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by

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Abstract

Maybe. Lemon's and signaling models generally deal with different welfare problems, the former with withdrawal of high quality sellers, and the latter with socially wasteful signals. However, with asymmetric information, high productivity workers may not (absent signaling) be employed where they are valued the most. If one's productivity is known in alternative employment, signaling that overcomes the lemon's problem at a cost will only occur if it increases welfare. If individual productivity is unknown in alternative employment, again signaling may occur and will overcome the lemon's problem, but it may lower welfare.

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1. *Introduction*

Two different strands of asymmetric information models have developed in the economics literature. First, George Akerlof (1970) analyzed problems when the price or wage reflects the average quality of sellers because buyers know less about quality than sellers. If seller reservation prices are positively related to quality, high quality sellers may be driven out of the market. This result is now known as the *lemon's problem* in which asymmetric information results in reduced welfare (versus costless information) because trades that could benefit buyers and sellers do not occur.

Second, Michael Spence (1974) considered how high quality sellers could, at some cost, signal their quality to buyers. Löfgren, Persson, and Weibull (2002) argue that Spence's work shows how the lemon's problem can be overcome. However, Löfgren *et al*. acknowledge that, in the general case examined by Spence, the alternative to a signaling equilibrium is pooling where all are paid a wage equal to expected productivity of these individuals. There is no withdrawal of high quality sellers from the market. Welfare in the standard signaling model is reduced because of the cost of signaling and the fact all signaling does is redistribute wealth from low quality sellers to high quality sellers (relative to a pooling equilibrium).[1]

Thus, lemon's and signaling models generally do not deal with the same kind of welfare loss, with the former concerned with the withdrawal of high quality sellers from where their services are valued the most, and the latter focused on expenditure on signaling that merely redistributes wealth. It would seem useful to consider when signaling might occur in what would otherwise be a lemon's market equilibrium. The intention herein is to consider labor markets with asymmetric information, and to address three questions.

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[1] In an appendix, Spence (1974) considers a two-sector model in which there is a social return to signaling. However, most signaling models ignore sorting gains. Exceptions are Perri (2013a) and the analysis herein.

First, we consider when a lemon's market would result. Second, we analyze whether the lemon's problem will be overcome via signaling (albeit at some cost). Third, we examine whether signaling is efficient, that is, whether signaling increases social welfare.

In the Akerlof (1970) model, there is one market so goods or services that are not sold are retained by sellers who value them less than buyers. Equivalently, suppose there are two sectors in which individuals can work, S1 and S2, and the value of high quality workers is greater in S1 than in S2. A lemon's problem then occurs if high quality workers are employed in S2 and not in S1. Because signaling is costly, even if signaling overcomes the lemon's problem, welfare will never be as high as it would be if information regarding individual productivity were freely available.

Lemon's markets have been considered in recent research. Fuchs and Skrzypacz (2012) consider the impact on welfare in a lemon's market when trade may be delayed. They suggest signaling via costly delay may increase welfare. Presumably the delay is to be imposed by government. They contrast this result to the Spence (1974) signaling model, where they argue that preventing signaling always increases welfare. As discussed above, the general signaling model does not allow for socially beneficial signaling. We consider cases herein where welfare may be increased via costly signaling by high quality sellers because there is a social gain to sorting those sellers to where they are valued the most, thereby overcoming a lemon's problem.

Kim (2012) considers sellers' incentives to segment the market when buyers make a take-it-or-leave-it offer. His model assumes costless communication by sellers before trade occurs. Social welfare can be increased by segmentation because high quality goods may trade when, absent segmentation, they would not trade. Low quality sellers may be better off because both the probability of trade and the price may increase due to segmentation.

Voorneveld and Weibull (2011) allow buyers to receive a noisy signal of quality. They show there is a positive probability high quality goods will trade even with uninformative signals. The seller does not choose a signal; instead, signals are costless and exogenous.

