III. Market Structure and Innovation

This section focuses on the economics literature that relates market structure to innovation. In particular, it reviews economics literature that analyzes how market structure can affect innovation. It not only identifies factors that may cause innovation to increase in competitive markets, but also considers the possibility that large firms in concentrated markets may undertake more innovative efforts. In addition, it considers the possibility that innovation and concentration levels are jointly determined by fundamental characteristics of the market, such as technological opportunities. Both theoretical and empirical literature is surveyed as part of this review.

A. Competition and Potential Competition Can Increase Innovative Activity

Economists have constructed theoretical models that indicate that incentives associated with outperforming rivals can encourage competitive firms to innovate. In some cases, it is the lure of supra-normal returns that encourages competitive firms to innovate. In others, innovative activity is promoted by the possibility that rivals will take customers, threatening the firm’s long-run existence. In contrasts, firms that are insulated from competitive pressures may chose a “quiet life,” and not undertake aggressive R&D programs.

In early work analyzing how the incentive to innovate varies across market structures, Arrow (1962) presented models in which a monopolist’s incentive to innovate is always less than competitors’ incentive to innovate. In Arrow’s model, which ignores the difficulties of appropriating the information generated by innovative efforts, a monopolist takes into account pre-innovation profits and produces less output, which means that the monopolist will earn fewer incremental profits from process innovation.

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46 As Hicks commented, “the best of all monopoly profits is a quiet life,” which implies that insulation from competition may lead to inefficient production and higher costs. Hicks (1935), p. 8.

47 Arrow (1962) uses a model in which the innovator licenses all firms that wish to use a cost reducing innovation that pay a royalty. Once the royalty is paid, all firms engage in perfect competition.
Economists have expanded on this early work by studying the relationship between innovative activity and market structure in other game theoretic models. For example, using a completely symmetric, Cournot-duopoly, new product game, economists have shown that, in equilibrium, both firms undertake more R&D than they would in the absence of rivalry. Some economists argue that an uncooperative outcome to such games is particularly likely because competitors tend to overestimate their own R&D abilities and underestimate the capabilities of rivals. Cooperative behavior (which includes both tacit and explicit collusion) is also less likely when R&D involves secret competitive activity which complicates the detection and punishment of cheating on a collusive outcome. Moreover, it has also been shown that an increase in the number of symmetric rivals can accelerate R&D, at least to some point. However, if the number of rivals is too large, it may be that the returns from R&D that an individual firm can capture are viewed as too small to justify R&D (both because of the sharing of the rents among more firms and because the size of the rents that are to be shared are reduced due to increased price competition), causing firms to do no R&D.

Yi (1999) extended Arrow’s analysis to models that assume Cournot competition. He found that for process innovation, if the innovation is not drastic (i.e., results in lower costs such

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48 Game theoretic models are models that predict market outcomes based on assumptions about the competitive interactions of firms. These competitive interactions are modeled by making behavioral assumptions about the firm strategies and the market outcomes that result when particular combinations of strategies are selected.

49 The Cournot model is an economic game in which the players each assume that the other players will maintain the output levels they produced in the previous period. A Cournot-duopoly is a Cournot game with two competing firms (players).

50 A new product game is a game in which at least one player has the option of introducing a new product.

51 Equilibrium occurs when no market actor has an incentive to change its behavior given the actions of the other market actors.

52 Scherer & Ross (1990), p. 634.


54 Scherer & Ross (1990), p. 636.

55 Scherer & Ross (1990), pp. 636-637.
that the firm’s monopoly price is below the cost of incumbent firms), the benefit of a small process innovation decreases with the number of firms under certain conditions. Intuitively this is because the benefit of a process innovation is correlated with output of the firm, which declines as the number of firms increases. Since output increases with the lower price resulting from the innovation, it is also intuitive that the result depends on the elasticity of demand. For constant elasticity of demand, the benefit of a small innovation may increase or decrease with \( N \) [the number of firms] up to and including 3 firms, but will decrease with \( N \) thereafter. These results hold for innovations up to the size of “almost drastic.”56

Boone (2001) generalized the results to include a parametric measure of the intensity of competition with Bertrand57 and Cournot competition as special cases. Boone considers firms with differing costs. He also assumes that the number of firms is determined endogenously by the cost history and the intensity of competition. The model uses three firms located in a triangle. Intensity of competition is measured by the inverse of travel cost. Boone assumes that the value paid by the highest bidder is positively correlated with the speed of technological progress. The discount factor is assumed to be constant across firms. In his model, the intensity of competition determines whether the lowest cost firm will purchase the innovation and at what value. He finds that under his assumptions, in weakly competitive industries with a stream of small innovations, a small rise in competition may reduce the speed of technological progress. He also finds that if competition is intense and innovations lead to major changes in technology, small increases in competition may speed innovation because the leader is under pressure to innovate because a failure to innovative would cause the leader to lose its competitive advantage.

