Article Title: An Equilibrium Model of Signaling, Production, and Exchange

Kjell Hausken
Faculty of Social Sciences
University of Stavanger
N-4036 Stavanger, Norway
E-mail: kjell.hausken@uis.no
Tel.: +47 51 831632, Tel. Dept: +47 51 831500, Fax: +47 51 831550

Version: February 16, 2006

Keywords: Signaling, screening, general equilibrium, production, consumption, exchange, trade, prices, sellers, buyers, inflation, search costs, Cobb-Douglas utilities.

Acknowledgment: I thank the late Jack Hirshleifer for useful discussions of ideas in the early phase of the development of this article, and Gertrud Fremling and David Hirshleifer for useful comments.

Journal of Economic Literature classification numbers: C6, C7, D5, D8, F1

Article Title: An Equilibrium Model of Signaling, Production, and Exchange

**Abstract**

This article provides an equilibrium model of signaling, production, and exchange. It goes beyond previous models by examining signaling in a setting in which sellers allocate resources between signaling and producing a good with a high versus low intrinsic quality. In contrast to partial equilibrium models where one side is often kept to its reservation value, both sides of the exchange are made worse off due to the distortive signaling activities. Buyers read signals, screen for quality of each good, choose prices optimally, and pay money in exchange. The Cobb-Douglas utilities depend on the amount of money received or kept, the intrinsic quality of each good, and the quantity consumed. The advantage of the model is to illustrate how sellers make tradeoffs between production and signaling, which can be verified empirically, and how buyers choose how much to purchase of high quality versus low quality goods. The total numbers of sellers of the two types determine the total production of goods in the market, and the total number of buyers determines the total presence of money in the market. A signaling attention function adjusts how buyers pay attention to signals. The competitiveness of the market plays a role. Signaling causes scarcity of goods which causes price inflation which is adjusted for. Search costs for choosiness are introduced for buyers screening for quality, which reduces the amount of money held by buyers, causing less to be paid to sellers.

## 1 Introduction

Production, consumption, and exchange have been central to economic theory for centuries. After some groundwork since the 1960s,[1] Spence (1973) asked the path breaking question of whether high quality producers can signal superior quality through costly effort. If so, do consumers use such signals to screen for quality? Spence seeked to explain how individuals with similar talents can have different returns to accumulation of human capital in form of education. His approach led to a continuum of informationally consistent equilibria. Riley (1975) and Rothschild and Stiglitz (1976) introduced competition in the screening dimension, timed the sequence of actions, and specified the information sets of the agents. Rothschild and Stiglitz (1976) reframed Spence's approach as a noncooperative game between the uninformed insurance companies and the consumers. See Lofgren et al. (2002) and Riley (2001) for historical reviews of signaling and screening, Riley (2002) for model testing, and e.g. Noldeke and Samuelson (1997) for a dynamic approach.

One main characteristic of today's signaling literature is that these are partial equilibrium models which in their simplest form may look as follows. The seller wants to sell one unit of a good and knows whether it has high or low quality. The buyer wants to buy the good but cannot observe the quality with certainty. The seller moves first by setting a take-it-or-leave it price which is the signal. The buyer decides whether or not to buy the good. The seller's expected profit is his price minus his valuation, multiplied with the probability that the buyer buys, plus his valuation multiplied with the probability that the buyer does not buy. The buyer's profit is his valuation of the good he happens to receive (high or low quality) minus his price, multiplied with the probability that he buys, plus his price multiplied with the probability that he does not buy. The seller may bluff by signaling an unreasonably high price. The buyer knows he may be bluffed, he may fear a lemon (Akerlof 1970), and will in equilibrium pay less than the high quality good is worth. Such asymmetric information thus causes market failure. The large literature on partial equilibrium models contains many variations. The good may have a continuum of qualities. Potential gains of trade may be possible, or guaranteed in the sense that the seller's valuation is lower than buyer's willingness to pay, for both the high quality and low quality good. The buyer may observe a noisy observation of the quality, and the seller may not know the buyer's perception of quality.

[1] Vickrey (1961) analyzed incentives for agents with private information, Mirrlees (1971) combined incentives with redistribution, and Akerlof (1970) showed how exchange can collapse with uncertainty about product quality.

This article develops a signaling model that intends to address the deficiencies of partial equilibrium models. First, we design a setting in which sellers allocate resources between signaling and producing a good which has high intrinsic quality for high quality producers, and low intrinsic quality for low quality producers. This demonstrates the tradeoff, which can be verified empirically, the seller makes between designing a production department for production, versus a sales/marketing department for signaling. Second, buyers read signals, screen for quality of each good, choose prices optimally, and pay money (or some numeraire good) in exchange. Third, all agents have Cobb-Douglas utilities. Each seller's two free choice variables are how much to consume of his own good and how much to signal. Each buyer's free choice variables are what prices to choose. Fourth, the total numbers of sellers of the two types determine the total production of goods in the market, and the total number of buyers determines the total presence of money in the market. Fifth, the competitiveness of the market plays a role through a signaling decisiveness parameter. Sixth, a power of truth parameter allows the buyer to be partly informed about the intrinsic qualities, scaled continuously from uninformed to fully informed. Seventh, price inflation is accounted for. Eighth, search costs for choosiness are introduced for the buyer, acknowledging that the process of distinguishing high quality from low quality goods is costly.

These characteristics are such that we refer to the model as a general equilibrium model of signaling.[2] General equilibrium models were common before the time before Spence (1973), and are of course also pervasive in economic theory today. The author believes that the dominant presence of partial equilibrium models within economic signaling theory should be supplemented with a general equilibrium model of signaling accounting for the eight characteristics outlined above.

Signaling has received some attention within biology where the focus is different. There has been little or no cross-fertilization. Partial equilibrium models is to the author's knowledge uncommon or not present within biology, whereas a general equilibrium approach is more common, and there is often a link to genetics. Examples are Bergstrom and Lachmann (1997), Bergstrom et al. (2002), Eshel et al. (2002), Getty (1998ab, 2002, 2005), Gintis et al. (2001), Grafen (1990ab), Hausken and Hirshleifer (2004), Houston (2003), Proulx et al. (2002), Zahavi (1975). Males come in two or more than two qualities, and females mate dependent on male signaling. Such models

[2] A search with the key words general equilibrium and signaling in the economics literature gives almost no hits.

have neither production, prices, nor consumption of goods, but males are analogous to producers or sellers who prefer their signals about quality to be believed. Similarly, females are buyers who screen for quality. The agents maximize utility interpreted as reproductive success.

Grafen (1990:537-538) briefly discusses the relation between biological and economic signaling. He argues that if economic signaling is to be interpreted biologically, it would be "as if the female had to pay a male an amount related to her assessment of his quality….. If females do pay a cost of a male's advertising, it is not a cost that benefits the male." He concludes that "despite the formal similarities, the biological models and Riley's (1979) model provide little mutual enlightenment." This may be one explanation of why biological and economic signaling have developed differently. This article illustrates a larger compatibility between biological and economic signaling. The buyer (female) pays a cost in the following sense because of the sellers' (males') signaling. Because of signaling each seller produces less (has lower net quality), and hence consumes less and delivers less to the buyer. Hence the buyer suffers a reduction in the amount of good x that she receives from the seller (gets a male that has wasted some of his resources on signaling).

This article starts out with a basic model of exchange without signaling in section 2. A good is produced in two qualities by high quality and low quality producers referred to as sellers. Buyers hold money with a fixed and known quality. Whether the good is of high or low quality is unknown to the buyers, so sellers have an incentive to signal quality. Introducing signaling in section 3, each seller makes a tradeoff between how much of his resource to invest into production versus signaling. Signaling is detrimental since it takes away resources from production. The utility from consuming a good arises only from the intrinsic quality of the good, and the quantity consumed. Sellers signal to boost sales. A signaling attention function adjusts how buyers pay attention to signals. Signaling causes decreased production and availability of the good which causes the price of good x to increase. To account for such price inflation, section 4 divides each buyer's monetary payment with an inflation factor, which means that the prices are divided by the same inflation factor. Section 5 incorporates screening search costs for the buyers, acknowledging that the process of distinguishing high quality from low quality goods is costly. Section 6 combines search costs and inflation adjustment. Section 7 concludes.

## 2 A model without signaling[3]

Consider two goods. The first is the numeraire good y which is money with known quality. The second is good x subject to quality differentials and unknown quality. There are n identical agents holding good y which we refer to as buyers. The buyers can be considered as holding various jobs which generate (produce) money as good y. We could more generally consider the numeraire good y as any good such as corn, which is produced by the buyers in the same manner as good x is produced by the sellers. The model thus applies equally well for goods in non-monetary exchange societies. We interpret good y as money which is straightforwardly associated with our present-day monetary societies. Buyers are more easily thought of as holding money when purchasing goods, and sellers are more easily thought of as being paid in money rather than some other numeraire good.

There are $n_1$ identical producers of the high quality good $x_1$ which we refer to as the high quality sellers. There are finally $n_2$ identical producers of the low quality good $x_2$ which we refer to as the low quality sellers. The quality differentials are quantitative. A unit of $x_1$ differs from a unit of $x_2$ only in the amount of the intrinsic quality contained therein. One unit of $x_i$ has intrinsic quality $z_i$, i=1,2, $z_1 \geq z_2$. One example is different mineral ores, whose quality depends only upon the % of the gold or iron contained. A second example is tomatoes which differ according to nutrient quality and other ingredients. A third example is cars which differ in speed, petrol consumption, durability, comfort, safety characteristics, etc..

We assume scalability along one dimension for tractability reasons. Future research may consider several dimensions of signalling, which is more complicated. Scalability along one dimension does not mean that one car is better than another car in equal proportions for all characteristics. It is quite possible that the high quality car is 70% better than the low quality car in safety, 30% worse in acceleration and maximum speed, and 40% better in comfort. Averaging out the three dimensions, the high quality car may then be, say, 50% better than the low quality car in an overall sense, dependent on the relative weighting of safety, comfort, and acceleration/speed. E.g., we may have $z_1=3$ and $z_2=2$. The intrinsic qualities $z_1$ and $z_2$ may thus be conceived as indices composed of arbitrarily many components. Cars that are sufficiently different from each other, such

[3] This section 2 can be written directly with signaling, replacing equations (1) and (12) with the corresponding signaling equations in section 3. However, for a general interest journal, the author currently believes that it is pedagogic to write this section without signaling to illustrate the difference between no signaling and signaling.

as family cars and sports cars, do not compete with each other through signaling and are considered as different goods, with different production and signaling processes targeting different consumers.[4]

The production constraints for sellers and buyers are

$R_i = a_i x_i, \quad R = ay, \quad i = 1,2$ Production constraint (1)

where R and $R_i$ are the resources (capital, labor, etc.) for buyers and sellers, respectively, and *a* and $a_i$ are unit production costs. Buyers with high paying jobs have low *a* which generates much money y. Similarly, sellers with efficient production facilities have low $a_i$ which generates much of good x. We hereafter suppress the specification i=1,2 in the equations.

