Endogenous Entry in Markets with Unobserved Quality[*]

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September 19, 2012

Abstract

In markets for experience or credence goods adverse selection can drive out higher quality products and services. This negative implication of asymmetric information about product quality for trading and welfare, poses the question of how such markets originate. We consider a market in which sellers make observable investment decisions to enter a market in which each seller's quality becomes private information. Entry has the tendency to lower prices, which may lead to adverse selection. The implied price collapse limits the amount of entry so that high prices are sustained in equilibrium, which results in above normal profits. The analysis suggests that rather than observing the canonical market collapse, markets with asymmetric information about product quality may instead be characterized by above normal profits even in markets with low measures of concentration and less entry than would be expected.

Keywords: adverse selection, asymmetric information, quality, experience goods, credence goods, entry, entry barriers

JEL classification: D8 (Information, Knowledge, and Uncertainty), D4 (Market Structure and Pricing), L1 (Market Structure, Firm Strategy, and Market Performance)

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1 Introduction

A long-standing concern is that asymmetric information about product quality can lead to market inefficiencies. The basic idea is familiar: There is a market in which products are differentiated only by their quality. Since buyers cannot observe the quality of individual goods *ex ante*, all qualities are sold for the same price. If sellers' costs are increasing in quality, then at that single price the highest quality products may not be offered, whereas lower quality ones are. Poor quality drives out good quality and the amount exchanged is inefficiently low, perhaps even zero.

The issue is generally illustrated with experience goods, *i.e.*, cases where quality is observed after purchase, but a similar dynamic can obviously also occur with credence goods, where asymmetric information can persist even after consumption. When customers must rely on a provider's expertise for professional or repair services (*e.g.*, medical treatment, legal or financial advice, or auto repairs) and are unable to assess the quality of the work performed even *ex post*, then a few bad apples cutting costs and quality can drive out all careful and duely diligent competitors—and the same can happen in markets in which certain product characteristics, *e.g.*, 'sustainable' or 'fair trade' remain unverified after consumption.

Many applications and extensions of these settings have been studied in the literature,[1] yet one fundamental issue has not garnered much attention: Given that especially high quality sellers and providers suffer the consequences of such adverse selection, the question arises of how they find themselves in such an unenviable situation. Equilibrium reasoning suggests that forward looking sellers should be able to anticipate and avoid such unfavorable outcomes.

In this paper we address this question by considering a two-stage game with endogenous entry into the market. In the first stage entrepreneurs make an observable investment to enter the market. Similar to Milgrom and Roberts (1986) and also Daughety and Reinganum

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[1]For some recent theoretical contributions on adverse selection of experience goods see, *e.g.*, Johnson and Waldman (2003), Hendel *et al.* (2005), Hörner and Vielle (2009), or Belleflamme and Peitz (2009); for more on credence goods in this context, see, *e.g.*, Dulleck and Kerschbamer (2006).

(1995, 2005), the quality and costs of the product or service resulting from the investment is random and unobservable to buyers. However, unlike these models of monopoly, we consider entry so that sellers who enter the market find themselves in the second stage in competition with others.

To fix ideas, consider a few examples. Land, grapes, casks, *etc.* are all verifiable inputs in viniculture. Yet the quality of the resulting wine often becomes private information of the vintner only after the initial investment is sunk.[2] Similarly, in horse breeding, while the stud and mare are verifiable, the characteristics of the foal are not. Or consider assisted tax preparation services. Accountants-in-training diligently study the tax codes while preparing for the CPA exam. However, upon taking up practice, some may find that simply applying the standard and most common deductions saves them time and effort and clients generally are unable to detect such corner-cutting. Car mechanics may enter the business with the desire to provide only the best of quality, but some may later find that for a used vehicle a used and reconditioned part is a 'better' match than the original manufacturer's replacement part, while customers generally remain none the wiser. Or consider the secondary mortgage market. Only after screening a mortgage application can the loan underwriter assess the risk of the borrower (*i.e.*, the quality of the loan), but when the originator securitizes the loan the quality can no longer be readily verified in the secondary market.[3]

In general, many trade associations and agencies certify certain inputs or processes of production, but not the quality of the final product. This is the case historically, for instance, with purity laws, appellation or guilds' marks; today Underwriter Laboratories in the United States, the *Technischer Überwachungsverein* (TÜV) in Germany, and the International Organization for Standardization (ISO) perform such accreditations. Similarly, professional organizations guarantee that certain qualifications are met by requiring the passing of pro-

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[2]While we primarily have in mind small, new vineyards, Ashenfelter (2008) notes that even when examining the most famous and well known *châteaux* considerable uncertainty about quality in the market for new wines exists.

[3]Not all information that can be gleaned in the underwriting process is verifiable and only hard information is transmitted into the secondary market. See Keys *et al.* (2010) for how this contributed to differential default risks of subprime mortgage-backed securities.

fessional exams, such as bar exams, medical exams, architect registration exams and the like, but these do not assure the elimination of quality variations in the delivery of services.

While the majority of the literature on adverse selection for experience and credence goods assumes unit or box-demand for a given quality level, we depart from this common assumption by modeling downward sloping demand. As a result, even incremental entry affects prices—which has critical implications for establishing the long run entry equilibrium. In particular, price changes may be substantial if adverse selection takes hold and the market collapses with bad quality driving out good quality, resulting in dramatic implications for profitability. Indeed, such an outcome can be viewed as a manifestation of the notion of ruinous or destructive competition. While economic research in this area generally focuses on uncertain demand (see, *e.g.*, Deneckere *et al.*, 1997) some, including legal scholars and policy makers (for instance, OECD, 2008, or Hovenkamp, 1989), see ruinous competition tied specifically to a deterioration in quality.[4] In anticipation of such outcomes, sellers rationally refrain from entering so that adverse selection and the associated market collapse coupled with a deterioration of quality does not arise in the market.[5]

When latent adverse selection manifests itself in this way it results in *ex ante* positive profits in the entry equilibrium.[6] That is, the potential for adverse selection works as a barrier to entry. An implication of this is that it would be difficult to find direct empirical support for adverse selection, even though it is a salient feature of the market studied. Indeed, empirical support for the presence of latent adverse selection might be found in indirect evidence such as otherwise unexplained supra-normal profits or less than expected entry.

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[4]As Hovenkamp (1989) notes, the role of dramatic quality deterioration has long been acknowledged (see, *e.g.*, Jenks, 1888, 1889 or Jones, 1914, 1920), but has, to our knowledge, not been formally modeled. An implication of our model is that under unforeseen negative demand shocks markets do experience dramatic crashes coupled with a deterioration of quality that can be interpreted as ruinous competition.

[5]Etro (2006) also notes the importance endogenous entry has in understanding the market equilibrium, in his case strategic substitutability no longer determines investment distortions.

[6]For a fixed market structure (*i.e.*, without entry) positive profit with asymmetric information can also arise, see for example, for the case of moral hazard Bennardo and Chiappori (2003), but also Klein and Leffler (1981), Creane (1994), and Dana (2001); and positive profit can persist even when entry is considered, when there is an exogenously given incumbent with advantages over potential entrants, see, *e.g.*, Schmalensee (1982), Farrell (1986), or Dell'Ariccia *et al.* (1999). More generally, on the importance of positive profit persistence when endogenizing entry, see Etro (2011).

Thus, the analysis suggests heretofore unrecognized factors in the empirical literature on how uncertainty affects entry. For instance, in our model price-cost margins (*i.e.*, profitability) are not necessarily related to concentration, so the analysis may shed light on the apparent empirical contradiction that—on the one hand—uncertainty has been found to have a greater negative impact on investment as the price-cost-margin increases (*e.g.*, Guiso and Parigi, 1999); but—on the other hand—the inverse relationship between uncertainty and investment has been shown to be stronger for more competitive environments (Ghosal and Loungani, 2000).

The basic intuition for why latent adverse selection can affect entry is easily illustrated in the following stylized example. Consider ten price-taking sellers each of whom has one indivisible unit. Sellers possess a technology that either provides a high quality product at cost 2.20, or a low quality product at cost of 1.50. Demand for high quality goods is given by $\overline{P} = 7(1 - 0.05Q)$; for low quality goods it is $\underline{P} = 2(1 - 0.05Q)$. The quality of an individual seller's product is unobservable, but it is known that half of the sellers offer high quality. Demand for goods of unknown quality is given by $\tilde{P} = (.5 \times 7 + .5 \times 2)(1 - 0.05Q) = 4.5(1 - 0.05Q)$. The equilibrium price for the goods of unobservable quality when all ten sellers provide one unit each is $P^* = 4.5(1 - 0.05 \times 10) = 2.25$, which is sufficient to cover the cost of both low and high quality providers, yielding an expected profit of 0.40.

A potential entrant is contemplating this market. The quality of the entrant's product is equally likely to be high or low *ex ante* (*e.g.*, this may be the result of R&D that is required to enter the industry) so her expected costs are $.5 \times 1.50 + .5 \times 2.20 = 1.85$. Should the seller enter this market? Remarkably, the answer is no.