None of the research just discussed deals with the issue of costly signaling by high quality sellers that resolves lemon's problems. In order to consider when a lemon's market results (absent signaling), and whether signaling (efficient or not) occurs, we proceed as follows. In the next section, we analyze a situation similar to the standard lemon's model in which one's alternative earnings are directly related to one's productivity in the primary labor market. In that case, asymmetric information concerning one's productivity exists only in the primary sector. In Section 3, we consider the case when asymmetric information is everywhere, so earnings in the primary and secondary sectors reflect average productivity in those sectors unless signaling occurs. A summary is contained in the fourth section.

Briefly, we find, if one's productivity is known in alternative employment, signaling that overcomes the lemon's problem may not occur, and will only occur if it increases welfare. If individual productivity is unknown in alternative employment (S2), and high quality sellers are *not* more valuable than low quality sellers in S2, signaling will always occur and increase welfare with a lemon's problem. If high quality sellers *are* more valuable than low quality sellers in S2, signaling may occur, will overcome the lemon's problem, but may lower welfare.

2. *Asymmetric information only in the primary sector*

Consider a world with two types of potential workers, *Highs* (*H*) and *Lows* (*L*), and two sectors, the primary sector, S1, and the secondary sector, S2. As in the usual lemon's model (Akerlof, 1970), it is assumed the alternative to primary sector employment is to receive compensation that is positively related to one's productivity in the primary sector. Thus, S2 could represent self-employment or leisure, which will not be true in the next section.

Productivity of an *H* in S1 = ax, $a > 1$, $x > 0$, and productivity of an *L* in S1 = x. In S2, productivity of an $H = kax$, and productivity of an $L = kx$, $0 < k < 1$. Let α equal the fraction of *H*s in the population, with α known to all.

Absent signaling, S1 firms cannot observe an individual's productivity, but, do learn average productivity. Thus, if both types are employed in S1, firms there compete for workers and offer the pooling wage equal to expected productivity, $W_{pool,1}$, with $W_{pool,1} = (\alpha a + 1 - \alpha)x$. If no *H*s are employed in S1, again, firms there learn who they get on average, so they would then pay a wage equal to x.

Now *H*s will apply to S2 if $W_{pool,1} < kax$, or if:

$$\alpha < \frac{ka-1}{a-1} \equiv \alpha^*. \tag{1}$$

A lemon's problem occurs if *H*s are employed in S2. Note, $ka > 1$ in order for a lemon's problem to be possible. If $ka \leq 1$, $\alpha^* \leq 0$. If $ka \leq 1$, then $kax \leq min\ W_{pool,1} = x$, so *H*s would go to S1. If $\alpha < \alpha^*$, *H*s go to S2 and earn kax, and *L*s go to S1 and earn x (since firms will learn only *L*s are in S1).

Thus, for a lemon's problem, we require two conditions:

i) $ka > 1$ or $k > 1/a$, and

ii) $\alpha < \alpha^*$.

If these two conditions hold, *L*s go to sector S1, where they are valued more than elsewhere, but, absent signaling, *H*s go to S2, where they are valued less than they are in S1.

This is the classic lemon's problem where the highest quality sellers are driven out of the market (S1) because the wage there would reflect expected productivity and not their actual (higher) productivity.

Consider the possibility of signaling by *H*s to reveal their productivity. The signal is denoted by y. Let the total cost of signaling be y for *L*s and y/g for *H*s, with $g > 1$. This is the usual assumption that signaling cost is inversely related to productivity. Also, assume y does not affect the productivity of an individual who signals.

In a signaling equilibrium, those who signal are viewed as *H*s and are offered ax in S1. Others are revealed as *L*s and are offered x in S1. For signaling to occur, *H*s must (weakly) prefer to be correctly viewed, and *L*s must not want to mimic them. Thus:

$$ax - y/g \geq x, \text{ and} \quad (2)$$

$$ax - y < x, \text{ so} \quad (3)$$

$$(a\text{-}1)x < y \leq g(a\text{-}1)x. \quad (4)$$

Riley (1979) and Cho and Kreps (1987) argue only the lowest level of the signal will survive experimentation by firms in hiring. Then this value of $y \equiv y_{Riley} \approx (a\text{-}1)x$. With $y = y_{Riley}$, the (net) payoff to an *H* from signaling is:

$$\frac{x}{g}[a(g-1)+1], \quad (5)$$

and *ineq*.(5) is clearly positive.