Seller i consumes a part $x_{ic}$ of his production $x_i$, and sells the remaining part $x_i$-$x_{ic}$ to the buyer for the price $P_i$. In exchange the seller gets $y_{ic}$ which is the monetary payment he gets from the buyer in terms of good y. That part of the high quality seller's production that the buyer purchases is valued by the buyer with the per unit price $P_1$, and that part of the low quality seller's production that the buyer purchases is valued by the buyer with the per unit price $P_2$. That is, $P_i$ is an interior terms-of-exchange price denoting the price of $x_i$-$x_{ic}$ in terms of the numeraire good y which, as money, has a price one per unit. The price $P_i$ is a free choice variable for the buyer consistently with the subjective theory of value.[5] Some economic theory considers sellers as price setters, but buyers choose whether or not to purchase at that price. If the price is unacceptable, there will be no buyers. In a deeper philosophical sense, this is consistent with letting the buyer be the ultimate price chooser. The subjective price $P_i$ may thus differ from the intrinsic quality $z_i$. Seller i's sale is accordingly valued at $P_i(x_i - x_{ic})$. The value of $y_{ic}$ to the seller is $1 \cdot y_{ic}$ where money y is valued at one. This gives seller i's market constraint

$1 \cdot y_{ic} = P_i(x_i - x_{ic})$ Seller i's market constraint (2)

[4] That is, family cars and sports cars are so different that they can coexist within the same niche without one driving out the other. Some empirics from population biology suggests the principle known as competitive exclusion. If the weight ratio of the animals exceeds 2 to 1, or the length difference exceeds 1.4 to 1, then the different species can coexist. If coexistence is possible, different signaling regimes apply for the two species (family cars versus sports cars). If coexistence is not possible, signaling is one factor that may drive the least fit species out of the niche. E.g., a hybrid family car/sports cars may be driven out of the market if it looks too much either like a family car or a sports cars.

[5] Subjective value theory is a main pillar of the Austrian school, and dates back to the medieval Scholastic philosophers. They assert that to possess value an object must be both useful and scarce (Hayek 1968). This can also be phrased such that the buyer determines the value of the object (Hobbes 1651).

Equation (2) simultaneously defines the price $P_i = y_{ic}/(x_i - x_{ic})$ as the amount of money y consumed by seller i divided by the amount of good x that seller i delivers to the buyer in exchange. As the buyer gets more, so that $x_i$-$x_{ic}$ increases, the per unit price $P_i$ decreases, which makes good $x_i$ cheaper. Conversely, if $x_i$-$x_{ic}$ decreases, good $x_i$ becomes more scarce for buyers, and the price $P_i$ increases. Also, as seller i gets more money y for a given amount $x_i$-$x_{ic}$ of good $x_i$, so that $y_{ic}$ increases, the price $P_i$ increases, since the buyer then pays more money y, and conversely if $y_{ic}$ decreases.

Analogously, the buyer's production is valued at $1 \cdot y$. The buyer consumes a part $y_c$ of her monetary possession y, which can mean enjoying money for its own sake, or burning money, but which more realistically means using the monetary possession to purchase other goods than good x. The buyer delivers as monetary payment the remaining part y-$y_c$ to the two types of sellers. In exchange the buyer gets $x_c$, which is a combination of $x_1$ and $x_2$, valued with the average intrinsic quality z.[6] We define z as the average of $z_1$ and $z_2$, weighted with the productions $n_1 x_1$ and $n_2 x_2$, i.e.

$$z = (z_1 n_1 x_1 + z_2 n_2 x_2)/(n_1 x_1 + n_2 x_2)$$ Average intrinsic quality (3)

This gives the buyer's market constraint

$$z x_c = 1 \cdot (y - y_c)$$ Buyer's market constraint (4)

The buyer's consumption $x_c$ is valued at the intrinsic quality z, which is what the buyer actually gets to consume, and not valued as a combination of $P_1$ and $P_2$. The prices $P_1$ and $P_2$ only play a role in the buyer's evaluation of $x_1$ and $x_2$. For the market to clear, the total consumption of money y must equal the total possession (which can be conceived as production if money is interpreted as a numeraire good) of money y. The $n_1$ high quality sellers consume $y_{1c}$ each, the $n_2$ low quality sellers consume $y_{2c}$ each, and the n buyers consume $y_c$ each. The total possession by the n buyers is *ny*. This gives

$$n_1 y_{1c} + n_2 y_{2c} + n y_c = ny$$ Market clearance of y (5)

Solving (5) with respect to y, inserting into (4), and solving with respect to $z x_c$ gives

$$z x_c = (n_1 y_{1c} + n_2 y_{2c})/n \quad (6)$$

[6] Although not used in the formal development, we can think of the symbol y as representing the quality-adjusted equivalent of x, so that y = zx.

Summing the LHS's of (2) and (4) for the $n_1$, $n_2$, n agents, and setting equal to the sum of the RHS's gives the redundant equation

$$n_1 y_{1c} + n_2 y_{2c} + nzx_c = P_1 n_1 (x_1 - x_{1c}) + P_2 n_2 (x_2 - x_{2c}) + n(y - y_c) \quad (7)$$

Subtracting (5) from (7) gives the redundant equation

$$nzx_c + P_1 n_1 x_{1c} + P_2 n_2 x_{2c} = P_1 n_1 x_1 + P_2 n_2 x_2 \quad \text{Redundant market clearance of x (8)}$$

which redundantly expresses that total consumption of x equals total production of x. Hence solving (8) with respect to $zx_c$ gives (6) when (2) is inserted.

The value of seller i's consumption of his own production is $z_i x_{ic}$, where the intrinsic quality $z_i$, and not $P_i$, plays a role. The seller needs no buyer to tell him how to value that part of his own production which he himself consumes. He simply enjoys the intrinsic quality $z_i$ of his production, just as the buyer enjoys the intrinsic quality 1 of her production.

We assume Cobb-Douglas utilities

$$U_i = (z_i x_{ic})^{\beta} y_{ic}^{1-\beta}, \quad U = (zx_c)^{\beta} y_c^{1-\beta}, \quad 0 \le \beta \le 1 \quad \text{Cobb-Douglas utilities (9)}$$

where U is the buyer's utility, $U_i$ is seller i's utility, and β is a parameter which expresses the relative preference for good x.

Each seller's strategic choice variable is how much, expressed as $x_{ic}$, of his own production $x_i$ valued at $z_i$ to consume. The remaining part, $x_i$-$x_{ic}$, he sells to the buyer in exchange for money $y_{ic}$. Each seller takes the price $P_i$ as given when choosing the optimal $x_{ic}$. Inserting (2) into (9), derivating $U_i$ with respect to $x_{ic}$, setting the derivative equal to zero, solving with respect to $x_{ic}$, and inserting $x_i$ from (1), gives

$$\frac{\partial U_i}{\partial x_{ic}} = 0 \quad \Rightarrow \quad x_{ic} = \beta x_i \quad \text{Seller i's FOC } (x_{ic}) \text{ (10)}$$

That's a very straightforward choice for seller i. He simply consumes a fraction β of his production, which is the relative weight he assigns to good $x_i$, that is, relative to money y, in his Cobb-Douglas utility. Expressed differently, equation (10) expresses that the representative seller i balances the marginal benefit against the marginal cost of consuming one additional unit $x_{ic}$ of his production $x_i$. The LHS of the equation is the marginal benefit of consuming $x_{ic}$, and it equals the RHS which is the marginal cost of $x_i$ multiplied with β which expresses how valuable is good $x_i$ relative to money

y. Equation (10) states that you consume more of your production if you value good $x_i$ more relative to money y. Inserting (10) into (2), (4), (6) gives

$$y_{ic} = P_i x_i (1-\beta), \quad zx_c = \frac{(P_1 n_1 x_1 + P_2 n_2 x_2)(1-\beta)}{n}, \quad y_c = y - zx_c \tag{11}$$

The representative buyer's strategic choice variable is which price $P_i$ she is willing to pay for each unit of the good $x_i=R_i/a_i$. Her choice is implicitly a choice of how much money y, that is y-$y_c$, to deliver to the sellers. The buyer sets the price ratio $P_1/P_2$ equal to the ratio $z_1/z_2$ of intrinsic qualities, i.e.

$$P_1 / P_2 = z_1 / z_2 \qquad \text{Price ratio (12)}$$

When choosing the optimal price $P_i$, the buyer uses (11) to determine the impact $P_i$ has on her consumption of $x_c$ valued at the intrinsic quality z, and her consumption of $y_c$ valued at one. Inserting (11) into (9), derivating U with respect to $P_i$, and setting the derivative equal to zero, gives

$$\frac{\partial U}{\partial P_i} = 0 \quad \Rightarrow \quad zx_c = \frac{(P_1 n_1 x_1 + P_2 n_2 x_2)(1-\beta)}{n} = \beta y \qquad \text{Buyer's FOC } (P_i) \text{ (13)}$$

Equation (13) becomes the same regardless of whether one derivates with respect to $P_1$ or $P_2$, due to the symmetric presence of $P_1$ and $P_2$ in (11), and thus in (9). Equation (13) expresses that the buyer balances the marginal benefit against the marginal cost of consuming one additional unit $x_c$ of the production x that she has purchased. The LHS of (13) is the marginal benefit of consuming $x_c$ valued intrinsically at z, and it equals the RHS which is the marginal cost of y, multiplied with β which expresses how valuable is good x.[7] Solving (12) and (13) with respect to $P_1$ and $P_2$ gives

$$P_1 = \frac{z_1 \beta n y}{(z_1 n_1 x_1 + z_2 n_2 x_2)(1-\beta)}, \quad P_2 = \frac{z_2 \beta n y}{(z_1 n_1 x_1 + z_2 n_2 x_2)(1-\beta)} \tag{14}$$

Four points are worth noting about (14). First, the presence of β in the numerator and 1-β in the denominator means that both prices increase as good x become more desirable relative to money y as expressed in the Cobb-Douglas utilities. Second, the presence of both $z_1$ and $z_2$ in the denominator, and $z_1$ and $z_2$ respectively in the numerator, means that the intrinsic qualities have a direct impact on the prices. Third, the presence of *ny* in the numerator means that higher total production by all buyers increases prices. This can also be interpreted as inflation if *ny* gets adjusted

[7] The equation system has 15 variables: $x_1,x_2,y,x_{1c},x_{2c},x_c,y_{1c},y_{2c},y_c,z,P_1,P_2,U_1,U_2,U$. Equations (1) and (9) provide three equations each, (2) and (10) provide two equations each, (3),(4),(5),(12),(13) provide one equation each, and (6),(7),(8),(11) are redundant. Equations (1),(3),(15),(16),(17) provide the 15 solutions.

to successively higher values without backing in actual possession of money y. Fourth, the presence of $n_1x_1$ and $n_2x_2$ in the denominator means that higher total production by all sellers decreases prices. If the sellers flood the market with good x, prices plummet. Inserting (14) into (10) and (11), and applying (1), gives[8]

$$P_1 = \frac{z_1\beta nR/a}{(z_1n_1R_1/a_1 + z_2n_2R_2/a_2)(1-\beta)}, \quad P_2 = \frac{z_2\beta nR/a}{(z_1n_1R_1/a_1 + z_2n_2R_2/a_2)(1-\beta)} \tag{15}$$

$$\begin{aligned} x_{ic} &= \frac{R_i\beta}{a_i}, \quad y_{ic} = \frac{P_i(1-\beta)}{\beta}x_{ic} = \frac{z_i\beta nRR_i/aa_i}{(z_1n_1R_1/a_1 + z_2n_2R_2/a_2)}, \\ zx_c &= \frac{R\beta}{a}, \quad y_c = \frac{z(1-\beta)}{\beta}x_c = \frac{R(1-\beta)}{a} \end{aligned} \tag{16}$$

Inserting (15) and (16) into (9) gives

$$U_i = P_i^{1-\beta}x_iz_i^\beta\beta^\beta(1-\beta)^{1-\beta} = \frac{z_iR_i\beta}{a_i}\left(\frac{nR/a}{z_1n_1R_1/a_1 + z_2n_2R_2/a_2}\right)^{1-\beta}, \quad U = \frac{R\beta^\beta(1-\beta)^{1-\beta}}{a} \tag{17}$$

I am not aware of anyone having made a development such as in this section, but believe that the phenomenon of exchange is well understood without the need for further interpretation. The results in this section without signaling constitute a benchmark with which we compare the signaling results over the next sections.

