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## Experience goods and provision of quality

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## Experience goods and provision of quality

*Klaus Kultti*

### Abstract

Delacroix and Shi (Pricing and signaling with frictions, *Journal of Economics Theory* 2013) study a model featuring buyers with unit demands and sellers with unit supplies. The sellers may produce a high- or a low-quality good. The buyers get a signal about quality but the signalling technology is quite specific; the signal is either completely revealing or uninformative. The author studies the same model with a symmetric signalling technology where high and low signals are always got with positive probability. As a consequence, whenever high-quality goods are produced also low-quality goods are produced. Instead of price posting the author studies trading by auctions. There are two equilibria, and the author quantifies the efficiency loss due to asymmetric information.

**JEL** D8 D82 D44

### Keywords

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# 1 Introduction

Information asymmetries are an unavoidable feature of many important markets. Private information about economically relevant aspects typically leads to sorting or signalling depending on whether the uninformed party or the informed party proposes the terms of trade. In both cases the bad types want to pretend to be good types; when separating them from the good types succeeds a price has to be paid in terms of overall efficiency.

In this paper we study a setting where there are different types of sellers. The good types offer a high-quality good and the bad types a low-quality good. As quality is not easily detected by buyers, low-quality goods are necessarily offered in equilibrium even when it would be socially optimal that all the sellers produce high-quality goods. We differ from most of the literature in that the types are endogenous as the sellers decide which quality to produce. Examples abound from used cars and other durable goods to restaurants and language courses.

We analyse the problem in a directed search model with a large number of buyers and sellers. Each seller is capacity constrained and has a unit of a good for sale. The buyers contact the sellers in an uncoordinated fashion, get an imperfect signal about the quality and then trades are consummated in auction.

A setting similar to ours is analysed in Delacroix and Shi (2013). There are two main differences. First, in their model the sellers post prices that direct the buyers' contact decisions. As the sellers are informed about the quality they offer, the prices acts as signals, too. In our model the sellers do not signal the quality but the trades are consummated in auction and buyers contact the sellers randomly.

Secondly, the signal technology in their model is quite specific; the buyers get either a signal that perfectly reveals the quality of the good or a completely uninformative signal. The result of this assumption is that all

the sellers produce either high-quality goods or low-quality goods. We consider a signal technology which is symmetric. Both high- and low-quality goods may result in high and low signals, and, as a consequence, whenever high-quality goods are produced also low-quality goods are produced.

There are two reasons not to consider price posting. First, as prices are chosen by the informed party they have a signalling role. There is a huge number of equilibria, and clear cut results are consequently difficult to obtain.<sup>1</sup>Second, there is the problem of commitment. With posted prices there would sometimes be no trading upon low signal even though the low-quality goods provide some utility. Auction does not suffer from this problem.

If high-quality goods are produced in equilibrium there are just two equilibria when the terms of trade are determined in an auction. In a high-activity equilibrium more than half of the sellers produce a high-quality good, and in a low-activity equilibrium less than half of the sellers produce a high-quality good. The fewness of equilibria allows straightforward comparison to the social optimum, and the evaluation of efficiency losses due to asymmetric information.

The literature on adverse selection and search, or even static adverse selection models with a large number of agents is too large to review here. The special feature of the present model is that it is about adverse selection with endogenous types. For example, Moreno and Wooders (2010) can be thought to belong to this variety but the mechanism is different. In their model the agents do not choose the types which are given at the outset. However, because of asymmetric information different types of agents trade with different probabilities, and this renders the equilibrium

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<sup>1</sup>There are equilibria where where the buyers never trade on low signal as well as equilibria where the buyers mix on low signal. Further, the equilibrium prices are not set in a strategic fashion but, roughly taken, they are determined quite mechanically by the proportion of sellers who produce a high-quality good.

distribution of types endogenous.

We bypass the problems of signalling and sorting by assuming that price formation is by auction. This allows us to focus on the relation of production decisions and the consequences of asymmetric information. Auctions are used by Peters and Severinov (1997) in a setting where the sellers are homogeneous and the buyers differ in their valuations. The auctions are with reserve prices, and direct the buyers' contact decisions the same way as prices do.