Given the assumptions about productivity and signaling cost, there are always values of y that will work for signaling in that Ls will not mimic Hs and the latter will have a positive net payoff from signaling, ignoring whether their payoff would be even higher from simply going to S2. In a standard signaling model with one sector, where the alternative to signaling is pooling in that sector, Mailath *et al*. (1993) argue the more able will deviate from a pooling equilibrium only when their payoff from signaling exceeds that from pooling, given $y = y_{Riley}$. Thus, in the model in this section, we should expect Hs to deviate from the equilibrium when they are employed in S2 at a wage of kax only if the signaling payoff in *ineq*.(5) exceeds kax, or if:

$$a[g(1-k) - 1] + 1 > 0. \tag{6}$$

A sufficient condition for Hs to prefer signaling to going to S2 is $g(1-k) \geq 1$. In general, signaling may occur, but will not if the productivity of Hs in S2 is large enough (k is large enough), or if the cost of signaling is too high (g is too low). These effects will be discussed further below.

If signaling occurs, welfare is increased. The social return is that each H who moves to S1 from S2 adds output on net of $ax(1-k)$, which is also the private return to an H, the wage gain. The cost is $\frac{y_{Riley}}{g} = \frac{(a-1)x}{g}$. The gain in output exceeds the cost if $ax(1-k) > \frac{(a-1)x}{g}$, or if $a[g(1-k) - 1] + 1 > 0$, which is the same as the private condition for Hs to prefer signaling to employment in S2 (*ineq*.(6)). Thus, Hs signal if and only if it pays socially to do so. There is no excessive signaling, but signaling may not be worth it. If *ineq*.(6) holds, signaling "solves" the lemon's problem, but only at a cost: [the number of Hs]$\times \frac{y_{Riley}}{g}$.

Why might it not pay to signal (privately or socially)? In a signaling equilibrium, the alternative to signaling is getting paid x versus ax with signaling. The productivity/wage difference $(a\text{-}1)x$, along with signaling cost of y for Ls, determines y_{Riley}. Yet the social and private gain to signaling versus no signaling is $ax(1\text{-}k)$, which is less than $(a\text{-}1)x$ if $1 < ka$. Thus, the productivity/wage difference between the two sectors for Hs may not be large enough to induce Hs to signal and get hired in S1 at a wage of ax.

Signaling occurs if *ineq*.(6) holds. We are less likely to have signaling as k increases, that is, as the wage/productivity in S2 increases for Hs. Now $\frac{1}{a} < k < 1$. Call the left hand side of *ineq*.(6) LHS. Now $\lim_{k \to \frac{1}{a}} LHS = (g - 1)(a - 1) > 0$, $\lim_{k \to 1} LHS = 1 - a < 0$, and $\frac{\partial LHS}{\partial k} < 0$. Thus, for a large enough value for k, signaling will not occur. With $g > 1$, $\lim_{g \to 1} LHS = 1 - ak < 0$, so, for a large enough marginal cost of signaling for Hs (small enough g), signaling will not occur.

Also, using *ineq*.(1), $\frac{\partial \alpha *}{\partial k} > 0$ and $\frac{\partial \alpha *}{\partial a} > 0$. A larger α^* implies it is more likely there is a lemon's problem, so the likelihood of a lemon's problem increases the larger are k and a.

Not surprisingly, the higher are earnings in S2 ($dk > 0$), the more likely there is a lemon's problem. However, why does an increase in a increase the chance of a lemon's problem since such an increase raises productivity in S1 more than in S2 for Hs? The reason is that whether we have a lemon's problem depends on the earnings of an H in S1 and in S2 absent signaling, $W_{pool,1}$ and kax, respectively. With $\frac{\partial W_{pool,1}}{\partial a} = \alpha x$, and $\frac{\partial (kax)}{\partial a} = kx$, if $\alpha < k$, S2 earnings rise faster than S1 earnings for Hs as a increases. Since, $\alpha < \alpha^*$ for a lemon's problem, if $\alpha^* < k$, $\alpha < k$, and indeed $\alpha^* < k$ for $k < 1$.