## 3 A model with signaling

To introduce signaling we replace the production constraint in (1) with

$R_i = a_ix_i + b_is_i, \quad R = ay$ Production constraint deducting signaling cost (18)

where $s_i$ is the signal by a representative seller of type i, $s_1 \geq s_2$, and $b_i$ is the unit cost of signaling, i.e. the conversion coefficient (assumed constant) between seller i's resource and level of signaling.[9] To illustrate (18) consider an example with a car manufacturer which is divided into a production department and a sales/marketing/advertizing/consumer-help department (sales/marketing

---

[8] Applying (1),(3),(16) gives $x_c = [(n_1R_1/a_1 + n_2R_2/a_2)\beta R/a]/[z_1n_1R_1/a_1 + z_2n_2R_2/a_2]$.

[9] Fremling and Posner (1999) analyze market signaling of personal characteristics. They consider an individual with an income I which is divided between nonconspicuous spending C versus enhancing status E, to illustrate individual behavior. Their objective is not to determine whether signaling is desirable or not from a societal point of view. They reinterpret many earlier experiments in terms of signaling.

department, for short). The example is similar to some internet shopping today. Everything done by the production department is production $x_i$, while everything done by the sales/marketing department is signaling $s_i$, as in (18). Section 2 considered the benchmark that the car manufacturer focuses 100% on production and 0% on sales/marketing. This means that $s_i=0$ which causes maximum production $x_i=R_i/a_i$. Let us consider the characteristics of that benchmark more thoroughly. The car manufacturer has no sales/marketing department, but a huge production department. We define production broadly to include normal service such as trucking, inventories, floor space, shelving, cashiers, baggers, parking lots, etc. As part of the production process the cars are lined up in a huge hall. The location and condition of the hall are determined to shelter the cars against weather, theft, and other hazards, as part of safe production, with no signaling purpose. Each car gets a huge technical specification card which is placed on the front window, generated as part of the production process to distinguish the cars from each other, and prevent that the production process gets messy. Imagine that no one initially knows that the huge hall of cars exist, since there is no advertisement for it. People may get to know that the hall of cars exist if they observe it in their neighborhood, or hear from others through word-of-mouth that such a hall exists. People in the neighborhood start showing up in the hall to look at the cars. There are no sales people inside the hall since the car manufacturer does not invest in sales, since $s_i=0$. People cannot steal the cars since the car manufacturer has installed alarms, as part of the production process to ensure safe production where nothing is stolen. Purchasing a car means inserting a credit card into a slot. After the payment has been registered, the alarm on the car is turned off, the car becomes drivable, and the buyer is provided with a card that allows opening a door through which the car can be driven out of the hall. Removing an unpaid car from the hall in some unorthodox manner activates an alarm at the police station which arrests the perpetrator and places the car back into the hall upon which the insurance company repairs any damage caused. The insurance premium is part of safe production.

Against this benchmark the car manufacturer contemplates boosting its sales/marketing department which we define as signaling. Whether signaling is good or bad depends to some extent on whether the signaling can contain useful information about various types of differences between the cars. General signals such as "these cars are high quality", glitzy pictures of cars, or balloons at the car sales dealership, contain little useful information. The impact of such signals depends on the makeup of the consumers. They may have value for some and no value for others. At the other extreme, car engineers may develop highly informative technical specifications which as signals may be incomprehensible for a lay audience. As a compromise, a possible signal is to claim that my product is excellent because of x,y, and z with a backup for the claims of x,y, and z. Signalers usually design a correlation between the cost of the signal and the impact they expect it to have, both when designing the content of the signal and the medium through which it is transmitted.[10] The cost of the signal is adjusted to be maximally productive with respect to the target audience.

Since we have defined the production department so broadly, it is possible for our purpose to define everything that occurs in the sales/marketing department as signaling $s_i$. The sales/marketing department does nothing to boost the production $x_i$ or improve the quality of cars, but quite the contrary reduces production since resources get diverted away from production. Signaling in this model is detrimental in that it takes away resources from production. The utility from consuming a good arises only from the intrinsic quality of the good and the amount consumed. However, the prices depend on perceptions generated by signaling. Hence how much each player gets of each good determines the Cobb-Douglas utility. What the sales/marketing department does is to make the consumers aware of the cars, and convince more consumers to buy cars. If car purchases increase sufficiently due to signaling, despite producing fewer cars in the production department, diverting resources away from production and into signaling is worth wile. Signaling is always costly, but may generate higher utility if a higher price for one's production is thereby obtained. Assuming zero signaling as a starting point, allowing consumers to better maximize utility subject to their income constraint, resources spent on signaling e.g. to provide consumer information, is more valuable than regular production, up to a point. The optimal balance between production and signaling occurs when the marginal benefits of production versus signaling are equal. That balance also depends on the unit costs $a_i$ and $b_i$ of production and signaling. Boosting the sales/marketing department means that the location and condition of the hall of cars are determined for optimal signaling effect. The hall's existence and the characteristics of the cars are marketed broadly and professionally in all media. In addition to a technical specification card on each car, the hall is full of competent sales and marketing people discussing cars with potential

[10] The internet becomes an increasingly important medium. Car manufacturers signal by allocating costs to develop the best internet presentations. Websites compare various aspects between cars, offer side-to-side comparisons of specific cars, price competition, recommend which cars go with differently sized drivers and passengers (tall, short, obese), and include articles on how well different cars do on speed, safety, reliability, etc..

consumers with the objective of boosting sales. The sales people add a personal touch to the sales process and provide information tailored to each consumer's needs.

Assume that the car manufacturer allocates 60% of its resource to the production department and 40% as signaling to the sales/marketing department. Each department makes further allocation into labor costs and other costs. For a firm with only one department, a 60%/40% split may be done by 60% of the work force in production and 40% in signaling, or that each employee spends 60% of his time on production and 40% of his time on signaling, or that each employee j is employed $p_j$% in production and $q_j$% in signaling, where the average $p_j$ over all employees is 60% and the average $q_j$ over all employees is 40%.

The example above suggests a method to measure the total size and cost of signaling, for individual sellers, firms, within various industries, and in society at large at the local or global level. Compiling empirics for how resources are divided between production and non-production provides such a measure. The measure becomes explicit if signaling is defined in a clear-cut manner such as everything allocated to a sales/marketing department. For more narrow definitions of signaling, a more careful analysis of the budget within, say, the sales/marketing department, is needed to determine the total cost of signaling.

We further replace the price ratio in (12) with the Signaling Attention Function (SAT)

$$\frac{P_1}{P_2}=\left(\frac{z_1}{z_2}\right)^k\left(\frac{s_1}{s_2}\right)^r, \quad k\geq 0, \quad r\geq 0 \qquad \text{Signaling Attention Function (19)}$$

where k is the power of truth parameter and r is the signaling decisiveness parameter. When k=r=0, the buyer has no information to distinguish the high quality good from the low quality good, and she sets equal price $P_1=P_2$. As r increases above one when k=0, signaling gains importance and the intrinsic qualities have no impact on the price ratio, and also no impact on the prices. When 0<r<1, the low quality producer gains disproportionally by enjoying a more favorable price ratio than that specified by the signaling ratio. When r=1, the price ratio equals the signaling ratio. When r>1, the high quality producer gains disproportionally. When $r=\infty$, the high quality producer enjoys an infinite price ratio by signaling marginally more than the low quality producer. The signaling decisiveness r is a characteristic of the market or industry where the sellers and buyers operate. Some markets are extremely fierce and competitive, with a large r. Other markets are more relaxed, with a small r. The competitiveness of a market may also change over time, causing r to fluctuate. This article considers a market at a given point in time when r has a fixed value.

Signaling influences prices when the buyer lacks the opportunity, ability, experience, competence, time, or capacity to detect the true intrinsic qualities. Detecting intrinsic quality differentials is difficult for almost all goods. Holding two different sophisticated material products in one's hand in a store may not be sufficient to detect quality differentials. The same holds for sophisticated immaterial products such as long distance traveling. For unsophisticated products, such as tomatoes, apples, grapes, inspecting the outside e.g. for degree of redness or shininess may not be sufficient to detect that the inside may be rotten or full of undesirable chemicals. Some differences may not become evident before the products reach old age. Goods can also be services. Examples are lawyers, real-estate agents, economic advisors, nannies, cleaners, doctors, hospitals, universities, schools, pre-schools. The buyers and consumers of goods and services are well advised to rely on signaling, to a small or large extent, as the circumstances suggest. This also suggests that the sellers are advised to signal optimally to maximize their utilities.

As k increases from zero to one, the power of truth[11] becomes gradually more prominent as the buyer improves her ability to distinguish the two products. Equation (19) reduces to (12) when k=1 and r=0, in which case signaling does not matter and the price ratio equals the ratio of the intrinsic qualities. This case applies for some very unsophisticated products such as nails which one gets the opportunity to test with a hammer. Increasing k above one is also possible and means that the high quality good gets a larger price than what its intrinsic quality justifies.

The four way diagram in Fig. 1 illustrates (18) and (19). The upper-right quadrant shows the range of seller 1's choices between production $x_1$ and signaling $s_1$ within his budget constraint given by his resource $R_1=2$. With $a_1=2/3$ and $b_1=1$, seller 1 can maximally produce $x_1=3$ when $s_1=0$, and can maximally (and hypothetically) signal $s_1=2$ when $x_1=0$. The diagonally opposite quadrant shows the corresponding choices for seller 2, ranging from $x_2=1$ when $s_2=0$ to $s_2=1$ when $x_2=0$, where $R_2=a_2=b_2=1$. The lower-right quadrant shows how the production of the two types of sellers combines to generate production $x_1$ and $x_2$. Multiplying with the total numbers of high quality and

---

[11] The power of truth ratio was first introduced by Hirshleifer and Osborne (2001) in a Litigation Success Function. The idea is that the outcome of a legal battle depends on the true degree of fault by the Defendant multiplied by the ratio of litigation efforts by the two sides raised to a parameter. When the parameter is zero or the two sides invest equal efforts, then legal efforts are totally ineffective as compared with the power of truth, i.e. the underlying merits of the case.

low quality sellers gives the total production $n_1x_1+n_2x_2$. The upper-left quadrant shows how the signaling $s_1$ and $s_2$ of the two types of sellers combine to generate the signaling ratio $s_1/s_2$ exemplified with two straight lines (dotted and dashed) emerging from the origin. The signaling ratio is raised to the signaling decisiveness parameter r, and multiplied with the power of truth ratio raised to k, to yield the price ratio $P_1/P_2$.