Since the entrant's level of quality is unobservable, market demand is—as before—given by $\tilde{P}$. If the seller enters the market, the price with eleven units on offer in the market is thus $P^* = 4.5(1 - 0.05 \times 11) \approx 2.03$. While this price is above the seller's *ex ante* expected costs of 1.85, it is insufficient to cover a high quality seller's cost of 2.20. *Ceteris paribus*, this need not be of concern to the eleventh seller, since she might contemplate entry in anticipation of becoming a low-quality provider. However, upon entry *some* high quality seller is driven

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out of the market. As a result, the average quality in the market is diminished. This implies a decrease of demand, reinforcing the reduction in price. In other words, adverse selection takes holds of the market and—as can readily be verified for this illustrative example—all high quality sellers leave the market.[7] With only low quality sellers left, demand is given by $\underline{P}$, and so the price is no greater than $P = 2(1 - 0.05 \times 5) = 1.50$,[8] which is the cost of producing low quality. Consequently, low quality sellers can at best only cover their costs and therefore make zero profit.

In sum, despite prices being well above cost when there are ten sellers in the market, if an additional seller enters the market, adverse selection sets in and the price plummets from 2.25 to 1.50. Hence, no investment made to enter the market—no matter how small—can be recovered. As a consequence no entry takes place: latent adverse selection in the market serves as an entry barrier protecting above normal profits and, in equilibrium, there is no adverse selection in the market: all sellers—high and low quality alike—are active in the market.

The underlying mechanism that generates the result is that prices are a function of both the quantity and the average quality sold in the market. Entry reduces prices due to increased quantity, but the price reduction triggers adverse selection, reducing average quality and further eroding profit, rendering initial entry costs unrecoverable. As a consequence, the entry equilibrium may result in positive profit, even with costless entry, while trade in the market does not exhibit adverse selection.

That these insights are not merely a peculiarity of the illustrative example is demonstrated in the more general framework introduced in Section 2. Welfare and potential policy implications of the equilibrium are are derived and it is shown that while the absence of adverse selection raises welfare compared to increased entry coupled with adverse selection, welfare still falls short of second-best levels. Section 2 is closed out with some technical

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[7]Consecutive market prices upon exit of 1, 2, 3, 4, 5 high-quality sellers are approximately 2.13, 2.17, 2.14, 2.00, 1.69; none of which are sufficient to cover the costs of producing high quality.

[8]There are at least the original five, but possibly six low quality sellers in the market depending on the investment outcome of the entrant.

conditions that differentiate markets with the potential for milder forms of adverse selection. These technical conditions are used when we examine the robustness of the findings by considering alternative frameworks in Section 3. In particular, while for heuristical reasons the base model deals with binary quality distributions, we extend the main insights to generalized quality distributions and, while the base model assumes price-taking behavior, we consider monopolistic sellers who choose reduced capacities due to latent adverse selection. Section 4 contains some concluding remarks, all proofs are collected in the Appendix.

2   Entry and Welfare in the Base Model

In this section we present the basic model with a binary distribution of quality. We consider the entry equilibrium, while distinguishing markets in which no high quality is provided when there is adverse selection ("complete" adverse selection) from those in which some high quality providers continue to sell ("partial" adverse selection). Thereafter we analyze the welfare properties of the equilibrium configurations and propose a revenue-neutral welfare enhancing tax-*cum*-subsidy scheme that results in the attainment of the second-best welfare optimum. We conclude with a discussion of technical conditions that differentiate markets in which partial adverse selection may occur from markets where this phenomenon does not arise. These technical conditions are then shown to hold with generalized (continuous) distributions of quality.

2.1   The Base Model

Consider a two-period model of a market for a good or service of which the quality characteristics are inherently unobservable to buyers. In the first period sellers spend $\iota \geq 0$ to cover expenses associated with securing requisite inputs, basic research and development outlays, or educational and certification fees to enter the market. Thereafter sellers obtain a production/service capacity that we normalize to 1.

Similar to the classic papers by Jovanovic (1982) and Hopenhayn (1992), the result of

the initial investment outlay is unknown *ex ante*, but has a binomial distribution: there is a probability τ that a seller's product is of high quality with unit cost of $\bar{c}$; and $(1 - \tau)$ is the probability that it is of low quality, costing $\underline{c}$.[9] At the end of the first period, the seller observes the quality that she can provide after her investment outlay of ι is sunk.[10]

The augmented cost for high quality either represents a production cost or can be thought of as an opportunity cost, as is done, for example in Daughety and Reinganum (2005), *i.e.*, all sellers have costs of $\underline{c}$, but high quality providers have an outside option valued at $\bar{c}$. The latter interpretation is pertinent if, for instance, there is an alternative use for the product, as is the case in Akerlof's (1970) archetypal paper in which used car owners may choose to keep their cars, horse-breeders who choose to hold on to some yearlings (Chezum and Wimmer, 1997), and lenders who keep mortgages on their books rather than selling them in the secondary market;[11] or if high-quality products can be sold in an alternative market in which quality is independently verified—as is the case in viniculture with vintners who can sell their grapes to a *négociant*, rather than selling under their own label (Lonsford, 2002a,b, Heimoff, 2009), or electronics manufacturers who sell their products to name brands for retail (see, *e.g.*, Financial Times Information, 2000), or lawyers, accountants, or doctors who can join a firm or hospital instead of being in private practice.[12]

In the second period market exchange takes place. Since quality is unobservable to buyers, the market clears at one price, P. Sellers act as price takers *vis-à-vis* that price and

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[9]Jovanovic (1982) and Hopenhayn (1992) consider *ex ante* unknown cost differences of sellers entering a market. In contrast to our work, however, these studies consider industry dynamics assuming a homogeneous product of known quality.

[10]As will become clear below when we discuss the equilibrium notion, whether or not the seller observes a rival's quality-realization is not germane, nor, for that matter, is the exact assumption governing the quality-determination process, provided that τ captures the expected quality across, but not necessarily within sellers.

[11]The commercial mortgage-backed security (CMBS) market is subject to adverse selection at the margin between loans that are securitized in-house by the originator and loans sold to competing CMBS underwriters, see Chu (2011).

[12]The two interpretations of the unit cost for high quality (*i.e.*, production costs or opportunity costs) are isomorphic whenever the investment outlay is not so low that sellers invest solely in the hopes of obtaining high quality for the alternate use. Consequently, all the derived results continue to hold under the opportunity cost interpretation provided that the critical thresholds on ι derived in the paper are shifted by the amount of this added profit opportunity.

make an output decision that maximizes their market profit (gross of entry expenditures, which are sunk at this stage) $\pi := P - c$, given their costs $c \in \{\underline{c}, \overline{c}\}$, with $0 < \underline{c} < \overline{c}$.

Following the classic literature on entry, and thereby departing from the large majority of the work on adverse selection and credence goods which relies on unit or box demand, we assume downward sloping demand. Specifically, inverse demand for (known) high quality goods or services is given by $\overline{P}(Q)$, whereas demand for low quality is $\underline{P}(Q) \, (< \overline{P}(Q), \forall Q)$—both twice continuously differentiable and strictly decreasing. The interpretation of demand for high and low quality is straightforward for experience goods—e.g., the former gives demand for wines that are recognized to be of high quality, whereas the latter applies to what is known to be an inferior wine. Or, willingness to pay is a function of the default risk associated with a mortgage. For the case of credence goods one can consider service of varying quality. For instance, high quality demand may apply to auto repairs that are conducted with a manufacturer's original replacement parts only; whereas low quality demand may reflect willingness to pay for repairs done with used or reconditioned parts procured on the second-hand market. Or, in the case of assisted tax preparation, the low quality demand might apply to tax returns that assure that they pass an audit by the taxing authority, but that might miss some eligible deductions or credits; whereas high quality demand reflects the willingness to pay if, in addition to passing muster, deductions and credits are also maximized.

While sellers know the quality characteristics of their offerings, quality is unobservable to buyers. That is, buyers do not know the quality of the given bottle of wine until it is purchased and consumed, the risk associated with a mortgage may not be revealed unless and until if defaults, motorists cannot even *ex post* determine which kind of parts were use in the repair, and tax payers never learn their counter-factual tax refund. However, we assume that buyers know the *ex ante* distribution of quality that can be delivered, given by τ. Moreover, at the beginning of the second period, buyers know the number of sellers that invested in order to sell in the market. On the basis of this, buyers form beliefs about the quality composition of overall market supply. Letting α denote the buyers' perception of

the fraction of high quality available in the market (which can differ from τ, depending on sellers' individual supply choices), inverse market demand is denoted by $P(Q, \alpha)$.

We require that since both demand for high quality $\overline{P}$ and demand for low quality $\underline{P}$ are strictly decreasing, $P(Q, \alpha)$ is strictly decreasing in its first argument. And, since $\overline{P} > \underline{P}$, market demand is increasing in its second argument, reflecting the greater willingness to pay for higher quality. For expositional ease and without loss of generality we let

$$P(Q, \alpha) := \alpha \overline{P}(Q) + (1 - \alpha)\underline{P}(Q). \tag{1}$$

In equilibrium, buyers' beliefs about the expected (*i.e.*, average) quality in the market are consistent with sellers' actions so that α correctly reflects the average quality of the goods in the market.

We assume that selling some high-quality is efficient, (*i.e.*, $\overline{c} < P(0, 1)$) and, in order to make entry attractive, that producing some low-quality is also efficient (*i.e.*, $\underline{c} < P(0, 0)$). As a result $Ec := \tau\overline{c} + (1 - \tau)\underline{c} < P(0, \tau)$ so that there is positive demand under the prior. Moreover, since we are interested in market constellations in which adverse selection may occur, we assume for convenience that when beliefs rule out the presence of high quality, the market price is insufficient to cover the costs of delivering high quality, *i.e.*, $P(0, 0) < \overline{c}$. Finally, we make the standard assumption that $\lim_{Q \to \infty} P(Q, \tau) = 0$.

