

# Endogenous Market Thickness and Honesty : A Quality Trap Model

Siddhartha Bandyopadhyay <sup>‡</sup>

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## Abstract

Many economies, particularly emerging or transition economies lack institutional arrangements (like ISO certification) to credibly signal product quality. The absence of such institutions leads to low levels of market activity with poor quality products on sale. In this paper, we use a dynamic framework with asymmetric information to model this phenomenon. Sellers choose the quality they produce and face a trade-off between producing a high quality product, which gives low one period returns but leads to higher future profits, and a low quality product, which gives higher one period returns but bars the seller from future market activity. Sellers' differ in how they discount the future and thus in how they evaluate this trade-off. Demand is endogenous and the number of buyers that enter the market depends on the quality of the products they expect to find. Market thickness (the buyer-seller ratio), product quality, prices and the distribution of seller types are all endogenously determined and multiple steady states may emerge. In general, a sufficient number of sellers need to be patient for multiple steady states to exist. Technology that involves 'learning by doing' may cause market segregation. Importantly, sellers' expectations about market thickness matter in determining the quality only if sellers believe that market thickness will be less than one.

**JEL classification: L14, L15, O12, O17.**

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<sup>‡</sup>Department of Economics, University of Birmingham, Birmingham B15 2TT, U.K.  
Email:s.bandyopadhyay@bham.ac.uk

# 1 Introduction

In this paper we provide an explanation for the wide variation in product quality and demand across economies (or markets) facing similar constraints in that quality of a product is not verifiable before consumption<sup>1</sup> and there are no institutional arrangements (like ISO certification) to provide credible signals. The basic idea is as follows: investment in quality is costly and thus worthwhile only when present and future demand for the product is expected to be high, while demand itself depends on the expected quality. Thus, if investment in high quality goods gives low present returns, such investment will be undertaken only if investors (or firms) have optimistic expectations about future market activity. Therefore, in the absence of an ex ante coordinating arrangement, an economy may fall into a low quality, low demand steady state.

This is a scenario typically faced by developing, emerging and transition economies where buyers face uncertainty about the quality of the products they buy in the marketplace and sellers face uncertainty about their present and future prospects in the market. Information in these economies about past market transactions is limited and exchange in the anonymous market place is potentially risky. In Russia and other transition economies, (see McMillan (1997), for instance, which discusses specific examples) it is reported that people get cheated if they buy from anonymous sellers, which is why very few people do. Since sellers have low expectations about meeting buyers in the market they find it optimal to cheat when they find a buyer, justifying the buyers' fears about transacting in the market. Thus, the economy may be caught in a vicious circle of expectations, which are self fulfilling, even though there may be nothing in the preferences of agents and the technology available to prevent the market from being very active with high quality products being sold. In such a scenario there is scope for intelligent policy intervention, which, by changing expectations, can take the economy from low levels of trade in the marketplace to high levels of self sustaining market activity.

Of course, this scenario is not confined to underdeveloped countries. The internet whose growing volume of trade is now widely acknowledged<sup>2</sup> faces this quality uncertainty problem as well, which in turn affects demand. As a recent article in The New York Times (see References) pointed out 'fraud had become a problem since the first online auctions...and auction fraud is now the most prevalent computer-related crime, according to the Internet Fraud Complaint Center.' This affects buyers as well. The report mentions reactions of buyers to this quality uncertainty saying that this affects their future entry in online transactions. Interestingly, in view of the model specification we adopt in this paper, there seems to be some evidence (see Resnick and Zeckhauser (2001)) from eBay that buyers place much less credence on positive

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<sup>1</sup>In other words this is the market for what is commonly called an 'experience good'.

<sup>2</sup>Neuman and Medvinsky (1997) note the dramatic growth of users and organizations reachable on the net in the last couple of years.

messages than on negative ones. Resnick and Zeckhauser's data suggests that prices and probability of trade do not depend significantly on the number of positive messages received about a seller. However, negative messages seem to matter, and the extreme negative message is a prosecution for fraud. The auction site eBay reports, according to Resnick and Zeckhauser, a small proportion of 'problem' trades. Other, less well-known, internet sites might be more prone to such problems. Presumably, the expectation that there will be relatively few problems on eBay is self-fulfilling (at least, this is what this paper will argue).

A few more illustrations about the type of markets which approximate our environment will help us fix ideas. Since we get multiple steady states with some involving high market activity some fairly "thick" markets in developed economies also share features of our model. An example which readily comes to mind is that of phone cards which offer the same number of minutes per dollar but often have differing quality. Again, travel agents offering the same price for air tickets and hotel bookings often end up providing different quality products-some indulge in outright cheating while others provide less facilities than advertised. The same can be said for the quality of service at various hotels as well as the food served in different restaurants whose menucards read alike. This is even more widely seen in the service sector (the large casual labor market for instance) where typically a fair amount of variation is seen in quality, which cannot be inferred from the prices being asked

## 1.1 Informal description of the model

To analyze this problem we develop a model of two sided asymmetric information to show how expectations about the quality of a product (good or service) induce a certain level of market thickness<sup>3</sup> (by which we mean the relative abundance of buyers to sellers), which in turn induces a certain average level of quality. Market thickness defined in this way is used to measure market activity.<sup>4</sup>

More specifically, buyers face uncertainty about the quality of the product they purchase and do not know the time preferences (discount factors) of individual sellers. Sellers face uncertainty about the valuations that buyers place on the quality of their products. Given the uncertainty that buyers face about quality, they may not find it optimal to purchase the product, while sellers facing this demand uncertainty may not find it worthwhile to invest in production of high quality products. Thus, multiple steady states may emerge -some involving low quality and low market thickness and some involving high quality and high market thickness.

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<sup>3</sup>Thus demand is endogenous unlike most models dealing with how demand can affect product quality (see Rogerson (1982), for example).

<sup>4</sup>This distinction is worth noting as the term 'market thickness' has been used differently by different people in the literature. (See McLaren (2000) who, in the introduction, discusses the different uses this term has in the literature.

We use a random matching technology to describe the meeting between buyers and sellers such that each seller meets the same expected number of buyers. As the survival of sellers in the market depends on the quality they produce (with high quality sellers surviving longer than low quality ones) we model the population dynamics describing the entry and exit of sellers. (Buyers are, however, short lived which is the same as assuming that they decide whether to purchase from the market each period based on the currently available market statistic without regard to their past experience) Given the population dynamics, the time preferences of sellers and the valuations of buyers, the possible steady state distribution of sellers, the average quality and the market thickness get endogenously determined. To focus our analysis on the characterization of the steady states we do not explicitly model prices to begin with but keep them exogenously fixed. We later relax this assumption and study how different pricing mechanisms affect the steady states and consider the effects on welfare.

## 1.2 Summary of results

We now provide a brief summary of our main results. An important thing to note is the difference between a static version of our model and the steady state characterization *a static version of our model yields the low quality, low market thickness outcome as the unique equilibrium while the dynamic model yields multiple steady states.*

In characterizing the steady states, we derive conditions under which multiple steady states emerge. It turns out that the patience of sellers and the profits from investing in high quality must reach a certain cutoff value for multiple steady states to emerge. However, if the relative proportion of high valuation buyers and patient sellers is large compared to low valuation buyers and impatient sellers we get only one steady state apart from the no trade equilibrium. Stability analysis shows that equilibria involving mixed strategies are unstable and those involving pure strategies are stable.

In comparing fixed prices to optimizing pricing behavior we find that most of our qualitative results about the steady states are not affected though for high enough prices intermediate steady states get ruled out which means prices may play a role in equilibrium selection. However, the distributional effects are ambiguous-the higher the proportion of low valuation buyers the lower are prices but there is a trade-off between quality and consumers surplus-with low prices, expected consumer's surplus may be higher but average quality is lower.

A couple of important by-products come out from this model. Since the steady state distribution of different sellers gets endogenously determined it points out the importance of time preferences and expectations about market conditions in determining the survival of new firms. A standard explanation in the literature is in terms

of different firms facing different random shocks (which determines their exit).<sup>5</sup>This model may perhaps provide a clue towards an alternate explanation. Another important result we get is that market thickness (which is an index of demand ) matters only upto a certain level and beyond that quality is driven by cost conditions and preferences only. This is analogous to the market exhibiting Keynesian features (being demand driven) upto a certain point and then exhibiting classical characteristics (where supply conditions drive the economy). This sharp result is partly an artefact of the specific matching technology used but the general intuition is that market thickness is more important when the market is relatively thin. This may partly explain why even flourishing markets are not invasion free from low quality products. Finally, we discuss how this model may shed light on such diverse issues as the problems transition economies are facing to the different quality of health care in various urban centers of a developing nation like India.

## 2 Related literature

A brief survey of earlier related work will help us understand how the present work differs from earlier models of this type. The analysis of quality variation in markets characterized by asymmetric information (leading to market thinness), of course dates back to Akerlof (1970). However, unlike the static lemons model, the distribution of quality and hence the average level of quality gets endogenously determined in our model, which is more representative of certain markets where sellers can typically decide the level of quality they choose to produce. Moreover, the results in Akerlof's paper are substantively different even if we allow for endogenous quality choice-yielding only one equilibrium. The reason is that the future expected payoffs are what may make costly investment attractive even though one period gains are lower. Hence, a static version of our model yields the low quality low demand equilibrium as the unique outcome.<sup>6</sup>

Thus, in some sense, our model is closely related to the models on endogenous quality choice in the Industrial Organization literature (see Shapiro (1983), for example). These models typically use reputation to sustain equilibria involving investment in quality which show one period losses. On the other hand, we analyze an environment where reputation is hard to develop and there is only some kind of negative reputation (or punishment). Hence, in our environment new players are indistinguishable from older ones and the average quality of the market is the only information that potential buyers of the product have. We discuss several markets where this is so.<sup>7</sup>

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<sup>5</sup>See Hopenhayn (1992) for instance.

<sup>6</sup>For variants of this which can yield multiplicity see Mas Colell, Whinston and Green (1998) pp. 438-444.

