Decision Making Under Conditions of Turbulence and Uncertainty: The Case of the Kinked Demand Curve

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A broad spectrum of economists has addressed the implications of non-marginal change for mainstream economic theory. Gray (1986) argues that mainstream theory is applicable to slowly-evolving economies which tend toward equilibrium. He argues that these models are relevant to certain "tranquil" periods of history. At other times, however, the macro economy is "turbulent," that is, subject to severe shocks and increasing uncertainty. These periods of turbulence may represent transitions from one tranquil period to another. Under turbulent conditions models involving slow, marginal changes which postulate low-cost attainment of equilibrium are inadequate. When the economy is in a period of punctuated complementary models are needed.

So far economists have merely recognized the problem of turbulent periods vis à vis standard theory. Little has been done to develop testable hypotheses in order rigorously to characterize economies under turbulent conditions. An approach that has the potential for such analytical rigor has been proposed by Heiner (1983, 1985). Building on the work of H. Simon (1955) and others, he develops a theory of behavior under conditions of pure uncertainty which may be used to examine economic behavior under turbulent conditions. Briefly, Heiner argues that pure uncertainty leads to rigid behavioral rules due to the difficulty of distinguishing preferred from less preferred behavior. According to Heiner:

Such uncertainty requires behavior to be governed by mechanisms that restrict the flexibility to choose potential actions, or which produce a selective slowness to information that might prompt particular actions to be chosen. These mechanisms simplify behavior to less-complex patterns, which are easier for an observer to recognize and predict. In the special case of no uncertainty, the behavior of perfectly informed, fully optimizing agents responding without complete flexibility to every perturbation in their environment would not produce easily recognizable patterns, but rather would be extremely difficult to predict. Thus, it is in the limits to maximizing that we will find the origin of predictable behavior. [Heiner 1983, p. 561]

Heiner's insight is that increasing uncertainty leads to increasingly predictable behavior, that is, increasingly inflexible rules of choice. Uncertainty may arise either from within or from outside the economic agent. The agent may have difficulty in evaluating information or the validity of the information itself may be uncertain. Heiner refers to this as a competence-

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difficulty (C-D) gap. The concept may be used to construct a "reliability condition" to determine when the flexibility of allowing the selection of some new action is likely to be permitted given the existence of pure uncertainty. Using Heiner's notation we have the inequality,

\[ r(U) \cdot w(U) = 1 - r(e) \cdot w(e) \]

Uncertainty (U) is negatively related to an agent's perceptual abilities and positively related to the complexity and instability of the environment (e). The reliability ratio \( r(U) \) (w(U)), given the probability of correctly responding under the "right" environmental circumstances relative to the probability of incorrectly responding under the "wrong" circumstances. In order to change a behavior pattern the reliability ratio must be greater than the tolerance limit, given by the right hand side of the inequality above. The gains \( g(e) \) multiplied by the probability of right conditions occurring \( w(e) \) must accumulate faster than the losses \( l(e) \) multiplied by the probability of wrong conditions occurring, \( 1 - w(e) \).

Following Heiner, some important implications of this formulation are:

1. The rarer the occurrence of right circumstances, the more reliable an agent must be in selecting an action. Thus, rules generating behavior change under uncertainty apply only to likely situations.
2. Selection processes based on the reliability condition will not approximate optimizing behavior. Even from the point of view of constrained optimization, non-maximizing behavior may persist over time.
3. The greater the degree of uncertainty the more predictable behavior will be. This is the most far-reaching conclusion of Heiner's work: "greater uncertainty will cause rule-governed behavior to exhibit increasingly predictable regularities, so that uncertainty becomes the basic source of predictable behavior." [Heiner 1983, p. 570]

Heiner's analysis, we believe, offers a way to incorporate truth uncertainty into economic analysis and in particular to examine some of the behavioral implications of periods of turbulence, periods when pure uncertainty may dominate economic decision-making. Such an analysis does have precedents in economic theory. The above implications of the reliability ratio fit precisely the description of oligopoly behavior given by the well-known kinked demand curve. That model describes oligopoly as being characterized by a great deal of uncertainty due to a high degree of interdependence among a few firms. Rigid prices arise because of this uncertainty, so that a range of cost and demand conditions may be associated with a particular price. Furthermore, in a dynamic formulation of the kinked demand curve model one would expect the time path of prices to be characterized by stability over a relatively long period, then by a rapid move to a new stable situation. The kinked demand model, then, has the potential to link the notion of uncertainty and rigid behavior to that of punctuated equilibrium.