Our assumptions characterizing the market equilibrium do not always identify a unique equilibrium. In particular, while maintaining that low quality is always delivered at prices exceeding $\underline{c}$, there is the possibility of a coordination failure in which high-quality sellers under-provide for no reason other than buyers do not expect them to provide. In order to assure that sellers' entry decisions are not driven by equilibrium selection, we use the Pareto selection criterion to eliminate all but one market equilibrium, whenever multiple equilibrium configurations concerning high quality output exist. This means that we restrict attention to the equilibrium with the greatest average quality of output in the market.[13] As a result

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[13]Wilson (1980) considers the possibility of multiple equilibrium configurations and notes that these can be Pareto-ranked by increasing prices; Rose (1993), however, finds that generally a unique equilibrium emerges. In our model there is multiplicity, including the possibility of more than one equilibrium with the same price so that average quality, rather than price, yields the relevant Pareto-ranking.

of this assumption, for any number of sellers n in the market there is a unique equilibrium price $P^*(n)$, which implies a well-defined expectation of market profit for the nth seller prior to entry, *i.e.*, $E\pi(n) = P^*(n) - Ec = P^*(n) - [\tau\bar{c} + (1 - \tau)\underline{c}]$.

For purposes of greater clarity and for expositional ease we make the following assumptions without loss of generality:

1. We treat the number of sellers n as coming from a continuum.[14]

2. We characterize symmetric equilibrium configurations in which sellers choose mixed strategies over binary production plans, *i.e.*, they choose a probability with which they either sell their full capacity, or exit the market.[15]

3. We consider sequential entry of sellers so that the equilibrium is determined by the last seller that expects to recover her entry costs of ι upon entering the market.[16]

2.2 Endogenous Entry and Market Equilibrium

Due to downward sloping demand for a given quality composition, as sellers enter the market the increase in supply drives down the market price. Consequently sellers' expected market profits are diminished upon entry. Entry continues up to the point where the marginal seller's expected market profit upon entering, $E\pi$, no longer exceeds the entry cost of ι. We consider how this process plays out in the equilibrium of the entry game, and what the implications of the entry equilibrium are on the market equilibrium.

We first consider high entry costs and demonstrate that in the resulting zero-profit entry equilibrium no adverse selection occurs in the market. Second, we consider lower entry costs (including the possibility of zero entry costs) and examine markets in which adverse selection

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[14]Consequently, any above-normal profit equilibrium is not due to the well-known integer constraint problem, but is a general characteristic of the equilibrium that occurs even when n is an integer.

[15]Other equilibrium configurations, involving asymmetric pure strategies, or fractional capacity utilization rates, yield identical insights.

[16]The equilibrium is qualitatively the same when assuming simultaneous entry decisions. In the special case of costless entry, the Pareto criterion yields that a seller refrains from entering when she is indifferent between entering or not.

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leads to all high quality being taken off the market so only low quality is traded.[17] We refer to this market outcome as "complete" adverse selection, and show that the possibility of complete adverse selection may function as a barrier to entry so that the entry equilibrium is associated with positive profits and there is no adverse selection in the market.

We conclude this subsection by considering a milder form of adverse selection in which some, but not all high quality is taken off the market. We show that with small (possibly even zero) entry costs adverse selection may still function as an entry barrier, resulting in an entry equilibrium with positive expected profit in concurrence with partial adverse selection; while complete adverse selection is prevented from occurring in the market equilibrium. We leave for later a more technical discussion of the conditions on demand, costs, and quality that allow for partial adverse selection to occur.

2.2.1 High Entry Cost: Zero Profit and No Adverse Selection

The entry equilibrium is determined once the marginal seller is left without positive overall expected profit when contemplating incurring the investment outlay of ι given the expected market profit upon entering. Thus, if entry costs ι are large, a seller must expect high market profits upon entry in order to enter the market. Since expected costs of the seller are exogenous, the only way to support high expected profits is through a high market price. However, a price that is high enough to induce entry of the last seller, may be sufficiently high so that all sellers in the market—regardless of their quality and cost characteristics— can cover their costs. Consequently, there is no adverse selection in the market when prices are sufficiently high. This leads to the first result, which is useful as a benchmark for later results because it establishes the conventional entry equilibrium outcome. Specifically, high entry costs imply a zero-profit entry condition and a market in which there is no adverse selection. A formal statement follows—all proofs are in the appendix.

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[17]Using the Pareto selection criterion in conjunction with our assumption that it is efficient to provide some low quality precludes a complete market collapse. However, these cases are easily subsumed in the current analysis.

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Proposition 1 (High Entry Costs Prevent Adverse Selection) *There exists an invest-ment cost $\bar{\iota}$ such that whenever $\iota \geq \bar{\iota}$,*

1. *if entry takes place, the equilibrium number of sellers n^* is implied by the market price that is equal to the total expected cost of the seller,* i.e., *$P(n^*, \tau) = \iota + Ec$;*

2. *sellers make zero expected profit,* i.e., *$E\pi - \iota = 0$; and*

3. *there is no adverse selection in the market,* i.e., *all high quality providers are active in the market and the average quality in the market is characterized by τ.*

In this equilibrium *ex ante* profits are zero and all sellers in the market are active. It follows that under endogenous entry adverse selection is not observed when there are sufficiently high entry costs despite the salient features of adverse selection being present. To put this more succinctly: when entry costs are high, few sellers enter. And when few sellers enter, a high price is sustained. And when the price is high, all sellers can cover their costs. Finally, when all sellers can cover their costs there is no adverse selection.

The critical threshold of entry costs noted in the proposition is given by $\bar{\iota} = (1-\tau)(\bar{c}-\underline{c})$. This threshold is exactly equal to the *ex ante* expected profit of a seller when the market price only just covers the cost of producing high quality, *i.e.,* when $P = \bar{c}$ so that only low quality providers obtain positive profit. We now turn to how endogenous entry affects markets when entry costs are lower.

2.2.2 Positive Profit and No Adverse Selection

We now suppose that entry costs are below the threshold identified in Proposition 1 and show that the resulting increase in entry still need not result in adverse selection. In order to demonstrate this, note first that for adverse selection to *not* occur all sellers must be offering their output for sale. This only happens if the resulting market price is no lower than the cost of producing high quality. Let $\bar{n}$ denote the largest number of sellers that the market can sustain under full production without adverse selection setting in. It follows that $\bar{n}$ is

implicitly given by

$$P(\overline{n}, \tau) = \overline{c}. \tag{2}$$

Sellers' expected market profits (*i.e.*, gross of entry costs ι, but before production costs are known) at $\overline{n}$ are given by

$$E\pi\left(\overline{n}\right) = P(\overline{n}, \tau) - [\tau\overline{c} + (1 - \tau)\underline{c}] = (1 - \tau)(\overline{c} - \underline{c}). \tag{3}$$

This is the critical threshold on entry costs, identified in Proposition 1, above which entry falls short of levels that may trigger adverse selection. We now derive the entry equilibrium when entry costs are below this level of *ex ante* expected market profit. That is, we consider cases in which, in contrast to Proposition 1, $\iota < \overline{\iota}$.

As noted, if sellers in excess of $\overline{n}$ enter the market, then adverse selection occurs. In the current analysis we restrict attention to the classic case of adverse selection in which high quality is completely driven out and only poor quality remains in the market.[18]

Proposition 2 (Adverse Selection as an Entry Barrier) *Suppose that for any amount of entry that induces a price below high quality cost when all entrants are active, i.e., $n > \overline{n}$, the market suffers from complete adverse selection and only low quality is traded in the market. Then there exists an investment cost $\underline{\iota} \in [0, \overline{\iota})$ such that for all $\iota \in [\underline{\iota}, \overline{\iota})$,*

1. *the equilibrium number of entrants results in an equilibrium price equal to high quality cost when all entrants are active so that $n^* = \overline{n}$;*

2. *sellers make positive expected profit, i.e., $E\pi - \iota > 0$; and*

3. *there is no adverse selection in the market, i.e., all high quality providers are active in the market and the average quality in the market is characterized by τ.*

Proposition 2 demonstrates that even with entry costs that do not limit entry to a zero-profit equilibrium, adverse selection need not occur in the market, as the potential for adverse selection itself can work as an effective entry barrier. Having assumed that it is efficient to

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[18]Necessary and sufficient conditions for this case are given in Subsection 2.4.

provide some low quality, a complete collapse (*i.e.*, a no-trade equilibrium) as in Akerlof's (1970) paper does not occur (although we can easily also allow for this outcome, and the insights follow even more readily). Nevertheless, when $\underline{\iota} = 0$ entry is limited to $n^* = \overline{n}$, resulting in above-normal expected profit of $(1 - \tau)(\overline{c} - \underline{c})$ in the entry equilibrium even with costless entry.

Propositions 1 and 2 together suggest that when one considers entry in markets in which there is asymmetric information about quality and costs, then adverse selection does not in fact take hold of the market whenever entry costs are above $\underline{\iota}$, where—depending on characteristics of demand, *ex ante* quality and costs—$\underline{\iota}$ can be arbitrarily small, or even zero. If entry costs are high, then the entry equilibrium is characterized by the common zero-profit condition. However, if entry costs are low, latent adverse selection leads to an entry equilibrium in which sellers' average market profits are above the cost of entry. These results may provide an explanation for why empirical research frequently fails to uncover direct or indirect evidence of adverse selection. However, the propositions suggest alternative tests for these markets, namely either high entry costs serving as a barrier to entry which prevents adverse selection from taking hold of the market (Proposition 1); or above normal profit without additional entry (Proposition 2).

