THE MARKET FOR TOMATOES
MARKET BREAKDOWN IN THE HIGH TECHNOLOGY ECONOMY

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PURPOSE
IN his seminal paper in 1970, Akerlof received the Nobel Prize in Economics for developing the model that he applied to the lemons market. The purpose of this paper is to generalize the findings of Akerlof to other perishable goods. In doing so, the market for tomatoes is chosen as the proxy for perishable goods.

Design/Methodology/Approach: *This paper employed various equilibria models such as the Fair Pricing Equilibrium model and the Separating Underpricing Equilibrium model. In addition, the paper also employed Pooling Equilibrium and Market Breakdown Equilibrium. In summary, the paper employed a variety of equilibrium models that are commonly used in economics and game theory studies.*

Findings: *We demonstrate that the model proposed by Akerlof over four decades ago has wider applicability than simply lemons. We demonstrate that such a model has particular relevance to the sale of high technology offerings and to the sale of rapid obsolescence goods or other time sensitive goods, such as tomatoes, under conditions of asymmetric information.*

Research Limitations/Implications: *One of the key limitations of this study is the fact that the model applied consisted of a set of equilibria models. In economics, there are other more sophisticated models available to empirically investigate this topic. Hence, the methodology could have been more empirically rigorous. Furthermore, we could have considered a basket of perishable goods as opposed to focusing exclusively on the market for tomatoes. In terms of implications, the study has wide reaching practical implications for areas such as IPOs, SEOs, and even the subprime mortgage market.*

Practical Implications: *This study has far reaching implications that go well beyond the market for tomatoes. The results can also be applied to the Initial Public Offering (IPO) market. This paper has demonstrated that market breakdown is the cause of the disappearance of best efforts offerings in the IPO market. In the case of IPOs, the evidence of market breakdown and the remedy for market breakdown is underwriting, where the investment banker essentially sets the price and certifies that the price is appropriate for its investor clients, guaranteeing full subscription to the offering. The study has demonstrated that venture capital firms are a remedy for the market breakdown in the IPO market. The study also proposes remedies for market breakdown in seasoned equity offerings (SEOs) and the subprime mortgage market. In summary, the study demonstrates that the model proposed has wide reaching practical implications.*

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Originality/Value: *Not since Akerlof's seminal work in 1970 has such a paper been attempted. Akerlof's paper was rather narrowly focused on the market for lemons. This paper used tomatoes, as opposed to lemons, as the proxy for perishable goods. This paper has also demonstrated the far reaching implications of the equilibria models employed. No paper to date has applied equilibria models to the sale of perishable goods while simultaneously attempting to show the far reaching practical implications of the model.*

Key Words: *Tomatoes, Game Theory, Pooling Equilibrium, Nash Equilibria, Fair Pricing Equilibrium, Separating Underpricing Equilibrium and Market Breakdown Equilibrium.*

The Model: A Sale of Perishable Goods with Random Observation and Right of Refusal

Consider the case of the sale of perishable goods, such as tomatoes, with random observation and with the right of refusal. The seller sets a price for his goods, after which the buyer either accepts or rejects the offer. Next, the buyer attempts to observe the quality of the goods to be delivered. Sometimes, observation will be successful, and sometimes not. In either case, the buyer has a chance to reconsider his bargain, prior to delivery. If, for instance, he is able to observe the goods, and if he ascertains that the value of the goods is less than the agreed price, he may rescind his purchase. Or, the buyer may get "cold feet", in certain circumstances, when observation is not possible, and he may rescind his purchase without observing the quality of the goods in question. But, an essential feature of this model is the perishability of the goods in question. This feature was first introduced by Cho (1993), and was later adapted by Fogelberg (1995), and Fogelberg and Griffith (2005). In the event that the buyer refuses to purchase the goods, or in the event that the buyer agrees to purchase the goods and then later rescinds his purchase, the seller's goods perish.

Without loss of generality, let the price of high quality tomatoes be 1 dollar and the price of low-quality tomatoes be λ dollars. Let the probability of high quality tomatoes be α and let the probability of observation be π., and let it be stipulated that all players are risk-neutral. For simplicity, we will confine ourselves to pure strategy Nash equilibria which meet the intuitive criterion of Cho and Kreps (1987).