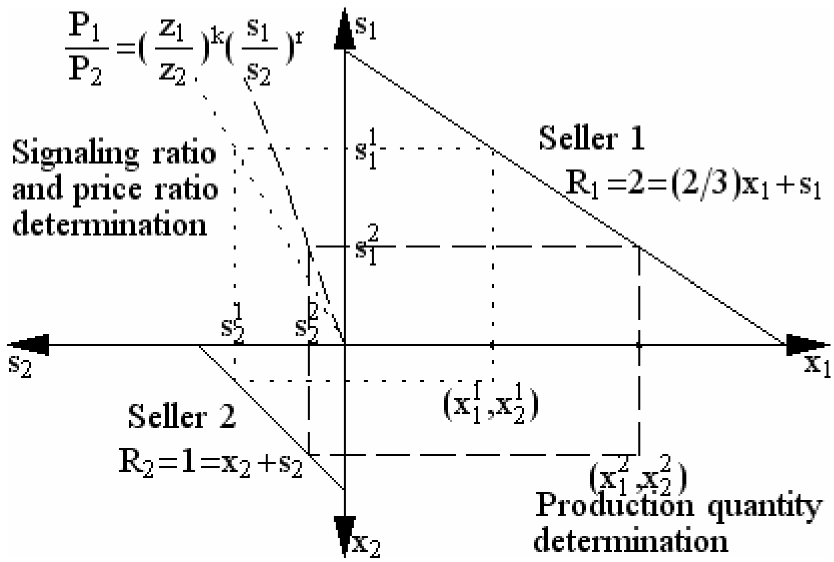


Fig. 1. Production quantity determination, and signaling ratio and price ratio determination.

The dotted rectangle in Fig. 1 shows one possible outcome of the postulated interaction. The sellers produce modestly $(x_1^1,x_2^1)$=(1,1/4), and signal strongly $(s_1^1,s_2^1)$=(4/3,3/4). The straight dotted line from the origin in the upper-left quadrant goes through this latter point which determines the signaling ratio $s_1^1/s_2^1$=16/9. The dashed rectangle shows an alternative outcome where the sellers produce more heavily $(x_1^2,x_2^2)$=(2,3/4), and signal modestly $(s_1^2,s_2^2)$=(2/3,1/4). The straight dashed line determines the signaling ratio $s_1^2/s_2^2$=8/3 which is larger than 16/9. It is quite possible for different rectangles to cause equal signaling ratios, and thus also equal price ratios, but the total production and total signaling are different for different rectangles.

The two additional free choice variables $s_1$ and $s_2$ for the two types of sellers are determined by two additional first order conditions. The Appendix shows that these are given by

$$s_i=\frac{rR_i(1-\beta)}{b_i(1+r(1-\beta))} \quad \Leftrightarrow \quad \frac{b_is_i}{r}=a_i(x_i-x_{ic}) \qquad \text{Seller i's FOC } (s_i) \ (20)$$

There is no point in signaling if your own good is all that matters to you. In that extreme case the sellers keep all their production for themselves. Hence sellers are self-sufficient, which means that they are not sellers when β=1, and they also do not receive anything from buyers. Consequently, $s_i$=0 when β=1. At the other extreme, if the sellers find no interest in consuming their own production, but merely produce in order to sell, then signaling becomes maximally important. Inserting β=0 into (20) gives $s_i = rR_i / [b_i(1+r)]$

The rightmost equation in (20) shows how seller i equates the total signaling cost $b_i s_i$, measured with the same denomination as his resources, divided by the signaling decisiveness $r$ (dimensionless) with that part of his production, $a_i(x_i - x_{ic})$, also measured with the same denomination as his resources, which is delivered to the buyer. As the decisiveness increases, seller i signals more, and conversely if the decisiveness decreases. Equation (20) expresses how seller i strikes an optimal balance between signaling and production for delivery. Seller i's signal depends on the decisiveness, which affects all agents, on his resources and unit signaling cost, the relative preference β for good x, and nothing else. That is, seller i's signal depends neither on the intrinsic qualities nor on the unit production cost.

Inserting i=1 and i=2 into (20), and inserting into (19) gives

$$\frac{s_1}{s_2} = \frac{R_1 b_2}{R_2 b_1}, \quad \frac{P_1}{P_2} = \left(\frac{z_1}{z_2}\right)^k \left(\frac{R_1 b_2}{R_2 b_1}\right)^r \tag{21}$$

The signaling ratio $s_1 / s_2$ increases if the high quality producer's resource increases or his unit signaling cost decreases, relative to that of the low quality producer. Raising the signaling ratio to the power r, and multiplying with the power of truth ratio gives the price ratio $P_1 / P_2$, which may thus differ significantly from the ratio $z_1 / z_2$ of the intrinsic qualities. Neither the signaling ratio nor the price ratio depends on the relative preference β for good x since both sellers have the same relative preference for good x versus money y.

Inserting (20) into $s_1 \geq s_2$ and rearranging gives

$$s_1 \geq s_2 \quad \Leftrightarrow \quad b_1 / b_2 \leq R_1 / R_2 \qquad \text{Truthful Signaling Condition (22)}$$

which is a requirement for truthful signaling. It can be interpreted as a "decreasing-proportional-marginal-cost" criterion for truthful signaling. It has commonly been believed that for a truthful signaling equilibrium the unit cost of signaling must be lower for the high quality producer than for the low quality producer, that is $b_1/b_2<1$. However, (22) shows that it is quite acceptable that $b_1/b_2>1$ provided that this disadvantage in higher unit signaling cost is sufficiently counterbalanced by the high quality producer's resource superiority in endowed quality, such that $R_1/R_2$ is sufficiently large. Interpreted in economic terms, both an income effect and a substitution effect are involved. Even if charged a higher price, an opulent consumer might purchase more than a poor person would – simply because he or she can afford to do so. Similarly here, a high quality producer may afford and find it optimal to signal more heavily than a low quality producer, despite higher unit cost of signaling.[12]

Inserting (20) into (18) and solving with respect to $x_i$ gives

$$x_i = \frac{R_i}{a_i(1+r(1-\beta))} \tag{23}$$

which reduces to (1) expressed as $x_i = R_i/a_i$ when r=0. This means that signaling has a very straightforward impact on production, simply reducing it with the factor $(1+r(1-\beta))$ in the denominator. When β is large so that sellers prefer their own production, the signaling decisiveness does not matter much for production, and sellers produce close to their maximum $R_i/a_i$. Conversely, when β is small so that sales are essential, the decisiveness matters more. As an example, with signaling decisiveness r=2 and β=1/2, the production is cut in half. As the signaling decisiveness approaches infinity, and β<1, the production approaches zero asymptotically. Endogenizing both production and signaling implies that "over-dissipation" always occurs. That is, since signaling is Pareto-inefficient, the sellers would always do better in aggregate never engaging in it. However, signaling can never outstrip the available resources in this model, in contrast to rent seeking models where the production is a fixed exogenously given constant. A rent seeking model allowing for signaling may thus allow both rent seeking and signaling to exceed available resources, which causes negative utilities. This is referred to as rent dissipation in the rent seeking literature. Simply replacing (1) with (23), that is inserting $x_i = R_i/[a_i(1+r(1-\beta))]$ instead of $x_i = R_i/a_i$, directly translates the solution without signaling into the solution with signaling. This makes

[12] Within the biology literature a similar result has been independently discovered by Eshel et al. (2002), Hausken and Hirshleifer (2004), Houston (2003), Proulx et al. (2002). See Getty (2005) for a recent interpretation.

equations (2)-(11) and (13) in section 2 directly applicable for this section with signaling. However, equation (12) has been replaced with the more general Signaling Attention Function in (19). Solving (19) and (13) with respect to $P_1$ and $P_2$ gives

$$P_1 = \frac{\left(\frac{z_1}{z_2}\right)^k \left(\frac{s_1}{s_2}\right)^r \beta n y}{\left[\left(\frac{z_1}{z_2}\right)^k \left(\frac{s_1}{s_2}\right)^r n_1 x_1 + n_2 x_2\right](1-\beta)}, \quad P_2 = \frac{\beta n y}{\left[\left(\frac{z_1}{z_2}\right)^k \left(\frac{s_1}{s_2}\right)^r n_1 x_1 + n_2 x_2\right](1-\beta)} \tag{24}$$

which of course reduces to (14) when k=1 and r=0. Four points can be made about (24) in addition to the four points after (14). First, k<1 gives lower power of truth than in (14), causing the high quality producer to suffer from a lower price than in (14). Second, k>1 causes a power of truth which exaggerates the intrinsic quality of the high quality product, causing the high quality producer to enjoy a higher price than in (14). Third, r<1 gives a disproportional advantage to the low quality producer despite his lower signal. Fourth, r>1 gives a disproportional advantage to the high quality producer, boosting the impact of his higher signal.

Inserting (20) and (23) and y=R/a into (24) gives

$$P_1 = \frac{\left(\frac{z_1}{z_2}\right)^k \left(\frac{R_1 b_2}{R_2 b_1}\right)^r (1+r(1-\beta))\beta \frac{nR}{a}}{\left[\left(\frac{z_1}{z_2}\right)^k \left(\frac{R_1 b_2}{R_2 b_1}\right)^r \frac{n_1 R_1}{a_1} + \frac{n_2 R_2}{a_2}\right](1-\beta)}, \quad P_2 = \frac{(1+r(1-\beta))\beta \frac{nR}{a}}{\left[\left(\frac{z_1}{z_2}\right)^k \left(\frac{R_1 b_2}{R_2 b_1}\right)^r \frac{n_1 R_1}{a_1} + \frac{n_2 R_2}{a_2}\right](1-\beta)} \tag{25}$$

Both prices increase in the signaling decisiveness when β<1. As the decisiveness approaches infinity, both prices also approach infinity. The reason is that the production of good x approaches zero, since the sellers waste all their resources on signaling. With good x becoming extremely scarce, buyers become willing to pay extremely much for good x since they value it with the parameter β. For a given r and β, to the extent the high quality producer has a larger resource $R_1$ and a lower unit cost $b_1$ of signaling than the low quality producer, he enjoys a higher price $P_1$ beyond that justified by the intrinsic quality $z_1$ being larger than $z_2$. For the special and uncommon case that $R_1 b_2 = R_2 b_1$ and k=1, equation (25) is equivalent to (15) except that both prices in (25) are multiplied with $(1+r(1-\beta))$.