2.2.3 Positive Profit with Partial Adverse Selection

Proposition 2 is concerned with the case of complete adverse selection in which all high quality providers exit and only low quality providers remain, should adverse selection set in. However, recall that given our assumption of downward sloping demand, prices are a function of not only the average quality in the market, but also of the quantity on offer in the market. And thus, sellers shutting down and exiting has—all else equal—the tendency to increase prices in the market. Hence, if entry beyond $\overline{n}$ takes place and the price is insufficient to cover the expense of providing high quality, some high quality sellers (albeit not necessarily all) opt out of the market and shut down. As this reduces the quantity on offer in the market, the price tends to rise, possibly allowing those high quality sellers that

did not opt out to cover their costs.

An illustration of this can be found with a minor modification of the example given in the introduction. If in that example the cost of producing high quality is lower, say, 2.10 rather than 2.20, then the eleventh seller will still enter the market. If she obtains high quality some high quality seller will surely exit, resulting in a price of about 2.13. However, entry of a twelfth seller would not take place, since this would necessarily trigger complete adverse selection and render any investment outlay unrecoverable, regardless of the seller's type. Hence the entry equilibrium would, once again, be characterized by complete adverse selection serving as an entry barrier that preserves above normal profit. And while partial adverse selection is a feature of the market equilibrium; complete adverse selection is not, as high quality remains present in the market.

Whether such an adjustment can take place in any given market depends critically on how sellers' choices affect the composition of quality and quantity in the market. To formalize this, recall demand as a function of quantity and average quality, given in (1) and reproduced here:

$$P(Q, \alpha) = \alpha \overline{P}(Q) + (1 - \alpha)\underline{P}(Q). \tag{4}$$

The proof of Proposition 2 relies on demand being increasing in its second argument. Specifically, notice that in markets that exhibit complete adverse selection with entry beyond $\overline{n}$, α takes on the value of either τ (no adverse selection) or 0 (complete adverse selection). This discontinuity (α switching from τ to 0) when adverse selection sets in is central to the positive profit result in Proposition 2. In departure from the previous analysis, we now consider situations in which both Q and α vary continuously as sellers in the market alter their production decisions continuously—potentially leading to partial adverse selection.

If entry beyond $\overline{n}$ takes place and all sellers remain in the market, then—by definition of $\overline{n}$—the price is below $\overline{c}$, so high quality providers make negative profit in the market. Consequently, at least some high quality providers will exit the market, which reduces market output. Since $P(Q, \alpha)$ is decreasing in its first argument, the reduction of output—all else equal—yields a higher market price. Note, however, that all else is not equal: as only

high quality providers exit the market the positive quantity effect is countered by a negative quality effect since the average quality of what remains in the market deteriorates (see Figure 1). With this we formalize the notion of "partial" adverse selection.
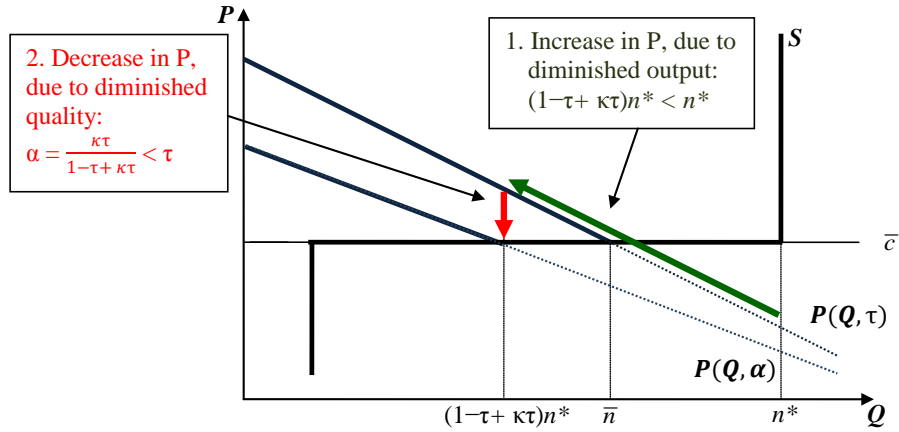

Figure 1: Two Effects of a Reduction in High-Quality Output

Lemma 1 (Partial Adverse Selection) *A market has the potential for an equilibrium with partial adverse selection whenever for some $n > \overline{n}$ there exists $\kappa \in (0,1)$ such that*

$$P\left((1 - \tau + \kappa\tau)n, \frac{\kappa\tau}{1 - \tau + \kappa\tau}\right) = \overline{c}; \tag{5}$$

in which case κ is the proportion of high quality sellers that remain in the market.

While we leave a more technical and detailed discussion of the conditions for the existence of partial adverse selection to the end of this section, it is worth noting at this stage that if several values for κ exist that satisfy (5), then the Pareto equilibrium selection criterion eliminates all but the largest of these. However, it is important to note that partial adverse selection need not exist in a given market: While high quality providers are indifferent between remaining in the market and exiting when the price is $\overline{c}$, their decisions affect average quality and thus buyers' willingness to pay. This, in turn, affects the market price for given market output and sellers are no longer indifferent between exiting or not at prices that are different from $\overline{c}$ so that sellers' production plans are adjusted. Thus, output and average quality must be determined simultaneously and must yield a price of $\overline{c}$. Such balancing is

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not always possible. Indeed, in the initial example used in the introduction to the paper no such balancing is possible so that partial adverse selection cannot occur.

Having formalized the condition for partial adverse selection, we now characterize the implications for entry when the condition holds.[19]

Proposition 3 (Partial Adverse Selection and Positive Profits) *Suppose that the market has the potential for partial adverse selection. Then there exists an investment cost $\underline{\iota}' \in [0, \bar{\iota})$ such that for all $\iota \in [\underline{\iota}', \bar{\iota})$,*

1. *the equilibrium number of entrants is greater than that which would result in an equilibrium price equal to high quality cost, i.e., $n^* > \bar{n}$;*

2. *sellers make positive expected profit, i.e., $E\pi - \iota > 0$; and*

3. *there is partial adverse selection with a fraction $\kappa \in (0,1)$ of high quality providers still operating in the market so that the fraction of high quality is $\alpha \in (0, \tau)$.*

When conditions on demand, the distribution of quality, and costs allow for partial adverse selection, this leads to entry beyond $\bar{n}$, whenever entry costs are not prohibitive, *i.e.*, they are not above $\bar{\iota}$. However, as some high quality sellers opt out of the market, average quality in the market deteriorates upon entry beyond $\bar{n}$. At some point continued entry leads to such a deterioration of average quality that buyers are no longer willing to pay a price that covers the costs of providing high quality, at which point further entry results in complete adverse selection in the market. That is, latent complete adverse selection still determines the equilibrium entry level.

A comparison between markets with the possibility of partial adverse selection with those where only complete adverse selection can occur is not directly possible, since these markets must differ in some aspects of demand, cost, or the exogenous quality parameter. However, it may nonetheless be worth noting that if the markets are sufficiently similar in the relevant

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[19]The analysis of high entry costs given in Proposition 1 is independent of whether the market has the potential for partial adverse selection.

aspects, then the threshold level identified under partial adverse selection, $\underline{\iota}'$, may be smaller than that under complete adverse selection, $\underline{\iota}$, since partial adverse selection permits entry beyond $\overline{n}$. In particular, if demand for low quality, the cost of producing low quality, and the exogenous probability of being of high quality are the same across markets and if demand for and costs of high quality are such that $\overline{n}$ is the same in both markets, then $\underline{\iota}' \leq \underline{\iota}$ with equality only when $\underline{\iota}' = \underline{\iota} = 0$.

Thus, loosely speaking, while markets with partial adverse selection are more prone to exhibit adverse welfare effects of adverse selection, a complete market collapse—and hence the most drastic implication for welfare—is more likely to be averted, since the critical threshold for entry costs is low. This observation naturally leads to a more detailed examination of welfare in these markets.

2.3   Welfare

The focus of the preceding analysis has been sellers' forward looking decisions based on their profit considerations. In this subsection we assess overall equilibrium welfare under endogenous entry in markets with adverse selection. To this end, let $CS(n)$ denote consumer surplus in the (unique) market equilibrium with n sellers and define $W(n) := CS(n) + nE\pi(n)$ as the total welfare in the market when n sellers have entered.

To begin, an implication of Proposition 1 is that when entry costs are above $\overline{\iota}$ the entry equilibrium yields the maximum welfare. This follows, since there is no adverse selection in the market and so there is no welfare loss in the market; and given that sellers' entry decisions yield zero expected profit, any increase in the welfare in the market upon entry is insufficient to offset additional entry costs. This insight does not apply to the cases of Propositions 2 and 3 since these equilibrium configurations are characterized by positive profits. However, as these equilibrium configurations also do not exhibit complete adverse selection, positive profits need not imply welfare losses compared to increased entry. Indeed, limited entry not only protects the above normal profits, but also protects consumer surplus in the market that arises because high quality is traded. Formally,

Proposition 4 (Welfare Preservation) *When investment costs are in the intermediate range, i.e., $\iota \in (\underline{\iota}, \overline{\iota})$ so that latent adverse selection serves as an entry barrier and $n^* = \overline{n}$, overall welfare is greater compared to market settings with an increased number of sellers entering.*

In other words, when entry costs are are such that $\iota \in (\underline{\iota}, \overline{\iota})$ (for complete adverse section and $\iota \in (\underline{\iota}', \overline{\iota})$ for partial adverse selection), entry beyond the entry equilibrium reduces market welfare, as the market collapses and complete adverse selection occurs. Hence, when endogenizing entry, the welfare losses associated with complete adverse selection are averted.