As is explained in more detail in Section II in the analysis of patent races, firms that perceive competition for technical opportunities may have a strong incentive to innovate. However, firms that see that they are behind in an innovation race may slow down their R&D

56 Yi (1999), p. 379. An innovation is defined to be drastic if the innovating firm’s monopoly price is below the other firms’ marginal costs.

57 Bertrand competition is an economic game in which competitors all assume that the other competitors will charge the same price that they charged in the previous period. It differs from Cournot competition because it focuses on prices as the competitive variable, rather than quantities (which Cournot competitors assume will not change between periods).
efforts since they perceive that there are fewer returns from such an effort.\textsuperscript{58}

Economists have shown that the threat of competition may lead to more innovation by incumbents, relative to potential entrants.\textsuperscript{59} For example, Gilbert and Newberry (1982) show that, under certain conditions, incumbents will have a greater marginal incentive to invest in R&D than will entrants, when entry is a serious threat. This encourages preemptive patenting leading to industries that tend to remain monopolized by the same firm. The monopolist will preemptively invest in R&D if the cost is less than the profits it would earn by preventing entry.\textsuperscript{60}

Extending the work of Gilbert and Newberry (1982), Reinganum (1983) assumes that the inventive process is stochastic rather than deterministic.\textsuperscript{61} As a result of this changed assumption, Reinganum finds that an incumbent will invest less on a given project than will a potential entrant. In the Reinganum model, the incumbent firm receives a flow of profits while it is in the process of innovating. The greater the investments that the firm makes in R&D, the sooner its existing product will be replaced and the shorter will be the period of time during which it receives the profit flow from its existing product. The incumbent effectively replaces its existing product with a more profitable product. Since an entrant profits from the results of its R&D, but has nothing in the market that will be displaced by the new product, the entrant has a greater marginal incentive to invest in R&D than does the incumbent.

Lin (1998) extends the Reinganum model using a two-stage game. Firms compete in the first stage, then engage in a patent race. Firms behave so as to “soften” rivals’ incentive for future R&D. The result is an equilibrium price that is higher than in the standard duopoly models and a slower pace of innovation than the standard duopoly equilibrium outcome. Coordination


\textsuperscript{59} For a discussion of this literature, see also Tirole (1994), pp. 394-399.

\textsuperscript{60} One key assumption in this work is that the date of an invention is a deterministic function of the time path of expenditures.

\textsuperscript{61} An inventive process that is “stochastic” has a random (uncertain) component to it. In contrast, a deterministic process is perfectly predictable given knowledge of the underlying behavioral relationships.
of R&D (e.g., through the formation of a joint venture by the competitors) eliminates the R&D threat and permits the standard duopoly outcome to be obtained. The results hold for both Cournot and Bertrand models. The welfare effects are ambiguous, depending on the degree of wasteful R&D in the patent race and the effect of the reduced product market price from cooperation.

Harris and Vickers (1985) extend the Gilbert and Newbery model by distinguishing two kinds of patent races. A “standard race” is one in which a price is awarded to the first player to reach the finishing line. An “asymmetrical race” it is also true that a prize is awarded if someone reaches the finishing line, but it is also true that one player loses something of value if one of his rivals reaches the finishing line (and as a result this player is content if nobody wins). Harris and Vickers model asymmetrical races, since they believe that this provides insights into patent races in which an incumbent firm’s principal, if not sole, concern is preventing potential rivals from entering his market. They find that in a model of an asymmetrical race the challenger is often deterred from making an effort to win the race because strategic interactions are such that incumbents would outdo any reasonable effort by the challenger. Moreover, to deter the challenger, the incumbent often does not need to complete the patent itself. On the other hand, there are some situations in which the challenger does proceed and cross the finishing line first. Nonetheless, they conclude that among the strategic advantages that an incumbent firm might enjoy in patent races (especially when the parties begin far from the finishing line) is the possibility that the incumbent will benefit from a result in which no one wins the patent race. Moreover, they suggest that this strategic advantage may underlie the persistence of market power in some markets.