Fair Pricing Equilibrium

In a fair pricing equilibrium, the seller of high quality tomatoes sets a price of 1 dollar, and the seller of low quality tomatoes sets a price of λ. If λ is high enough, the seller of low quality tomatoes has no incentive to cheat, since he is better off taking λ, instead of gambling that observation will not be possible prior to delivery.

A fair pricing equilibrium will occur when the buyer will never get "cold feet", even when observation is impossible, since only high quality sellers would choose a price of 1 dollar.

$$(1-\pi) \leq \lambda \tag{1}$$

Separating-underpricing equilibrium

Next, we come to the separating-underpricing equilibrium. In this equilibrium, λ is not large enough to discourage the seller of low quality tomatoes from cheating, and so the seller of high quality tomatoes must reduce his price to the point where the seller of low quality tomatoes no longer has an incentive to cheat. The highest price that satisfies this constraint is:

$$P_S = \frac{\lambda}{(1-\pi)} \tag{2}$$

This represents the "best" price that the high quality seller can charge, without giving the low quality seller an incentive to cheat, and thus it corresponds to the intuitive criterion of Cho and Krebs (1987).

The separating-underpricing equilibrium is similar to the fair pricing equilibrium, except for the fact that the seller of high quality tomatoes is forced to discount his price. As in the fair pricing equilibrium, the buyer will never get "cold feet", even if observation is impossible.

A separating-underpricing equilibrium will occur whenever the separating price P_S is greater than the pooling price P_P, where

$$P_P = \alpha + (1-\alpha)\lambda \tag{3}$$

and where the high quality seller is better off taking the price P_S than he would be, setting a price of 1 dollar and gambling that a successful observation would take place. Thus, a separating-underpricing equilibrium will take place when

$$\max\{\pi, P_P\} \le P_S \le 1 \tag{4}$$

$$\text{or when } \max\left\{\pi(1-\pi), \frac{\alpha(1-\pi)}{1-(1-\alpha)(1-\pi)}\right\} \le \lambda \le (1-\pi) \tag{5}$$

The "best" separating underpricing equilibrium is supported by the beliefs that all goods priced at P_S are high quality goods and that goods offered at any other price are low quality with value λ. However, if observation occurs and if the goods are observed to be of some lower value, the purchase offer is withdrawn without renegotiation of the price. Further, since the goods are time sensitive, they will perish before another sale can be arranged.

The fair pricing and separating-underpricing equilibria are collectively referred to as separating equilibria, because players can draw inferences about the players' types by the strategy which they follow. In other words, by adopting a certain strategy, players signal their type, or endowment characteristics. Of course, separating equilibria and signaling were the centerpiece of Spence's (1973) education game, and the Rothschild and Stiglitz (1976) insurance game. In both of these studies, high quality players were able to distinguish themselves by making observable decisions. In the case of the Spence education game, job applicants are able to distinguish themselves by completing a college curriculum. In the Rothschild and Stiglitz insurance game, conscientious drivers are able to distinguish themselves to the insurance company by choosing an insurance policy with a high deductible.

Pooling Equilibrium

Sometimes, the value of low quality tomatoes λ is so low that the low quality seller has very little to lose by cheating. Of course, if observation is successful, his sale will fall through. If that happens, his goods will perish. Nevertheless, he is still better off gambling that observation will not take place. In the pooling equilibrium, it is no longer optimal for the seller of high quality tomatoes to prevent cheating, since he is better off allowing for pooling. In the pooling market, the seller can make no credible claim of quality, and so the maximum price, the buyer will be willing to pay, without observation, is

$$P_P = \alpha + (1-\alpha)\lambda \tag{6}$$

and the buyer will withdraw his purchase offer, in the event that observation is successful and the goods are deemed to be of low quality.