Nevertheless, the fact that profit is not competed away in the entry process suggests the potential for welfare improving policies. Indeed, it is still possible for a welfare-maximizing competition agency to raise welfare, even when the quality of the individual sellers is also unobservable to the government agency (*i.e.*, second-best welfare maximization). To see this, note that while entry beyond $\overline{n}$ necessarily (weakly) reduces the market price, incremental entry beyond $\overline{n}$ coupled with a commitment to full production by all sellers (including all high quality sellers, who then operate at a loss) yields a price that is above expected overall costs (including entry costs), *i.e.*, $P(n + \epsilon, \tau) > \tau\overline{c} + (1 - \tau)\underline{c} + \iota$, with ϵ small, but positive. Such incremental entry increases welfare because the gain to buyers, due to increased output and increased average quality, is greater than the loss to high quality sellers from producing without being able to cover all costs. Hence, the equilibrium entry level is less than the second best welfare optimum.

It may seem counter-intuitive that it is socially optimal to have a high quality seller sell in the market in which she earns negative economic profits, but the high quality seller creates a positive externality by increasing the average quality in the market. Thus, the constrained welfare-optimal amount of entry, denoted by n^{**}, is obtained when entry costs are just offset by market profit under (forced) full production, *i.e.*, $P(n^{**}, \tau) = \tau\overline{c} + (1 - \tau)\underline{c} + \iota$.

Thus, while forward-looking sellers refrain from entering and thereby prevent the welfare losses associated with adverse selection, the entry level is inefficient compared to the second-best welfare optimum. Despite entry being socially insufficient, the traditional solution to

increase entry—*i.e.*, subsidizing entry—does not work. This is because the additional entry that the subsidy induces does not result in the positive market externality of high quality output, since at the point of the production/provision decision, the subsidy is sunk and high quality providers are better off exiting the market. That is, the negative welfare effects of limited entry are not curbed by the introduction of an entry subsidy. Indeed, this suggests a further indirect test for the presence of adverse selection in markets, namely that entry subsidies (short of the remaining above-normal profit) do not affect the market equilibrium.

Although an entry subsidy does not move the market towards the second-best welfare maximum, the classic solution of offering a production subsidy for sellers in the market does so, provided that this policy is announced before entry occurs. Specifically, a production subsidy that covers the high quality seller's short-fall of revenue over costs, *i.e.*, $\bar{c} - P(n^{**}, \tau)$, results in the second best welfare optimum: all high quality sellers are able to cover their costs of production when n^{**} sellers enter, as they sell their product at the price of $P(n^{**}, \tau)$ and obtain the subsidy. This outcome, however, continues to result in positive *ex ante* (expected) profits, since high quality sellers break even and low quality sellers make positive profit. Nevertheless, despite the positive profits at this new level of entry, additional sellers do not enter, as otherwise this added entry again reduces prices to a level where adverse selection sets in, which renders investment costs unrecoverable.

It should be noted that the welfare-increasing policy can be made revenue-neutral. This is done by imposing an entry tax in the first period equal to the value of the subsidy. With this tax and the production subsidy, expected profits for the n^{**} sellers that enter are zero. Consequently, such a revenue neutral policy is welfare enhancing even if the subsidy and tax fall short of the optimal level, since the increased entry coupled with the positive market externality from sustained production of high quality raises welfare. If, instead, the tax and subsidy is set above the optimum, then the optimal level of entry (*i.e.*, n^{**}) followed by full production still results, because entry greater than n^{**} generates negative profits and so entry beyond n^{**} does not occur. We summarize this discussion in the following proposition.

Proposition 5 (Revenue-Neutral Welfare Optimizing Policy) *The second best social*

welfare optimum can be achieved with a period-two production subsidy and a revenue-neutralizing period-one investment tax. Moreover, even if the government sets the wrong subsidy level, as long as there is a revenue-neutralizing investment tax, welfare increases.

An advantage of such a combined policy in which sellers are first taxed and later subsidized is that the policy is easy to implement. In contrast to previous suggestions that restrict the subsidy to high-quality providers, there is no need for the verification of a seller's quality as all sellers receive the subsidy. Hence, sellers need not worry about the possibility of an erroneous or faulty application of the subsidy rule, which otherwise might lead high-quality providers to refrain from producing.

Despite the fact that the proposed policy in Proposition 5 does not require verification of quality since the subsidy applies indiscriminately to all sellers, the policy is costless due to its revenue-neutrality. Hence the government need not know if there is latent adverse selection, that is, if there is no latent adverse selection, then the investment-entry decision is unaffected. A final advantage of the proposed policy is that, since the policy is revenue neutral, an industry will only lobby for it when the policy increases overall welfare.

2.4   Conditions For Complete Adverse Selection

Since the notion of partial adverse selection is novel to this paper we examine when it can arise. The conditions obtained facilitate the analysis of the extensions and generalizations studied in the next section. As a matter of nomenclature, we refer to a market in which complete adverse selection may occur, but partial adverse selection cannot happen, as a market with "complete adverse selection" (even though in equilibrium there is no adverse selection when $\iota > \underline{\iota}$). We otherwise speak of a market with "partial adverse selection" (even though this market exhibits complete adverse selection when $\iota < \underline{\iota}'$).

In line with Lemma 1 let κ denote the proportion of high quality sellers that have entered into and remained in the market (so that the proportion $(1-\kappa)$ of high quality providers exit after having initially entered). Then, for a given number of sellers in the market n, market output is given by $Q(\kappa|n) := (1 - \tau + \kappa\tau)n$; and the proportion of high quality in the market

is given by $\alpha(\kappa) := \frac{\kappa\tau}{1-\tau+\kappa\tau}$. Define the market price (*i.e.*, a seller's revenue) for given n and given κ by

$$\mathcal{P}(\kappa|n) := P(Q(\kappa|n), \alpha(\kappa)) = \alpha(\kappa)\overline{P}(Q(\kappa|n)) + (1-\alpha(\kappa))\underline{P}(Q(\kappa|n)). \tag{6}$$

This representation allows one to consider how the market price varies with incremental changes in the proportion of high quality output in the market. In particular, it serves to show how the exit of a high quality seller has two countervailing effects on price (as depicted in Figure 1). Thus,

$$\mathcal{P}'(\kappa|n) = \frac{d\mathcal{P}}{d\kappa} = \frac{\partial P}{\partial Q}\frac{dQ}{d\kappa} + \frac{\partial P}{\partial\alpha}\frac{d\alpha}{d\kappa} = \underbrace{\left((1-\alpha)\underline{P}' + \alpha\overline{P}'\right)\tau n}_{\text{Quantity Effect}} + \underbrace{\left(\overline{P} - \underline{P}\right)\frac{\tau(1-\tau)}{(1-\tau+\kappa\tau)^2}}_{\text{Quality Effect}}.$$

When considering a reduction in κ, the first term is the slope of the demand curve for a given quality composition of output, so this term captures the positive price effect of a reduction in output (*cf.* Figure 1). This term is weighted by τ, since only high quality sellers exit. The second term measures the (negative) effect on the price premium that buyers are willing to pay for high quality over low quality, weighted by the marginal impact of decreases in average quality, due to a reduction in κ (see Figure 1). Whether these two effects can offset each other in such a way to establish a market price that leaves high quality sellers indifferent about remaining in the market, *i.e.*, $\mathcal{P}(\kappa) = \bar{c}$, determines whether a market can exhibit "partial adverse selection" (Lemma 1). In particular then, a market cannot exhibit partial adverse selection whenever

$$\mathcal{P}(\kappa|n) < \mathcal{P}(1|\bar{n}) = \bar{c}, \qquad \forall\kappa \in [0, 1] \text{ and } n > \bar{n}. \tag{7}$$

In order to better interpret the condition, consider a market in which there are currently $\bar{n}$ sellers so that the market price is just sufficient to cover the cost of high quality production, *i.e.*, $\mathcal{P}(1|\bar{n}) = P(\bar{n}) = \bar{c}$. At this point, for complete adverse selection to not occur, the negative price effects of incremental entry of average quality must be offset by the positive price effects of incremental exit of high quality, when taking account of the negative price effect of deterioration of quality in the market as average quality enters and high quality

exits. Formally, suppose that $\mathcal{P}'(1|\overline{n}) < 0$ (which is a sufficient condition for a market with partial adverse selection). This states that a marginal reduction in high quality leads to an increase in the price when the market is at $\overline{n}$. Note that $\mathcal{P}'$ is continuous in n. Therefore a marginal change in n does not change the sign of $\mathcal{P}'$, implying that an increase in price, due to incremental entry beyond $\overline{n}$, can be offset by an incremental reduction in high quality output. If this is not the case, then the possibility that an incremental reduction in high quality can yield partial adverse selection is precluded. This yields,

Lemma 2 (Necessary Condition for Complete Adverse Selection) *A necessary condition for a market with complete adverse selection (*i.e.*, no partial adverse selection) is that*

$$\mathcal{P}'(1|\overline{n}) \geq 0.$$

The condition given in Lemma 2 is not sufficient to assure that (7) holds, since partial adverse selection need not be the result of a marginal adjustment process. In particular, there are market constellations in which upon incremental entry beyond $\overline{n}$ partial adverse selection emerges due to a (potentially large) positive measure of high quality sellers exiting. Indeed, in the example given in the introduction, if the cost of producing high quality is given by 2.15, rather than 2.20, then upon entry of the eleventh seller in the market, the cost of high quality cannot be recovered even after the exit of one high-quality provider as the price drops to 2.13. However, if *two* high quality providers *simultaneously* exit, the price increases to 2.17, which is sufficient to cover high quality costs. That is, while a marginal reduction in high quality output may not suffice to restore an equilibrium, a large reduction (falling short of complete shut-down of high quality) may yield an equilibrium with partial adverse selection.