A version of auction is used by Albrecht et al. (2016). They study a housing market where both the sellers' and the buyers' valuations are private. The sellers quote an asking price, and the buyers can either accept it or make a counter offer; if at least two buyers accept an auction ensues. The asking price directs the buyers' contact decisions, too, while in our model the contacts are completely random.

In-Koo and Matsui (2015) study the efficiency effects of asymmetric information in an adverse selection model. They avoid issues of signalling by assuming that when a buyer and a seller meet, a third party proposes the terms of trade. They find that the outcome is inefficient even when the search frictions vanish.

## 2 The model

There is a unit mass of sellers and a mass  $\theta$  of buyers. The sellers produce a good for sale, and the good can be of high or low quality. Production of a high-quality good costs  $c > 0$ , while the cost of producing a low-quality good is normalised to zero. Buyers have unit demands; consumption of a high-quality good yields utility 1, and consumption of a low-quality good yields utility  $v \in [0, 1)$ ; the low quality good could also yield negative utility but we ignore that case.

The trades are consummated in an auction with no reservation price. If

a seller meets just one buyer the latter one makes a take-it-or-leave-it offer, while if a seller meets several buyers they bid the price to their reservation level. The buyers do not observe the quality but they get an informative signal about it. If a good is of high quality (hq) they get a high signal (hs) with probability  $\sigma > \frac{1}{2}$ , and if a good is of low quality (lq) they get a low signal (ls) with probability  $\sigma > \frac{1}{2}$ .

One feature of the equilibrium is immediately clear. It is not possible that all the sellers produce a high-quality good. If this were the case then the buyers would buy also when they receive a low signal, and then a seller could deviate by producing a low-quality good saving  $c$ . We denote by  $\omega \in [0, 1]$  the proportion of sellers who produce a high-quality good.

A buyer has to evaluate the probabilities by which he receives a high-quality good conditional on the signal he receives. The relevant probabilities are calculated next. A buyer expects to get a high signal with probability  $Pr(hs) = \sigma\omega + (1 - \sigma)(1 - \omega)$ . The probabilities of a high-quality good on given signals are given by  $Pr(hq | hs) = \frac{Pr(hs|hq)Pr(hq)}{Pr(hs)} = \frac{\sigma\omega}{\sigma\omega + (1-\sigma)(1-\omega)}$ , and  $Pr(hq | ls) = \frac{(1-\sigma)\omega}{(1-\sigma)\omega + \sigma(1-\omega)}$ .

The buyers contact the sellers randomly which results in meetings that are governed by the urn-ball meeting technology. A seller is contacted by  $k$  buyers with probability  $e^{-\theta} \frac{\theta^k}{k!}$ .

## 2.1 Equilibrium

In auction the optimal behaviour is to bid zero if there are no other bidders, and to raise one's bid until it reaches one's valuation if there are other bidders. As every buyer is identical the optimal behaviour in auction results in the seller getting his reservation utility or all the buyers getting their reservation utilities. Updating the beliefs, given the signal, is mechanical as the agents' strategies are so simple. This leaves the production decision as the only non-trivial choice.

**Definition 1.** A symmetric equilibrium consist of the buyers' bidding strategy in auction, and the sellers' strategy of producing a high-quality good. Given the proportion of high-quality sellers  $\omega$  a buyer's offer in auction is zero if he is the only buyer, and if there are other buyers the optimal strategy is to raise the bid up to the buyer's valuation. Seller  $i$ 's strategy consists of the probability  $\sigma_i = \omega$  of producing the high-quality good, such that it is a best response to the other sellers' and buyers' strategies.