<sup>7</sup>The Internet has tried to develop a system of reputation but that is at best partially successful. ebay has a system of buyer feedback. The value of positive feedback left by buyers is of doubtful value, often left by friends or associates of the seller and are thus less reliable than negative feedback

Moreover, demand is not endogenous in these models and thus one gets a unique outcome in these ‘reputation’ models.<sup>8</sup> Again, multiple equilibria models are not new in the literature, nor are the multiplier effects of policy intervention or other exogenous perturbations. In that way, this shares some of the features of most multiple equilibria models, in particular, exhibiting strategic complementarities as in the Cooper John model (see Cooper and John, (1988) and Cooper (1999)). However, typically these models are static in nature and have an inbuilt increasing returns property either in the matching technology (see for instance Diamond (1982)) or in the payoff functions of players. In other words, these pure coordination models represent one shot games where future expectations do not determine current actions.<sup>9</sup> Such calculations about the future and comparison of current gains against future losses are however typical of a firm’s optimizing behavior-what varies is the value attached by different firms to current as against future payoffs. In this paper, we explicitly model this dynamic optimizing behavior. In its focus on multiplicity of equilibria as an explanation of underdevelopment, this relates to earlier literature, most notably, Murphy, Shleifer and Vishny (MSV, (1989)) but these papers also do not examine the intertemporal maximization behavior of agents and are more akin to the search models of coordination failure. Since there is no linkage across time it is quite consistent in the MSV model to have an economy coordinating on a high level of economic activity today to coordinate on a low one tomorrow. Thus, these models are not suited to analyzing transition dynamics, learning and the importance of expectations about future market conditions in shaping current behavior. More importantly, these static models cannot be used for simultaneously studying endogenous quality choice and demand which is determined by the interaction between buyers and sellers. The present model, by contrast, explicitly models this intertemporal process and rationalizes the existence of multiple steady states when firms forego high current profit in order to yield higher future returns and has a structure which can be used to study the importance of out of equilibrium dynamics and forward looking behavior in changing the long run state of the market or economy. It also models how the distribution of population evolves over time which few of these papers do. (An exception is Banerjee and Newman , (1993) who model how the distribution of population changes. However, their concern is with the interaction between occupational decisions and the distribution of wealth ,which is very different from the present work.). This interlinkage across time has been cap-

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which closely corresponds with our model. (see the NYT article earlier cit. and Resnick and Zeckhauser (2001) for details. The latter note that in the data set they look at, existing sellers do not enjoy a boost in price over new entrants.)

<sup>8</sup>There are endogenous quality choice models in the money literature as well but their purpose is to show how money acts as a uniform quality good and can help reduce the quality uncertainty when goods are exchanged against money as opposed to goods against goods.(See Williamson and Wright (1994), for an example of such work.)

<sup>9</sup>For a somewhat different type of model focusing on failure of coordination leading to suboptimal equilibria see Basu (1986). In his model different conjectures lead to different equilibria , showing how crucially expectations matter .

tured in a somewhat different context by Ghosh and Ray (1996) where buyers make repeated entry into the market and hence market history matters but their paper deals with the levels of cooperation which can be sustained when bad past conduct of sellers cannot be punished.<sup>10</sup> Another related work is that of Kranton (1996) which shows how increases in market thickness can cause alternate forms of exchange (like reciprocal exchange) to diminish, while the widespread use of personalized exchange can itself cause markets to remain thin, hence causing such exchanges to persist over time. The questions addressed viz. the interaction between two different institutions for exchange and the model she uses are completely different from this present work. Finally, mention may be made of the important literature which looks at sustaining co operation when there are no official law enforcement agencies (see in particular Tirole (1996) who looks at a scenario where only one party has an incentive to cheat and Dixit (2003) where both parties may cheat). The role of intermediaries while not discussed formally in this paper is an important complementary area of research.

The paper proceeds as follows. The next section sets up the basic model. In section 4 we do a steady state analysis. Section 5 considers the implications of regulated pricing vs. (some version of) optimized prices. Section 6 discusses illustrations and extensions. Most of the proofs are in Appendix 1. Appendix 2 considers a modification of the basic model to show how technologies involving scale economies over time, perhaps due to ‘learning by doing’, helps us in overcoming the uncertainty about quality under certain parameter values.

### 3 The model

This is an infinite horizon model with discrete time. There are two sides of the market, buyers and sellers. Each period the market opens and two types of objects are on sale—a high quality type and a low quality type. Buyers have differing valuations for the high quality good. For simplicity, we consider only two types of buyers, those with a low valuation which we denote by  $V_L$  and those with a high valuation denoted by  $V_H$ . (We assume that low valuation goods are uniformly valued by all buyers and we normalize it to 0.)<sup>11</sup> Sellers are also of two types, those with a low discount factor  $\delta_l$  and those with a high discount factor  $\delta_h$ . (This discount factor can be interpreted

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<sup>10</sup>For an interesting study of how history can matter and related dynamics see Adsera and Ray (2000). There are also other dynamic models eg. models of repeated purchases (see Hendel and Lizzeri, (1999)) but their concern is very different from the present work.

<sup>11</sup>The assumption of no gains from trade in the low quality good simplifies the exposition but makes no difference as shown in Appendix 2. Thus this assumption is not restrictive. However, we work out a case in the Appendix to show that it can make a difference when the costs are time dependent perhaps because there is ‘learning by doing’. In that case separating equilibria can emerge.

as a survival probability.)<sup>12</sup> Thus, there are four types of agents in the economy.<sup>13</sup>

Cost, technology and endowments are as follows. High quality goods are produced at a higher cost than low quality goods—we normalize the cost of low quality goods to 0 and the high quality is produced at constant cost per unit denoted by  $c$ . However, given the asymmetry of information, all goods in the market are sold at a uniform price which we assume to be fixed exogenously at  $p$ .<sup>14</sup> Note also that sellers have excess capacity and can produce goods to demand. Given constant unit costs, gains per unit from the high quality good is also a constant every period which we denote by  $\pi = p - c$ .

There is asymmetric information of the following type - buyers cannot distinguish between the low and high quality good before purchase.<sup>15</sup> Moreover, they do not know the type of the sellers (i.e. the discount factor of an individual seller) but only the ratio of the two types of sellers in the population. Sellers also cannot distinguish the two types of buyers and know only the ratio of the two types. The past history of market transactions is summarized by two parameters giving the ratio of buyers to sellers (market thickness) and the ratio of high quality goods to low quality goods sold every period. The history of individual transactions that have taken place in the past is not known but these summary statistics are known to all agents. Given these, buyers and sellers have to form expectations about the market thickness and quality at the beginning of each period.

Matching is random in that at any instant in time each seller may meet  $q$  buyers (i.e.  $q$  is the expected number of buyers per seller every period i.e. it is the market thickness in that period)<sup>16</sup>

Buyers are expected utility maximizers and base their entry decision on the expected gains from trade. Thus, a buyer's decision is based on his valuation and his expectation of acquiring the high quality object. He enters if his expected utility from buying the good is greater than the price he pays for it. Sellers are also expected

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<sup>12</sup>By allowing randomizations we get continuity in our endogenous variables (quality and market thickness) which is why we do not believe this framework to be unduly restrictive.

<sup>13</sup>It is important to mention that though we are dealing with finite numbers, we assume that no agent in the economy believes that his action has any influence on market outcome.

<sup>14</sup>We endogenize prices in the next section.

<sup>15</sup>The earlier example of phone cards comes readily to mind as an example of an experience good where one discovers the true value of the card only after one has used it—a high quality one gives the advertised number of minutes and quality sound, a low one would give less minutes than advertised and poor quality of sound .

<sup>16</sup>The matching technology can be thought of as follows. For the case of less buyers than sellers, assign each buyer to a seller until there are no more buyers. Considering all possible permutations of sellers gives us  $n_t/S$  as the matching probability. When there are more buyers than sellers, first assign the same number of buyers per seller. The remaining buyers are matched as in the case with less buyers than sellers giving us the required result. For a continuum of sellers it is helpful to think of this as some approximation of large discrete numbers. See Binmore and Herrero (1988) who get this result for a continuum. Thus we circumvent the problem that for two continuous interval there is a one to one correspondence between them.

utility maximizers and maximize the present discounted value of lifetime earnings. Each period they can sell a low quality good and face a lower continuation payoff (in the form of being identified by the buyer who presumably spreads this information) from then on or sell a high quality good and face a higher continuation payoff. We assume that the future payoffs after selling the low quality good is 0. This can be thought of as being driven out of the market forever.<sup>17</sup> The seller's decision thus depends on his forecast about future market conditions (i.e. the future possibilities of being matched with a buyer which is the same as his forecast about future market thickness) and his discount factor. Specifically, we assume that the seller forms point estimates about future market thickness for all future time periods upto infinity. We do not, however, specify an explicit mechanism by which his expectations are formed. Thus the sellers' trade-off is a high one period gain and nothing thereafter to a low one period gain and a probability of future sales in the same market. From now on, selling a low quality object will be referred to as cheating. Buyers' decisions to purchase from a seller will be referred to as entering the market.

To concentrate on the sellers' problem we assume the buyers live only one period. Each period there is a potential pool of buyers some of whom choose to enter the market and others choose not to enter. If they enter they may purchase only one unit of the good. Every period there is again a fresh pool who base their decision on the currently available market information (i.e. the summary statistics available of past transactions) about the probability of being cheated.<sup>18</sup>

The population dynamics of the sellers are however more complicated. Every period sellers who are matched and cheat are thrown out (i.e. dishonest sellers who are matched die with probability 1) and a fraction of the unmatched sellers (if  $q$  is less than 1) die. The rate at which they die can be calculated from their survival probabilities. At the same time new sellers of either type enter in an exogenously fixed proportion. Thus, given the fixed ratio at which sellers are replaced, the existing distribution of the two types every period together with the market thickness and the decisions of the two types determine the ratio of the two types (the state variable) in the population next period. In other words, the distribution of population evolves endogenously.

Thus, while for a buyer a strategy is simply an action i.e. a decision whether to enter the market or not enter based on his expectations about the probability of getting a high quality object, for a seller a strategy is more complicated and has to specify his action every period as well as for all periods to come and will essentially be a sequence of actions cheat and not cheat depending on past history and future expectations.