The analog of (16) for signaling is

$$x_{ic}=\frac{R_i\beta}{a_i(1+r(1-\beta))},\quad y_{ic}=\frac{P_i(1-\beta)}{\beta}x_{ic}=\frac{P_iR_i(1-\beta)}{a_i(1+r(1-\beta))},$$

$$zx_c=\frac{R\beta}{a},\quad y_c=\frac{z(1-\beta)}{\beta}x_c=\frac{R(1-\beta)}{a}, \tag{26}$$

$$y_{1c}=\frac{\left(\frac{z_1}{z_2}\right)^k\left(\frac{R_1b_2}{R_2b_1}\right)^r\beta\frac{nRR_1}{aa_1}}{\left(\frac{z_1}{z_2}\right)^k\left(\frac{R_1b_2}{R_2b_1}\right)^r\frac{n_1R_1}{a_1}+\frac{n_2R_2}{a_2}},\quad y_{2c}=\frac{\beta\frac{nRR_2}{aa_2}}{\left(\frac{z_1}{z_2}\right)^k\left(\frac{R_1b_2}{R_2b_1}\right)^r\frac{n_1R_1}{a_1}+\frac{n_2R_2}{a_2}}$$

Note the equivalence with non signaling in (16) for the buyers' consumption $zx_c$ and $y_c$. For the sellers' consumption, there is division with $(1+r(1-\beta))$ for good x, but no such division for money y due to the insertion of $P_i$ from (25). Signaling takes no toll on neither the sellers' nor the buyers' consumption of money y, but impacts the relative consumption of money y by the high quality versus low quality sellers. The high quality seller enjoys the ratio $[R_1b_2/(R_2b_1)]^r$ in $y_{1c}$ in (26) which is larger than one if he enjoys a larger resource and a lower unit cost of signaling than the low quality producer, and much larger than one if also r is large. In this case he enjoys a higher consumption $y_{1c}$ of money y beyond that justified by the intrinsic quality $z_1$ being larger than $z_2$. Finally, the utilities are

$$U_i=P_i^{1-\beta}x_iz_i^{\beta}\beta^{\beta}(1-\beta)^{1-\beta},\quad U=\frac{R\beta^{\beta}(1-\beta)^{1-\beta}}{a},$$

$$U_1=\frac{R_1\beta}{a_1}\left(\frac{z_1}{(1+r(1-\beta))}\right)^{\beta}\left(\frac{\left(\frac{z_1}{z_2}\right)^k\left(\frac{R_1b_2}{R_2b_1}\right)^r\frac{nR}{a}}{\left(\frac{z_1}{z_2}\right)^k\left(\frac{R_1b_2}{R_2b_1}\right)^r\frac{n_1R_1}{a_1}+\frac{n_2R_2}{a_2}}\right)^{1-\beta}, \tag{27}$$

$$U_2=\frac{R_2\beta}{a_2}\left(\frac{z_2}{(1+r(1-\beta))}\right)^{\beta}\left(\frac{\frac{nR}{a}}{\left(\frac{z_1}{z_2}\right)^k\left(\frac{R_1b_2}{R_2b_1}\right)^r\frac{n_1R_1}{a_1}+\frac{n_2R_2}{a_2}}\right)^{1-\beta}$$

The first line in (27) is equivalent to (17) which shows that the basic structure of the Cobb-Douglas utilities is the same with and without signaling. Inserting the different price $P_i$ and different production $x_i$ with signaling gives the second and third lines for the seller utilities, which are lower than that of (17). Equation (23) shows that a large β does not reduce production much compared with the non signaling case. Similarly in (27), a large β is beneficial for the seller utilities. However, a large decisiveness reduces the utilities to sellers due to the presence of $(1+r(1-\beta))$ in the denominator. Inserting k=1 and r=0 into (27) causes reduction of (27) to (17).

When $x_i$ has been determined by (23) and as illustrated in Fig. 1, and $P_i$ has been determined by (25), seller i determines $x_{ic} = \beta x_i$ from (10) or (26) and $y_{ic} = P_i[(1-\beta)/\beta]x_{ic}$ from (11) or (26). This is illustrated in Fig. 2 where the dotted lines exemplify $x_{ic}^1$ and $y_{ic}^1$, where β=0.5 and $P_i$=$z_i$=1. The utility isoquants for seller i are shown with dashed and dotted lines for five values of $U_i$ given by (9). If seller i signals strongly, the price $P_i$ increases, and the angle of the dashed line giving $y_{ic}$ increases, while $x_{ic}$ decreases because of the resource constraint. The angle is 45 degrees in Fig. 2.

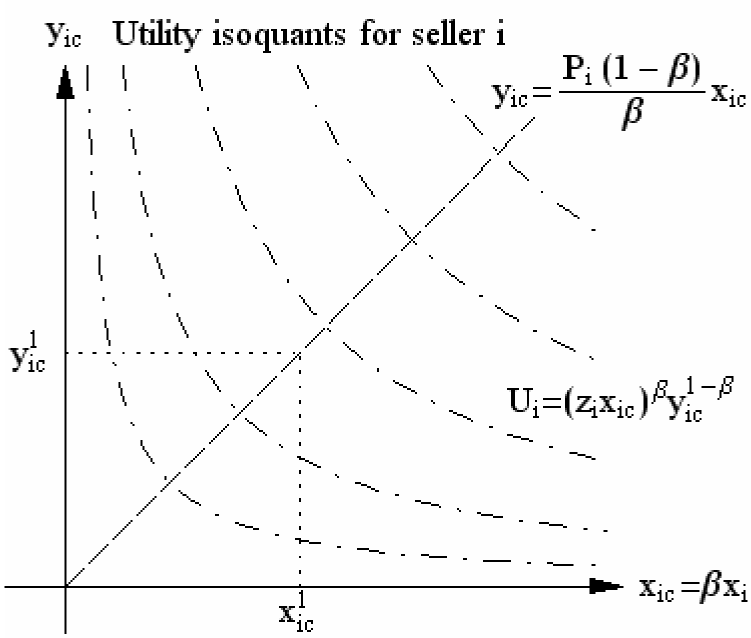


Fig. 2. Consumption $x_{ic}$ and $y_{ic}$, and utility isoquants $U_i$ for seller i.

For the buyer, $zx_c$ and $y_c$ are determined by (11) or (26), and z is determined by (3), which gives $x_c$ and $y_c = z[(1-\beta)/\beta]x_c$ illustrated with the dashed line in Fig. 3. The dashed line crosses the buyer's resource constraint y=R/a=$zx_c + y_c$ given by (4) and shown with a solid line. The crossing point gives the buyer's consumption exemplified with $x_c^1$ and $y_c^1$ shown with dotted lines, where β=0.5 and R=a=z=1. The utility isoquants for the buyer are shown with dashed and dotted lines for five values of U given by (9). If the weighted intrinsic quality z of good x increases, or β decreases, then the angle of the dashed line giving $y_c$ increases, while $x_c$ decreases because of the resource constraint. The angle is 45 degrees in Fig. 3.

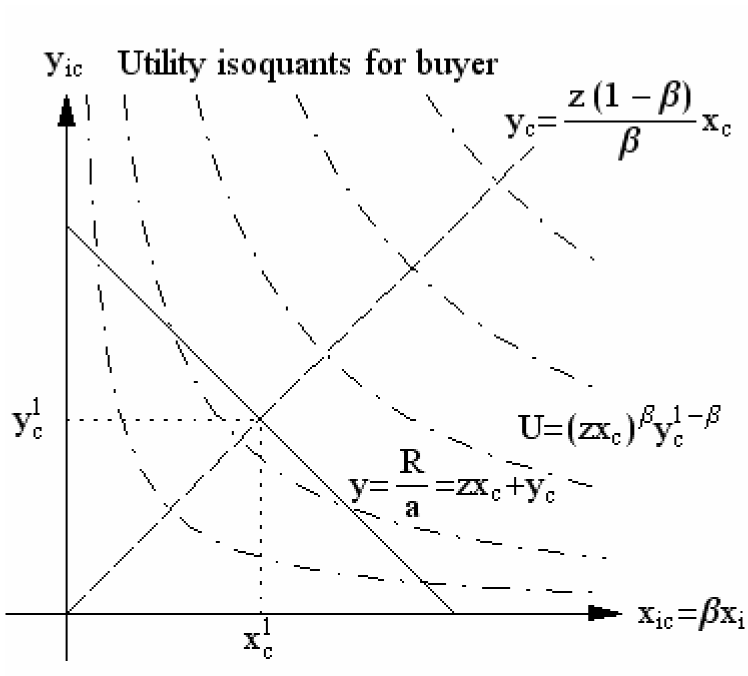


Fig. 3. Consumption $x_c$ and $y_c$, resource constraint, and utility isoquants U for the buyer.

This section shows that with signaling, the sellers suffer lower production, lower consumption of good x, and lower utilities, while the buyers enjoy the same production, the same consumption of both goods, and the same utilities. In the next section we remove this asymmetry between sellers and buyers.

**4 Adjusting the signaling model to account for price inflation**

One characteristic of the model in section 3 is that the buyer consumes the same portion $(1-\beta)y$ of her possession of money, pays the same portion $\beta y$ of her amount of money to the seller, and receives the same utility regardless of the amount of signaling by the sellers. That is, even when she receives almost nothing of good x from the seller in exchange for her fixed delivery of $\beta y$, she receives the same utility. The reason for this is that there is no fixed reference point to assess the value of that part of good x that she receives. When the supply of x goes down, the scarcity of good x causes the price to go up according to the price definition in (11), $P_i = y_{ic} / [x_i(1-\beta)]$, which applies for both signaling and non signaling, though $x_i$ is lower with signaling. We refer to the factor $(1+r(1-\beta))$ in the prices as the inflation factor. It approaches infinity when the decisiveness approaches infinity. Removing this factor from the prices in (25) gives the inflation adjusted signaling prices

$$P_1 = \frac{\left(\frac{z_1}{z_2}\right)^k \left(\frac{R_1 b_2}{R_2 b_1}\right)^r \beta \frac{nR}{a}}{\left[\left(\frac{z_1}{z_2}\right)^k \left(\frac{R_1 b_2}{R_2 b_1}\right)^r \frac{n_1 R_1}{a_1} + \frac{n_2 R_2}{a_2}\right](1-\beta)}, \quad P_2 = \frac{\beta \frac{nR}{a}}{\left[\left(\frac{z_1}{z_2}\right)^k \left(\frac{R_1 b_2}{R_2 b_1}\right)^r \frac{n_1 R_1}{a_1} + \frac{n_2 R_2}{a_2}\right](1-\beta)} \tag{28}$$

The two types of sellers still affect prices through the factor $[R_1 b_2 / (R_2 b_1)]^r$ which depends on their resources and unit signaling costs, and on the signaling decisiveness. Removing $(1+r(1-\beta))$ on the one hand removes inflation, and on the other hand removes the differential impact that $(1-\beta)$, multiplied by r, has on inflation. That is, a high preference for money y, which means a high $(1-\beta)$, means more inflation when the signaling decisiveness is high. To understand (28), consider $P_i n_i R_i / a_i$ which expresses the total value of all the type i sellers' production in the benchmark case of no signaling. That is, it multiplies the unit price $P_i$ with the production $R_i / a_i$ assuming no waste on signaling, which is multiplied with the number $n_i$ of sellers of type i.

*Inflation adjustment property 1. The total value $P_1 n_1 R_1 / a_1 + P_2 n_2 R_2 / a_2$ of the production of all sellers of the two types in the benchmark case of no signaling equals $nR\beta / [a(1-\beta)]$ for both the non signaling prices in (15) and for the inflation adjusted signaling prices in (28), but equals the larger expression $nR\beta(1+r(1-\beta)) / [a(1-\beta)]$ for the regular inflated signaling prices in (25).*

The proof follows from insertion into the specified equations. This property provides a common benchmark for non signaling and signaling in the sense that the total value of the production of all sellers, measured by the benchmark case of no waste on signaling, is the same without and with signaling when adjusting for inflation. The prices may still differ for non signaling and signaling, since (15) and (28) are different, but a common benchmark $nR\beta/[a(1-\beta)]$ has been determined.