Katz and Shapiro (1987) considered the possibility that a firm might benefit from its rival’s innovation. In their model, each firm compares the profits that it would earn assuming no innovation with the profits that it would earn should it be the innovator and, separately, with the profits it would earn if a competitor does the innovating. The authors note that when patents are

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63 Id., p. 477.
not perfect, and the innovation is not essential to survival, imitation might occur. If a firm can imitate its rival quickly, effectively, and at low cost, it may benefit from a discovery made by a competitor. Even when patents are so strong that imitation is impossible, licensing may allow a firm to profit from a rival’s innovation. For minor innovations, Katz and Shapiro find that the industry leader will typically be the innovator, whether or not imitation and licensing are feasible. In markets where patent protection is strong, they find that major innovations will be made by industry leaders. But if imitation is easy, the innovators will be smaller firms or entrants.

Boone (1998) notes that an individual company’s response to competitive pressure will depend on its own cost level relative to those of its opponents. As a result, the effects of competitive pressure on the innovation response of firms will differ across firms. Because of this, any study that tries to find a single innovation response for all firms in an industry will be flawed. An increase in competitive pressure may raise some firms’ incentives to innovate, but decrease those of other firms. Also, Boone shows that an increase in competitive pressure cannot increase incentives for both fundamental research and development at the industry level. In Boone’s model, an increase in competition cannot increase overall efficiency in the market and also increase the number of new products introduced into the market.64

Bonanno and Haworth (1996) examined two questions with regard to the effect of competition on innovation. First, they considered whether cost-reducing innovations are positively or negatively correlated with the intensity of competition. Second, they analyzed what factors might be important to a firm when deciding whether to engage in process (cost reducing) innovation or product (quality improving) innovation.

To address the first question, they considered two industries that were identical except that one has Cournot competition and the other had Bertrand competition. They assumed that the industry characterized by Cournot competition was less competitive, because this process leads to lower output and higher prices. The authors found that any given cost reduction increased profits more in the case of Cournot competition than in the case of Bertrand competition. Thus,

64 Boone (1998).
they concluded that there are cost-reducing innovations that would be pursued under Cournot that would not be pursued under the more competitive Bertrand scenario.

With respect to the second question, Bonanno and Haworth found that the degree of competition in a market does affect the choice between process and product innovation. A firm with a high quality product is more likely to go for product innovation if it is a Bertrand competitor, and process information if it is a Cournot competitor. In a Bertrand regime, a cost reduction has a negative strategic effect that leads to more competition so that the new equilibrium following process innovation would lower prices for both firms. Product innovation will lead to a price increase for the innovator, but might either increase or decrease the price of the other firm. A firm with a low quality product is more likely to go for process innovation if it is a Bertrand competitor, but will prefer product innovation if it is a Cournot competitor. Process innovation by the firm with a low-quality product has negative strategic effects, so the innovator and the competitor will both lower their prices. Product innovation by the firm with the low quality product would potentially have positive strategic effects, since it shifts the innovator’s reaction curve up.

B. **Innovation by Large Firms in Concentrated Markets**

The conclusion that competitive market structure will lead to dynamic efficiency has been challenged by a number of economists. Schumpeter (1942) is most often cited as the originator of the view that atomistic firms operating in competitive markets may not be as dynamically efficient as a larger firm operating in a more concentrated market. Specifically, Schumpeter concludes that “What we have got to accept is that it [the large-scale establishment or unit of control] has come to be the most powerful engine of progress and . . . long-run expansion of total output . . . through this strategy which looks so restrictive when viewed in the individual case and from the individual point of time.”

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65 The results are likely to be dependent on the particular models that were employed and may not be present in more general models.


Schumpeter’s argument has been interpreted in two slightly different ways. First, it could be that large firms are more innovative than smaller firms. Second, it could be that firms in concentrated industries undertake more innovation. While both theories may be consistent, there are differences and they have spawned somewhat different empirical tests of the “Schumpeter Hypothesis.”