I. THE KINKED DEMAND CURVE

The kinked demand curve was formulated by Sweezy in 1939 (a similar explanation of oligopoly was given that same year by Hall and Hitch) to explain rigid prices in markets characterized by oligopoly. This model, in spite of its acknowledged deficiencies as a dynamic explanation of how prices are formed, has become a standard part of almost every modern microeconomic text. The kink in the oligopolist's demand curve results from the tendency of such producers to match any price decreases by rivals and the tendency not to match price increases. The kink is associated with a discontinuity in the marginal revenue curve below the kink. The marginal revenue curve is vertical directly under the kink so that there may be a range in which marginal costs may vary without having an effect on price or output.

Considering the importance given to the kinked demand curve in microeconomic texts, and the controversy surrounding the theory, there have been surprisingly few studies testing for its existence. Separate studies by Stigler (1947), J. Simon (1969), Prineaux and Bonnail (1974), and Prineaux and Smith (1976) reject the theory. A recent study by Carlton (1986), using Stigler's data, gives support to the theory. There are problems, however, with most of these studies which make their results inconclusive. Stigler, for example, compared price rigidity in oligopolistic industries relative to those characterized by monopolies. No significant difference in the number of price changes were found and on this Stigler rejected the kinked demand curve hypothesis. Problems with this study include a very small sample size (only two monopolies were included) and the fact that the industries considered actually represent a continuum of concentration between oligopoly and monopoly (for example, steel, automobiles, and aluminum) (see Prineaux and Bonnail for further discussion of Stigler's study). J. Simon (1969) used a simple procedure of counting price changes of magazine advertising rates. He classified magazines as "monopolistic" or "competitive" then compares the mean number of changes for the two groups, and concludes that there is no difference between them. His arbitrary classification, small sample size, and lack of statistical testing make his conclusions questionable. In fact, to the extent that the magazine industry fits the definition of oligopoly, his statement that his data "shows a lack of flexibility in business advertising rates generally," supports the kinked demand curve hypothesis.

The Stigler and J. Simon studies, as well as those by Prineaux and Smith, and Prineaux and Bonnail argue against the existence of the kinked demand curve because the number of price changes during a particular period of time does not seem to be very different between oligopoly and other types of market organization. In our framework, examining the time pattern as well as the frequency of price changes under conditions of oligopoly is also important. The raw number of price changes may in fact be similar in oligopoly and perfect competition. Under conditions of concentration, however, these changes should be clustered in time and should punctuate relatively long periods of no change. Carlton (1986) finds frequent small price changes in markets characterized by oligopoly as well as evidence for price stickiness. During periods of turbulence there may in fact be more price changes as firms seek, through trial and error, to establish a new equilibrium in the industry. In the framework we are using, all concentrated market structures, oligopoly, duopoly, and monopoly, are characterized by a high degree of uncertainty with respect to market price signals; oligopoly and duopoly for reasons of interdependence discussed above, and monopoly because of the lack of price signals to and from similar firms. Because price signals are the basic source of information in a competitive economy, information needed by monopolists to judge their own situation is lacking. A meaningful test should be between industries characterized by competition and those characterized by significant concentration. Prineaux and Bonnail (1974, p. 859), in their study of electric utility firms, conclude that "oligopolists changed prices more often than monopolists and there was a marked tendency to follow a competitor's price increase." They assert that both these outcomes are consistent with the kinked demand curve theory. In fact, both these outcomes are consistent with the theory if viewed in terms of the Heiner framework. Monopolist's prices should be more stable than those of oligopolists because of more uncertainty due to the lack of any market specific price signals in monopoly industries. Also, Prineaux and
Bomblis's finding that oligopolists change their prices together, when those prices change, does not preclude the existence of kinks, and is consistent with an uncertainty-based explanation of such price changes. Once pressures for a price change build up the switch from one stable equilibrium to another should be rapid and should involve all sellers together.