We now consider conditions that render Lemma 2 sufficient for a market with complete adverse selection.

Lemma 3 (Sufficient Condition for Complete Adverse Selection) *A sufficient condition for a market with complete adverse selection (given the condition in Lemma 2) is*

that

$$\mathcal{P}''(\kappa|\overline{n}) \neq 0,$$

i.e., $\mathcal{P}(\kappa)$ *is either strictly concave or strictly convex in κ when evaluated at $\overline{n}$.*

Lemma 3 essentially imposes a regularity condition on the price adjustment process as quantity and quality vary. The condition can be made weaker, since high quality being driven entirely off the market only requires that once—for a fixed number of sellers in the market—the price reaches an extremum under variation in the quality make-up of supply, then this extremum is not just local, but also global. For instance, either quasi-concavity or quasi-convexity of $\mathcal{P}$ is also sufficient to guarantee the desired result.

We close this section with two final observations. First, while the primary argument made is applied to conditions when there are $\overline{n}$ sellers in the market, the proof of Lemma 3 establishes that partial adverse selection can be ruled out for measurable entry beyond $\overline{n}$ (*i.e.*, a coordinated simultaneous entry of several sellers). Second, it is straightforward to show that Lemma 3 always holds when demand is not too convex (*e.g.*, linear) and the price premium function (*viz.*, $\overline{P} - \underline{P}$) is either decreasing or elastic whenever it is increasing.

3 Robustness and Extensions

In this section we offer some results on the robustness of the insights by considering a generalization and by discussing some extensions.

3.1 Multiple Periods

An obvious extension is to allow for additional periods of trading. This makes entry more attractive because there are more periods in which to recover entry costs; and it may open the door for consumers to learn about quality—at least for the case where the good in question is an experience good, rather than a credence good. However, such extensions only have a quantitative and not a qualitative impact on the equilibrium. Thus, for the case of a credence

good where learning does not take place even *ex post*, letting π denote the present value of the discounted future profit stream is iso-morphic with the current model, yielding exactly the same results. For the case of experience goods, where buyers learn the quality characteristics over time (be it through repeat purchases or word-of-mouth, *etc.*), a good reputation leads to augmented future profit for high quality producers. But this is qualitatively equivalent to simply assuming a lower cost for the production of high quality, and therefore such an extension also results only in quantitative, but not qualitative differences compared to the base model.

3.2 Continuous Distribution of Quality

Though we considered discrete distributions of quality thus far, the results do not depend on discreteness. Specifically, suppose that quality, indexed by s, is distributed *ex ante* according to the strictly increasing and twice differentiable distribution function $F(s)$ on $[\underline{s}, \overline{s}]$. The cost associated with providing quality index s is given by the strictly increasing twice differentiable function $C(s)$. Given the Pareto selection criterion in conjunction with the law of one price, if it is profitable for a seller of quality index $\sigma \in [\underline{s}, \overline{s}]$ to sell, it is also profitable for all sellers with quality index $s \leq \sigma$ to sell. All other assumptions on sellers remain the same. In particular, we consider a continuum of sellers who each observe an independent draw from the distribution of quality parameters $F(s)$ upon entry. Consequently there is no aggregate uncertainty and the distribution of quality among the sellers in the market is also characterized by $F(s)$.[20]

Demand for quality s is given by $p(Q, s)$, which is twice differentiable and decreasing in market output Q and increasing in quality s. Define demand for the case that σ is the highest level of quality on offer by $P(Q, \sigma) := \int_{\underline{s}}^{\sigma} \frac{p(Q,s)}{F(\sigma)} dF(s)$ and it follows that $P(Q, \sigma)$ is also twice differentiable, decreasing in Q, and increasing in σ. Assume that the lowest quality alone cannot support efficient market transactions, *i.e.*, $P(0, \underline{s}) \leq C(\underline{s})$; whereas

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[20]An implication of the continuous distribution of quality is that in contrast to the previous section the equilibrium entails pure strategies.

there is potential for trade given the *ex ante* average quality, *i.e.*, $P(0, \bar{s}) > C(\bar{s})$. Assuming $\lim_{Q \to \infty} P(Q, \sigma) = 0$ yields that $\bar{n}$ is implied by $P(\bar{n}, \bar{s}) = C(\bar{s})$.

It readily follows that the analogue to Proposition 1 holds with $\bar{\iota} = C(\bar{s}) - Ec$, where $Ec := \int_{\underline{s}}^{\bar{s}} C(y) dF(y)$ is the expected cost of a seller under the prior. For this case n^* is then implied by $P(n^*, \bar{s}) = \iota + Ec$ with $\iota \geq \bar{\iota}$.

In order to distinguish the cases of complete adverse selection from partial adverse selection define similarly to (6),

$$\mathcal{E}(\sigma|n) := P(nF(\sigma), \sigma) - C(\sigma). \tag{8}$$

That is, $\mathcal{E}(\sigma|n)$ is the equilibrium market profit (*i.e.*, the earnings) of the marginal seller with quality index σ, given that n sellers are in the market.[21]

We define complete adverse selection in this context as a case where a marginal deterioration of quality leads to a market collapse, *i.e.*, a discrete drop in average quality and market price so that no sellers continue to provide. In contrast, partial adverse selection entails marginal exit of high quality in such a way that prices adjust smoothly to the altered conditions in the composition of supply. Hence, analogous to (7), the condition that characterizes markets with complete adverse selection is given by

$$\mathcal{E}(\sigma|n) < \mathcal{E}(\bar{s}|\bar{n}) = 0, \qquad \forall \sigma \in [\underline{s}, \bar{s}] \text{ and } n > \bar{n}.$$

The necessary and sufficient conditions for a market to exhibit complete adverse selection are derived analogous to Lemmata 2 and 3, yielding

$$\mathcal{E}'(\bar{s}|\bar{n}) \neq 0.$$

Intuitively speaking the necessary condition assures that if entry beyond $\bar{n}$ takes place so that the price decreases due to the increased supply, profit of sellers at the upper end of the quality support decrease, which implies that a positive measure of high quality sellers

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[21]Because in the two-type case there is only one cost-type (the high cost seller) who makes the marginal decision on whether to provide, (6) does not contain an expression for costs. Here each seller has distinct costs which must be considered explicitly.

must cease production. The sufficient condition then guarantees that not only do a positive measure of sellers near the upper end of the quality support exit, but so do in fact sellers of all quality types.

Given these conditions, the results of positive profits and no adverse selection in the market (Proposition 2) and positive profits with partial adverse selection (Proposition 3) carry over with only minor qualifications to the current setting as illustrated in the following two examples.

Example 1 (Positive Profits and No Adverse Selection) *Let quality be distributed uniformly on the unit interval, i.e., $F(s) = s$ on $[0,1]$ and let costs be given by $C(s) = \sqrt{s}/3$. Demand for given quality is $p(Q,s) = s(1-Q)$, so $P(Q,\sigma) = \int_0^\sigma \frac{s(1-Q)}{\sigma}ds = (\sigma/2)(1-Q)$.*

Given these parameters, $\mathcal{E}(\sigma|n) = (\sigma/2)(1-n\sigma) - \sqrt{\sigma}/3$ and $\mathcal{E}'(\sigma|n) = 1/2 - n\sigma - 1/6\sqrt{\sigma}$. The full production threshold $\overline{n}$ is implied by $P(\overline{n}, 1) = C(1)$, i.e., $(1/2)(1-\overline{n}) = 1/3$, so $\overline{n} = 1/3$. Thus, $\mathcal{E}'(\sigma = 1|n = 1/3) = 1/2 - 1/3 - 1/6 = 0$, so the necessary condition for complete adverse selection is met. Note that when entry is at $\overline{n} = 1/3$ average market profits are given by $P(\overline{n}, \overline{s}) - \int_{\underline{s}}^{\overline{s}} C(s)dF(s) = P(1/3, 1) - \int_0^1 (\sqrt{s}/3)ds = (1/2)(1 - 1/3) - 2/9 = 1/9$. Hence, $\overline{\iota} = 1/9$.

Now consider $n > \overline{n} = 1/3$ and note that the highest quality provider's market profit must be zero. From (8) we have

$$\mathcal{E}(\sigma|n > \overline{n}) = P(nF(\sigma), \sigma) - C(\sigma) = \frac{\sigma}{2}(1 - n\sigma) - \frac{\sqrt{\sigma}}{3} = 0. \qquad (9)$$

However, for all $n > \overline{n} = 1/3$, (9) does not have a non-negative root in σ so there exists no market equilibrium with production for $n > \overline{n}$ and therefore $\underline{\iota} = 0$, $n^* = \overline{n} = 1/3$ and in the entry equilibrium sellers make an average profit of $1/9 - \iota > 0$.

Example 2 (Positive Profits with Partial Adverse Selection) *Consider Example 1, now with costs given by $C(s) = \sqrt{s}/4$. Then $\overline{n} = 1/2$, since $(1/2)(1-\overline{n}) = 1/4$; and $\mathcal{E}'(\sigma = 1|n = 1/2) = 1/2 - 1/2 - 1/8 = -1/8 < 0$, so the necessary condition for complete adverse selection is violated (i.e., the sufficient condition for partial adverse selection is met).*

Note that when $\overline{n} = 1/2$ sellers enter, average market profits are $P(1/2, 1) - \int_0^1 (\sqrt{s}/4)ds = (1/2)(1 - 1/2) - 1/6 = 1/12$, so $\overline{\iota} = 1/12$.