Assume that proportion  $\omega$  of sellers produces a high-quality good. If a buyer gets a high signal he expects the good to be of high quality with probability  $\frac{\sigma\omega}{\sigma\omega+(1-\sigma)(1-\omega)}$ , and if he receives a low signal he expects the good to be of high quality with probability  $\frac{(1-\sigma)\omega}{(1-\sigma)\omega+\sigma(1-\omega)}$ . If a seller meets only one buyer this buyer offers the seller's reservation value zero. If two or more buyers contact the seller they engage in a bidding contest where the price rises to  $\frac{\sigma\omega+(1-\sigma)(1-\omega)v}{\sigma\omega+(1-\sigma)(1-\omega)}$  if the signal is high, or to  $\frac{(1-\sigma)\omega+\sigma(1-\omega)v}{(1-\sigma)\omega+\sigma(1-\omega)}$  if the signal is low.

Consequently, high- and low-quality sellers' expected pay-offs are given by

$$(1 - e^{-\theta} - \theta e^{-\theta}) \left[ \sigma \frac{\sigma\omega + (1-\sigma)(1-\omega)v}{\sigma\omega + (1-\sigma)(1-\omega)} + (1-\sigma) \frac{(1-\sigma)\omega + \sigma(1-\omega)v}{(1-\sigma)\omega + \sigma(1-\omega)} \right] - c \quad (1)$$

and

$$(1 - e^{-\theta} - \theta e^{-\theta}) \left[ \sigma \frac{(1-\sigma)\omega + \sigma(1-\omega)v}{(1-\sigma)\omega + \sigma(1-\omega)} + (1-\sigma) \frac{\sigma\omega + (1-\sigma)(1-\omega)v}{\sigma\omega + (1-\sigma)(1-\omega)} \right] \quad (2)$$

In equilibrium the utilities have to be equal which is equivalent to

$$(1 - e^{-\theta} - \theta e^{-\theta}) (2\sigma - 1) \left[ \frac{\sigma\omega + (1-\sigma)(1-\omega)v}{\sigma\omega + (1-\sigma)(1-\omega)} - \frac{(1-\sigma)\omega + \sigma(1-\omega)v}{(1-\sigma)\omega + \sigma(1-\omega)} \right] = c \quad (3)$$

A buyer receives strictly positive utility only when no other buyers contact the seller, and his utility is given by

$$e^{-\theta} [\omega + (1 - \omega)v] \quad (4)$$

Condition (3) determines the possible equilibrium fractions of high-quality producers. Expressing (3) as a second degree equation in  $\omega$  we get

$$\begin{aligned} & \omega^2(2\sigma - 1)^2 \left[ (1 - e^{-\theta} - \theta e^{-\theta})(1 - v) - c \right] \\ & - \omega(2\sigma - 1)^2 \left[ (1 - e^{-\theta} - \theta e^{-\theta})(1 - v) - c \right] + \sigma(1 - \sigma)c = 0 \end{aligned} \quad (5)$$

Next we show that there are two viable solutions to the equation when  $c$  is within reasonable limits. Denoting  $B = (2\sigma - 1)^2 \left[ (1 - e^{-\theta} - \theta e^{-\theta})(1 - v) - c \right]$  the solutions are given by

$$\omega = \frac{B \pm \sqrt{B^2 - 4B\sigma(1 - \sigma)c}}{2B} \quad (6)$$

Now there are two possibilities: Either  $B \leq 0$  or  $B > 0$ . The first case results in solutions one of which is greater than unity, and the other negative. Consequently, the only possibility is that  $B > 0$ . This implies a restriction for the cost,  $c < (1 - e^{-\theta} - \theta e^{-\theta})(1 - v)$ . The discriminant also has to be positive which implies  $c \leq (2\sigma - 1)^2(1 - e^{-\theta} - \theta e^{-\theta})(1 - v)$ . The latter condition is stricter and this is what we assume in the sequel.