II. AN EXPLANATION OF OLIGOPOLY BEHAVIOR

In our analysis below, we assume that the firm is operating in a concentrated market. It encounters uncertainty due to the interdependence of its own pricing decisions and those of its rivals. It is receiving signals from the market in the form of current relative price changes. Its decision problem is to choose which set of actions to adopt in response to those signals so that it can remain on the long-run profit maximizing path. According to neoclassical theory any signal (any new information) will affect a reconsideration of contingency plans and will lead to a change in plans if a new set of actions can be found which will increase expected profits. This is not the case in Heiner's framework. Some actions which would lead to higher expected profits will not be adopted if expected gains do not satisfy the reliability ratio. Empirically, this means that firms will not respond to all relative price changes in the predicted manner. This is precisely the reason for the kink in the kinked demand curve.

The position and stability of the kink is a reflection of patterns of choice in oligopoly markets. The decision process involved may be decomposed into two stages. Signals from the environment provide observable information about the true state, then individual firms use this information to make price and output decisions (Heiner 1983, 1985). Uncertainty may arise from the environment in the form of confusing or contradictory signals; for example, widely fluctuating input prices or price change in both directions by rivals. One would also expect that a larger degree of concentration in an industry would be associated with greater uncertainty because of increasing feedback effects of price and output decisions. One would expect prices to be "sticky" around a given kink; there should be a corridor within which changes in the economic environment will not affect prices. During normal periods prices should remain within a fairly narrow range. During turbulent periods, however, external conditions change so much that the corridor is breached and significant price changes occur until a new stable situation is reached. Over time, then, the pattern of price changes will appear as in figure 1 below. It should be noted that the pattern through time need not take the form of a staircase of equal rises. In fact, the magnitude of the rises and the spacing of the steps will almost certainly be unequal.

The two main characteristics implied by the above diagram are (1) the average duration of a price "event" will be longer in oligopoly markets, and (2) when price changes do occur they will be larger.

In our model we assume the firm is a profit maximizer. It is interested in determining the future state of cost and demand conditions at time t + 1. These states we label s ∈ S. The firm has a repertoire of actions, a ∈ A. A subset of these actions will maximize the firm's profit given the occurrence of a in state s. We make the strong assumption that once the agent decides what state will hold, no mistakes are made in choosing the action. The agent decides on the possible configuration of the states based on the market information available to it through current transactions. The decision making process goes as follows. At time t the firm has only more or less subjective guesses as to the probability of future states. First decisions are made when first quantities are offered. Quantity changes generate information which may be used to update subjective prior information. To do this the firm uses Heiner's reliability ratio and picks the s with the highest reliability. According to the firm's belief, a is predetermined and a is selected on that basis. Since no mistakes are made in choosing s, if the actions do not have the expected results, the firm lowers its estimate of the reliability of the incoming information. As time passes, with no change in s, the firm obtains a more reliable probability distribution of information concerning s. At a first approximation we assume that the firm is interested only in future demand and cost conditions. These constitute the state s. Demand and cost changes are initiated by two types of events; extra-industry events and intra-industry events. Examples of extra-industry events are secular shifts in demand and costs and business cycle fluctuations. Intra-industry events are the actions of rivals, also cause shifts in demand and costs. These could, of course, be correlated if, for example, rival firms change their actions based on business cycle conditions as in various forms of limit pricing.

In a competitive industry market signals reflect only extra-industry events, because by assumption the large number of firms prevents rivals from making a perceptible difference in the market. Under the pure competition assumption uncertainty arises only from random demand shocks and periodic fluctuations. In a stable moving equilibrium where such events...
occur with predictable frequency, the probability distribution of information will be tightened as time passes. Eventually, the agent will reduce these distributions to a stable mean and variance and will be correct, on the average, in predicting the correct state. Under this type of structure uncertainty is reduced to risk and the neoclassical model is appropriate. If market information has a high reliability, the firm makes only marginal changes in its pricing and production decisions and change through time is gradual.

The environment facing an oligopolistic firm is quite different. In addition to extra-industry shocks the firm must also deal with intra-industry events which shift its own demand curve. In the absence of extra-market information about rival's strategy, the market signals are not enough to allow the firm to make a distinction between exogenous and endogenous demand shifts. However, such a distinction is necessary in order to make proper pricing and output decisions. Choosing a correct s depends on knowing the correct $s$. Confidence as to the source of demand shifts will lead to sub-optimal decision making. In an environment where firms are involved in multi-stage games, i.e. they change strategies frequently to gain an advantage, market signals lose much of their informational content. When information is uncertain, firms fall back on rigid behavioral rules. They are reluctant to change price based on market signals.