Economists have developed a number of situations in which a large firm in a concentrated industry may have an incentive to invest more heavily in innovative activity than a smaller firm in a less concentrated industry. Some of these explanations are based on the premise that innovative activity is less costly for large firms. Other explanations are based on the belief that large firms may obtain more benefits from innovative efforts.

The principal basis for believing that large firms may have lower innovation costs is that there are significant economies of scale in the innovative process. Economies of scale in the innovation process may be generated in three ways. First, firms that undertake large amounts of R&D may be able to employ more specialized resources, reducing the marginal costs of innovation. Second, to the extent that innovation involves significant fixed costs, large scale firms will face smaller average total costs because they can average the fixed costs of their innovative effort over a greater level of output. Third, large firms may be able to support a larger portfolio of R&D efforts, increasing the likelihood that it will develop an improved product or process, which makes large-scale innovation efforts less risky.

The costs of innovative activity may also be smaller for large firms if the cost of investment capital is lower. As a result, some economists have hypothesized that large firms will undertake more innovation because they have access to inexpensive capital. In some cases, economists have argued that inexpensive capital is generated internally. Specifically, it is argued

68 The empirical literature is reviewed in Section III.C of this appendix.

69 Scherer & Ross (1990), p. 652.


71 Scherer & Ross (1990), p. 652.
that monopolistic profits are used to fund increased innovative activities. However, others have argued that large firms face lower capital costs in capital markets.

Economists have identified a number of factors that may increase the benefits of innovation to large firms in concentrated markets relative to smaller firms. First, large firms may obtain a larger total benefit from a process innovation that lowers production costs because a given percentage decline in costs will lead to greater cost savings when it is applied to a larger number of units of production. Second, a large firm may be more likely to benefit from an innovative effort because it is more likely to be diversified into a number of different products, which will increase the likelihood that a discovery will be applicable to one of its businesses. Third, large firms may be able to market new products more effectively, increasing the value of new product development to them, which encourages innovative activity.

C. Empirical Studies of the Relationship Between Market Concentration or Firm Size and Innovation.

As indicated above, Schumpeter (1942) led economists to two hypotheses: (1) Large firms are more likely to undertake innovation than small firms and (2) Higher levels of innovative activity are more likely to be observed in concentrated industries. This section considers the numerous empirical studies economists have done to test the two “Schumpeterian hypotheses.”

Summary data on R&D activity provides some support for Schumpeter’s hypotheses. Historically, large enterprises have performed a significant share of formal R&D (e.g., firms with

72 “One hypothesis is that profits accumulated through the exercise of monopoly power are a key source of funds to support costly and risky innovation.” Scherer & Ross (1990), p. 630.

73 Scherer & Ross (1990), p. 652.


75 “[A] monopoly may create superior incentives to invent [because] appropriability may be greater under monopoly than under competition.” Arrow (1962). See also, Scherer & Ross (1990), p. 659. However, there is limited empirical support for this proposition. See, e.g., Scott, (1988) and Cohen et al. (1987). However, larger firms do appear to do more basic R&D. See, e.g., Link & Long (1981).
more than 10,000 employees performed more than 80% of formal R&D). As Figure III shows, large firms continue to perform a significant share of the R&D. However, as Figure III also shows, smaller firms have performed an increasing share in recent years. Moreover, it has long been the case that small firms have performed a significant share of R&D. For example, Jewkes, Sawers, and Stillerman (1969) reviews seventy important Twentieth Century inventions and finds that only 24 had their origins in industrial research laboratories.

Figure III.
Large Firms Fund Most R&D,
But Small Firm R&D Has Been Increasing Faster

In an effort to test the two Schumpeterian hypotheses, economists have undertaken numerous statistical studies that have attempted to control for the myriad of factors that affect innovation besides firm size and market concentration. These studies have been reviewed by a number of economists. As a result, rather than reproducing an exhaustive review of the literature, this section identifies key findings, focusing on more recent findings. The discussion distinguishes between relationships between firm size and innovation and market concentration

76 Scherer & Ross (1990), p. 652.
77 Scherer & Ross (1990), p. 654.
and innovation, since the economics literature has focused on both relationships.