**Assumption 1.** *The cost of producing a high-quality good satisfies  $c < (2\sigma - 1)^2(1 - e^{-\theta} - \theta e^{-\theta})(1 - v)$ .*

We gather the results of the above analysis in



**Proposition 1.** *Suppose that trades are consummated by auction and Assumption 1 holds. Then there exists a low-activity equilibrium and a high-activity equilibrium where the proportions of high-quality good producers are given by  $\omega = \frac{B \pm \sqrt{B^2 - 4B\sigma(1-\sigma)c}}{2B}$ ,  $B = (2\sigma - 1)^2 [(1 - e^{-\theta} - \theta e^{-\theta})(1 - v) - c]$ .*

Notice that as  $c$  approaches  $(2\sigma - 1)^2 (1 - e^{-\theta} - \theta e^{-\theta})(1 - v)$  or the discriminant approaches zero there is just one solution  $\omega = \frac{1}{2}$ . When the accuracy of the signal grows, or  $\sigma$  approaches unity there are two solutions  $\omega = 0$  and  $\omega = 1$ . In the low activity equilibrium no-one produces a high-quality good even if the cost of production is very small. This is, of course, just a limit of equilibria under asymmetric information. When the signal is perfect there is only one equilibrium, i.e., everyone produces a high-quality good as long as  $c < (1 - e^{-\theta} - \theta e^{-\theta})(1 - v)$ , and if the inequality is reversed everyone produces a low-quality good.

The range of costs that allow equilibria with high-quality goods is determined by Assumption 1. The higher the utility from the low-quality good the smaller the cost of producing the high-quality good has to be if Assumption 1 is to be satisfied. In the limit when  $v$  approaches unity the cost must go to zero. To the contrary, when the number of buyers or  $\theta$  grows without limit the range of feasible costs grows: this makes sense as the sellers are more willing to incur the costs as the probability of meeting two or more buyers increases.

## 2.2 Planner's solution and graphical analysis

Let us assume that a planner can choose the proportion of high-quality good sellers. As each meeting results in a trade regardless of the signal the

welfare, or the number of trades, is given by

$$(1 - e^{-\theta}) [\omega + (1 - \omega)v] - \omega c \quad (7)$$

and the derivative of (7) with respect to  $\omega$  by  $(1 - e^{-\theta})(1 - v) - c$ . This is positive if  $(1 - e^{-\theta})(1 - v) > c$  and the planner's solution is that there should be as many high-quality producers as possible. If the inequality is reversed then the planner's solution is that no-one produces a high-quality good.

The social optimum and the decentralised solution are clearly different. For instance, it is socially optimal to produce high-quality goods as long as  $c < (1 - e^{-\theta})(1 - v)$ , while in the decentralised market this happens only under more stringent condition, or when  $c < (2\sigma - 1)^2(1 - e^{-\theta} - \theta e^{-\theta})(1 - v)$ .

Next we numerically study the degree of inefficiency in two cases, namely under relatively low demand,  $\theta = 1$ , and relatively high demand,  $\theta = 10$ . Under Assumption 1 the high activity equilibrium is the more efficient one, and we compare this to the social optimum. The ratio of the value of trades in equilibrium to that in the social optimum is given by

$$\frac{(1 - e^{-\theta}) [\omega + (1 - \omega)v] - \omega c}{1 - e^{-\theta} - c} \quad (8)$$

where  $\omega = \frac{B + \sqrt{B^2 - 4B\sigma(1 - \sigma)c}}{2B}$ .

We fix the the value of the low-quality good to  $v = 0.1$  as low values of  $v$  lead to higher efficiency loss than high values. We then allow the signal to be either relatively inaccurate,  $\sigma = 0.6$ , or relatively accurate,  $\sigma = 0.9$ . By Assumption 1, under relatively low demand the values of  $c$  in the two cases have to satisfy  $c < 0.00951268$  and  $c < 0.152203$ . Under relatively high demand the cost has to satisfy  $c < 0.035982$  and  $c < 0.575712$ , respectively. The following figures depict how the efficiency declines with  $c$ ;

value unity in the vertical axis indicates that the value of trades in the decentralised solution is the same as in the social optimum. Quite naturally efficiency decreases when the cost of producing the high-quality good increases as more sellers produce the low-quality good. The more important observation is the range of costs that supports at least some high-quality production. Under both low and high demand it becomes more than ten-fold when accuracy of the signal increases from  $\sigma = 0.6$  to  $\sigma = 0.9$ .