Signaling causes the sellers to deliver less of good x to the buyers. With the regular signaling prices in (25), the buyers in aggregate pay the same monetary amount $n\beta y$ to the sellers in exchange. Accordingly, there is no division with the inflation factor $(1+r(1-\beta))$ in the sellers' monetary consumption $y_{1c}$ and $y_{2c}$ in (26). With inflation adjusted signaling prices, $y_{1c}$ and $y_{2c}$ are indeed divided by $(1+r(1-\beta))$. Using market clearance of money y in (5) to determine $y_c$, and (4) or (11) to determine $zx_c$, gives

$$x_{ic} = \frac{\beta R_i}{a_i(1+r(1-\beta))}, \quad y_{ic} = \frac{P_i R_i(1-\beta)}{a_i(1+r(1-\beta))}, \quad zx_c = \frac{R\beta}{a(1+r(1-\beta))}, \quad y_c = \frac{R(1+r)(1-\beta)}{a(1+r(1-\beta))} \tag{29}$$

Comparing (29) with the first line in (26) shows, first, that each seller consumes the same amount of good x with signaling prices and inflation adjusted signaling prices. Second, each seller consumes less of money y in (29) since the prices are divided by $(1+r(1-\beta))$. Third, each buyer consumes less of good x in (29) since signaling causes less of good x to be produced, exchanged, and consumed, and with inflation adjustment this causes division with $(1+r(1-\beta))$. Fourth, each buyer consumes more of money y in (29) since paying less to the seller allows her to keep more money for herself. Inserting (29) into the Cobb-Douglas utilities in (9) gives

$$U_i = P_i^{1-\beta} x_i z_i^{\beta} \beta^{\beta}(1-\beta)^{1-\beta}, \quad U = \frac{R(1+r)^{1-\beta}\beta^{\beta}(1-\beta)^{1-\beta}}{a(1+r(1-\beta))},$$

$$U_1 = \frac{R_1\beta z_1^{\beta}}{a_1(1+r(1-\beta))}\left(\frac{\left(\frac{z_1}{z_2}\right)^k\left(\frac{R_1 b_2}{R_2 b_1}\right)^r \frac{nR}{a}}{\left(\frac{z_1}{z_2}\right)^k\left(\frac{R_1 b_2}{R_2 b_1}\right)^r \frac{n_1 R_1}{a_1} + \frac{n_2 R_2}{a_2}}\right)^{1-\beta}, \tag{30}$$

$$U_2 = \frac{R_2\beta z_2^{\beta}}{a_2(1+r(1-\beta))}\left(\frac{\frac{nR}{a}}{\left(\frac{z_1}{z_2}\right)^k\left(\frac{R_1 b_2}{R_2 b_1}\right)^r \frac{n_1 R_1}{a_1} + \frac{n_2 R_2}{a_2}}\right)^{1-\beta}$$

The presence of $P_i^{1-\beta}$ in the seller utilities in (17), (27), (30) causes inflation adjustment, which entails division with the inflation factor $(1+r(1-\beta))$, to imply division with the inflation factor raised to $(1-\beta)$. Dividing the inflation adjusted signaling utilities in (30) with the regular signaling utilities in (27) gives

$$\frac{U_i(\textit{infl. adj. signaling})}{U_i(\textit{regular signaling})}=\frac{1}{(1+r(1-\beta))^{1-\beta}}<1,\quad \frac{U(\textit{infl. adj. signaling})}{U(\textit{regular signaling})}=\frac{(1+r)^{1-\beta}}{1+r(1-\beta)}<1 \tag{31}$$

which show lower utilities for both sellers and buyers. Equations (27) and (30) have in common that sellers suffer lower utilities because signaling diverts attention from production causing less consumption of good x. However, with inflation adjustment, the sellers suffer even lower utilities because their reduced delivery of good x earns them a lower price and thus less of money y in exchange. Equations (17) and (27) give the same utility for the buyers, even though they get less of good x with signaling. The reason is the inflated prices which camouflage what the buyers actually consume of good x. With infinite prices they get nothing of good x, but pay the same amount of money y to the sellers. With inflation adjustment, the buyers keep more money y for their own consumption, and accordingly get less of good x than they would optimally prefer without signaling. Consequently, with signaling and inflation adjustment the buyers earn lower utility than without signaling.

As an alternative to dividing the prices with the inflation factor $(1+r(1-\beta))$, referred to as inflation adjustment, this section can equally well be written with a focus on what buyers and sellers actually exchange with each other in terms of goods. Without signaling the buyer delivers $zx_c=y-y_c=\beta R/a$ to the seller, as shown in (4) and (11) inserting (1). With signaling, assume that each buyer instead decides to deliver the smaller amount $zx_c=y-y_c=R\beta/[a(1+r(1-\beta))]$, determined by dividing the non signaling payment (delivery) of money y with the factor $(1+r(1-\beta))$. As can be seen from (29), this is exactly the value of $zx_c$ determined by inflation adjustment of prices. For (13) to be valid, this implies that the prices are divided by $(1+r(1-\beta))$. Hence adjusting the prices with the inflation factor, or dividing the buyer's payment of money y with the same factor, is equivalent.

## 5 Buyer screening search costs for choosiness

The previous sections have assumed that the buyer reads the signals $s_1$ and $s_2$, is affected by the power of truth ratio $(z_1/z_2)^k$, but otherwise converts her entire resource R into generating money y at unit production cost a, where y=R/a is defined in (1). In praxis the buyer invests time and effort, and thus resources R, into screening and distinguishing the high quality good $x_1$ with intrinsic quality $z_1$ from the low quality good $x_2$ with intrinsic quality $z_2$. She travels back and forth between producers, she discusses with producers, other buyers, experts and others, she compares the goods with each other, and she gradually learns more about the goods. We refer to the cost of this investment as search costs for choosiness.[13] The buyer is choosy regarding her choice of good $x_1$ versus good $x_2$, which is costly. To account for the buyer's two kinds of investment, we replace the production constraint in (18) with

$$R_i = a_i x_i + b_i s_i, \quad y = \frac{R}{a}\left(1 - h(P_1 - P_2)\frac{z_2}{z_1}\right) \qquad \text{New production constraint (32)}$$

which deducts both signaling cost for the sellers and search costs for choosiness for the buyer. The larger is the buyer's search costs for choosiness, the less she invests into generating money y. That is, here monetary possession y becomes lower due to subtraction of search costs. The buyer's search costs for choosiness satisfies two assumptions.

*A1. The larger is the difference between the intrinsic qualities $z_1$ and $z_2$, expressed with a large ratio $z_1/z_2$, the smaller is the search costs for choosiness, since it is easier to detect a large difference than a small difference in intrinsic quality.*

*A2. The larger is the difference between the prices $P_1$ and $P_2$ chosen by the buyer, expressed with $P_1$-$P_2$, the larger is the search costs for choosiness, since the buyer can be expected to invest more effort to justify a basis for such a price difference.*

Applying assumptions 1 and 2 multiplicatively gives $(P_1 - P_2)z_2 / z_1$, which we multiply with a parameter h adjusted to ensure that $h(P_1 - P_2)z_2 / z_1 < 1$. This ensures that the buyer divides her resource into production and search costs for choosiness, and that none of the costs alone or in sum exceed her available resource R which would yield a negative monetary possession.

---

[13] Hausken and Hirshleifer (2004) introduce a "congestion function" to avoid that females mate exclusively with high quality males. Females may have to wait in line for preferred males, or spend time and effort searching for them. For economic signaling congestion does not operate in this manner. Hence we refer to search costs for choosiness.

Also in this section equations (2)-(11) and (13) in section 2 are applicable, and additionally (19) which implies (20)-(23). However, the buyer's FOC in (13) does not apply since the buyer's new production constraint in (32) depends on the prices $P_1$ and $P_2$. The symmetric presence of $P_1$ and $P_2$ in $zx_c$, $y_c$, and y in (11) and (9) made it irrelevant in (13) whether derivation was made with respect to $P_1$ and $P_2$. Although $P_1$ and $P_2$ are still symmetrically present in $zx_c$, they are not symmetrically present in y in (32), and thus also not in $y_c = y - zx_c$, nor in the utility in (9). The nature of screening search costs for choosiness, regardless of how (32) is designed, amounts to introducing an asymmetry between the high quality producer and the low quality producer, and thus between $P_1$ and $P_2$. Consequently, in this section we let the buyer choose $P_1$ optimally, where $P_2$ follows from the signaling attention function in (19). Calculating the new buyer's FOC gives

$$\frac{\partial U}{\partial P_1} = 0 \quad \Rightarrow \quad (P_1 n_1 x_1 + P_2 n_2 x_2)(1-\beta) = \beta \frac{nR}{a} - h\frac{nRz_2}{az_1}\left(\frac{P_2 n_2 x_2 (1-\beta)}{n_1 x_1} + (P_1 - P_2\beta)\right)$$

New buyer's FOC ($P_1$) (33)

which reduces to (13) when h=0. Solving (19) and (33) with respect to $P_1$ and $P_2$, and inserting $x_i$ from (23), gives

$$P_1 = \frac{\left(\frac{z_1}{z_2}\right)^k \left(\frac{R_1 b_2}{R_2 b_1}\right)^r (1+r(1-\beta))\beta\frac{nR}{a}}{\left[\left(\frac{z_1}{z_2}\right)^k \left(\frac{R_1 b_2}{R_2 b_1}\right)^r \frac{n_1 R_1}{a_1} + \frac{n_2 R_2}{a_2}\right](1-\beta) + h\frac{nRz_2}{az_1}(1+r(1-\beta))\left[\left(\frac{z_1}{z_2}\right)^k \left(\frac{R_1 b_2}{R_2 b_1}\right)^r + \frac{n_2 R_2 a_1}{n_1 R_1 a_2}(1-\beta) - \beta\right]},$$

$$P_2 = \frac{(1+r(1-\beta))\beta\frac{nR}{a}}{\left[\left(\frac{z_1}{z_2}\right)^k \left(\frac{R_1 b_2}{R_2 b_1}\right)^r \frac{n_1 R_1}{a_1} + \frac{n_2 R_2}{a_2}\right](1-\beta) + h\frac{nRz_2}{az_1}(1+r(1-\beta))\left[\left(\frac{z_1}{z_2}\right)^k \left(\frac{R_1 b_2}{R_2 b_1}\right)^r + \frac{n_2 R_2 a_1}{n_1 R_1 a_2}(1-\beta) - \beta\right]}$$