An equilibrium is a strategy profile where every player is playing his best response

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<sup>17</sup>This is merely a convenient assumption. All we need is that those who produce high quality goods face better future payoffs than those who produce low quality goods.

<sup>18</sup>All this means is that buyers are not basing their decision on entering the market each period based on their past experience but on the current information about market conditions.

to the strategy of others. A steady state is a more restricted class of equilibria where every period the parameters of the model are unchanged-that is every period the same number of buyers enter and the same number of sellers cheat. Births equal deaths and the ratio in which the two types are born is exogenous and given by  $a$  and  $1 - a$ . In steady state, given this inflow, the distribution of the two types of sellers in the population are unchanged.

More formally, let  $N$  denote the stock of potential buyers and  $n_t$  those who enter the market in period  $t$ . Let  $S$  denote the stock of sellers which is a constant.<sup>19</sup> Thus  $q_t = n_t/S$  (In steady state the time subscripts can be dropped.)

**Buyers' objective function**

Buyer of type  $i$  solves the following problem  $\max(xV_i - p, 0)$  ( $i = H, L$ ) where  $x$  is the probability of meeting an honest seller. Thus, for a buyer, his strategy is simply whether to enter or not enter. We denote his set of strategies (which are the same as his set of available actions ) by  $A$ .

**Sellers' objective function**

In time period  $t$  seller  $j$  maximizes  $V_j(q_t, q_{t+1}, q_{t+2}, \dots) = \max(V_C, V_{NC})$  where the subscripts  $C$  and  $NC$  are used to distinguish the discounted payoffs from deciding to be dishonest in period  $t$  (cheat) and honest in period  $t$  respectively. The  $V$  function looks a little different depending on whether  $q$  is less than or greater than 1.(Note that at  $q < 1$  it is interpreted as a probability of a match)

For  $q$  less than 1,  $V_C = pq_t + (1 - q_t)\delta E(V(q'))$  where  $V(q')$  is the continuation payoff if an optimal policy is followed from period  $t + 1$  ( $q'$  is used as a shorthand for the sequence of future market thickness).  $E$  is used to denote the fact that this is the expected continuation payoff of the sellers based on his (point) estimates about future market thickness. This equation is explained very simply-with probability  $q$  a cheat meets a buyer, gets  $p$  units of money and 0 thereafter. With a probability  $1 - q$  he does not meet a buyer and simply goes through the same optimization process again based on the expected value of the current market statistic. This is discounted by seller of type  $j$  ( $j = h, l$ ) at the rate  $\delta_j$ .

Similarly,  $V_{NC} = q_t(\pi + \delta V(q')) + (1 - q_t)\delta E(V(q'))$ .

Thus a seller simply chooses the maximum of these. In the steady state we shall see that he will choose a stationary strategy (or randomize) when called upon to move. The set of possible strategies (which we denote by  $\Omega$ ) is of course much larger. Thus, possible (but not optimal) strategies for a seller are being dishonest in period 1, 2, ..and so on.<sup>20</sup>

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<sup>19</sup>This can be thought of as a limit imposed by the available space in the marketplace-there are only  $S$  slots and we further assume that they are filled every period-hence total births equal total deaths in each period but the distribution of sellers outside the steady state can change. In steady state, the distribution every period is the same but is not equal to the constant proportion of births of the two types every period.

<sup>20</sup>Note, that while randomizing, if a player randomizes with probability  $z$  over an action  $A$ , we mean that  $z$  fraction of players play  $A$  with probability 1. As we are dealing with large numbers this does not make much difference, though it is, strictly speaking, correct only for a continuum

For  $q$  greater than 1  $V_c = pq_t$  and  $V_{NC} = \pi q_t + \delta E(V(q_t))$

Thus given  $(n, S, A, \Omega, EU, V, \delta, N^L, S^l, x)_t^\infty, q)_t^\infty$  we have all the components of a Bayesian game ( $N^L$  and  $S^l$  are the number of  $V_L$  buyers and the number of  $\delta_l$  sellers) and the natural solution concept to employ is a Perfect Bayesian Nash (with out of equilibrium beliefs appropriately defined). However, in the next section we concentrate on a more restricted class of solutions viz. the steady state where the market parameters are unchanging.

## 4 Steady State Analysis

Here, we analyze the market when the parameters of the model are unchanging over time. There is a constant ratio of the two types of buyers and a constant ratio of the two types of sellers. Given that, the market thickness ( $q = n/S$ ) as well as the level of honesty ( $x$ ) is constant. (We keep  $p$  exogenously fixed in this section for convenience).

Formally a steady state is defined as follows

**Definition 1** *A steady state is a pair  $(n, x)$  ,for a given price,  $p$ , such that*

1. *Buyers maximize expected utility.*
2. *Sellers maximize lifetime discounted payoffs.*
3.  $0 \leq x \leq 1, 0 \leq n \leq N$ .

We now characterize the steady state for the two type case.

Let  $x$  be the probability of meeting an honest seller<sup>21</sup> and let  $\gamma$  and  $1 - \gamma$  be the (steady state) fractions of the two types of sellers  $\delta_h$  and  $\delta_l$  in the market. We use  $s_i$  to denote the probability that type  $i$  seller is honest. ( $i = l, h$ .) Thus,  $x = \gamma s_h + (1 - \gamma) s_l$ . For a buyer, denote by  $b_i$  the probability of entry in the market and by  $n_i$  the number of type  $i$  buyers. ( $i = L, H$ ). Given our assumption on buyers' valuations ( $V_L < V_H$ ) and sellers' discount factors, ( $\delta_l < \delta_h$ ) the admissible randomizations for buyers and sellers can be divided into the following cases:

<b>Buyer</b>	$\mathbf{b}_L = \mathbf{b}_H = 0$	$\mathbf{b}_L = \mathbf{0} < \mathbf{b}_H < \mathbf{1}$
	$\mathbf{b}_L = \mathbf{0} < \mathbf{b}_H = \mathbf{1}$	$\mathbf{0} < \mathbf{b}_L < \mathbf{b}_H = \mathbf{1}$
<b>Seller</b>	$\mathbf{s}_L = \mathbf{s}_H = 0$	$\mathbf{s}_L = \mathbf{0} < \mathbf{s}_H < \mathbf{1}$
	$\mathbf{s}_L = \mathbf{0} < \mathbf{s}_H = \mathbf{1}$	$\mathbf{0} < \mathbf{s}_L < \mathbf{s}_H = \mathbf{1}$
		$\mathbf{s}_L = \mathbf{s}_H = \mathbf{1}$

Steady state equations giving us the fraction of each type of seller is obtained by equating total births and deaths. Births are in an exogenously fixed ratio. In a steady state, the fraction of each type of seller in the market will be unchanged. When there

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of agents, which we do not have in this paper. However, it ensures that the market thickness and quality are not random variables and thus we are able to talk of steady state values of the variables rather than steady state distributions of these variables.

<sup>21</sup>We take that to be equal to the proportion of high quality goods sold which is a fair approximation for a large population. Since we are doing ex ante maximization this seems reasonable.

are fewer buyers than sellers the following two equations provide exact expressions for these quantities:<sup>22</sup>

$$S\gamma ((1 - q)(1 - \delta_h) + q(1 - s_h + s_h(1 - \delta_h))) = aB \quad (1)$$

$$S(1 - \gamma)((1 - q)(1 - \delta_l) + q(1 - s_l + s_l(1 - \delta_l))) = (1 - a)B \quad (2)$$

$$D \equiv B \quad (3)$$

Here,  $a$  denotes the exogenously fixed ratio of type  $\delta_h$  sellers entering the population,  $D$  the number of deaths each period and  $B$  denotes the total number of births in that period. Note that  $D = B$  always holds where  $D$  is obtained from adding the first two equations. This is because we have assumed that the total number of births is always equal to total number of deaths (fixed number of sellers in the market). In addition, in steady state the above two equations hold i.e. in steady state the number of deaths of each type of seller is equal to the number of births of each type. The equation can be explained quite simply—the unmatched fraction of sellers  $(1 - q)$  die at a rate  $1 - \delta$ . The fraction of matched sellers is  $q$ . They are honest with a probability  $1 - s$  in which case they die at their natural rate of  $1 - \delta$ . The dishonest fraction ( $qs$ ) die with probability 1.<sup>23</sup>

From this we can find out the steady state ratio of sellers for the different types of randomizations. Together with the buyers' and sellers' incentive constraints we can get the possible equilibria in our model. The following Lemma gives us the simplified steady state expressions for the buyers' and sellers' optimization problem.

**Lemma 1** *In steady state and for  $q < 1$  the sellers' decision problem simplifies to the following rule:*

*Seller  $j$  is honest iff*

$$\frac{(p - c)q}{1 - \delta_j} \geq \frac{pq}{1 - (1 - q)\delta_j}$$

*is indifferent if this holds with equality).*

**Proof.** In steady state  $\gamma_t = \gamma$ ,  $q_t = q$  and  $x_t = x$ . Given this, a seller of type  $j$  chooses to maximize  $V = \text{Max}(V_C, V_{NC})$ . Putting  $q_t = q$  for all  $t$  we get

$$V_C = \frac{pq}{1 - (1 - q)\delta_j}$$

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<sup>22</sup>Note that the distribution of sellers in the population will not, in general, be equal to the distribution of new born sellers. This is because impatient sellers survive for shorter periods which is why the exogenous ratio of births must have higher proportion of impatient types than in the population.

<sup>23</sup>Of course, there is an integer problem here in that the number of sellers may be fractions. Since we are dealing with large numbers we ignore this. In any case this is not germane to our analysis.

and

$$V_{NC} = \frac{(p - c)q}{1 - \delta_j}$$

. Thus, the seller chooses the maximum of the two. ■

When  $q$  is greater than 1 the steady state equations get simplified. Now there is no uncertainty about meeting a buyer- $q$  is simply the expected number of buyers every period. Thus, dishonest sellers die with probability 1 and the steady state equations reduce to

$$S_\gamma(1 - s_h + s_h(1 - \delta_h)) = aD \quad (4)$$

$$S(1 - \gamma)(1 - s_l + s_l(1 - \delta_l)) = (1 - a)D \quad (5)$$

We can work out the different types of steady states using the admissible values of buyers' and sellers' randomizations. Together with the incentive constraints we can find out what steady states can be supported for different parameter values. We look at this in detail in the appendix. Even without the detailed algebra, however, we can understand what is going on quite clearly by drawing graphs of how the thickness of markets change (because of the buyers' entry decision) with the steady state level of honesty and how the level of honesty changes with the market thickness. The intersection of the two curves gives us the possible steady states.