The pooling equilibrium will occur when

$$\max\{\pi, P_S\} \le P_P \le 1 \tag{7}$$

$$\text{or when } \frac{\pi-\alpha}{1-\alpha} \le \lambda \le \frac{\alpha(1-\pi)}{1-(1-\alpha)(1-\pi)} \tag{8}$$

The pooling equilibrium is supported by the beliefs that all goods are pooled goods of average value P_P, unless they are observed to have some other value. However, if observation occurs and if the goods are observed to be of some lower value, the purchase offer is withdrawn without renegotiation of the price. Further, since the goods are time sensitive, they will perish before another sale can be arranged.

Thus, the pooling equilibrium results in the deadweight loss of

$$DWL = (1-\alpha)\,\pi\,\lambda \tag{9}$$

Market breakdown equilibrium

Finally, we get to the market breakdown equilibrium. Market breakdown was first identified by Akerlof (1970), in his study of the market for "lemons", or low quality used cars. In Akerlof's market breakdown equilibrium, the high quality sellers have an incentive to boycott the used car market altogether, and buyers assume that all cars sold through that market are of low quality. The paradox is that this is still a Nash equilibrium, since no player has an incentive to unilaterally change his strategy, given the strategies of the other players.

Our model is a little different from that of Akerlof (1970). In our model, with perishable goods, a market breakdown occurs when the high quality seller has an incentive to defect from the pooling equilibrium or from the separating-underpricing equilibrium and to set a price of 1 dollar and gamble that observation will take place.

Hence, the resulting equilibrium is where the buyer announces that he will treat all goods as low quality unless observation occurs and unless the goods are observed to be of high quality. In this equilibrium, seller of high valued goods adopts a price of one dollar, and the seller of low quality goods adopts a price of λ, but all high quality goods perish, unless observation occurs.

Our market breakdown equilibrium occurs when

$$\max\left\{P_P, P_S\right\} < \pi \le 1 \tag{10}$$

$$\text{or when } \lambda < \min\left\{\pi(1-\pi), \frac{\pi-\alpha}{1-\alpha}\right\} \tag{11}$$

In this equilibrium all high quality goods perish, unless they are observed to be of high quality. Thus, the market breakdown equilibrium results in a deadweight loss of

$$DWL = \alpha(1-\pi) \tag{12}$$

Numerical Example

To illustrate the various equilibria, we present the case where $\alpha = 0.5$ and $\pi = 0.6$. When λ is set at 0.75, a fair pricing equilbrium results. The low quality seller is better off with a sure 0.75 dollars than he is with a 0.40 chance of getting 1 dollar.

When λ is reduced to 0.30, full fair pricing is no longer possible, and the high quality seller is forced to discount his price to 0.75 in order to discourage cheating. In this separating-underpricing equilibrium, high quality tomatoes sell for 0.75 and low quality tomatoes sell for 0.30, since a 40 percent chance of getting 0.75 is no better than a sure 0.30. Further, in this market no buyer gets "cold feet", in the event that observation is impossible.

When is reduced to 0.22, it is no longer optimal for the high quality seller to prevent cheating. Of course, he could prevent cheating by adopting a price of 0.55, but it is no longer optimal to do so, since

he is better off adopting a price of 0.61 and allowing for pooling with the sellers of low quality tomatoes. In this pooling equilibrium, no buyer gets "cold feet", in the event that observation does not occur, but when observation occurs and when the buyer sees that the quality is low, he will withdraw his purchase offer. In this market 60 percent of low quality tomatoes are observed, their purchase offers are withdrawn, and they spoil.

When λ is reduced to 0.16, a true market breakdown results. At this point, the pooling price would be 0.58, but the high quality seller is better off gambling that observation will occur, since a 0.60 chance of getting 1 dollar is better than a sure 0.58. In this market, the buyer announces that he will treat all tomatoes as low quality, unless observation takes place and unless the tomatoes are observed to be of high quality. In this market, the seller with low quality tomatoes adopts a price of 0.16 and the seller with high quality tomatoes adopts a price of 1.00, and 40 percent of all high quality tomatoes (where observation has not taken place) will end up spoiling. In every case where observation is not possible, the seller gets "cold feet", and rescinds his purchase offer.