1. **Firm Size and Innovation**

Economists have found a positive relationship between firm size and the likelihood that a firm performs R&D.\(^{79}\) While early work was based on somewhat limited data,\(^{80}\) more recent work that allows one to control for industry effects (i.e., to control for other industry characteristics that might affect the performance of R&D) has confirmed the basic relationship.\(^{81}\)

Early studies found that R&D rose more than proportionately with firm size. However, these studies did not control for industry effects and thus may have reported biased statistics.\(^{82}\) Subsequent work, most notably Scherer (1965), suggested that innovation increases more than proportionately with firm size only up to some size level. This view was the consensus view during the 1980s.\(^{83}\) More recent work suggests that “R&D rises monotonically with firm size, and proportionately beyond some modest firm size threshold.”\(^{84}\) In addition, economists have often found that R&D varies “closely with firm size within industries, with size typically explaining over half of its variation.”\(^{85}\) As a result, economists increasingly came to believe that “large firms did not possess any advantages in R&D competition.”\(^{86}\) Specifically, “studies not only confirmed that large firms do not conduct a disproportionate amount of R&D relative to size, but also indicated that large firms actually generate fewer innovations per dollar of R&D

\(^{79}\) For a contrary view, see Schmookler (1959).

\(^{80}\) Villard (1958); Nelson et al. (1967).

\(^{81}\) Bound et al. (1984) and Cohen et al. (1987). For a general discussion of the use of the FTC’s line of business data to study structural relationships, such as the concentration-margin relationship, see Salinger (1990).

\(^{82}\) Illustrative of these early studies are Horowitz (1962) and Hamberg (1964).

\(^{83}\) See, e.g., Scherer (1980), Kamien & Schwartz (1982).


\(^{85}\) Id.

than smaller firms, which has been widely interpreted as reflecting a disadvantage of size.”

More recent work by Cohen & Klepper (1996a) suggests that some modification of the previously existing consensus may be in order. Specifically, they report evidence that increased size may be associated with increased R&D (and more productive R&D) because firms with larger business units can spread the costs associated with R&D over greater sales revenues. In addition, they found that, “for the firms in the FTC data set, the close relationship between R&D and size appears to be due principally to business unit [subsidiary or division level] rather than corporate level factors.” In a related study, Cohen and Klepper (1996b) find that the relationship between firm size and innovation is stronger for process innovations than for product innovations. They caution, however, that their findings do not indicate that large firms are the engines of economic growth, nor do they indicate that there are no disadvantages to large size.

2. Market Concentration and Innovation

Economists have explored how today’s market structure affects the level of innovation. As Scherer & Ross (1990) point out, “[m]ost studies for the United States and other leading nations reveal a positive correlation between concentration and industry R&D/sales ratios, or

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87 Id. Other studies done during this time period found that inter-industry differences in R&D intensity have a much more significant effect on the level of R&D than differences in the size of firms within an industry. See, e.g., Cohen et al (1987).

88 Id., p. 938.


90 Schumpeter was also concerned with how the incentive to innovate was related to ex post market structure (and associated market power). There has been substantially less research on this issue. Phillips (1966) discusses this possibility.
cruder proxies of these ratios.”\textsuperscript{91} However, there are some contrary results. For example, a few studies have found that that concentration is negatively associated with R&D.\textsuperscript{92}

In related work, Greer and Rhoades found that market power as measured by concentration is positively correlated with productivity changes.\textsuperscript{93} However, the inclusion of R&D expenditures in the equation eliminated the explanatory power (statistical significance) of market concentration. Some have interpreted this result as indicating that “the chain of causation appears to run from higher R&D spending, which is correlated with seller concentration, to higher productivity growth.”\textsuperscript{94}

While most studies have focused on a linear relationship between market concentration and innovation, Scherer (1967) found that there may be a non-linear relationship. Specifically, it is possible that innovation increases with concentration up to some point and then declines. This finding has been replicated by others.\textsuperscript{95}