(34)

which reduces to (25) when h=0. The additional term multiplied with h in the denominator causes the prices $P_1$ and $P_2$ to be lower than the signaling prices in (25). Inserting (34) into (32) gives

$$y = \frac{\frac{R}{a}\left[\left(\frac{z_1}{z_2}\right)^k \left(\frac{R_1 b_2}{R_2 b_1}\right)^r \frac{n_1 R_1}{a_1} + \frac{n_2 R_2}{a_2}\right](1-\beta)\left[1 + h\frac{nRa_1 z_2}{n_1 R_1 a z_1}(1+r(1-\beta))\right]}{\left[\left(\frac{z_1}{z_2}\right)^k \left(\frac{R_1 b_2}{R_2 b_1}\right)^r \frac{n_1 R_1}{a_1} + \frac{n_2 R_2}{a_2}\right](1-\beta) + h\frac{nRz_2}{az_1}(1+r(1-\beta))\left[\left(\frac{z_1}{z_2}\right)^k \left(\frac{R_1 b_2}{R_2 b_1}\right)^r + \frac{n_2 R_2 a_1}{n_1 R_1 a_2}(1-\beta) - \beta\right]} \quad (35)$$

which reduces to (1) and (18), that is y=R/a, when h=0. The buyer's monetary possession y is of course lower in (35) due to search costs for choosiness. The first line in (26) is replaced with

$$x_{ic} = \frac{\beta R_i}{a_i(1+r(1-\beta))}, \quad y_{ic} = \frac{P_i R_i(1-\beta)}{a_i(1+r(1-\beta))}, \quad zx_c = \beta y, \quad y_c = (1-\beta)y \tag{36}$$

Compared with (26), the seller's consumption of good x remains the same. The seller's consumption of money y is lower due to lower prices $P_1$ and $P_2$. The buyer's consumption of good x is lower since she delivers less of money y to the seller. Finally, the buyer's consumption of money is lower since her monetary possession y is lower due to search costs for choosiness. Inserting (36) into the (9) gives

$$U_i = P_i^{1-\beta} x_i z_i^{\beta} \beta^{\beta} (1-\beta)^{1-\beta}, \quad U = y\beta^{\beta}(1-\beta)^{1-\beta} \tag{37}$$

where $P_i$ and y are given by (34) and (35). Compared with (27), seller i's utility is lower due to lower price $P_i$, and the buyer's utility is lower due to lower monetary possession due to search costs for choosiness. Hence whereas signaling in (27) in section 3, where inflation also plays a role, causes lower utility to the sellers, and the same utility to the buyers as for non signaling, the solution in (37) gives lower utility to sellers, since prices decrease, and lower utility to buyers, since search costs for choosiness cause buyers to possess less money, compared with section 3.

**6 Screening search costs for choosiness and inflation adjusted signaling**

The additive presence of a term multiplied with h in the denominator in (34) implies that dividing the prices with $(1+r(1-\beta))$ does not satisfy the inflation adjustment property 1 in section 4. This section adjusts for inflation in two alternative manners.

*Inflation adjustment property 2. The prices are divided by* $(1+r(1-\beta))$*, which is equivalent to dividing the buyer's payment (delivery) of money y with* $(1+r(1-\beta))$.

Since the inflation factor $(1+r(1-\beta))$ is present in both the numerator and denominator in the inflated prices in (34), merely dividing with this factor as in inflation adjustment property 2 may not be fully satisfactory. Let us therefore motivate a more sophisticated property. The agents' consumption and utilities are

$$x_{ic}=\frac{\beta R_i}{a_i(1+r(1-\beta))},\quad y_{ic}=\frac{P_iR_i(1-\beta)}{a_i(1+r(1-\beta))},\quad zx_c=\frac{\beta y}{(1+r(1-\beta))},\quad y_c=\frac{y(1+r)(1-\beta)}{(1+r(1-\beta))} \tag{38}$$

$$U_i=P_i^{1-\beta}x_iz_i^{\beta}\beta^{\beta}(1-\beta)^{1-\beta},\quad U=\frac{y(1+r)^{1-\beta}\beta^{\beta}(1-\beta)^{1-\beta}}{(1+r(1-\beta))} \tag{39}$$

The utilities are lower with than without inflation adjustment for both sellers and buyers for the same reasons as in section 4. Compared with the case without inflation adjusted signaling in section 5, the sellers suffer lower utility due to the lower prices due to receiving less money, and the buyers suffer lower utility since they pay less money in exchange for less of good x than what would be optimal without signaling.

As an alternative without signaling, inserting r=0 and k=1 into (34) and (35) gives the prices

$$P_1=\frac{\frac{z_1}{z_2}\beta\frac{nR}{a}}{\left[\frac{z_1}{z_2}\frac{n_1R_1}{a_1}+\frac{n_2R_2}{a_2}\right](1-\beta)+h\frac{nRz_2}{az_1}\left[\frac{z_1}{z_2}+\frac{n_2R_2a_1}{n_1R_1a_2}(1-\beta)-\beta\right]},$$

$$P_2=\frac{\beta\frac{nR}{a}}{\left[\frac{z_1}{z_2}\frac{n_1R_1}{a_1}+\frac{n_2R_2}{a_2}\right](1-\beta)+h\frac{nRz_2}{az_1}\left[\frac{z_1}{z_2}+\frac{n_2R_2a_1}{n_1R_1a_2}(1-\beta)-\beta\right]} \tag{40}$$

and production

$$y=\frac{\frac{R}{a}\left[\frac{z_1}{z_2}\frac{n_1R_1}{a_1}+\frac{n_2R_2}{a_2}\right](1-\beta)\left[1+h\frac{nRa_1z_2}{n_1R_1az_1}\right]}{\left[\frac{z_1}{z_2}\frac{n_1R_1}{a_1}+\frac{n_2R_2}{a_2}\right](1-\beta)+h\frac{nRz_2}{az_1}\left[\frac{z_1}{z_2}+\frac{n_2R_2a_1}{n_1R_1a_2}(1-\beta)-\beta\right]} \tag{41}$$

The total value of the production of all sellers of the two types is

$$\frac{P_1n_1R_1}{a_1}+\frac{P_2n_2R_2}{a_2}=\frac{\beta\frac{nR}{a}\left(\frac{z_1}{z_2}\frac{n_1R_1}{a_1}+\frac{n_2R_2}{a_2}\right)}{\left[\frac{z_1}{z_2}\frac{n_1R_1}{a_1}+\frac{n_2R_2}{a_2}\right](1-\beta)+h\frac{nRz_2}{az_1}\left[\frac{z_1}{z_2}+\frac{n_2R_2a_1}{n_1R_1a_2}(1-\beta)-\beta\right]} \tag{42}$$

Inspired by (40) and (41) we propose the inflation adjusted signaling prices

$$P_1 = \frac{\left(\frac{z_1}{z_2}\right)^k \left(\frac{R_1 b_2}{R_2 b_1}\right)^r \beta \frac{nR}{a}}{\left[\left(\frac{z_1}{z_2}\right)^k \left(\frac{R_1 b_2}{R_2 b_1}\right)^r \frac{n_1 R_1}{a_1} + \frac{n_2 R_2}{a_2}\right](1-\beta) + h\frac{nRz_2}{az_1}\left[\left(\frac{z_1}{z_2}\right)^k \left(\frac{R_1 b_2}{R_2 b_1}\right)^r + \frac{n_2 R_2 a_1}{n_1 R_1 a_2}(1-\beta) - \beta\right]},$$

$$P_2 = \frac{\beta \frac{nR}{a}}{\left[\left(\frac{z_1}{z_2}\right)^k \left(\frac{R_1 b_2}{R_2 b_1}\right)^r \frac{n_1 R_1}{a_1} + \frac{n_2 R_2}{a_2}\right](1-\beta) + h\frac{nRz_2}{az_1}\left[\left(\frac{z_1}{z_2}\right)^k \left(\frac{R_1 b_2}{R_2 b_1}\right)^r + \frac{n_2 R_2 a_1}{n_1 R_1 a_2}(1-\beta) - \beta\right]} \tag{43}$$

determined by removing the inflation factor $(1+r(1-\beta))$ from both the numerator, and the term multiplied with h in the denominator, in the prices in (34). The total value of the production of all sellers of the two types is

$$\frac{P_1 n_1 R_1}{a_1} + \frac{P_2 n_2 R_2}{a_2} = \frac{\beta \frac{nR}{a}\left(\left(\frac{z_1}{z_2}\right)^k \left(\frac{R_1 b_2}{R_2 b_1}\right)^r \frac{n_1 R_1}{a_1} + \frac{n_2 R_2}{a_2}\right)}{\left[\left(\frac{z_1}{z_2}\right)^k \left(\frac{R_1 b_2}{R_2 b_1}\right)^r \frac{n_1 R_1}{a_1} + \frac{n_2 R_2}{a_2}\right](1-\beta) + h\frac{nRz_2}{az_1}\left[\left(\frac{z_1}{z_2}\right)^k \left(\frac{R_1 b_2}{R_2 b_1}\right)^r + \frac{n_2 R_2 a_1}{n_1 R_1 a_2}(1-\beta) - \beta\right]} \tag{44}$$

Equations (42) and (44) are equivalent when $\left(\frac{z_1}{z_2}\right)^k \left(\frac{R_1 b_2}{R_2 b_1}\right)^r = \frac{z_1}{z_2}$, which is possible without removing signaling. Hence we consider (42) as an alternative benchmark for inflation adjustment. In accordance with this motivation, we propose the following inflation adjustment property.

*Inflation adjustment property 3. The total value $P_1 n_1 R_1 / a_1 + P_2 n_2 R_2 / a_2$ of the production of all sellers of the two types in the benchmark case of search costs for choosiness and no signaling equals the expression in (42) for both the non signaling prices in (40) and for the inflation adjusted signaling prices in (43) when $\left(\frac{z_1}{z_2}\right)^k \left(\frac{R_1 b_2}{R_2 b_1}\right)^r = \frac{z_1}{z_2}$, but equals a larger expression for the inflated signaling prices in (34).*

Inserting the inflation adjusted prices in (43) into (32) gives the production

$$y=\frac{\dfrac{R}{a}\left[\left(\dfrac{z_1}{z_2}\right)^k\left(\dfrac{R_1b_2}{R_2b_1}\right)^r\dfrac{n_1R_1}{a_1}+\dfrac{n_2R_2}{a_2}\right](1-\beta)\left[1+h\dfrac{nRa_1z_2}{n_1R_1az_1}\right]}{\left[\left(\dfrac{z_1}{z_2}\right)^k\left(\dfrac{R_1b_2}{R_2b_1}\right)^r\dfrac{n_1R_1}{a_1}+\dfrac{n_2R_2}{a_2}\right](1-\beta)+h\dfrac{nRz_2}{az_1}\left[\left(\dfrac{z_1}{z_2}\right)^k\left(\dfrac{R_1b_2}{R_2b_1}\right)^r+\dfrac{n_2R_2a_1}{n_1R_1a_2}(1-\beta)-\beta\right]} \tag{45}$$

The agents' consumption and utilities are as in (38) and (39). The inflation adjustment property 3 gives larger prices than the inflation adjustment property 2 due to removal of the inflation factor $(1+r(1-\beta))$ in both the numerator and denominator of the prices. This gives higher utility to the sellers who get paid more in terms of money y in exchange for their delivery of good x. Accordingly the utility to buyers is lower. Table 1 briefly categorizes some characteristics of sections 2,3,4,5,6.

| Section | Seller i's $x_{ic}$ | Seller i's $y_{ic}$ | Buyer's $zx_c$ | Buyer's $y_c$ |
|---|---|---|---|---|
| 2 No signaling | $\beta x_i$ | $P_i x_i(1-\beta)$ | $\beta y$ | $(1-\beta)y$ |
| 3 Signaling | Lower | Similar | The same | The same |
| 4 Inflation adjustment | The same as with signaling | Lower | Lower | Higher |
| 5 Search costs for choosiness | The same as with signaling | Lower than with signaling | Lower than with signaling | Lower than with signaling |
| 6 Search costs for choosiness and inflation adjusted signaling | The same as with signaling | Lower than without inflation adjustment | Lower than without inflation adjustment | Higher than without inflation adjustment |

| Section | Prices | Seller i's utility | Buyer's utility |
|---|---|---|---|
| 2 No signaling | $P_i=\dfrac{z_i\beta nR/a}{(z_1n_1R_1/a_1+z_2n_2R_2/a_2)(1-\beta)}$ | $P_i^{1-\beta}x_iz_i^\beta\beta^\beta(1-\beta)^{1-\beta}$ | $y\beta^\beta(1-\beta)^{1-\beta}$ |
| 3 Signaling | Higher | Lower | The same |
| 4 Inflation adjustment | Similar to no signaling | Lower than with signaling | Lower |
| 5 Search costs for choosiness | Lower than with signaling | Lower than with signaling | Lower than with signaling |
| 6 Search costs for choosiness and inflation adjusted signaling | Lower than without inflation adjustment | Lower than without inflation adjustment | Lower than without inflation adjustment |

Table 1. A categorization of characteristics for sections 2,3,4,5,6.

