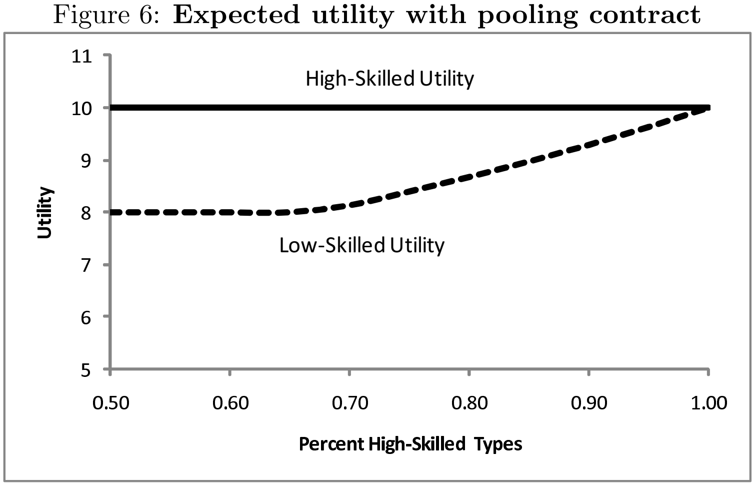



High Type Expected Wage $= 0.7 * w_{1000} + 0.3 * w_{500}$

Low Type Expected Wage $= 0.3 * w_{1000} + 0.7 * w_{1000}$

Expected Profit $= p_H$ * (High Type Expected Wage) + $(1 - p_H)$ * (Low Type Expected Wage)

Figure 6: **Expected utility with pooling contract**




High Type Expected Utility $= 0.7 * \sqrt{w_{1000}} + 0.3 * \sqrt{w_{500}}$
Low Type Expected Utility $= 0.3 * \sqrt{w_{1000}} + 0.7 * \sqrt{w_{500}}$

Table 1: **Summary of Auditing Results**

| | Equilibrium price | Welfare Gain Per Traded Asset | Welfare Gain Per Tradable Asset | Potential Welfare Gain Per Tradable Asset |
|---|---|---|---|---|
| No Audit | | | | |
| $0 \leq v \leq 3$ | 0 | 0 | 0 | 0.75 |
| Two Partition Audit | | | | |
| $0 \leq v \leq 1.5$ | 0 | | | |
| $1.5 \leq v \leq 3$ | 3.375 | | | |
| Total | N/A | 1.125 | 0.5625 | 0.75 |
| Three Partition Audit | | | | |
| $0 \leq v \leq 1$ | 0 | | | |
| $1 \leq v \leq 2$ | 2.25 | | | |
| $2 \leq v \leq 3$ | 3.75 | | | |
| Total | N/A | 1 | 0.6667 | 0.75 |

Table 2: **Summary of Labor Market Results**

| | $w_{1000}$ | $w_{500}$ | $E_{high}$ | $E_{low}$ | $U_{high}$ | $U_{low}$ | Expected Pay | Expected Revenue | Net Profit |
|---|---|---|---|---|---|---|---|---|---|
| High-Skilled Observable | 100 | 100 | 100 | N/A | 10 | N/A | 100 | 850 | 750 |
| Low-Skilled Observable | 64 | 64 | N/A | 64 | N/A | 8 | 64 | 650 | 586 |
| Only High-Skilled Apply | 132.25 | 42.25 | 105.25 | N/A | 10 | N/A | 105.25 | 850 | 744.75 |
| Only Low-Skilled Apply | 64 | 64 | N/A | 64 | N/A | 8 | 64 | 650 | 586 |
| Both Types Apply | 132.25 | 42.25 | 105.25 | 69.25 | 10 | 8 | 87.25 | 750 | 662.75 |