For certain parametrizations which yield multiplicity, we plot two graphs illustrating this. In figure 1 we plot the level of honesty ( $x$ ) as a function of market thickness ( $q$ ). Note that more thickness can never induce less honesty so the curve will never slope down.<sup>24</sup> In figure 1 upto  $q_h$  both types prefer to be dishonest so  $x$  is zero. At  $q_h$  the sellers with discount factor  $\delta_h$  are indifferent to being honest and dishonest. So they randomize-as  $s_h$ , which is the randomization probability of type  $\delta_h$  being honest rises, so does the steady state level of honesty. Beyond  $q_h$  type  $\delta_h$  strictly prefers to be honest and type  $\delta_l$  still prefers to be honest. However if  $q$  is less than 1 it increases the probability of matching and impatient sellers get knocked out faster which means that the steady state level of the impatient type gets lowered thereby raising the level of honesty. (The mathematics showing the convex shape is worked out in the appendix). At  $q_l$  the  $\delta_l$  type is indifferent and beyond that both types prefer to be honest. Note that this is not the only possible shape of the curve. There are some conditions on the minimum amount of patience and gains from trade for sellers to decide to be honest at some level of market thickness. Moreover, when the market thickness is such that  $q$  is unity or more we will see how these conditions entirely determine sellers behavior (beyond  $q = 1$  market thickness has no effect on the level of honesty). Thus this curve can be thought of as the sellers response curve.

In figure 2 we plot the response of buyers ( and hence market thickness) to the level of honesty. The interpretation is similar but there is no convex portion because

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<sup>24</sup>The sufficient condition for multiplicity ensures this.

buyers live only 1 period and thus their steady state is not endogenously determined. We call this the buyers' response curve.

In figure 3 we plot the two curves together and their intersection gives us the steady states. In general, we get multiple steady states. We now present some propositions about the existence of multiple steady states and bounds on market thickness( $q$ ) which induce this. All the proofs are in the Appendix.

**Proposition 1** *If multiple equilibria exists,  $p\delta_j - c \geq 0$  for at least one  $j$  ( $j=l,h$ ).and*

$$N \leq \frac{c(1 - \delta_j)}{(p - c)\delta_j}$$

*.(Necessary condition)*

*If  $p\delta_j - c \geq 0$  for all  $j$  and*

$$N \leq \frac{c(1 - \delta_j)}{(p - c)\delta_j}$$

*for all  $j$  or  $N \geq S$  then multiple equilibria exists. (Sufficient condition)*

These are conditions on the minimum level of patience and gains from trade necessary to ensure that at least one type of seller finds it optimal to be honest at some level of market thickness. Moreover the sellers and buyers decision must be mutually consistent in the sense that the level of honesty of type  $j$  seller must induce that market thickness at which they choose to be honest).

**Proposition 2** *Non degenerate multiple equilibria exist if the necessary and sufficient conditions in Proposition 1 are satisfied and in addition*

$$\frac{p}{V_H} < x^* < \frac{p}{V_L}$$

*and*

$$q_h < \frac{n_H}{S} < q_l$$

*where  $x^*$  =the maximum value of  $x$  when  $q = q_h$ , where*

$$q_l = \frac{c(1 - \delta_l)}{(p - c)\delta_l}$$

*and*

$$q_h = \frac{c(1 - \delta_h)}{(p - c)\delta_h}$$

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<sup>25</sup> $x^*$  can be calculated using the steady state equations. In case 2 worked out in Appendix 1 putting  $s_h = 1$  we can find  $\gamma$  and hence  $x^*$ .

This proposition sets conditions on the proportion of the two types on either side of the market. Intuitively, this means that if there are too many patient sellers or high valuation buyers the only steady state involving positive trade will have the high quality goods on sale with all buyers entering. The intuition is clear from figure 3. As the steady states can be Pareto ranked we can speak of non degenerate states as first, second etc. in ascending order of quality and demand. Given the conditions in this proposition, we can characterize the first non degenerate steady state quite sharply i.e. we can calculate the randomizations by buyers and sellers that support this. Corollary 1 formalizes this.

**Corollary 1** *If Proposition 2 holds then the first non zero steady state involves randomization by type H buyers and type h sellers with the level of honesty at  $x_h$  and the market thickness at  $q_h$ . Thus, the corresponding randomizations can be calculated.*

Figure 3 makes this quite clear.

**Proposition 3** *If  $q > 1$  then the equilibria are entirely dependent on the gains from trade ( $p - c$ ) and the discount factors ( $\delta$ ).*

The intuition is that beyond a certain level of market thickness ( $q = 1$ ) gains from being honest and cheating go up by the same factor so whatever was optimal for a seller at some market thickness ( greater than unity) still remains optimal.

## 4.1 A discussion of stability

We give an intuitive analysis of the stability of our equilibria. The difficulty of formalizing the argument arises from the fact that there are three variables which change over time viz.  $q, x$  and  $\gamma$ . Thus it becomes impossible to analyze stability in terms of the figures since the sellers response curves are drawn for steady state values of  $\gamma$ . We can of course define a law of motion which will map  $q_t, x_t, \gamma_t$  into  $q_{t+1}, x_{t+1}, \gamma_{t+1}$ . However, this will be quite complicated as the law of motion will look different in different segments of the  $q, x, \gamma$  plane . We leave such a formal analysis for future research. Here, we provide an informal argument to show how the system behaves when players follow a static expectation rule to decide on their strategies every period. We will analyze the system for local perturbations around the steady state in different regions.

Consider the following rule to analyze stability in this model. If any point  $(q, x, \gamma)$  is not a steady state of the model buyers assume that this will be the current value of  $x, \gamma$  and optimize accordingly. In similar vein, sellers assume this to be the values of  $q, \gamma$  which will prevail forever and reoptimize accordingly. Following this rule it turns out that the odd equilibria are stable and the even equilibria are unstable. This is

because the odd equilibria involve pure strategies<sup>26</sup> and the even equilibria involve mixed strategies. Therefore, for local perturbations around a steady state involving mixed strategies a large fraction of agents change their actions (they were indifferent between two pure strategies in equilibrium) causing a big movement away from the steady state while for pure strategies local perturbations (with static expectations) do not change the strategies of agents as the inequalities which decide their optimal action are unaffected.

To see this more clearly it is useful to divide the  $(q, x)$  plane into different parts as the state variable (the distribution of  $\delta_l$  and  $\delta_h$ ) takes different values in different regions. Thus for any given  $q, x$  and a corresponding distribution( $\gamma$ ) of the two types of sellers our adjustment process will give us a new  $q, x$  and  $\gamma$ .

For illustrative purposes, we consider small changes in  $q$  and  $x$  holding  $\gamma$  at the steady state level and then track the system as agents reoptimize using the static expectation rule. Let us denote by  $q^*(x)$  and  $x^*(q)$  the optimal level of market thickness and honesty as functions of honesty and market thickness respectively. When we have a non steady state value of  $x$  buyers adjust their behavior in the sense that next period's buyers take that to be the expected value of  $x$  and behave accordingly. Thus, when  $x < x_h$  no buyer enters, so starting from a non steady state pair  $(q_t, x_t)$ ,  $q_{t+1} = 0$ . Similarly for  $x > x_l$  we would have  $q_{t+1}$  jumping to  $N/S$ . For the seller things are a bit more complicated because of their population dynamics. The static adjustment rule is that both types take the expected value of the market statistic  $q$  in period  $t + 1$  to be the same as the observed  $q$  in  $t$  and optimize accordingly. Thus, for  $q < q_h$  both types cheat in period  $t + 1$ . If  $q$  indeed remained unchanged the population death rate next period would be given by the following expression

$$\frac{(1 - \delta_h + q)\gamma_t}{(1 - \delta_l + q)(1 - \gamma_t)}.$$

Therefore, in the region where  $q < q_h$  and  $x < x_h$  we would have the ratio of the two types converging to the ratio given by the expression

$$\left(\frac{\gamma}{1 - \gamma}\right) = \frac{(1 - \delta_l)a}{(1 - \delta_h)(1 - a)}.$$

(This is quite intuitive since the initial value of  $x$  was positive which would have implied a higher value of  $\gamma$  for any positive  $q$ . This is because at least a proportion of the high type of seller was being honest and hence their death rate was lower than that given by the right hand side of the above expression. Now with  $x = 0$  both types are getting knocked out at the rate given by the above expression lowering  $\gamma$  until equality is established).<sup>27</sup> Note of course that this only implies local stability of the  $(0, 0)$  steady state-to see this take  $q = 0$  and  $x = 1$  and see that we get cyclical

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<sup>26</sup>These pure strategies must be strict.

<sup>27</sup>If  $x = 0$  to begin with the equation is already satisfied.

behavior. To see that the second equilibrium is unstable notice that for a value of  $x$  greater than the steady state value  $q$  jumps to  $\frac{n_h}{S}$  (since at the steady state value they were indifferent any slightly bigger value would cause all of them to strictly prefer to enter the market). Similarly, with  $q$  greater than the equilibrium value all patient sellers switch to honesty, the value of  $\gamma$  goes up and the level of honesty rises. As the  $\delta_i$  sellers die faster  $x$  reaches the limiting value given by the intersection with the buyers response curve and the economy reaches the next steady state. The analysis being similar we do not describe this for all the regions.

## 5 Price Mechanisms

So far prices were exogenous in the model. It was a useful first simplification and it can be justified by thinking of the good in question having a regulated price (we can think of the government, for instance, fixing the price but being unable to control the quality—a typical feature of various developing and transition economies.). We now look at how the model behaves when we explicitly introduce a mechanism for price formation. We briefly consider the implications for this model when prices are posted in the market by sellers and see how it differs depending on whether this is posted before or after matching. We consider alternate specifications to see what sort of equilibrium prices can be supported.