## 7 Conclusion

An equilibrium model of signaling, production, and exchange is presented. It goes beyond previous models by examining signaling in a setting in which sellers allocate resources between signaling and producing a good with a high versus low intrinsic quality. In contrast to partial equilibrium models where one side is often kept to its reservation value, both sides of the exchange are made worse off due to the distortive signaling activities. Buyers read signals, screen for quality of each good, choose prices optimally, and pay money (or some numeraire good) in exchange. The article supplements partial equilibrium models common within economic theory since Spence's (1973) contribution. The differences between partial equilibrium models and the general equilibrium approach in this article are outlined in the introduction.

A basic model of exchange without signaling is developed as a reference standard. On the one side there are high quality and low quality producers (sellers) in given numbers producing good x with two unknown qualities. On the other side there are buyers in a given number producing the numeraire good y which is money with known quality and a price one per unit. The buyers can be thought of as possessing money which they generate in some manner. How much to consume of good x is each seller's free choice variable, and what price to choose is each buyer's free choice variable. The Cobb-Douglas utilities depend on the amount of money received or kept, the intrinsic quality of each good, and the quantity of each good consumed.

Introducing signaling, each seller makes a tradeoff between how much of his resource to invest into production versus signaling. Signaling boosts sales but diverts resources away from production, causing less to be produced. The utility from consuming a good arises from the intrinsic quality, and how much is consumed Signaling is each seller's second free choice variable. A signaling attention function adjusts how buyers pay attention to signals. It depends on the ratio of the signals by the high quality and low quality sellers, the competitiveness of the market expressed with a signaling decisiveness parameter, and the ratio of the intrinsic qualities of good x raised to a power of truth parameter. Signaling causes lower utility for sellers. The advantage of the model is to illustrate how sellers make tradeoffs between production and signaling, which can be verified empirically, and how buyers choose how much to purchase of high quality versus low quality goods. The total numbers of sellers of the two types determine the total production of goods in the market, and the total number of buyers determines the total presence of money in the market.

Signaling causes decreased availability (scarcity) of good x which causes the price of good x to increase. In the basic signaling model the buyer pays the seller the same amount in terms of money y as without signaling. However, since the price of good x is higher, she receives a lower amount of good x in return. In terms of what she actually gets to consume of goods she thus suffers a loss because of signaling. To account for such price inflation, each buyer's payment of money y is divided with an inflation factor which satisfies a specified inflation adjustment property, which means that the prices are divided by the same inflation factor. This gives an even lower utility to sellers who get less of money y. The buyers get lower utility than without signaling since they keep a larger amount of money y, and get a smaller amount of good x, than they would optimally prefer.

Screening product quality is no easy task for buyers. Introducing search costs for choosiness, each buyer makes a tradeoff between how much money y to pay for good x in the two qualities, given that she has a preference for both money and good x. Search costs are especially high if she seeks to establish a large price differential between the high quality and low quality product, and if the actual difference in intrinsic qualities is small. Compared with the signaling solution, both sellers and buyers get lower utilities since some of the buyers' money is wasted on search costs, leaving buyers to hold less money, and to pay less money to sellers in exchange for good x. The article finally combines buyer search costs and inflation adjustment. Compared with the case without inflation adjusted signaling, sellers get lower utility due to lower prices, and buyers get lower utility since they do not get the optimal mixture of good x and money y. Future research may work to endogenize the signaling decisiveness parameter, which seems to be no easy task.

**Appendix**

Given the buyers' choice of the price $P_1$, on the seller side there will be in equilibrium a chosen pair of signaling levels $s_1$ and $s_2$ for the two seller types. Given that, within each type of sellers, all sellers are identical, each individual seller's chosen signaling level is independent of the choices of the other sellers of his type. So for each seller type we can think of a typical or representative individual as optimizing by differentiating $U_1$ or $U_2$, as the case may be, with respect to the respective signaling levels $s_1$ or $s_2$. The result below has been confirmed by considering a fraction of deviants within each seller type signaling $s_i$' rather than $s_i$. Derivating the utility of a deviating seller with respect to his deviant signal, taking the non-deviating signals $s_i$ as given, and the signals by the other seller type as given, gives the same result when subsequently assuming that in equilibrium there is no deviation: $s_i' = s_i$. Solving (18) with respect to $x_1$ for i=1 gives $x_1 = (R_1 - b_1 s_1)/a_1$. Inserting into (2) and applying (10) gives $y_{1c} = P_1(R_1 - b_1 s_1)(1-\beta)/a_1$. Solving (19) with respect to $P_1$, inserting $P_1$ into this equation, and inserting $y_{1c}$ into (9), and simplifying, gives

$$U_1 = \left( P_2 \left( \frac{z_1}{z_2} \right)^k \left( \frac{s_1}{s_2} \right)^r \right)^{1-\beta} \frac{(R_1 - b_1 s_1)}{a_1} z_1^\beta \beta^\beta (1-\beta)^{1-\beta} \tag{A1}$$

Equation (A1) can also be obtained by inserting $x_1$ and $P_1$, determined by (18) and (19), into the leftmost equation in (17). Derivating $U_1$ with respect to $s_1$, and setting the derivative equal to zero, gives

$$\partial U_1 / \partial s_1 = 0 \quad \Rightarrow \quad b_1 s_1 = r(R_1 - b_1 s_1)(1-\beta) \quad \Leftrightarrow \quad b_1 s_1 / r = a_1 (x_1 - x_{1c}) \quad \text{Seller 1's FOC } (s_1) \tag{A2}$$

where the rightmost equation follows from using (10) and (18). Analogous reasoning for seller 2 gives (20).

**References**

Akerlof, G. (1970), "The Market for 'Lemons': Qualitative Uncertainty and the Market Mechanism," Quarterly Journal of Economics 84, 488-500.

Bergstrom, Carl T. and Michael Lachmann, 1997. Signalling among relatives. I. Is costly signalling too costly? Philosophical Transactions of the Royal Society of London, Series B 352, 609-617.

Bergstrom, Carl T., Szabolcs Számádo and Michael Lachmann, 2002. Separating equilibria in continuous signalling games. Philosophical Transactions of the Royal Society of London, Series B 357 (1427): 1595-1606.

Eshel, Ilan, Frans Jacobs, and Emilia Sansone, 2002, A long-term genetic model for the evolution of sexual preference: the theories of Fisher and Zahavi re-examined, Journal of Mathematical Biology 45: 1-21.

Fremling, G. and Posner, R. (1999), "Market Signaling of Personal Characteristics," University of Chicago Law School, John M. Olin Law & Economics Working Paper No. 87.

Getty, T., 1998a. Handicap signalling: when fecundity and viability do not add up. Animal Behaviour 56: 127-130.

Getty, T., 1998b. Reliable signalling need not be a handicap. Animal Behaviour 56: 253-255.

Getty, T., 2002. Signalling health versus parasites. American Naturalist 159 (4): 363-371.

Getty, T., 2005. Sexual selection is not like sports handicapping. TREE, forthcoming.

Gintis, H., Smith, E.A., and Bowles, S. (2001), "Costly Signaling and Cooperation," Journal of Theoretical Biology 213, 103-119.

Grafen, Alan, 1990a. Sexual selection unhandicapped by the Fisher process. Journal of Theoretical Biology 144: 473-516.

Grafen, Alan, 1990b. Biological signals as handicaps. Journal of Theoretical Biology 144: 517-546.

Hausken, K. and Hirshleifer, J. (2004), "The Truthful Signalling Hypothesis: An Explicit General Equilibrium Model," Journal of Theoretical Biology 228, 4, 497-511.

Hayek, F.A. (1968), "Economic Thought VI: The Austrian School," in David L. Sills (ed.), International Encyclopedia of the Social Sciences, New York: Macmillan and Free Press, p. 458.

Hirshleifer, J. and Osborne, E. (2001), "Truth, Effort, and the Legal Battle," Public Choice 108, 169-195.

Hobbes, T. (1651), Leviathan, J.M. Dent & Sons Ltd., London, 1973.

Houston, A.I. 2003. How does an individual's optimal behaviour depend on its quality? An analysis based on relative ability. Evol. Ecol. Res. 5, 195-212.

Lofgren, K.G., Persson, T., and Weibull, J.W. (2002), "Markets with Asymmetric Information: The Contributions of George Akerlof, Michael Spence and Joseph Stiglitz," Scandinavian Journal of Economics 104, 2, 195-211.

Mirrlees, J. (1971), "An Exploration in the Theory of Optimum Income Taxation," Review of Economic Studies 38, 175-208.

Noldeke, G. and Samuelson, L. (1997), "A Dynamic Model of Equilibrium Selection in Signaling Markets," Journal of Economic Theory 73, 1, 118-156.

Proulx, S.R., Day, T. and Rowe, L. 2002. Older males signal more reliably. Proc. Roy. Soc. Lond. B. 269, 2291-2299.

Riley, J.G. (1975), "Competitive Signalling," Journal of Economic Theory 10, 2, 174-186.

Riley, J.G. (1979), "Informational Equilibrium," Econometrica 47, 331-359.

Riley, J.G. (2001), "Silver Signals: Twenty-Five Years of Screening and Signaling," Journal of Economic Literature XXXIX, 432-478.

Riley, J.G. (2002), "Weak and Strong Signals," Scandinavian Journal of Economics 104, 2, 213-236.

Rothschild, M. and Stiglitz, J. (1976), "Equilibrium in Competitive Equilibrium Markets: An Essay on the Economics of Imperfect Information," Quarterly Journal of Economics 90, 629-649.

Spence, A.M. (1973), "Job Market Signaling," Quarterly Journal of Economics 87, 355-379.

Vickrey, W. (1961), "Counterspeculation, Auctions and Competitive Sealed Tenders," Journal of Finance 16, 41-50.

Zahavi, Amotz, 1975. Mate selection – A selection for a handicap. Journal of Theoretical Biology 53, 205-214.