Some early work by economists suggested that innovation might have deconcentrating effects.\textsuperscript{96} Subsequent work has suggested that innovation and entry are sometimes associated with each other.\textsuperscript{97} Granger causality tests performed by Geroski (1991a, 1991b) suggest that entry may cause innovation, rather than vice versa.\textsuperscript{98} Similarly, others have found that innovation may be associated with the growth of smaller firms or entry, which may lead to lower

\begin{itemize}
  \item \textsuperscript{91} Scherer & Ross (1990), p. 646. \textit{See also}, Baldwin & Scott (1987).
  \item \textsuperscript{92} \textit{See, e.g.}, Williamson (1965); Bozeman and Link (1983); Mukhopadhyary (1985).
  \item \textsuperscript{93} Greer & Rhoades, (1976). \textit{See also}, Amato & Ryan (1981).
  \item \textsuperscript{94} Scherer & Ross (1990), p. 645.
  \item \textsuperscript{95} \textit{See, e.g.}, Scott (1984) and Levin et al., (1985).
  \item \textsuperscript{96} Blair (1948).
  \item \textsuperscript{97} \textit{See e.g.}, Geroski (1990, 1991a, 1991b)
  \item \textsuperscript{98} Granger causality tests are statistical tests that are designed to test for causal relationships between economic variables in a statistical study.
\end{itemize}
concentration in innovative markets. Moreover, Gort & Konakayama (1982) found that entry rates were higher than exit rates in the early stages of major product developments, which suggests that product innovation can have a deconcentrating effect. However, Geroski observes that the presence of significant industry fixed effects implies that other structural characteristics of markets may simultaneously determine both innovation and entry.

Numerous economists have observed that the results that relate concentration to innovation are sensitive to industry characteristics. For example, Scott (1984) and Levin et al. (1985) found that the addition of variables that controlled for differences in company characteristics and industry characteristics eliminated the statistical significance of concentration as an explanation for variations in innovative activity, suggesting that the statistical significance that was observed in some regressions may be a statistical artifact of statistical relationships involving fundamental industry characteristics.

D. Fundamental Structural Characteristics of Technology May Determine Market Structure and Innovative Activity

Economists have recognized that both concentration and R&D efforts may be simultaneously determined by other market characteristics. Specifically, it may be that “the market structure affecting R&D decisions is not given, but endogenously determined by technology and competition.”

A number of economists have explored the relationship between innovation and

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100 See Section D below for a discussion of the simultaneous determination of innovation and market concentration.
102 Concentration was included in these regressions in two forms: expenditures and expenditures squared. The coefficients on both of these variables were insignificant when company and industry effects were included in the regressions. Regressions are statistical tests that are designed to estimate statistical relationships between variables. Statistical relationships are revealed in regression coefficients that are produced by the statistical test. When the statistical test is done properly, the regression coefficients can be interpreted to identify the likely direction and statistical significance of the relationships between the variables.
concentration by using multi-equation models in which concentration and R&D are both simultaneously determined by other factors.\textsuperscript{104} When performed, statistical tests support the view that both innovation and concentration are simultaneously determined.\textsuperscript{105} As a result, some have concluded that “[r]ecent empirical works suggests that R&D intensity and market structure are jointly determined by technology, the characteristics of demand, the institutional framework, strategic interaction and chance.”\textsuperscript{106}

One of the market characteristics that may simultaneously shape both market structure and innovation is the set of technological opportunities that firms face. Specifically, if rich technological opportunities mean that an innovator may not be able to retain significant rents because others will develop competing innovations (as may be the case when there are numerous technological opportunities), one may not see as much innovative activity in unconcentrated markets where there are rich technological opportunities as one sees in more concentrated markets.\textsuperscript{107} In a study that uses levels of innovative activity at one point in time to control for technological opportunities in the industry at other points in time, it was observed that higher seller concentration was associated with less innovation.\textsuperscript{108} Some have concluded that “interindustry differences in technological opportunity, however measured, have much greater power in explaining varying R&D or innovation intensities than differences in such market structure indices as concentration.”\textsuperscript{109}

\textsuperscript{103} Scherer & Ross (1990), p. 642.
\textsuperscript{104} See, e.g., Farber (1981); Wahlroos and Backstrom (1982); Connolly and Hirschey (1984); Levin & Reiss (1984); and Levin et al. (1985).
\textsuperscript{105} Simulation models also support this view. See, e.g., Nelson and Winter (1978).
\textsuperscript{106} Symeonidis (1996).
\textsuperscript{107} Scherer (1984); Comanor (1967).
\textsuperscript{108} Geroski, (1990).
\textsuperscript{109} Scherer & Ross (1990), p. 648.