More precisely, suppose the timing of the process is as follows:

Sellers post prices, buyers look at prices and choose the seller with the lower price—randomly if prices are the same. In this case it is not difficult to see that the sellers compete away all their surplus. However, this cannot be an equilibrium since at the level where sellers are robbed of all surplus they would prefer to produce the low quality good. Buyers correctly assess this leading to only low quality goods sold at a price of zero (or no trade) as the only sustainable steady state.<sup>28</sup> This provides one more example of how competitive pricing can be harmful and can justify government intervention in regulating prices even when it cannot regulate quality. The recent debate about the effect of competitive pricing on the quality of LASIK surgery (see, for instance, The Washington Post, February 22, 2000 for a chatty piece summarizing these fears) seems to be based on this type of argument.

Now think of the same type of story but with different beliefs about the buyers interpreting a lower price as a signal of low quality. In that case, a whole range of prices can be sustained, from the price which satisfies at least one of the sellers incentive constraints to the monopoly price which robs the high type of all the surplus. Whether this entire range can be satisfied of course depend on the parameter values (cost, preferences and valuations) and the analysis would be much the same as with fixed prices. The welfare effects would vary as the different prices leave buyers and sellers with different surplus.

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<sup>28</sup>This is similar to what happens in a symmetric Bertrand game.

Finally, consider a mechanism a la Diamond (1971).

Buyers are matched with sellers randomly. Sellers announce prices. A buyer has information only about the price announcement of the seller with whom he is matched. A buyer then decides whether to buy or not. If a buyer does not buy, he can be rematched at a small cost  $\epsilon$ . We assume that in every match each type of buyer will have a cutoff value, if the announced price is above that he will want to be rematched (or leave the market)-otherwise he will buy.

We first provide an informal analysis of what the equilibrium of this game will look like. Intuitively, a few things seem evident-both type of sellers will announce the same price since any lower price will effectively signal his low quality good. This would contradict the fact that we cannot have a separating equilibrium in this environment (see Appendix 2). Moreover, given the rematching cost, any equilibrium which is efficient implies agreement in the first period.<sup>29</sup> If sellers announce prices such that only the high type of buyer enters, the buyer will be rid of all his surplus. Moreover, in any stationary equilibrium, the price will be such that the low type of buyer will always be kept to his reservation level since at any lower price the seller can always charge a higher price, cause the low type to enter and be better off. This is also intuitive - if he does not enter at that price he gets zero surplus - if he enters the price at which he buys will be such that his expected net utility is zero. Next, we will see that a price of either  $p_l$  or  $p_h$  will prevail which are the prices which keeps the low and high type buyer with no expected surplus respectively. We can show this by taking any arbitrary lower price and show that the seller who is matched always does better by raising price by  $\epsilon$ . We formalize this in three propositions one of which basically spells out the incentive constraints which need to be satisfied.

**Proposition 4 (*Price Proposition 1*)** *For steady states with positive levels of trade to exist the steady state equilibrium price ( $p^*$ ) must be the same for all sellers.*

**Proof.** For the same types of sellers and buyers (i.e. discount factor and valuation) suppose  $p^*$  was different i.e. the equilibrium price configuration had different sellers charging different prices. Any price which differs by  $\epsilon$  cannot be an equilibrium since either the seller charging the lower price should increase the price and increase his profit or the seller charging the higher price should decrease his price to increase his expected profit. This is because at price  $p$  if the buyer is buying from a seller so will he at price  $p - \epsilon$ . However, at price  $p$ , if no one is willing to buy, clearly sellers must lower price for trade to occur. Now consider any set of arbitrary prices differing by more than  $\epsilon$ . Consider any but the highest price at which the buyer is willing to trade in this configuration of prices. Call this arbitrarily selected price charged by a seller  $p_a$ . He should also be willing to trade at  $p_a + \epsilon$  because of the rematching cost. Thus, for the same types of sellers and buyers (i.e. discount factor and valuation)

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<sup>29</sup>It might be possible to construct Nash equilibria involving delays but there does not seem reasonable beliefs to support that. In particular, they would not be sequentially rational.

the argument in Diamond (1971) holds. Suppose, different types of sellers charge different prices. This implies existence of a separating equilibrium which has been shown not to exist. Finally, different buyers cannot be charged different prices as sellers cannot distinguish types, hence price announcements cannot be conditioned on buyer types. ■

**Proposition 5 (Price Proposition 2)** *A property of this equilibrium price  $p^*$  is that  $p^*\delta \geq c$  for at least one  $j$  ( $j=l,h$ ) and  $\max(xV_i - p^*, 0) \geq 0$  for at least one  $i$  ( $i = L, H$ ) where  $x$  is a steady state level of honesty consistent with  $p^*$ . Further, if  $q < 1$ , then*

$$q \geq \frac{c(1 - \delta_i)}{\delta_i(p - c)}$$

*has to hold.*

**Proof.** From the necessary condition for multiplicity we know that  $p^*\delta \geq c_i$  for at least one  $i$ , sets bounds below which the equilibrium price cannot fall in a non zero steady state. If this did not hold the seller's incentive constraint to produce high quality is violated for both types -knowing this buyers will not pay any positive price for the good. The second part of the proposition is the incentive constraint of the buyer to enter which must be satisfied. Finally, the market thickness must satisfy the incentive constraint of the seller. ■

**Proposition 6 (Price Proposition 3)** *Let  $p_l$  and  $p_h$  be the maximum prices at which the low type and high type buyer would enter the market (for a given market thickness). The equilibrium price  $p^* = p_l$  or  $p_h$  depending on whether*

$$\frac{N}{S}p_l \geq \frac{n_2}{S}p_h$$

*or vice versa for all sellers.*

**Proof.** Consider some other price  $p'$  different from  $p^*$ . Now if  $p' \leq p^*$  a seller  $j$  should be able to raise it by  $\epsilon/k$  ( $k \geq 1$ ) and it would still be optimal for the buyer to buy (since buying at the next round of matching at  $p'$  is equivalent to buying in the present round at  $p' + \epsilon$ ). Again  $p' \geq p^*$  lowers profits in expected terms. The price is  $p_l$  if the gains from selling at  $p_l$  to all buyers exceed that from selling at a higher price  $p_h$  to only the high type of buyer depending on the population distribution of the two types. Since  $\frac{N}{S}p_l$  and  $\frac{n_2}{S}p_h$  gives the expected revenue from the two types. The greater of the two determines the equilibrium price. ■

As with the case of exogenous pricing, a number of cases arise and many of them are similar. We thus do not do a detailed analysis for all the cases but note that the following possibilities can arise viz. :  $p_l$  is the price and all buyers enter because at that expected level of honesty ( $x$ ) all buyers get positive expected utility (i.e.  $xV_i \geq p^* \forall i$  or  $p_h$  is the price and only the high valuation types enter.) Randomizations are

of course possible, at  $p_l$  the impatient seller may randomize which may be sustained by a fraction of the low valuation buyers entering)

Some welfare considerations are however worth analyzing in comparing fixed price vs. posted prices. If the low valuation buyer was participating in the market by entering at the fixed price it is likely that he had positive surplus-in the posted price environment he is always held to his reservation level of utility. Thus the low type buyer can never be better off when sellers (optimally) choose prices. The high valued buyer may or may not be better off-if  $p_l$  is the prevailing price it would depend on whether this gives him more surplus than the fixed price situation (i.e. whether  $xV_H - p \geq x'V_H - p^*$  where  $x$  and  $x'$  denote the steady state levels of honesty with fixed and posted prices respectively. Note that there can be no unambiguous answer as there are multiple steady states in both situations). Moreover, the low type creates an externality for the higher type as the higher the proportion of low types in the population of buyers the more likely that  $p_l$  will be charged. What about sellers? It might appear that he would be better off since he is now optimally choosing prices but the analysis is not so simple because we need to specify the steady states across which we are comparing. Thus this is true only when we compare steady states with the same level of market activity. We can also say something about quality. If the optimal  $p$  (i.e. the  $p$  satisfying the three price proposition) satisfies the conditions for both types of sellers to produce the high quality good, consistent with the buyer's maximization exercise, such a price can effectively serve as a signaling mechanism indicating high quality. Thus, in such a case it might be worthwhile for a central authority with a preference for consumer welfare as well as quality to try fixing the price at a level at which both types of sellers are honest so that the buyer is also left with some surplus.

That,of course, is not the only way to endogenize prices. Another asymmetry comes to mind-if dishonest sellers can be identified it might seem natural that we should also be able to identify honest sellers which means that existing sellers should enjoy a market advantage over new entrants. This is missing in the simple matching technology we have outlined. However, if old sellers charge higher prices ,we can find a distribution of prices according to how well established a seller is. An equilibrium configuration would have different subgroups of buyers being catered to by different sellers-thus we would have price variation and market segmentation as we so often do in the real world. That, however, is a topic for a separate line of research which we do not pursue here. In our information structure only dishonesty is identified-the remaining market players are either honest or new entrants who cannot be distinguished. One can think of this as a society where complaints are recorded -a lack of complaints indicates either good behavior or past inactivity and are indistinguishable for the agents at the beginning of market activity each period. This seems a reasonably good approximation for transition and emerging economies where past history of sellers are hard to come by .There is punishment for bad conduct (perhaps in the form of public announcements. See Greif, Milgrom and Weingast,(1994) for one ex-

ample of such an authority where complaints could be recorded) but the emerging marketplace has no effective mechanism to record past individual activities. We can also justify this for cases where information is available for pooled samples only ,as in the market for milk, where milk from different farmers is mixed and can only be traced back when there are complaints.<sup>30</sup>

## 6 Extensions and Applications

Here we give some illustrations of markets where our model may provide some insight and discuss some extensions to the basic model.

### 6.1 Illustrations:

#### *1. Transition economies*

Russia and several erstwhile communist countries underwent a transition and from centralized planning moved towards a market economy. Hence the potential to switch to high quality was created with a move to a market based structure. However, as noted in McMillan (earlier cit.) ‘New firms find it difficult to sell their products...(due to the) problem of finding potential customers’. Thus, there was inadequate market information and in most of Vietnam private enterprise ‘Most firms ..sold only to local customers’ causing the market to remain thin. To get out of it Mcmillan discusses the role of ‘chambers of commerce, credit bureaus, and trade organizations which seems consistent with the policy recommendations our model has to offer. The fact that this did in fact occur in various economies as a result of conscious policy bears out our argument that there was nothing missing in technology or preferences which was keeping these economies at low levels of trade with dubious quality on sale.