Assuming there is a lemon's problem, that is, $ka > 1$and $\alpha < \alpha^*$, using *ineq*.(6), an increase in a has an ambiguous effect on whether signaling occurs because it increases the wage for an H with signaling in S1, the wage for an H in S2, and y_{Riley}. As discussed above, an increase in g lowers signaling cost for an H, and a decrease in k lowers S2 earnings for an H, so both would make signaling more likely.

3. *Asymmetric information is everywhere*

For now, we keep the same assumptions as before, except suppose firms in S2 only infer average productivity as is the case in S1. In this case, S2 cannot be leisure. S2 *could* be self-employment if customers have a problem judging the quality of work by the self-employed.

Now $W_{pool,2} = (\alpha a + 1 - \alpha)kx < W_{pool,1}$. In this case, absent signaling, there is no lemon's problem---all would be in S1. If signaling occurs, welfare is reduced. All signaling does is redistribute wealth from the less able to the more able as individuals are identified and paid their individual productivity and not $W_{pool,1}$. This is the classic signaling problem (Spence, 1974) when the signal neither adds to one's productivity nor provides a social gain by sorting individuals to the job where they are most productive.[2]

To have a lemon's problem, it must be the case Hs are more productive in S1 than in S2. With an H's productivity equal to ax in S1 ($a > 1$), let an H have productivity of fx in S2, with $f < a$. Unless Ls have higher productivity in S2 than in S1, we still have $W_{pool,2} < W_{pool,1}$. Thus, suppose Ls have productivity in S2 of bx, with L's productivity in S1 equal to x as before, and $b > 1$.[3] Now it is possible to have $W_{pool,2} > W_{pool,1}$. If that is the case, all will be in S2 absent signaling since, as discussed before, if only Ls go to S1, ultimately firms there learn who they

[2] It is easy to see Hs will signal if $\alpha < \frac{g-1}{g}$ in this case.

[3] The less able can have higher *gross* productivity in S1 than in S2, which may be sensible if S1 reflects jobs with more skill than in S2. Suppose there is a fixed cost per individual in S1, as in Oi (1962), but there is no fixed cost in S2. Then the *net* productivity of Ls in S1 can be less than their net productivity in S2.

have attracted on average and offer a wage of x. With signaling, society gains because *H*s are sorted to S1 where they are more productive. With or without signaling, *L*s are employed in S2 (where they are more productive). Thus, this problem differs from the standard lemon's situation where low quality sellers may end up in S1. However, the problem is similar to the usual lemon's result in that high quality sellers are more valuable in S1, but are employed in S2 (absent signaling).

Note, if $W_{pool,2} < W_{pool,1}$, signaling *may* improve welfare because it results in *L*s being sorted to S2 where they are more productive. There are both private and social returns to signaling, with the former the gain in earnings for *H*s when they are paid ax with signaling versus $W_{pool,1}$ without signaling. These returns are not the same, so signaling may occur when it lowers welfare (but benefits *H*s). This problem does not involve a lemon's situation, and is considered in detail in Perri (2013a), so it will receive no more attention herein.

With $W_{pool,2} = [\alpha f + (1 - \alpha)b]x$, and $W_{pool,1} = (\alpha a + 1 - \alpha)x$, then $W_{pool,2} > W_{pool,1}$ if:

$$\alpha = \frac{b-1}{a-f+b-1} \equiv \alpha^{**}. \tag{7}$$

A lemon's problem exists (without signaling) if $\alpha < \alpha^{**}$. We have the following effects of f, b, and a on α^{**}:

$$\frac{\partial \alpha^{**}}{\partial f} > 0,\ \frac{\partial \alpha^{**}}{\partial b} > 0, \text{ and } \frac{\partial \alpha^{**}}{\partial a} < 0. \tag{8}$$

Both a larger f and a larger b cause an increase in $W_{pool,2}$, and an increase in a increases $W_{pool,1}$. The larger the pooling wage in S2 or the smaller the pooling wage in S1, the more likely pooling is in S2. Assuming $\alpha < \alpha^{**}$, we look at the possibilities when $f \gtrless b$.