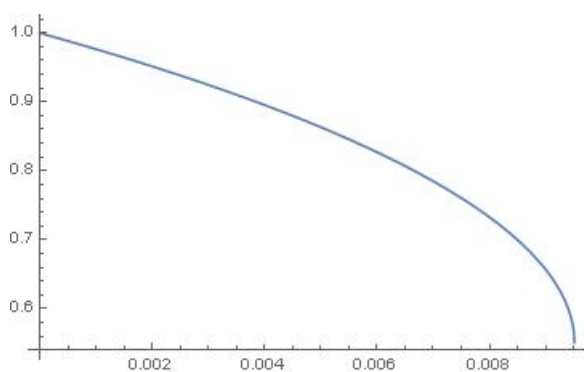


Figure 1. Relative efficiency, low demand  $\theta = 1$ , low accuracy  $\sigma = 0.6$ .

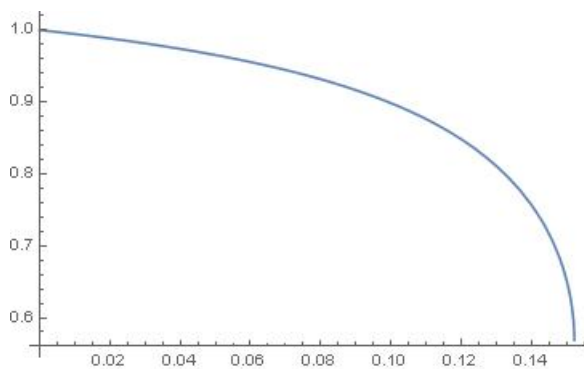


Figure 2. Relative efficiency, low demand  $\theta = 1$ , high accuracy  $\sigma = 0.9$ .

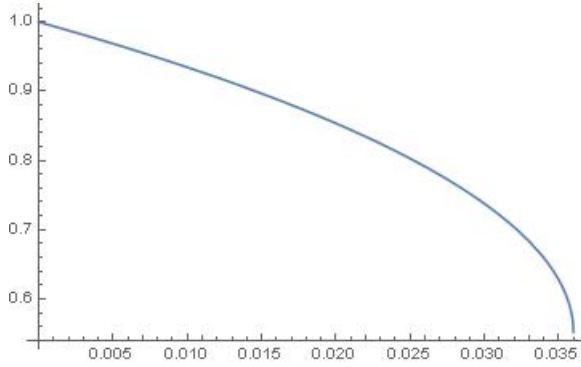


Figure 3. Relative efficiency, high demand  $\theta = 10$ , low accuracy  $\sigma = 0.6$ .

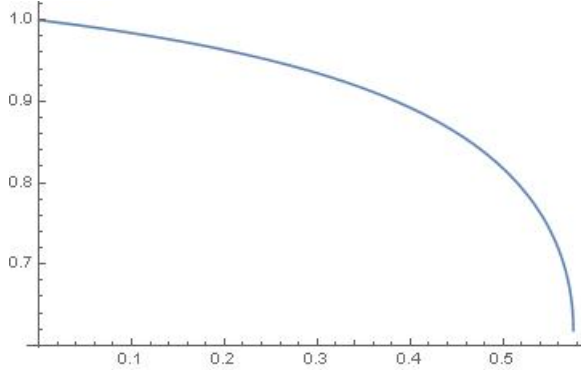


Figure 4. Relative efficiency, high demand  $\theta = 10$ , high accuracy  $\sigma = 0.9$ .

The planner's solution is an ideal benchmark. What policy can achieve, at least in principle, is a choice between equilibria. For this reason the efficiency difference between low-activity and high-activity equilibria is a magnitude of interest. We measure this by calculating the difference in welfare between the equilibria, and comparing it to the social optimum. In the low-activity equilibrium the proportion of high-quality producers is  $\omega_L = \frac{B - \sqrt{B^2 - 4B\sigma(1-\sigma)c}}{2B} = \frac{1}{2} - \sqrt{\frac{1}{4} - \frac{\sigma(1-\sigma)c}{B}}$  and in the high-activity equilibrium  $\omega_H = \frac{B + \sqrt{B^2 - 4B\sigma(1-\sigma)c}}{2B} = \frac{1}{2} + \sqrt{\frac{1}{4} - \frac{\sigma(1-\sigma)c}{B}}$ . The difference be-