Differentiating between the Pooling Equilibrium and Market Breakdown

At this point, we need to differentiate between the pooling equilibrium and true market breakdown. To the casual observer, it would seem that a high percentage of low quality tomatoes, and a high degree of spoilage would constitute a market breakdown, but that is not what our model indicates. A high degree of spoilage can also occur in the pooling equilibrium when, upon observation, the buyer sees that the goods are of low quality and rescinds his purchase offer. True market breakdown, of the sort first identified by Akerlof (1970), occurs when high quality goods perish because of a failure to achieve observation.

What causes market breakdown?

If we define the critical level of λ as follows

$$\lambda^* = \min\left\{\pi(1-\pi), \frac{\pi-\alpha}{1-\alpha}\right\} \tag{13}$$

we can rewrite as $\lambda^* = \phi\left\{\pi(1-\pi)\right\} + (1-\phi)\left\{\frac{\pi-\alpha}{1-\alpha}\right\}$ (14)

where ϕ is a dummy variable taking on the values of 0 or 1 respectively,

where $\phi = 0$ when $\pi(1-\pi) \geq \frac{\pi-\alpha}{1-\alpha}$ (15a)

and $\phi = 1$ when $\pi(1-\pi) \leq \frac{\pi-\alpha}{1-\alpha}$ (15b)

Taking a partial derivative with respect to π (the probability with which observation takes place) yields the following partial

$$\frac{\partial \lambda^*}{\partial \pi} = \phi(1-2\pi) + (1-\phi)\frac{1-\alpha}{(1-\alpha)^2} \tag{16}$$

which has an indeterminate sign; and taking a partial derivative with respect to α (the percentage of high quality goods) yields the following partial:

$$\frac{\partial \lambda^*}{\partial \alpha} = \phi(0) - (1-\phi)\left\{\frac{1-\alpha}{(1-\alpha)^2}\right\} \leq 0 \qquad (17)$$

which is either 0 or negative. From this, we can conclude that a high percentage of low quality goods may cause a market breakdown and that a large spread between the high and low values (1-λ) may also cause a market breakdown. This latter condition explains why market breakdown may become more common as emerging technologies become harder to value.

The Disappearance of Best Efforts Initial Public Offerings

In the last ten years, we have seen a drastic decline in the number of best efforts initial public offerings. Since a bulk of new offerings involve firms with new technologies, and since the rapid obsolescence of new technologies, increased competition among technology firms, and weakened protection for intellectual property rights has made it increasingly difficult to place a value on such firms, it is easy to understand why market breakdown has occurred in the best efforts IPO market.

Certification as Remedy for Market Breakdown in the IPO Market

Back in the days of the 'hot' market for best efforts offerings, there arose dispute over the causes for the underpricing of best efforts offerings. Some, such as Allen and Faulhaber (1989) and Cho (1993) hypothesized that underpricing resulted from signaling in a separating underpricing equilibrium. Others, such as Levis (1990) hypothesized that underpricing was compensation for a "winners curse", in a pooling equilibrium. Fogelberg (1995) provided additional evidence in support of the "winners curse" hypothesis. But of course, the question is now moot, since best efforts IPOs have virtually disappeared.

It now appears that market breakdown is the cause of the disappearance of best efforts offerings, giving credence to the certification hypothesis of Booth and Smith (1986), Viscusi (1978), and others. As we contend, certification is now the most common remedy to market breakdown. Not only is certification a remedy for market breakdown, but certification is also an evidence of market breakdown in the uncertified market. In the case of initial public offerings, the evidence of market breakdown and the remedy for market breakdown is underwriting, where the investment banker essentially sets the price and certifies that the price is appropriate for its investor clients, guaranteeing full subscription to the offering. While certification does not eliminate all uncertainty regarding valuation, it does reduce the degree of uncertainty below levels which would otherwise result in market failure. Studies which promote the certification function of intermediaries include Booth and Smith (1986), Viscusi (1978), and others.