Now, analogous to (9), the equilibrium condition for the highest level of quality for entry beyond $\overline{n} = 1/2$ is given by

$$\mathcal{E}(\sigma|n > \overline{n}) = \frac{\sigma}{2}(1 - n\sigma) - \frac{\sqrt{\sigma}}{4} = 0. \tag{10}$$

This equation does have a root in σ provided that $n \leq 16/27$, but not for entry beyond that, so $\overline{n}' = 16/27$. At $\overline{n}'$ (10) reveals that $\sigma = 9/16$. A seller's expected market profit (after entry, but before quality and costs are realized) at this point is given by $F(\sigma)\mathcal{E}(\sigma|\overline{n}') = 9/256$. So for $\iota \in [0, 9/256)$, $n^* = 16/27$ and equilibrium profit is $9/256 - \iota > 0$.

The main distinction between Proposition 3 for the discrete case and Example 2 for a continuous distribution of quality concerns sellers' profits under partial adverse selection. In particular, where in Proposition 3 sellers retain positive profit for any entry cost between $\underline{\iota}'$ and $\overline{\iota}$, this is not the case in Example 2. Specifically, the entry equilibrium configuration for $\iota \in [9/256, 1/12 = \overline{\iota}]$ entails zero expected profit as sellers enter beyond $\overline{n} = 1/2$ and quality gradually adjusts with the implied price decline. However, such gradual adjustment is not possible beyond $n^* = 16/27$ at which point a positive profit equilibrium emerges when entry costs are below $9/256$.

3.3 Monopolistic Markets

Having shown that limited entry and above normal profit can occur even under costless entry in Walrasian markets due to latent adverse selection, we briefly consider the case of monopolistic markets.[22] As the monopoly market implies restricted entry, it is clear that profits are expected to occur in equilibrium and therefore the point of this section is to demonstrate that latent adverse selection nonetheless affects the market equilibrium. In particular, the potential for adverse selection still leads to "limited entry," but now in terms

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[22]Since Akerlof's seminal paper much of the theoretical literature has actually departed from his analysis by focusing on monopoly settings (and thereby precluding entry). See, *e.g.*, Milgrom and Roberts (1986), Daughety and Reinganum (1995), but also the more recent work by Hendel and Lizzeri (2002) and Belleflamme and Peitz (2009).

of a reduced capacity choice by the monopolistic seller. Coupled with the result is, similar to the other models, that the market equilibrium exhibits no adverse selection.

Formally, we suppose that the seller incurs an investment outlay of ι in order to obtain an observable production capacity which, for purposes of congruence with the base model, we denote by n. After the capacity decision, the seller observes the quality of her product as being high with probability τ or otherwise low. To not distract from the point at hand, we preclude signalling equilibrium configurations by assuming that low quality alone cannot sustain sales, which implies that a low quality-provider will always mimic the strategy of the high-quality provider, thus, eliminating any separating equilibrium. Once the seller knows her quality and costs, she chooses a price and then provides output $Q \leq n$.

Example 3 (Reduced Capacity Choice) *Suppose $\tau = 2/3$; demand for known high quality is given by $\overline{P} = 6(1 - 0.05Q)$, whereas there is no demand for low quality. Hence demand for average quality is $P = 4(1 - 0.05Q)$. Unit cost of high quality is $\overline{c} = 3$ and $\underline{c} = 0$. Buyers (rationally) anticipate that a high quality provider would leave capacity unused, if the price is below $\overline{c}$, since this price is below the unit cost of production. However, above this price, as either type would in fact sell (and the low quality provider would sell whatever the high quality provider sells at these prices), demand follows the demand for expected quality. In sum*

$$
P = \begin{cases} 4(1 - 0.05Q) & \text{if } Q < 5 \\ 0 & \text{if } Q \geq 5. \end{cases}
$$

Thus, the seller will only be able to sell when facing demand of $P = 4(1 - 0.05Q)$. If the seller has high costs, it provides $Q^* = 2.5$, which is also provided if the seller has low cost in order to mimic the high cost seller. Hence $n^* = 2.5$.

In contrast, if the seller were to be known to provide high quality her output is 5 and it is 0 if it is known to provide low quality, yielding an average output of $n^{FI} := (2/3)5 + (1/3)0 = 10/3 > 2.5 = n^*$. And optimal output under average quality provided at average costs is $n^{Avge} := 5 > 2.5 = n^*$. Thus, one obtains reduced capacity compared to either benchmark with $\iota = 0$.

Since positive profit naturally occurs in the monopolistic setting, this cannot be used to empirically detect the impact of the potential of adverse selection on the market. Notice, however, that if data can be obtained on the expectation of marginal costs, then if this average is below marginal revenue this is an empirical indication of lower than expected capacity, due to latent adverse selection.

4   Conclusion

In this paper we examine how asymmetric information about quality affects markets outcomes when the heretofore exogenous number of sellers is made endogenous. Sellers enter through a fixed investment after which nature chooses the quality of the seller's product that is unobservable to buyers. It is found that the potential for adverse selection—low quality providers driving out high quality ones—affects the market even though adverse selection does not arise in equilibrium. Indeed, such latent adverse selection leads to entry equilibrium configurations with positive profits, even under the assumption of costless entry.

Unobserved adverse selection in conjunction with positive profits is due to the interaction of two classic mechanisms. First, as demand slopes downward less entry results in higher prices. Second, average quality is increasing in market prices so that if the market price is high enough, then high quality providers are willing to remain in the market. Hence, zero profits may no longer define the entry equilibrium. Instead the entry equilibrium is defined by the greatest level of entry under which adverse selection does not occur *ex post*. That is, latent adverse selection is an entry barrier, and whenever it defines the entry equilibrium then equilibrium profits are positive even under costless entry.

We show that the insights—*viz.* limited entry, positive equilibrium profits that exceed entry costs, and the absence of observed adverse selection—hold for multi-period settings and with generalized (continuous) distributions; and the result of latent adverse selection as an entry barrier carries over to the monopoly setting in the form of reduced capacity choices.

The theoretical analysis provides some additional insights. First, the role of downward

sloping demand suggests it may play an important role in models of endogenous quality that heretofore have used unit demand—indeed, in our setting downward sloping demand gives rise to a form of "partial" adverse selection in which only some high quality providers exit the market. Secondly, it is found that the equilibrium outcome of limited entry prevents welfare losses stemming from adverse selection so that overall welfare is greater despite profits not dissipating. Nevertheless, welfare can be raised further through a revenue-neutral policy of an investment tax and a production subsidy. The revenue neutrality implies that even an incorrectly set tax and subsidy raises welfare.

As the model yields equilibrium configurations in which adverse selection is not an equilibrium phenomenon the paper may contribute to understanding why empirical evidence of adverse selection is lacking in many settings. Thus, as Riley (2002) notes, research seeking empirical support for the potential role of introductory prices, advertising or warranties in overcoming the adverse selection problem draw at best only mixed conclusions.[23] These studies do, however, provide evidence for some of the underlying assumptions of the basic model, namely that even when products are differentiated by quality, they may be subject to the law of one price so that higher quality does not command a price-premium. Moreover, these findings also suggest that high quality is not actually driven off the market.

The equilibrium constellations derived in our paper suggest that in industries with high entry costs one would not find either direct or indirect empirical evidence of adverse selection, even though the market exhibits the characteristics for adverse selection. In cases of lower entry costs, indirect empirical evidence for latent adverse selection can be found in the absence of actual adverse selection coupled with positive profits that are not competed away. These observations taken together imply a negative correlation between entry costs and profitability, which may be a contributing explanation to the somewhat counter-intuitive

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[23]Indeed, many studies seeking direct or indirect empirical verification for adverse selection in various settings have similarly found only relatively weak evidence. Studies showing lacking evidence of methods of overcoming adverse selection are Gerstner (1985), Hjorth-Andersen (1991), Caves and Greene (1996), or Ackerberg (2003); for contrasting findings see Wiener (1985). Studies that fail to identify adverse selection directly or indirectly include, *e.g.*, Bond (1982), Lacko (1986), Genesove (1993), or Sultan (2008), but also see Dionne *et al.* (2009).

empirical finding that entry is slow to react to high profits.[24]

In addition to the many instances mentioned in the paper, the insights and conclusions from the model may pertain to industries with frequent innovations, as in these instances the results of recurring investments and R&D are often not known with certainty *ex ante* and product life-cycles may be sufficiently short to result in frequent new 'investment/entry' even by previously existing firms, *e.g.*, consumer electronics. Similar situations may arise when output is tied to heterogenous inputs (*e.g.*, in order to diversify bottleneck risks many manufacturers multi-source their procurement which can result in non-uniform quality across suppliers and subsequent variations in the quality of the final product); and in high-end agricultural (*e.g.*, viniculture, where quality is subject to exogenous shocks such as weather) and animal breeding, which entails uncertain and hard-to-verify outcomes (*e.g.*, horse-breeding, where lineage does not guarantee winnings).