tween welfare created in the equilibria is given by  $(1 - e^{-\theta}) [\omega_H + (1 - \omega_H)v] - \omega_H c - (1 - e^{-\theta}) [\omega_L + (1 - \omega_L)v] + \omega_L c$  which after a little simplification can be expressed as  $2\sqrt{\frac{1}{4} - \frac{\sigma(1-\sigma)c}{B}} [(1 - e^{-\theta}) (1 - v) - c]$ . The relative improvement of moving from low-activity to high-activity equilibrium is then given by

$$\frac{2\sqrt{\frac{1}{4} - \frac{\sigma(1-\sigma)c}{B}} [(1 - e^{-\theta}) (1 - v) - c]}{1 - e^{-\theta} - c} \quad (9)$$

In figure 5 we depict the above magnitude as a function of the cost of producing the high-quality good for the same parameter values as we did for the relative efficiency in figure 1. The magnitudes corresponding to the parameter values of figures 2 - 4 are almost identical, and are not shown. The main message is that when costs are close to zero the efficiency gain is around 90%. When the cost approaches the upper limit the gain goes to zero as then the two equilibria converge to  $\omega = \frac{1}{2}$ .

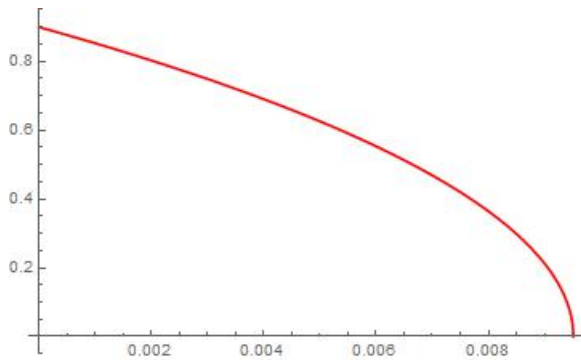


Figure 5. Relative efficiency increase, low demand  $\theta = 1$ , low accuracy  $\sigma = 0.6$ .

### 3 Conclusion

In this note we consider a setting where the sellers' types, i.e., the qualities they offer, are endogeneously determined, and the buyers receive a non-degenerate and symmetric signal about the type. To avoid issues of signalling we postulate that the terms of trade are determined in auctions rather than by price posting. We find that there are just two equilibria, a high- and a low-activity one. When knowledge about quality is imperfect there are necessarily sellers who provide low-quality goods. The higher the cost of high-quality production, and the less accurate the buyers' information about quality the more severe the problem is. There are parameter values where it would be socially optimal that everyone produces a high-quality good, but in the decentralised market everyone produces a low-quality good.

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Appendix.

Mathematica code used to generate Figures 1 - 4. The Plot-command is for Figure 1; the others are got by proper choice of parameter values. Correspondence with the symbols in the text is  $s \rightarrow \sigma$ ,  $x \rightarrow \theta$ ,  $v \rightarrow v$  and  $c \rightarrow c$ .

$$b[s_, x_, v_, c_] := (2 s - 1)^2 ((1 - \text{Exp}[-x] - x \text{Exp}[-x]) (1 - v) - c)$$

$$\text{omega}[s_, x_, v_, c_] := (b[s, x, v, c] + \text{Sqrt}[(b[s, x, v, c])^2 - 4 b[s, x, v, c] s (1 - s) c]) / (2 b[s, x, v, c])$$

$$\text{SR}[s_, x_, v_, c_] := ((1 - \text{Exp}[-x]) (\text{omega}[s, x, v, c] + (1 - \text{omega}[s, x, v, c]) v) - \text{omega}[s, x, v, c] c) / (1 - \text{Exp}[-x] - c)$$

$$\text{Plot}[\text{SR}[0.6, 1., 0.1, c], \{c, 0, 0.00951268\}]$$



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