Venture Capital as Remedy for Market Breakdown in the IPO Market

In other cases, venture capital has begun to overtake initial public offerings as a source of start-up capital for firms with emerging technology, following Admati and Pfleiderer (1994) and Lerner (1994). Often, these venture capital firms that are closely held venture capital firms specialized in a particular technology sector. While these venture capital firms are somewhat limited in the amount of funding which they are able to provide, it is generally enough to meet the emerging technology firm's initial funding requirements, until a second round of financing can be arranged.

R and D Mergers as Remedy for Market Breakdown in the SEO Market

Not only there is market breakdown on the IPO market for individual equity offerings of firms with emerging technology, but there is market breakdown in the market for seasoned equity offerings (SEO) as well. As Fogelberg and Griffith (2005) have documented, firms in the high technology sector traditionally seek merger with established technology companies in order to secure the additional

funding needed so that they can complete their research. As predicted, these mergers traditionally take the form of stock for cash transactions, which provides the necessary funding to complete the research.

In the high technology sector such as pharaceuticals, additional funding for research comes from other technology firms with the capability of evaluating the quality of the ongoing research. The net result of this type of funding is that the bulk of research in high technology sectors is outsourced to small start-up R and D firms.

Bundling as Remedy for Market Breakdown in the Subprime Mortgage Market

We do not normally think of mortgage securities as obsolescent, or time sensitive, but in a real sense a mortgage which has been offered and subsequently rejected on the mortgage market becomes a "tainted asset", which is no longer marketable at standard rates. Thus, it is properly characterized as a "time sensitive" asset. Further, it has become increasingly difficult to place a value on individual mortgages in the subprime mortgage market because of the heightened uncertainty regarding the value of the underlying property or soundness of the mortgagor.

Thus, the bundling of many mortgages together in a single mortgage security serves as a remedy for market breakdown in two ways. First, the bundling serves to reduce the adverse selection problem. Second, the bundling of many mortgage assets into a single mortgage security serves to reduce the range between high and low values (1-*l*), since valuation is done on an average, rather than individual basis.

Increasing Role for Financial Intermediation in the High Technology Economy as Remedy for Market Breakdown

Throughout history, market breakdown has given rise to financial intermediaries and financial services. The market breakdown in the market for individual loans gave rise to commercial banks. The market breakdown in initial public offerings gave rise to investment bankers. Today, various market breakdowns have resulted in an entire spectrum of financial services, from the geologists who provide feasibility studies for oil and gas drilling partnerships, to the commercial banks that provide gap financing and super gap financing for motion picture partnerships. We anticipate that certification and financial intermediation will continue to provide a critical role in providing funding for the high technology economy.

Conclusions and Recommendations

This study proposes a more general game theory model in which the lemons market, or market breakdown equilibrium of Akerlof (1970), appears as a special case. The research shows that the lemons market, or market breakdown equilibrium, becomes increasingly common in the high technology economy where the valuation of new technologies becomes increasingly difficult. A model has been proposed for the sale of perishable goods (using tomatoes as a proxy) with random observation where the buyer has the right to withdraw his purchase offer. Researchers also demonstrate that such a model has particular relevance to the sale of high technology offerings and to the sale of time sensitive goods under conditions of asymmetric information. It focuses upon the market breakdown equilibrium in order to explain such phenomena as the disappearance of best efforts IPOs, to explain the breakdown in the subprime mortgage market, and to explain why particular solutions to the lemons market problem will emerge in a high technology economy. This paper has wide reaching implications that go beyond simply the market for lemons and tomatoes. The various equilibria models proposed in this paper has implications for the IPO market, the SEO market and even the subprime mortgage market.

Future Areas of Research

As we conclude this paper, we would like to suggest some potential extensions to this study as avenues for future research. This study suggested a model that may be applicable to perishable goods using tomatoes as a proxy. Given the proliferation of applicable technology, which makes it easier to track

inventory and change prices, future studies might want to investigate the usage of dynamic pricing strategies by sellers of perishable goods.

Another potential avenue for future research lies in further investigation of the so called consumer factor which was first investigated by Ge and Zhang (2011). They proposed that marginal value is a decreasing function of capacity and an increasing function of the consumer factor. There are numerous other avenues for research in the field of considering the consumer factor in determining pricing strategy as a function of the regions where the perishable goods are marketed.

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