First, consider what is necessary for signaling to occur. Those who signal are hired in S1 at a wage of ax, and those who do not signal go to S2 at a wage of bx (since Ls are more productive in S2 than in S1). For signaling to occur, we have the usual conditions (Hs weakly prefer signaling, and Ls prefer being correctly identified):

$$ax - y/g \geq bx, \text{ and} \tag{9}$$

$$ax - y < bx, \text{ so} \tag{10}$$

$$(a\text{-}b)x < y \leq g(a\text{-}b)x. \tag{11}$$

Thus, $y_{Riley} \approx (a\text{-}b)x$, and an H's net payoff from signaling is (with $y = y_{Riley}$) $\frac{x}{g}[a(g-1)+b]$. Suppose $f = b$. Alternative (to S1) productivity is the same for either type, and Ls are more productive in S2 than in S1.[4] Then, the determination of y_{Riley} involves the same payoff, $(a\text{-}b)x$, as the decision for an H whether to deviate from a pooling equilibrium since $W_{pool,2} = fx = bx$. In this case, Hs always prefer signaling to employment in S2, and signaling always increases welfare since $(a\text{-}b)x - \frac{y_{Riley}}{g} = (a\text{-}b)x\left(\frac{g-1}{g}\right) > 0$. Again, the assumptions about productivity and signaling cost guarantee there is always a signaling equilibrium with a positive payoff for Hs, but not that Hs would prefer signaling to pooling. However, with $f = b$, signaling

[4] This is essentially the same case as in the signaling problem of Hirshleifer and Riley (1992, p.424) and in the lemon's problem in Mas-Colell, Whinston, and Green (1995, p.459).

always occurs and increases welfare. If $f < b$, Hs have even more incentive to signal, so the results are the same as when $f = b$.

Now, if $f > b$, since Hs have a payoff from signaling equal to $\frac{x}{g}[a(g-1)+b]$, and Hs earn $W_{pool,2} = [\alpha f + (1 - \alpha)b]x$ inS2, Hs prefer signaling to pooling in S2 only if:

$$\alpha < \frac{(g-1)(a-b)}{g(f-b)} \equiv \alpha^{***}.\text{[5]} \tag{12}$$

There is a lemon's problem absent signaling (Hs would be in S2) only if $\alpha < \alpha^{**}$, and Hs prefer signaling to pooling in S2 only if $\alpha < \alpha^{***}$. To have a lemon's problem and signaling, we must have $\alpha < min(\alpha^{**}, \alpha^{***})$. Signaling increases welfare only if $(a - f)x > \frac{y_{Riley}}{g} = \left(\frac{a-b}{g}\right)x$, or if:

$$f > \frac{(g-1)a+b}{g} \equiv f^{*}. \tag{13}$$

Previously, we have seen no case when inefficient signaling may occur. The reason we could have inefficient signaling in this situation is as follows. The social gain from an H signaling is $(a\text{-}f)x$---the greater output for an H in S1 versus S2. The decision by an H to deviate from pooling in S2 involves comparing ax with $W_{pool,2}$.With $f > b$, $W_{pool,2} < fx$. Since the private gain to an H from signaling, ax- $W_{pool,2}$, exceeds the social gain, we can have signaling that lowers welfare.

[5] If g is large enough, $\alpha^{***} \geq 1$, in which case Hs always prefer signaling to pooling in S2.

Table One shows values for f* for specific values of a, b, and g. We then show a value of f that is slightly greater than f*, which yields α** and α***.

To have lemons and inefficient signaling, we must have $\alpha < min$ (α**, α***) and $f > f$*. Derivatives of α** are found in *eq*.(8). We also have:

$$\frac{\partial\alpha***}{\partial f} < 0,\ \frac{\partial\alpha***}{\partial b} > 0, \frac{\partial\alpha***}{\partial a} > 0,\ \frac{\partial\alpha***}{\partial g} > 0, \text{ and} \quad (14)$$

$$\frac{\partial f*}{\partial b} > 0,\ \frac{\partial f*}{\partial a} > 0, \text{ and } \frac{\partial f*}{\partial g} > 0. \quad (15)$$