#### *2. Differing quality of medical facilities in various big cities in India.*

Individual buyers of medical services usually try to assess the quality of the service being offered at various centers but are unlikely to have detailed knowledge of

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<sup>30</sup>As noted earlier, in ebay both good and bad comments can be recorded but good comments have less credence as sellers often leave good comments to boost each other’s market. Complaints or bad comments have to be verified

In traded items across countries some products are not identified by individual seller/supplier. However when found defective the individual seller is tracked down and has to pay a penalty. The same is true for milk from farmers in most states in the US where the milk is pooled before being sold. Tracking farmers would be attempted only if there is a complaint. Moreover, the idea that pooled history is available and determines optimal decision has been explored in a different context by Tirole (1996) which conforms in a milder way to our idea that past individual histories are imperfectly observed.

Note, also, that there may be strategic reasons for buyers not to reveal information to others about ‘good’ sellers /products (as in the case of certain software but we do not analyze this here.)

individual providers and depend on the reputation of the center or ‘group’ with which the provider is associated. It is part of ‘folk knowledge’ that various cities in India offer medical facilities which show wide variation in quality, especially as perceived by consumers (patients). Some of the ‘Centers of excellence’ enjoy a market share which does not seem to stem from any fundamental difference in primitives i.e. the technology of medical centers and the qualifications of doctors. As perceived quality is hard to measure, there has been no rigorous study of this. However in detailed case studies undertaken by UNDP (see Bandyopadhyay and Gupta 1997 a and b) certain illuminating facts about the organs transplant scenario came out which are worth noting.

There is a wide variation in the number of transplants carried out in East India and South India -comparing big cities in the South, the average number of transplants in 2 major centers in Chennai ( a big city in the South) total over 300 and there are quite a few other centers in Chennai where the yearly average is around 100. In contrast, in Calcutta, the major city in the East where such surgery is carried out, the total number in the two major centers in ten years adds to less than four hundred (other centers contribute a negligible amount -transplants are occasional features there.) Thus the ‘market thickness’ is vastly different with Calcutta having, on an average, customers (transplant recipients) of about thirty five in the two major centers as against over three hundred in Chennai. However, the qualifications of doctors are equivalent in both cities and the Hospitals have comparable facilities (both centers in Calcutta satisfy the rigorous specifications required to obtain licence under The Transplantation of Human Organs Rules, 1995).It also appears from the study (earlier cit.) that the quality, as measured by patient satisfaction, is low. From detailed questioning of patients about quality of care, behavior of doctors and nursing staff etc. the authors note widespread satisfaction in patients who have undergone transplants in Madras as opposed to Calcutta. Indeed they conclude ‘The phenomenon of transplant migration has been continuing over the years as more and more patients in need of a kidney move to other parts of India , notably Chennai, Vellore and Bangalore ...hospitals (in Calcutta) have suffered because of charges of negligence ..in health care.’ Thus, the hypothesis of quality being directly related to market thickness seems borne out.

Table 1 shows the differences in market thickness and customer satisfaction in the two cities:

Hospital	Location	Average no. of transplants/year (1988-96)	Patient satisfaction
Apollo	Chennai	100-120	High
Willingdon	Chennai	100	High
Belle Vue	Calcutta	20	Low
Woodlands	Calcutta	15	Low

What is more interesting is that following the passage of The Transplantation of Human Organs Act, 1994, regulating transplants in the country, it has become more difficult to get permission in the South for non local patients causing a shift towards

getting transplanted in their nearest locality. This increased demand has been also matched by increases in the level of quality service provided by the above two centers in Calcutta which has recently seen high turnover coupled with higher patient satisfaction. In fact, this increased demand has caused another center (Wockhardt Medical & Research Centre) to start doing kidney transplants in Calcutta, clearly showing how markets are responding to demand. It is difficult to identify a factor which systematically explains this which is why we think that our multiplicity explanation is convincing.

### *3 The Service sector: Taxicabs at day and night.*

An interesting phenomena that has been observed is the different service provided by taxicabs at day and night at various airports and railway stations. At night, when traffic is thin cabs tend to provide poor quality, cheating customers by overcharging, taking longer routes and even indulging in outright robbery. At day the service is noticeably better when the flow of passengers is larger. Passengers, in turn, seem to respond to this by relying on taxicabs more heavily during the day and less during the night. This seems to be because the future gains from not cheating is higher at day in the form of getting more passengers than at night. At night time many more tourists make arrangements by asking friends and relatives to meet them or even waiting at the Airport till day before taking a cab. Assuming that the distribution of tourist types and cab drivers are the same in the day and night this seems a good example of demand and quality reinforcing each other. Data on the ratio of tourists who use taxicabs in the day as against those who use it at night should bear this out. Note, that this seems to be a worldwide phenomenon and attempts are made to deal with this by having prepaid cab service available at airports and railway stations where a centralized agency keeps track of passengers assigned to cabs whose license numbers are noted. (This is based on personal experience, conversations with several people and newspaper reports, thus no specific source is cited.)

## **6.2 Extensions and policy issues**

We would also like to extend the model to cover cases where reputation matters and try to explain promotion and hiring within firms. Consider different tiers of jobs. Labor starts from the lowest rung (say working at Mc Donald's at minimum wages), if they shirk they are dismissed by their employer but they can costlessly enter a similar job at the lowest rung. If they perform well, they are rewarded by being assigned jobs in a higher rung next period. Given differing time preferences, there is an equilibrium with labor employed at different rungs. Now consider the effect of improved monitoring. (say different branches of Mc Donald's can develop a network to identify past cheats.) In general, the equilibrium flow of people moving to different jobs will now vary. We expect that a society with a similar structure but different information processing environments will have differing levels of welfare-it would be interesting to study the evolution of a society as it's information system improves.

The ability of agents to signal their types and the costs of signalling could also be important determinants of why such economies could differ.

We think our simple model can be readily modified to capture the idea that there are good and bad pockets in an economy and that the transition from one to the other is often the result of an exogenous change in the environment. The static lemons model is often used to explain the presence of a suboptimal market size when increased trade is beneficial to every agent. This model provides a somewhat different justification for this inoptimality and provides a dynamic framework showing that a central authority facing nearly the same informational constraints can do better by breaking the initial coordination problem. It can successfully explain transitions (why a Mafia ridden state may re-emerge as a tourist attraction spot following stern law enforcement) while the static lemons model would predict that informational constraints will continue to inhibit the market.

A brief policy discussion seems appropriate. This framework suggests that markets with fairly similar fundamentals can converge to quite different steady states. Thus the question arises about what policies can take the economy out of a ‘bad’ steady state? The obvious answer is changing expectations but it is not quite clear what that means in real terms.<sup>31</sup> It might therefore make sense to talk of ‘small’ changes in parameter value, say a one shot marginal increase in law enforcement. A temporary change in a parameter value matters because by perturbing expectations it can take an economy towards a ‘good’ steady state. As a practical matter, setting up quality certification boards would help-if producers have to go through a quality check they will no longer be able to produce low quality goods removing the uncertainty that buyers face. Thus buyers would no longer hesitate to come to the market-effectively once this process starts we would in fact no longer require such boards-we would have self sustaining system. The market (like a brand name) would be trusted for its quality products and it would continue to live up to that to maintain its future prospects. Thus, in our model quality certification boards only have a temporary role to play. By contrast, the traditional argument that foreign competition would improve quality is not predicted by our model. If anything, matters can become worse-buyers having the option of switching to a known foreign brand would leave the existing market reducing market thickness further and worsen the incentives for sellers to invest in quality.<sup>32</sup> A case in study is Russia post-Perestroika

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<sup>31</sup>An interesting possibility is the use of local currency to signal demand to local investors who have to decide whether to invest in a costly technology while facing uncertain demand. This is a possibility suggested by Jayaraman and Oak (2001). However, there are several limitations as pointed out by the authors themselves. In particular, apart from the credibility issue of introducing such currency, for this to work in our set up, consumers must have no uncertainty regarding whether they want a locally produced good.

<sup>32</sup>The fact that in a market with imperfect information about quality, late entrants may be dissuaded from entering if firms already in the market enjoy a reputation has been recognized before (see Mayer (1984) and Grossman and Horn (1988)). Thus, it seems natural to believe that a firm with an established reputation may capture the market in an environment characterized by imperfect

when Russians can travel to Europe and acquire good quality second hand cars—the Russian car industry continues to produce cars of inferior quality.<sup>33</sup> Thus, if helping the domestic industry to grow is an objective, the entry of firms with established reputation may be harmful. However, liberalization will make the consumer better off (by lowering prices) at the cost of the domestic producer and welfare analysis is not possible on an a priori basis. This merely points out that the introduction of foreign competition is not unambiguously beneficial. The evaluation of welfare requires a general equilibrium analysis which our model does not permit. A policy prescription which does come out is that any liberalizing policy which allows access to cheaper technology for producing high quality goods is unambiguously beneficial as it increases the incentives for producers to invest in quality.

In conclusion, we would like to list the most promising areas for future research. An important issue is finding out the conditions for prices to signal quality when low quality goods also offer some surplus, In Appendix 2 we characterize a separating equilibrium showing how technologies which involve decreasing costs over time (perhaps because of ‘learning by doing’) can use prices to effectively separate high good producers from low good producers, causing market segmentation and resolving the quality uncertainty. Another area of future research is to study the impact of foreign competitors in this environment when there is scope for technology diffusion. This needs to be looked at in greater detail, in particular, studying the impact on easing borrowing constraints and subsidizing producers who adopt this new technology. Moreover changing conditions are likely to affect perceptions about the future - thus it maybe worthwhile looking at how  $\delta$  evolves over time . Another thing we want to do is explicitly modeling transitions and learning and looking at the effect of exogenous shocks to the system (like better law enforcement, shift of policy from protecting domestic markets to liberalizing trade). We hope that this simple framework we have set up will permit such issues to be explored in the future.