Appendix of Proofs

Proof of Proposition 1. Suppose first that no adverse selection occurs in the market. Then demand is given by $P(Q, \alpha) = P(n, \tau)$. Since $P(n, \tau)$ is decreasing in n, entry ceases once the price is just sufficient to cover the expected production cost Ec and the entry cost ι, *i.e.*, equilibrium entry is defined by $P(n^*, \tau) = \iota + Ec$, proving the first statement. At this price, expected market profits are $E\pi = P(n^*, \tau) - Ec = \iota$, proving the second statement. In order to confirm our initial supposition it must be that the price is sufficiently high to cover the costs of the high quality provider. That is, $P(n^*, \tau) = \iota + Ec = \iota + \tau\bar{c} + (1 - \tau)\underline{c} \geq \bar{c}$. Let $\bar{\iota} = (1 - \tau)(\bar{c} - \underline{c})$. $\qquad\square$

Proof of Proposition 2. An implication of Lemma 1 is that since $\iota < \bar{\iota}$ entry assuredly takes place at least till $\bar{n}$. Beyond that, take the proposed entry equilibrium as given and consider the marginal seller at n^*. Since $n^* = \bar{n}$, incremental entry triggers adverse selection. Because the market then exhibits complete adverse selection, all high quality providers shut

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[24]See, *e.g.*, Geroski's widely cited review of the empirical literature on entry (Geroski, 1995, p. 427).

down. Thus, the only possibility of obtaining positive market profit for the marginal seller is if it is a low quality (and hence low cost) provider. Upon entry, if all low quality sellers provide, the resulting market price is $P\left((1-\tau)\overline{n},0\right)$. If $P\left((1-\tau)\overline{n},0\right) \leq \underline{c}$, then sellers make no profit so that incremental entry beyond $n^* = \overline{n}$ does not pay off, even under the assumption of costless entry. Hence, let $\underline{\iota} = 0$ and all three statements of the proposition follow readily.

Suppose instead that $P\left((1-\tau)\overline{n},0\right) > \underline{c}$. Then, if the marginal seller enters and is a low quality provider, her profit is $P\left((1-\tau)\overline{n},0\right)-\underline{c}$. Hence, the marginal seller's expected market profit prior to but conditioned on incremental entry is given by $(1-\tau)\left(P\left((1-\tau)\overline{n},0\right)-\underline{c}\right)$. Let $\underline{\iota} = (1-\tau)\left(P\left((1-\tau)\overline{n},0\right)-\underline{c}\right)$ and it is clear that entry beyond $\overline{n}$ does not take place.

Note finally that since $P\left((1-\tau)\overline{n},0\right) < P\left(0,0\right) < \overline{c}$, it follows that $\underline{\iota} < \overline{\iota}$. This establishes that equilibrium profits are positive, since $E\pi(n^*) = E\pi(\overline{n}) = P(\overline{n},\tau) - Ec = \overline{c} - (\tau\overline{c} + (1-\tau)\underline{c}) = (1-\tau)(\overline{c} - \underline{c}) = \overline{\iota} > \underline{\iota}$. $\qquad\square$

Proof of Lemma 1. First, by definition of $\overline{n}$ there exists a full-production equilibrium with no adverse selection for $n \leq \overline{n}$. Thus, given the Pareto equilibrium selection criterion, partial adverse selection cannot occur for any $n \leq \overline{n}$, so we require that $n > \overline{n}$ (which precludes $\kappa = 1$).

Second, note that $P < \overline{c}$ cannot be an equilibrium since it entails negative market profits for high quality providers, which are avoided by shutting down (implying $\kappa = 0$); and $P > \overline{c}$ cannot be an equilibrium as an idle high-quality provider increases profit by producing and selling a unit of the good. Hence, for an equilibrium with partial adverse selection to occur, it must be that $P = \overline{c}$.

At this price all low quality sellers provide, yielding output of $(1-\tau)n$. If a fraction κ of the τn high quality sellers provide, market output is thus $(1-\tau+\kappa\tau)n$ and the proportion of high quality is $\frac{\kappa\tau}{1-\tau+\kappa\tau}$. Therefore the existence of a κ such that (5) holds for some $n > \overline{n}$ is a necessary and sufficient condition for the market to have an equilibrium with partial adverse selection. $\qquad\square$

Proof of Proposition 3. As in the proof to Proposition 2, note that an implication of

Proposition 1 is that since $\iota < \bar{\iota}$ entry assuredly takes place at least till $\bar{n}$. However, unlike in the proof of Proposition 2, from Lemma 1, given partial adverse selection there exists $n > \bar{n}$ such that the expected market price is $P = \bar{c}$; and, therefore, entry continues beyond $\bar{n}$; confirming the first claim in the proposition.

Now define $\bar{n}'$ as the largest number of sellers such that partial adverse selection can be sustained, i.e., $P(\bar{n}') = \bar{c}$ and $P(n) < \bar{c}, \forall n > \bar{n}'$. Then the remainder of the proof follows the proof of Proposition 2 *mutatis mutandis* with $\bar{n}'$ replacing $\bar{n}$. In particular, if $P((1-\tau)\bar{n}', 0) \le \underline{c}$, let $\underline{\iota}' = 0$; and if $P((1-\tau)\bar{n}', 0) > \underline{c}$, let $\underline{\iota}' = (1-\tau)(P((1-\tau)\bar{n}', 0) - \underline{c})$. $\square$

Proof of Proposition 4. Note first that market welfare is increasing in n for $n \le \bar{n}$. Consider now welfare for $n \ge \bar{n}$ and denote by κ the portion of high quality sellers who provide in the market so that $\kappa = 0$ in markets with complete adverse selection and $\kappa \in (0,1)$ in markets with partial adverse selection. Market output is thus given by $Q = (1 - \tau + \kappa\tau)n$ and the proportion of high quality in the market is given by $\alpha = \frac{\kappa\tau}{1-\tau+\kappa\tau} < \tau$.

Welfare at $\bar{n}$ is given by

$$W(\bar{n}) = CS(\bar{n}) + \bar{n} \times E\pi(\bar{n}) = \int_0^{\bar{n}} \left[\tau\overline{P} + (1-\tau)\underline{P} - \bar{c}\right] dQ + \int_0^{\bar{n}} (1-\tau)(\bar{c} - \underline{c}) dQ$$

$$= \int_0^{(1-\alpha)\bar{n}} \left[\tau\overline{P} + (1-\tau)\underline{P} - \bar{c}\right] dQ + \int_{(1-\alpha)\bar{n}}^{\bar{n}} \left[\tau\overline{P} + (1-\tau)\underline{P} - \bar{c}\right] dQ$$

$$+ \int_0^{(1-\alpha)\bar{n}} (\bar{c} - \underline{c}) dQ + \int_{(1-\alpha)\bar{n}}^{(1-\tau)\bar{n}} (\bar{c} - \underline{c}) dQ.$$

The second and fourth integral are both positive, let their sum be denoted by A; and the first and third can be combined to yield

$$W(\bar{n}) = \int_0^{(1-\alpha)\bar{n}} \left[\tau\overline{P} + (1-\tau)\underline{P} - \underline{c}\right] dQ + A.$$

When replacing τ with α in the integral, the integral itself is the market welfare under incremental entry beyond $\bar{n}$. However, as $\tau > \alpha$, $\overline{P} > \underline{P} > 0$ and $A > 0$, there is a discrete fall in welfare upon entry beyond $\bar{n}$. Note lastly that for entry beyond that welfare decreases as average profit weakly decreases and output and average quality also decrease; with another discrete fall in welfare at $\bar{n}'$ in the case of markets with partial adverse selection. $\square$

Proof of Lemma 3. If $\mathcal{P}(\kappa|\overline{n})$ is convex, then it lies below any of its secant lines. Consider the secant line constructed from the points $\kappa = 0$ and $\kappa = 1$, *i.e.*, $\mathcal{S}(\kappa) := \mathcal{P}(0|\overline{n}) + [\mathcal{P}(1|\overline{n}) - \mathcal{P}(0|\overline{n})]\kappa$; or $\mathcal{S}(\kappa) = (1-\kappa)P((1-\tau)\overline{n}, 0) + \kappa\overline{c}$, since $\mathcal{P}(0|\overline{n}) = P((1-\tau)\overline{n}, 0)$ and $\mathcal{P}(1|\overline{n}) = \overline{c}$. Notice that $P((1-\tau)\overline{n}, 0) < P(0, 0)$, since P is decreasing in its first argument. Since $P(0,0) < \overline{c}$, it follows that $\mathcal{P}(\kappa|\overline{n}) < \mathcal{S}(\kappa) < (1-\kappa)P(0,0) + \kappa\overline{c} < \overline{c}$, $\forall \kappa \in (0,1)$.

Now suppose that $\mathcal{P}(\kappa|\overline{n})$ is concave. Then the function lies below any of its tangent lines. Since $\mathcal{P}'(1|\overline{n}) > 0$, it therefore follows that $\mathcal{P}(\kappa|\overline{n}) < \mathcal{P}(1|\overline{n}) = \overline{c}$, $\forall \kappa < 1$. Hence, regardless of whether $\mathcal{P}(\kappa|\overline{n})$ is concave or convex, $\mathcal{P}(\kappa|\overline{n}) < \overline{c}$, $\forall \kappa \in (0,1)$ so that incremental entry beyond $\overline{n}$ does not result in partial adverse selection.

Note finally that $\frac{d}{dn}\mathcal{P} = \left((1-\alpha)\underline{P}' + \alpha\overline{P}'\right)(1-\tau+\tau\kappa) < 0$ so that $\mathcal{P}(\kappa|n) < \overline{c}$, $\forall n > \overline{n}$, violating Lemma 1 and, thus, ruling out partial adverse selection for any $n \geq \overline{n}$. $\qquad\square$

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