Table One. Values for f* as a function of a, b, and g. Values for α** and α*** for $f > f$*.

a	*b*	*g*	*f**	*f*	α**	α ***
2	1.5	2	1.75	1.8	.833	.714
2	1.25	2	1.625	1.7	.833	.455
2	1.5	1.5	1.667	1.7	.833	.625
2	1.25	1.5	1.5	1.6	.714	.4
2	1.5	1.25	1.6	1.7	.5	.625
2	1.25	1.25	1.4	1.5	.6	.333

Consider the effect of a change in exogenous variables (a, b, f, and g) on the likelihood of a lemon's problem absent signaling ($\alpha < \alpha$**), the likelihood *H*s would choose signaling over pooling in S2 ($\alpha < \alpha$***), and the likelihood signaling raises welfare---is efficient--- ($f < f$*).

• *An increase in H's productivity in S1 (da > 0).* It is less likely there is a lemon's problem because pooling is more likely to be in S1. If there is a lemon's problem, it is more likely *H*s prefer signaling to pooling since an increase in a increases the wage for those identified to be *H*s, and has no effect on $W_{pool,2}$. Since a greater a increases the social return to screening more than it increase the social cost, x versus $\frac{x}{g}$, it is more likely signaling is efficient as a increases.

• *An increase in L's productivity in S2 (db > 0).* An increase in b increases $W_{pool,2}$, with $W_{pool,1}$ unchanged, so there is a greater likelihood of a lemon's problem. A larger b decreases the cost of signaling by lowering y_{Riley}, so signaling is more likely to be preferred to pooling in S2, and is more likely to be efficient.

• *An increase in H's productivity in S2 (df > 0).* Since $W_{pool,2}$ is increased, and $W_{pool,1}$ is unaffected, it is more likely there is a lemon's problem. With $W_{pool,2}$ increased, given a lemon's problem, it is less likely signaling occurs, and, with *Hs* more productive in S2 as d$f > 0$, it is less likely signaling is efficient.

• *A decrease in H's cost of signaling (dg > 0).* Since there is no effect on either $W_{pool,1}$ or $W_{pool,2}$, the likelihood of a lemon's problem is unaffected. It is more likely signaling is preferred to pooling by *H*s (with or without lemons, that is, whether pooling is in S1 or S2), and that signaling is efficient.

To have an unambiguous effect on the likelihood efficient signaling will occur, an exogenous variable must not, for example, increase the likelihood a lemon's result occurs (absent signaling, *H*s would be in S2), but decrease the likelihood of signaling, given a lemon's problem. Clearly a and f have ambiguous effects on the likelihood of efficient signaling. Not surprisingly, a lower marginal cost of signaling for *H*s, increases the likelihood signaling occurs and is efficient, and does not affect the chance a lemon's problem would exist. An increase in *L*'s productivity in S2 increases the likelihood of a lemon's problem and the likelihood signaling will occur and be efficient (by lowering y_{Riley}). In sum, both lower signaling cost for the more able (*H*s), and greater productivity for the less able (*L*s) in the sector where the more able are less valuable (S2) lead to a greater likelihood signaling efficiently solves a lemon's problem.

4. Summary

We considered labor markets with lemon's problems in order to determine whether costly signaling as in Spence (1974) could overcome the lemon's problem considered in Akerlof (1970). With one exception, we found that, although signaling might not occur, it will occur only if signaling increases welfare. The exception is if, in alternative employment, individual productivity is unknown, and high quality sellers are more valuable than low quality sellers. Then signaling may occur, and will overcome the lemon's problem, but may lower welfare. In the same case, except when high quality sellers are *not* more productive than low quality sellers in alternative employment, signaling *always* occurs and increases welfare.

We combine lemon's and signaling models which usually deal with different welfare problems, the former with withdrawal of high quality sellers, and the latter with socially wasteful signals. Also, our results add to the literature that considers a possible social value of signaling.[6] Even if the signal (say education) does not directly add to individual productivity, we find it may increase welfare by overcoming the lemon's problem.

[6] See Spence (1974), Perri (2013a), and Perri (2013b).

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