**Appendix 1** We work out the steady states in detail for the case of more sellers

than buyers . For more buyers than sellers the expressions differ but the analysis is simpler—we briefly discuss that after working through the various cases for  $q < 1$ .

**Case 1:**  $s_l = s_h = 0$

The steady state ratio

$$\left( \frac{\gamma}{1 - \gamma} \right) = \frac{(1 - \delta_l)a}{(1 - \delta_h)(1 - a)}$$

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information.

<sup>33</sup>The important thing to note is that here, used cars seem to have better reputation than new cars, perhaps because the counteracting institutions of the type mentioned by Akerlof (earlier cit.) may have developed. An empirical study by Bond (1982) notes the absence of a market for lemons in the used trucks industry. Thus, what is important is not the type of product in question but whether there are credible ways to signal quality.

when  $q < 1$

(otherwise the steady state equations is simply  $\frac{a}{1-a}$ . However in equilibrium  $q$  is 0 since  $x = 0$  and the optimal response is  $b_1 = b_2 = 0$ )

**Case 2:**  $s_l = 0 < s_h < 1$

The steady state ratio is found by equating the ratio of deaths of the two types to the exogenously given births (or inflow). Thus we have

$$\frac{\gamma((1-q)(1-\delta_h) + q((1-s_h) + s_h(1-\delta_h)))}{(1-\gamma)(q + (1-q)(1-\delta_l))} = \frac{a}{1-a}$$

Now we can solve for  $q$  by looking at the sellers decision problem. For the seller of type  $\delta_h$  to be randomizing it must be that he is indifferent to cheating and being honest. Hence the payoffs from cheating and being honest must be equal. Hence we get

$$\frac{(p-c)q}{1-\delta_h} = \frac{pq}{1-(1-q)\delta_h}$$

where the left hand side represents the gains from being honest and the right hand side the gains from cheating. Solving for  $q$  we get

$$q = \frac{c(1-\delta_h)}{(p-c)\delta_h}$$

Substituting in the buyers entry problem we can find out the number of buyers who enter and from that  $\gamma$  and hence  $s_h$  can be solved. More precisely since  $S$  (the total stock of sellers) is known from  $q$  we can calculate  $n$  (those buyers who enter in that period), If  $n$  is greater than  $N$  (the population of potential buyers) then there is no solution. If  $n$  is less than the type of  $V_H$  buyers then we calculate the randomization  $\alpha$  so that only  $n$  buyers enter. At this it must be that these buyers are indifferent hence  $xV_H = 1$  giving us the value of  $x$  and hence  $\gamma$ . Thus  $h_2$  can be calculated. If  $n$  equals the number of type  $V_H$  buyers then  $1/V_H \leq x < 1/V_L$  and hence admissible ranges of  $\gamma$  and hence  $s_h$  can be found. (this would correspond to a continuum of equilibria). For  $n$  such that type  $V_2$  always enters and type  $V_L$  is indifferent  $x$  can again be precisely calculated and hence  $\gamma$  and  $s_h$  can be solved. Finally if  $n = N$  then we can again solve for the admissible ranges of steady states and seller randomizations.

**Case 3 :**  $s_l = 0 < s_h = 1$

The steady state equation is given by

$$\frac{\gamma(1-\delta_h)}{(1-\gamma)(q + (1-q)(1-\delta_l))} = \frac{a}{1-a}$$

and

$$\frac{c(1-\delta_h)}{(p-c)\delta_h} < q < \frac{c(1-\delta_l)}{(p-c)\delta_l}$$

must hold. Now for each  $q$  in this range find  $\gamma$  and hence  $x$ . This gives us the level of honesty induced by the different values of  $q$ . (this gives us the sellers response

curve). Now for each of this  $x$  so found find the level of  $q$  this induces by looking at the buyers maximization problem, This gives the buyers response curve. If the  $x$  induced by a value of  $q$  in turn induces the same  $q$  we have an equilibrium point.

**Case 4 :**  $0 < s_l < s_h = 1$

With the impatient sellers randomizing the steady state equation is given by

$$\frac{\gamma(1 - \delta_h)}{(1 - \gamma)((1 - q)(1 - \delta_l) + q((1 - s_l) + s_l(1 - \delta_l)))} = \frac{a}{1 - a}.$$

The value of  $q$  is found by equating the gains from honesty and cheating for the  $\delta_l$  type of seller giving us

$$q = \frac{c(1 - \delta_l)}{(p - c)\delta_l}$$

Plugging in the buyers maximization problem we get  $x$  and substituting these values in the steady state equation gives us the equilibrium randomization for the seller.

**Case 5:**  $s_l = s_h = 1$

With both types being honest the steady state becomes

$$\frac{\gamma(1 - \delta_h)}{(1 - \gamma)(1 - \delta_l)} = \frac{a}{1 - a}$$

Note this must induce both types of buyers to enter (since  $x = 1, V_i > 1$  for  $i = L, H$  by assumption ) -with only high quality objects on sale all potential buyers must find it optimal to enter(otherwise they would not be potential buyers!).

When  $q > 1$  we know that sellers behavior is independent of  $q$ . Thus their choice is dependent only on whether  $p\delta > c$  or the converse. Depending on that each type of sellers behavior is determined. As there is no more uncertainty about matching we do not have the part with  $1 - q$ . The analysis is similar except that if  $s = 0$  for any type at  $q \geq 1$  it is always 0.

Proof of proposition 1:

**Proof.** Suppose not, This would imply that  $p\delta < c$ . We have to show that this cannot be if the gains from cheating are always lower than the gains from honesty. We can see this from the sellers discounted present value of gains from the two types of behavior

For  $q < 1$  we have

$$\frac{\pi q}{1 - \delta} > \frac{pq}{1 - (1 - q)\delta}$$

which gives us

$$q > \frac{c(1 - \delta)}{(p - c)k\delta}$$

(substituting  $p - c$  for  $\pi$ ). Since  $q < 1$  implies that

$$\frac{c(1 - \delta)}{(p - c)k\delta} < 1.$$

For this to be true we must have  $p\delta > c$  contradicting the hypothesis that  $p\delta < c$

For  $q > 1$

$$\frac{\pi q}{1 - \delta} > pq$$

which again gives us  $p\delta > c$ .

**Sufficiency:** Consider the  $q$  for which both types of sellers are honest. (This will always be the case for  $q \geq 1$  since the condition for honest behavior viz.  $p\delta > c$  holds for both  $i$ ). Thus,  $x = 1$  which implies both types of buyers enter. Thus apart from the no trade equilibrium the full honesty equilibrium with full entry holds. For this we of course require that the  $q$  at which this occurs is not incompatible with the total number of potential buyers i.e.  $qS \leq n$ . ■

Proof of proposition 2:

**Proof.** Figure 3 makes this quite clear. The first intersection on the positive quadrant is ensured by the given condition. We now need to show at least a second intersection exists. If the configuration is as shown in figure 3 it is obvious. Otherwise by proposition 0 (sufficient condition) we know that at  $q$  max there is an equilibrium with full honesty and full entry. ■

Proof of corollary 1:

**Proof.** The proof is clear from figure 3. Given condition 2  $x_2$  must lie to the left of  $x^*$  and  $q_2$  must lie below  $n_2/S$ . Thus, this gives us the first intersection of the 2 curves beyond the origin. The buyers randomization is got by simply equating  $\alpha n_2 = q_2$ . ( $\alpha$  is the randomization probability of buyers of valuation  $V_2$ ). For the seller we calculate this from the steady state equation (case 2). ■

Proof of proposition 3:

**Proof.** When  $n \geq S$  the analysis is much simpler. Now the sellers' behavior is entirely driven by cost conditions and preferences. That is easy to see. Consider the gains from cheating—that is simply  $pq$  (there is no chance of being unmatched so sellers are driven out from the market after matching and selling the low quality product. From honesty it is simply  $\frac{\pi q}{1 - \delta_i}$ . Thus, for honesty to be optimal  $pq \geq \frac{\pi q}{1 - \delta_i}$  which implies that  $p - p\delta_i \geq \pi$ . This can be written as  $p\delta_i \geq c$ . This is independent of  $q$ . Thus, cost conditions (which determine profit for a given price  $p$ ) and preferences ( $\delta$ ) entirely determine the behavior of sellers. ■

*To show that the steady state level of honesty rises as market thickness increases and the inequalities in case 3 hold.*

**Proof.** The steady state equation is

$$\frac{\gamma(1 - \delta_h)}{(1 - \gamma)(q + (1 - q)(1 - \delta_l))} = \frac{a}{1 - a}$$

which gives us

$$\frac{\gamma}{1 - \gamma} = b(q + (1 - q)(1 - \delta_l))$$

where  $b$  is a constant

$$\frac{a}{(1 - a)(1 - \delta_h)}).$$

This simplifies to

$$\gamma = 1 - \frac{1}{1 + b(1 - \delta_l + q\delta_l)}$$

.Taking derivatives we have

$$\frac{d\gamma}{dq} = \frac{\delta_l}{(1 + b - b\delta_l + bq\delta_l)^2} > 0$$

showing that it is increasing in  $q$ . The second derivative is

$$\frac{d^2\gamma}{dq^2} = -\frac{2\delta_l^2}{(1 + b - b\delta_l + bq\delta_l)^3} < 0$$

justifying the shape of the curve. ■

**Appendix 2** Here, we show that there is no separating equilibrium ( in steady state) given that the low valued good has some value in trade when both sellers face the same technology, which has the same unit cost over time. However, we see that separating equilibria may emerge when cost of technology for individual firms decrease over time.

Let  $V_H^h, V_H^l, V_L^h, V_L^l$  denote the value of the high good for the high type of buyer, the value of the low quality good for the high type of buyer, the value of the high good for the low type and the value of the low good for the low type respectively.

One of the conditions for a separating equilibrium is that one type of seller prefers to produce the high type of good and the other the low type and charge separate prices which reveal that.