III. PRICE CHANGES IN OLIGOPOLY MARKETS

Our framework does not predict absolute price stickiness. It predicts that large price changes will be increasingly infrequent as we move up the scale from perfect competition to monopoly; prices in concentrated industries should be stable for longer time periods. The industries we have in mind are those where no clear price leader or cartels have emerged. In such industries, quantity changes will not immediately lead to price changes, as the reliability of information will be too low to justify the expected risk of losses due to such changes. However, if high demand repeats time after time, the likelihood of an extra-industry demand shift increases. If a quantity change is due to an action initiated by one of the firms, loss of sales as the other firms hold their prices low will force a return to the lower equilibrium price. Thus through time, enough observations will be accumulated to increase the reliability of information and the firm will become relatively certain that the quantity change is the result of a secular change in demand. After this "higher demand" state is selected, action of increasing the price to a new equilibrium will be undertaken.

The same scenario applies equally well for price changes due to changes in cost conditions. Suppose that the individual firm is unable to hire enough labor and raw materials at the going prices and is forced to pay higher rewards to factors of production. Under neoclassical conditions, higher costs should lead to a higher price equilibrium. This will not necessarily happen if the firm is uncertain whether all firms or just itself is subject to these higher cost conditions. For example, an increase in labor costs may reflect the firm's inability to bargain a favorable labor contract rather than an industry-wide labor shortage. If so increases in prices will be self-defeating. In any case, the decision to pass on changes in input costs to output prices will depend on the reliability of market information. The more competitive the industry, the more will price and cost information apply to all the firms in that industry. The more concentration, the more unreliable that information will be as a reflection of market conditions affecting rival firms. Input costs will tend to be passed on more quickly under competitive conditions than under conditions of market concentration.

IV. A FORMAL STATEMENT OF THE PROBLEM

The firm's decision problem, then, is to pick that action $s$ which will maximize the expected value of its in the state $S_i$ or to choose $s$ so that $E(a|S_i) > E(a|S_j)$ for all $i = j$.

Again, we make the assumption that there is no competence gap. If the agent receives enough correct information to decide what the actual state is, it will always pick the right action. Mistakes arise because market information is insufficient or unreliable. This being the case the reliability ratio becomes [Heiner 1985].

\[
\frac{\gamma}{\delta} = \frac{\int \mathcal{R}_i(x) \mathcal{W}_i}{\int \mathcal{R}_j(x) \mathcal{W}_j}
\]

where $x$ indexes "right time" with respect to information and $s$ indexes "right time" with respect to states. Thus,

\[
S_i = \{x, \mathcal{W}_i\}
\]

The next question is how the information about these states is generated? We assume that information signals, $X_i$, come solely from changes in quantities sold per time unit, which indicate shifts in demand. Also we have assumed that choosing a correct response depends only on whether demand shifts are due to exogenous events, $X_i$, or by the actions of rivals, $X_i$. Given this, we assume that information is generated by the following multivariate process:

\[
X_i = f(X_i, X_j)
\]

Given our assumptions, Heiner's reliability ratio (2) above can be expressed as,

\[
\frac{\gamma}{\delta} = \frac{\int \mathcal{R}_i(x) \mathcal{W}_i}{\int \mathcal{R}_j(x) \mathcal{W}_j}
\]

This ratio can be interpreted as the ratio of two likelihoods. The numerator is the likelihood that the change in quantity demanded signals an extra-industry shift in demand. The denominator is the likelihood that the change in the quantity demanded signals an intra-industry demand shift. Those likelihoods sum to 1, so $\gamma/\delta$ gives the relative probability of the two events. Since we have defined the information set as having only these two members, then $\mathcal{P}(X_i) = p$, given that $0 \leq p \leq 1$; then $\gamma/\delta = p/1-p$. Next compare this to the tolerance limit,

\[
\frac{p}{1-p} \geq \frac{\int \mathcal{R}_i(x) \mathcal{W}_i}{\int \mathcal{R}_j(x) \mathcal{W}_j}
\]

Two limiting cases of $\gamma/\delta$ are of special interest:

1. $p(X_i) = 0$. This is the case when the firm is situated in a competitive industry, where by definition competitors cannot change the level of industry demand. In this case $\gamma/\delta \rightarrow \infty$ and whenever $G(a) > L(a)$, the price change will be made.