WLOG let the impatient seller prefer the low quality good and let that be sold at a price  $p_l$  and the high quality at  $p_h$ . The market thickness for the two goods are  $q_h$  and  $q_l$ . For a separating equilibrium it must be that

$$\frac{p_l - c_l}{1 - \delta_l} q_l \geq \frac{p_h - c_h}{1 - \delta_l} q_h$$

which is independent of the discount factor! Hence no separating equilibrium is

possible, because the seller type who gets less can mimic the other.<sup>34</sup>

What do we require to have separation? A possibility is where the technology shows scale economies over time (learning by doing perhaps). Let  $k$  denote the scale factor in the sense that  $c_t = kc_{t+1}$ .

A separating equilibrium is characterized by a sequence of prices of the two goods, market thickness, costs of production of the two goods. Under the steady state assumption the conditions this needs to satisfy can be summarized by the following equations. (We work this for the case of less buyers than sellers-the case with more buyers as well as where one of the situations involve more buyers than sellers and another the converse can be easily worked out.)

$$\begin{aligned} \frac{p_l q_l}{1 - \delta_l} &\geq \text{Max} \left( \sum q_h (p_h - k^t c_h) \delta_l^t, \frac{p_h q_h}{1 - (1 - q_h) \delta_l} \right) (IC_l) \\ \sum q_h (p_h - k^t c_h) \delta_h^t &\geq \text{Max} \left( \frac{p_h q_h}{1 - (1 - q_h) \delta_h}, \frac{p_l q_l}{1 - \delta_h} \right) (IC_h) \\ V_H^h - p_h &\geq V_H^l - p_l (IC_H) \\ V_L^l - p_l &\geq V_L^h - p_h (IC_H) \end{aligned}$$

The first condition ( $IC_l$ ) says that for a low discount type of seller the gains from producing the low quality good and selling it as one outweighs the one period gain from selling the low quality good as a high quality good (cheating) or from the present discounted value of selling the high quality good. Similarly ( $IC_h$ ) says the high discount type prefers to sell a high quality product to cheating or selling a low quality product forever. The buyer's incentive constraints are given by ( $IC_H$ ) and ( $IC_H$ ) which says that high valuation buyers prefer to buy the high quality good at the going price to a low quality good while low quality buyers prefer to buy the low quality good. The separating equilibrium is possible because the value of the declining cost of technology has different value to different sellers-the value of future gains from the technology is more to the patient seller. The fact that the low quality good also has surplus implies that for some prices and market thickness impatient sellers prefer selling low quality goods at a lower price to making high one period gains from passing them off as high quality ones. (We assume of course that the individual rationality constraints are satisfied.). Note, of course, that this just shows the existence of such prices-we also need to show under what mechanism these would be equilibrium prices.

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<sup>34</sup>This contrasts with the literature on prices signaling quality. Two papers which show separation and partial separation are Wolinsky (1983) and Bandyopadhyay, Chatterjee and Vasavada(2001). They also have asymmetric information and sellers who can choose the quality to produce which is akin to our environment but their results differ considerably as the tradeoffs are somewhat different. In particular, the sellers have different costs which cause this separation while we allow every seller access to the same technology.

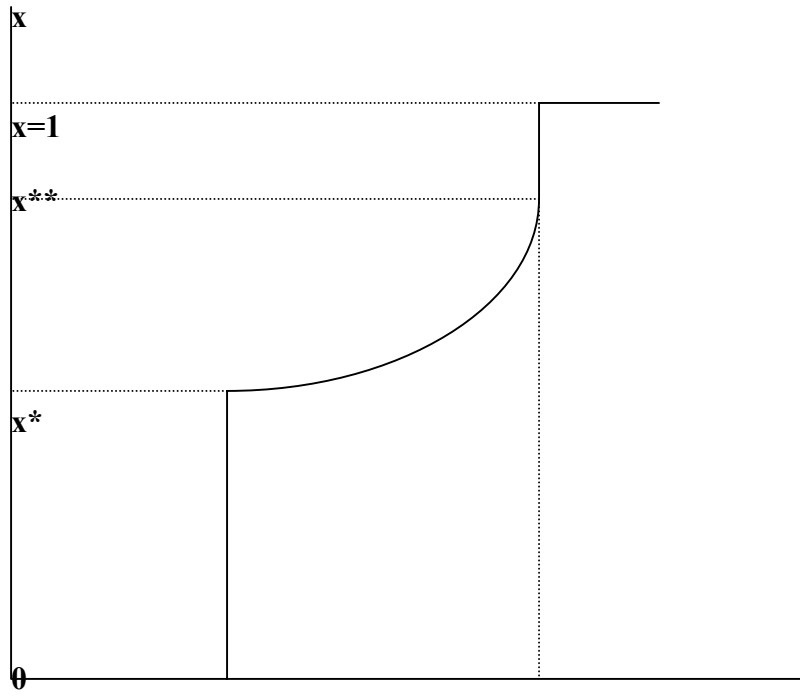
This result is robust to prices declining as costs of production in the high technology falls. This is because for the seller who adopts the technology for the first time the costs still remain high as there are no spillovers. With spillovers which make cost decline over time for all producers regardless of whether they adopted this earlier this no longer holds and there may be an optimal time before everyone switches to the technology of the ‘high end’ good. Studying the effects of such spillovers on the evolution of the market is an interesting area for future research.

We note that this does not in any way rule out multiple equilibria - this separating equilibria is one of various possible equilibria.

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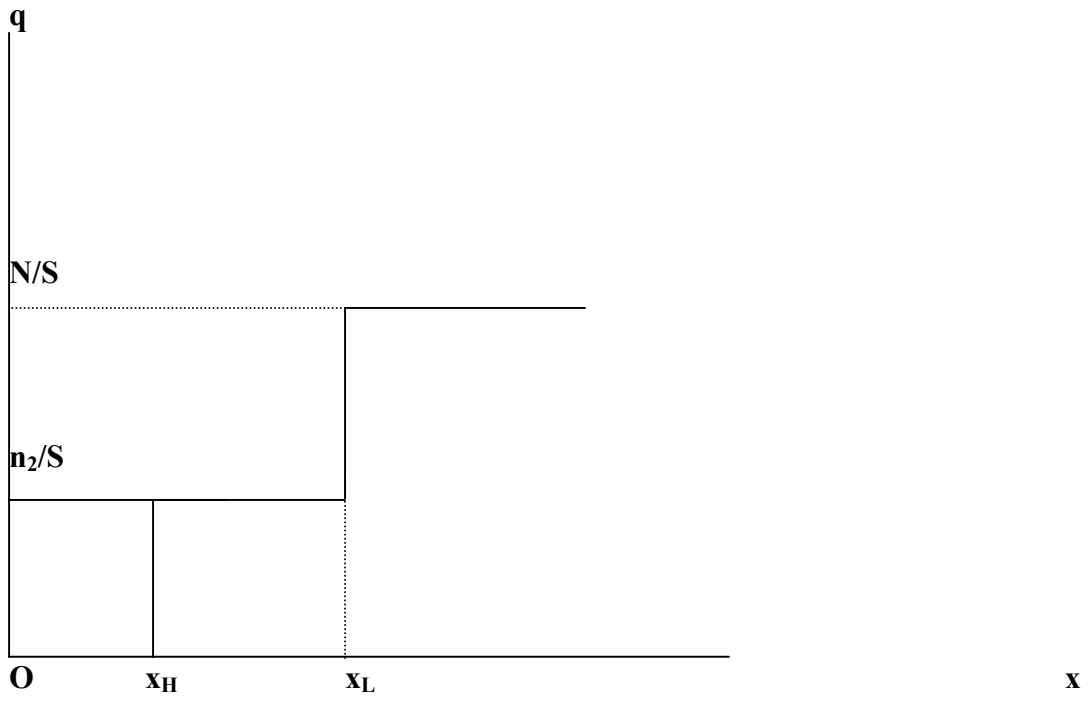


**Fig 1**

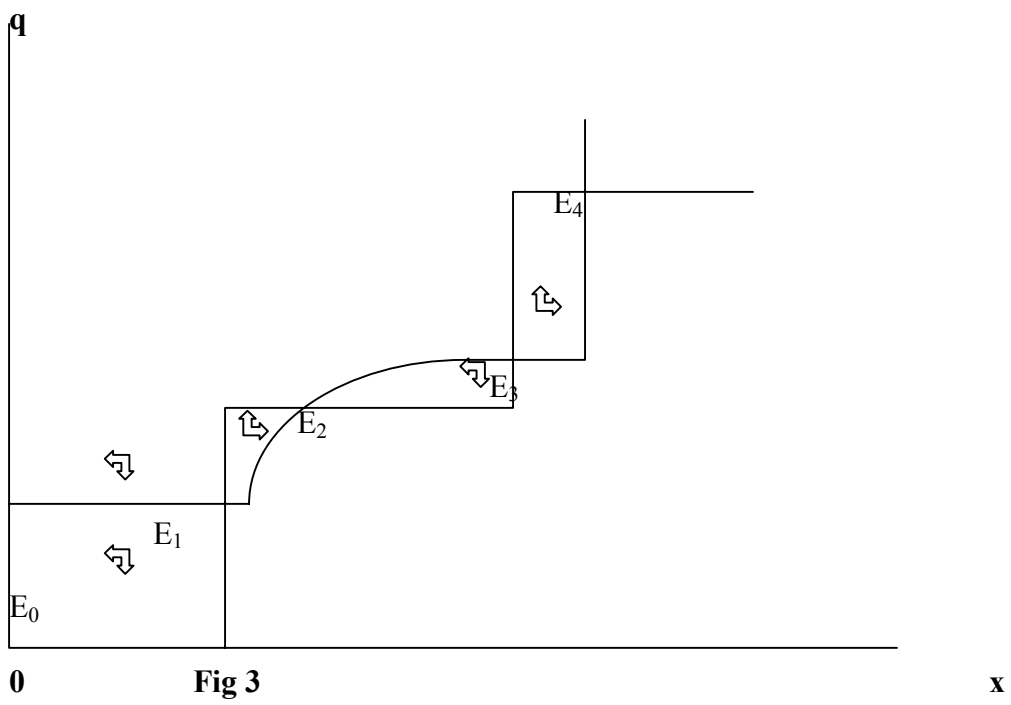
$q_h$

$q_l$

$q$



**Fig 2**



**Fig 3**