2. $p(X_i) = 1$. This is the case if the economy is in a stationary equilibrium and the firm is in a concentrated, combative industry. In this case, $\gamma/\delta \rightarrow 0$. If this is the case, the firm will never change its price regardless of the change in quantity demanded.

It is important to note that the reliability ratio does not stay constant. Suppose that industry demand shifts exogenously ($X_i$ changes). In a dynamic setting the firm will observe only that there has been an increase in the quantity demanded. Initially, the reliability ratio
may not be high enough to induce the firm to change its price. However, after each period the firm will see that it is making a mistake by not changing its price. After each observation both likelihoods will be updated. Experience will increase \( \gamma \) and eventually it will be high enough to warrant a price change. One would expect that the longer it takes the firm to adjust its price the larger will be the required price change to restore the firm to its profit maximizing path.

V. AN EMPIRICAL TEST

The framework above leads to the prediction that the average duration of a particular price should increase with uncertainty. Since price uncertainty increases with concentration there should be a positive correlation between industry concentration and price stickiness. This is the relationship found by Carlton in a study of 32 very specific products using Siqgler and Kindahl’s original data for the period 1957 through 1966. These data were collected from buyers based on actual transaction prices. Insofar as possible these data were corrected for discounting and for changes in product specification. Carlton found a significant correlation between the concentration ratio and the duration of price rigidity. One shortcoming of Carlton’s study is that in the 1963 Census of Manufacturers, the one pertinent to the time period considered, only four-digit concentration ratios were published. Thus the correspondence between his five-digit price data and the concentration ratio used was not exact.

We tested the relationship between the concentration ratio and the duration of price rigidity using monthly five-digit data for the producer’s price index (PPI), published by the Bureau of Labor Statistics. BLS data have been criticized by Siqgler and others for inaccurately measuring transaction prices. In recent years, however, BLS has made substantial improvements in its data collection procedures. Every effort is now made to encourage companies to supply actual transaction prices at the time of shipment, rather than list prices. Using this data we were able to verify Carlton’s finding for the period 1976 through 1980. We used a random sample of 40 five-digit producer price indices matched with five-digit concentration ratios published in the 1977 Census of Manufacturers. The average duration of price rigidity is calculated as a simple average of the number of months a price remains unchanged. For example, for a monthly series of prices \( P_t \), the average duration would be two months: 

\[
\text{AVED} = \frac{1}{n} \sum_{t=1}^{n} (P_{t+1} - P_{t})
\]

The above estimate indicates that for every 10 percent increase in the concentration ratio prices remain rigid an extra 2.8 months.

A second prediction, discussed above, is that price changes, on average, should be larger under conditions of concentration. Prices remain unchanged relatively longer, as shown above, but when they change they have further to reach a new stable position. Using the above data we tested this hypothesis by regressing the average size of each price change for a given industry against that industry’s concentration ratio. These OLS results are:

\[
\text{AVECH} = 0.578 + 1.507 \text{CR4} \quad R^2 = 0.14
\]

APPENDIX

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<th>SIC Code</th>
<th>Description</th>
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<td>20924</td>
<td>Frozen packaged shellfish &amp; other seafood</td>
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<td>21110</td>
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<td>Spun polyester blends</td>
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<td>26217</td>
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<td>26552</td>
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<td>Synthetic organic medicinal chemicals</td>
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<td>33541</td>
<td>Extruded aluminum rod, bar, etc.</td>
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<tr>
<td>33552</td>
<td>Rolled aluminum rod, &amp; structural shapes</td>
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Aluminum alloy wire
Hand tools, saws, blades, saw accessories
Builder's hardware
Plumbing fixtures
Diesel engines
Harvesting machinery
Power cranes, draglines, shovels & parts
Oilfield and gasfield production machinery
Lashes
Welding and cutting apparatus
Chem. manf. industries machinery
Taper roller bearings
Duplicating machines
Pneumatic and hydraulic cylinders
Fractional horsepower motors
Integral h.p. motors and generators
Commercial and institutional electric lighting
Industrial type electric lighting fixtures
Transistors
Electronic connectors
Integrating instruments, electrical
Test equipment for electrical, radio, comm. circuits
Chemical fire extinguishing equipment.

BIBLIOGRAPHY